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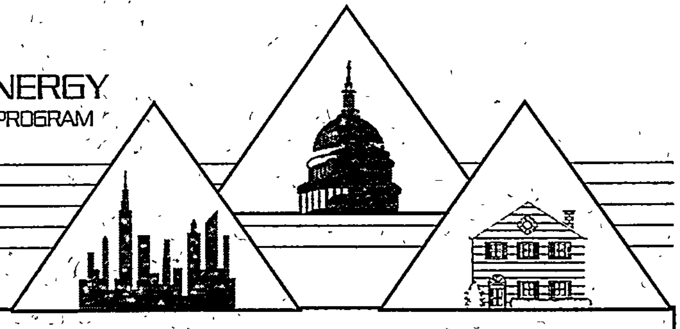
US DEPARTMENT OF ENERGY
BUILDING STANDARDS AND GUIDELINES PROGRAM



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Vol. 1
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Energy-Efficient Buildings Program Evaluations, Volume 1: Findings and Recommendations

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April 1997

For more information about the Building Standards and Guidelines Program, call the Hot Line at 800-270-CODE.

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ENERGY EFFICIENCY & RENEWABLE ENERGY
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ENERGY-EFFICIENT BUILDINGS PROGRAM EVALUATIONS, VOLUME 1: FINDINGS AND RECOMMENDATIONS

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April 1997

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest National Laboratory
Richland, Washington 99352

SUMMARY

This study was conducted for the U.S. Department of Energy (DOE) by Pacific Northwest National Laboratory (PNNL). DOE operates the Building Standards and Guidelines Program (BSGP) to increase the effectiveness of building energy codes, standards, and guidelines. The main purpose of this report is to lay the groundwork for conducting an overall evaluation of the program and its effectiveness. Another purpose of this report is to summarize an extensive set of relevant evaluations and provide a building efficiency and program evaluation information resource for program designers, managers, and evaluators.

This study presents information from 119 evaluations that have been conducted of both utility and code programs related to energy efficiency in new residential and commercial buildings. We used the information in these evaluations to identify major themes and lessons learned from utility and code programs. We also used the information to gain insights into appropriate evaluation methodologies and establish guidelines for designing future evaluations and an evaluation of the BSGP.

We conducted an extensive search to identify past evaluations. We then summarized the information presented in each report. Evaluations were categorized by type of building, program type, evaluation type, and other characteristics.

Several guidelines emerged from the evaluations that suggested ways to conduct successful building energy-efficiency programs. The report summarizes these findings.

The report also presents general lessons about evaluating programs that have implications for future evaluations included the following. The evaluations provided the basis for developing an effective evaluation approach for residential building energy-efficiency codes and other energy-efficiency programs and other insights for conducting commercial building program evaluations. The findings for conducting effective evaluations are categorized by steps in the evaluation process.

The summaries of the evaluations are available in *Energy-Efficient Buildings Program Evaluations, Volume 2: Evaluation Summaries*, DOE/EE/OBT-11569, Vol. 2, by Lee, Mayi, and Edgmon. An electronic version of the summaries can be obtained by calling 1-800-270-CODE.

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ACRONYMS

AAHX:	Air-to-air heat exchanger
AC:	Air conditioner
ACH:	Air changers per hour
ADM:	ADM Associates, Inc.
aMW:	Average megawatts
ASHRAE:	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASP:	Alternative service provider
AWC:	Association of Washington Cities
B.C.:	British Columbia
BCA:	Building Code Agency (Oregon)
BDL:	DOE-2 Building Description Language
BECo:	Boston Edison Company
BESP:	DOE/PNNL Building Energy Standards Program (now called the Building Standards and Guidelines Program)
BPA:	Bonneville Power Administration
BSGP:	DOE/PNNL Building Standards and Guidelines Program
CABO-MEC:	Council of American Building Officials' Model Energy Code
CAD:	Computer Aided Design
CALPAS3:	Computer program used in California for residential code compliance
CALRES:	Computer program used in California for residential building analysis
CCAP:	Clinton Administration's Climate Change Action Plan
CCCP:	Baltimore Gas and Electric's Comprehensive Commercial Construction Program
CCH:	Pacific Gas & Electric's California Comfort Home program
CDA:	Conditional Demand Analysis
CEC:	California Energy Commission
CECO:	San Francisco's Commercial Energy Conservation Ordinance
CFL:	Compact fluorescent light
CFR:	Code of Federal Regulations
CMP:	Central Maine Power
CVPS:	Central Vermont Public Service Corporation
CZ:	Climate zone
DCA :	Department of Community Affairs
DEEP:	Database on Energy Efficiency Programs

DFE:	Southern California Edison's Design for Excellence new construction program
DHW:	Domestic hot water
DNEE:	Designated national evaluation entity
DOE:	U.S. Department of Energy
DPS:	Vermont's or Minnesota's Department of Public Service
DSM:	Demand-side management
DVA:	Department of Veterans Affairs
EA (EAP):	BPA's Early Adopter Program
ECC:	Northeast Utilities' Energy Conscious Construction program
ECH:	Energy Crafted Home program
ECM:	Energy conservation measure
EEM:	Energy-efficiency mortgage
ELCAP:	End-Use Load and Consumer Assessment Program
EMC:	Energy Management Committee
EPAct:	The National Energy Policy Act of 1992
EPI:	Florida's Energy Performance Index, which is the ratio of as-built points to base points
ES-IDT:	Energy Standards Intelligent Design Tool
ESCO:	Energy services company
ESD:	Energy Smart Design
E$P:	Energy Savings Program
EUI:	End-use intensity
EUM:	End-use metering
EWG:	Evaluation Working Group
FHA:	Federal Housing Administration
FmHA:	Farmers Home Administration
FPL:	Florida Power & Light
FSEC:	Florida Solar Energy Center
GPC:	Georgia Power Company
GWh:	Gigawatt-hour
HPW:	High performance window
HRU:	Heat recovery unit
HUD:	U.S. Department of Housing and Urban Development
HVAC:	Heating, ventilation, and air-conditioning
ICBO:	International Conference of Building Officials
IEAL:	International Energy Associates Limited
IES:	Illuminating Engineering Society
IOU:	Investor-owned utility

IRP:	Integrated resource plan or planning
ISAAC:	Integrated System for Analysis of Acquisitions
kW:	Kilowatt
kWh:	Kilowatt-hour
LCP:	Least-cost utility plan or planning
LPD:	Lighting power density
LTCAP:	Long-term Commercial Acquisition Process
MAP:	Manual of Accepted Practices
MAP:	BPA Manufactured Housing Acquisition Program
MCS:	Model Conservation Standards
MEC:	Model Energy Code
MF:	Multi-family
MICROPAS:	A computer model for analyzing energy use
MLGW	Memphis Light, Gas and Water
MPR:	Major Projects Rule
MW:	Megawatt
MWh:	Megawatt-hour
NAC:	Normalized annual consumption
NBC:	New building construction
NBD:	New building design
NCSBCS:	National Conference of States on Building Codes and Standards
NEES:	New England Electric Service Co.
NIA:	Non-Integrated Areas Pilot Program
NPPC:	Northwest Power Planning Council
NREL:	National Renewable Energy Laboratory
NRNC:	PG&E's Non-Residential New Construction program
NU:	Northeast Utilities
NWEC:	Northwest Energy Code
NWPPA:	Northwest Public Power Association
NYSE-STAR:	New York State Energy STAR program
NYSEO:	New York State Energy Office
O&M:	Operations and maintenance
ORNL:	Oak Ridge National Laboratory
OSU:	Oregon State University
OTTV:	Overall thermal transmissivity value
PEPCo:	Potomac Electric Power Company
PFT:	Perfluorocarbon tracer
PGE:	Portland General Electric

PG&E:	Pacific Gas & Electric
PNNL:	Pacific Northwest National Laboratory (formerly Pacific Northwest Laboratory)
PRISM:	Princeton Scorekeeping Method
PSCo:	Public Service Company of Colorado
RCDP:	Residential Construction Demonstration Program
REEP:	Residential Energy-Efficiency Program
RMI:	Resource Management International, Inc.
RNC:	Residential new construction
RSDP:	Residential Standards Demonstration Program
SAE:	Statistically-adjusted engineering model
SCE:	Southern California Edison
SDG&E:	San Diego Gas & Electric Co.
SEER:	Seasonal Energy Efficiency Ratio
SEO:	State energy office
SF:	Single-family home
SFD:	Single-family detached home
SGC:	Super Good Cents
SRC:	Synergic Resources Corporation
TCL:	Tacoma City Light
TMY:	Typical meteorological year
TRC:	Total resource cost
U-value:	Thermal transmittance per unit area
UA-value:	Overall thermal transmittance
UWCTP:	University of Washington Component Test Program
WSEC:	Washington State Energy Code
WSEO:	Washington State Energy Office

1.0 BACKGROUND AND PURPOSE

This study was conducted for the U.S. Department of Energy (DOE) by Pacific Northwest National Laboratory (PNNL). This chapter explains the origins of the study, study purpose, methodology, and the contents of this report.

1.1 BACKGROUND

DOE operates the Building Standards and Guidelines Program (BSGP) to increase the effectiveness of building energy codes, standards, and guidelines. PNNL provides technical support to DOE in the BSGP. Numerous activities have been conducted by DOE and PNNL under the program for more than a decade and, although DOE has reported on these activities to Congress and has conducted numerous assessments of the program, no large-scale program evaluation has yet occurred. The main purpose of this report is to lay the groundwork for conducting an overall evaluation of the program and its effectiveness. Another purpose of this report is to summarize an extensive set of relevant evaluations and provide a building efficiency and program evaluation information resource for program designers, managers, and evaluators.

DOE's standards program has been designed and conducted in response to a series of federal laws. The most sweeping recent legislation affecting the program is the Energy Policy Act of 1992 (EPAct). Title I, Section 101, of EPAct requires DOE to take the following actions:

- Support states updating building energy codes by providing technical assistance and incentive funding.
- Issue determinations of whether revisions to two existing national codes would improve building energy efficiency.
- Establish energy standards for new federal buildings.
- Support the updating of voluntary building codes.

EPAct (Title XVI, Sec. 1605(b)) also sets the following requirements related to greenhouse gases:

- Establish greenhouse gas emissions data.

- Report annually on greenhouse gas emissions reductions due to energy efficiency and other measures.

Through the Administration's Climate Change Action Plan (CCAP), the following specific requirements were established:

- Ensure that at least 40 states upgrade their residential and commercial building energy codes
- Ensure designer and builder training to understand and use the upgraded codes
- ensure effective code enforcement and compliance.
- Evaluate processes and impacts.

In an effort to begin addressing the effectiveness of the BSGP and fulfilling these legislative requirements, PNNL conducted this study for DOE. This study presents information from 119 evaluations that have been conducted of both utility and code programs related to energy efficiency in new residential and commercial buildings.[a] We used the information in these evaluations to identify major themes and lessons learned from utility and code programs. We also used the information to gain insights into appropriate evaluation methodologies and establish guidelines for designing future evaluations and an evaluation of the BSGP. Because we found the evaluations to be a useful compendium of information, summaries of all the evaluations that we reviewed are presented in *Energy-Efficient Buildings Program Evaluations, Volume 2: Evaluation Summaries*, DOE/EE/OBT-11569, Vol. 2, by Lee, Mayi, and Edgmon. An electronic version of the summaries can be obtained by calling 1-800-270-CODE.

1.2 STUDY METHODOLOGY

To conduct this study, we started with a comprehensive search to identify past evaluations. Because of the extensive literature available on utility demand-side management (DSM) programs and the relevance of residential and commercial new building DSM programs to energy code programs, we included evaluations of building DSM programs in our search. We obtained a copy of each evaluation and reviewed it in detail. We then summarized the information presented in each report. The summaries included the following:

(a) Note that 121 studies were reviewed; however, only 119 were directly relevant to new building programs. All 121 studies are summarized in Volume 2.

- study title
- publication date
- study sponsor
- authors
- building type (commercial or residential)
- type of program (code or utility)
- evaluation type (process or impact)
- evaluation purpose (formative or summative)
- part of process addressed (development, adoption, implementation, compliance, or enforcement)
- stakeholders targeted
- program description
- process evaluation method (if applicable)
- impact evaluation method (if applicable)
- program findings
- methodology findings
- program recommendations
- methodology recommendations.

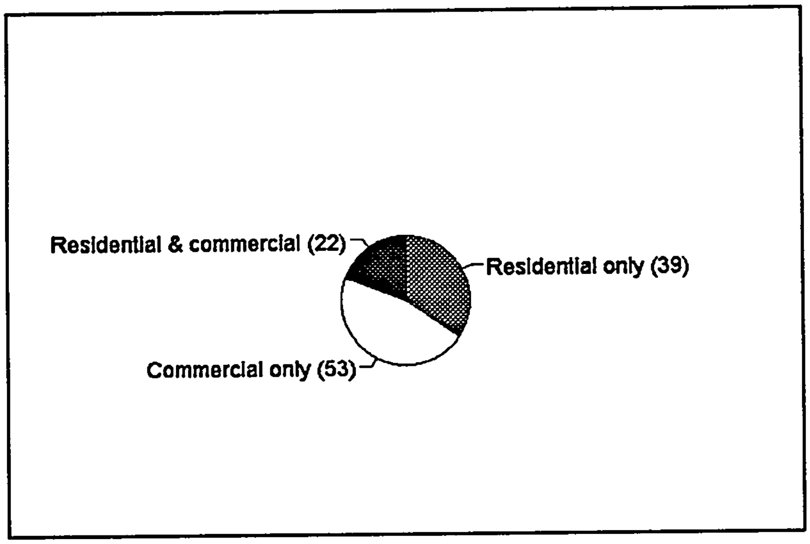

FIGURE 1.1. Building Types

Figure 1.1 shows that about one third of the evaluations we reviewed were for programs that applied to residential buildings only; about half were for commercial building programs; and about one fifth were for programs that applied to both residential and commercial buildings.

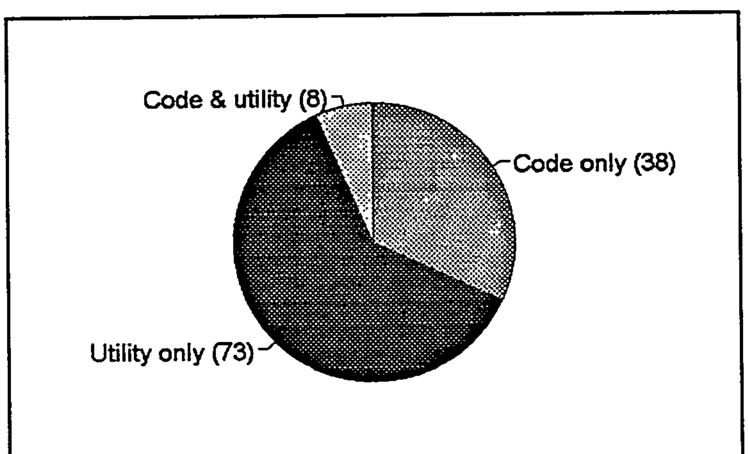

FIGURE 1.2. Program Types

Figure 1.2 shows that about one third of the evaluations applied to code-only programs; about 60%

applied to utility-only programs; and 7% applied to both code and utility programs.

We also categorized each report based on the type of evaluation it presented. Process evaluations focus on the processes that occur in a program. Ideally, they clarify the relationships between the processes and program outcomes, but often they are limited to descriptions of the processes and some assessment of the effectiveness of the processes. Impact (or outcome) evaluations focus on what effects the program produced. Both process and impact evaluations could be useful to the purposes of the present study. As show in Figure 1.3, the evaluations were split about equally between process and impact evaluations and about 10% of the evaluations included both components.

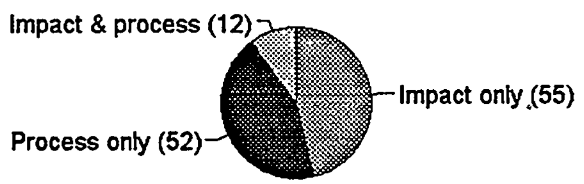

FIGURE 1.3. Evaluation Types

For categorization purposes, we also classified each evaluation as formative or summative. Formative evaluations refer to those conducted mainly for the purpose of guiding program improvements, usually during the development or revision phase of a program. The audience is usually those people involved in running the program. Summative evaluations, in contrast, usually occur after a program ends or is fully functional. They are intended to provide information to an audience or decision maker outside the program who may be interested in implementing the program elsewhere or changing or terminating the existing program. Few of the reports we reviewed explicitly specified whether they were summative or formative, but we made our own assessment. About 56% of the evaluations were classified as formative only, about 42% were summative only, and the remainder were a combination. For the purposes of our study, summative evaluations tended to be most useful.

We entered the evaluation summaries into a text database software package (askSam). This software package permitted a wide variety of text data searches. We used the software to help develop a list of acronyms, which is included in this document. We then used key words and phrases to help develop a list of themes to examine. Using these themes, we extracted relevant information from the evaluations and used this information to develop generalizable program findings and recommendations. We also used this approach to develop a list of common evaluation methodology findings. These methodology findings provided the basis for recommendations about conducting a large-scale evaluation for the BSGP.

1.3 REPORT ORGANIZATION

Chapter 2 summarizes the findings and recommendations that emerged from the utility program evaluations we reviewed. Information is organized by findings and recommendations that applied to 1) both residential and commercial building programs, 2) residential building programs alone, and 3) commercial building programs alone. This chapter ends with a discussion of the linkage between utility programs and code programs.

Chapter 3 presents similar information for code programs. It is organized in the same way as Chapter 2.

Chapter 4 presents evaluation methodology findings from both utility and code program evaluations. The information is organized according to the topics that emerged from the reviewed reports.

Chapter 5 outlines guidelines for conducting building energy-efficiency program evaluations. These guidelines provide a starting point from which to design an evaluation to support the BSGP.

As noted earlier, a summary of each evaluation is available in *Energy-Efficient Buildings Program Evaluations, Volume 2: Evaluation Summaries*, DOE/EE/OBT-11569, Vol. 2, by Lee, Mayi, and Edgmon. An electronic version of the summaries can be obtained by calling 1-800-270-CODE.

2.0 UTILITY PROGRAM EVALUATION FINDINGS

This chapter summarizes the most important findings from the utility program evaluations we reviewed. It emphasizes those that were the most common and most significant.

2.1 INTRODUCTION

Out of the sample of 119 evaluations reviewed for this report, 73 focused on utility DSM programs exclusively and 8 addressed both utility and code programs. The utility DSM programs were for new residential and commercial buildings and included approaches such as marketing, providing technical and design assistance, and providing financial incentives.

We identified findings and lessons learned that were the most frequently mentioned across all the utility program evaluations. Listed according to how frequently they appeared, the findings and lessons applied to the following topics: 1) incentives and financial assistance, 2) training and education, 3) design and technical assistance, 4) data collection and tracking, 5) program marketing and promotion, 6) program cost-effectiveness, 7) the program design and implementation process, and 8) cooperation and coordination among different stakeholders.

We documented those findings, lessons learned, and recommendations that emerged in each of these eight categories across both commercial and residential building utility programs. These are presented in Section 2.2. Those items that were unique to residential building program evaluations were then identified and they are presented in Section 2.3. Items that were unique to commercial building program evaluations were then noted and they are presented in Section 2.4. The final section discusses the influence of DSM programs on code programs.

2.2 FINDINGS COMMON TO RESIDENTIAL AND COMMERCIAL PROGRAMS

Most of the major findings and recommendations were consistent across both residential and commercial building utility program evaluations. The following sections discuss these general results by major topic area.

2.2.1 Incentives and Financial Assistance

The most frequently mentioned issue in the utility program evaluations involved incentives and financial assistance. Participation in both residential and commercial building DSM programs was closely linked with incentives. Commercial building owners and design teams and residential home owners and builders generally expected energy-efficiency measures to increase first cost and also had doubts about the performance of efficient equipment and components. Incentives and financial assistance were shown to help attract potential participants to programs because of their effects on reducing the impacts of higher costs and alleviating concerns about performance risk.

In both commercial and residential building programs, non-financial incentives (such as public recognition) were recommended as well. For both building types, it was recommended that incentives be simple enough to understand and be flexible enough to accommodate a wide range of possible participants.

2.2.2 Training and Education

For both residential and commercial building programs, inaccurate information or a lack of knowledge often diminished program participation. Training and education were recommended frequently as ways to alleviate these problems.

Home owners and commercial building developers and owners often ranked energy efficiency low in their priorities, in part because they lacked complete information or had incorrect information. Many members of these groups were not aware of the range of choices available for energy-efficiency improvements and their benefits. In the residential sector, concerns about aesthetics and, as noted earlier, expected cost increases associated with energy-efficiency measures limited program participation.

As mentioned earlier, in both the residential and commercial building sectors the perception that many energy-efficiency technologies were unproven and, therefore, risky investments, reduced willingness to invest in energy-efficiency improvements. Commercial building owners and developers and their design teams were skeptical about the performance of new high-efficiency technologies. Because these technologies were unfamiliar to them, they did not trust their performance claims and considered them financially risky.

Education about energy-efficiency measures could help reduce misinformation about costs and risks. For both commercial and residential building stakeholders, education on energy-efficiency has had direct effects on program participation and has been shown to spill over to the market, increasing awareness of energy-efficiency construction practices and their benefits and reducing uncertainties even among program non-participants. One important theme that was especially powerful in the commercial building sector was how much higher the cost was to retrofit energy-efficiency measures than to install them when constructing the buildings. Education and information transfer tended to increase the knowledge of building buyers, thus increasing the demand for energy-efficiency construction practices from designers, builders, and developers.

Several evaluations recommended training, as well as education, for both the residential and commercial building sectors. For commercial buildings, training building operators on energy-efficiency measures and operation was often recommended. Training was also recommended in the form of design assistance for building design teams to incorporate energy efficiency measures at the early stage in the building design process. For both residential and commercial building utility programs, evaluations recommended training utility staff to improve their skills and knowledge associated with energy efficiency.

2.2.3 Design and Technical Assistance

As suggested in the previous section, design and technical assistance were identified as important utility program considerations in several evaluations. Because these tended to be mentioned more commonly in evaluations of commercial building programs, they are discussed in detail later in that section.

2.2.4 Data Collection and Tracking

For both residential and commercial building programs, two main issues were raised about data collection and tracking: uniformity of data collected and continuity of data to keep up with program changes. Evaluations recommended that data collection capture and reflect changes in the program by maintaining tracking continuously throughout the program. A primary reason to do so was that if the energy-efficiency measures changed during construction, the savings estimates could also be modified. Several evaluations noted that the methods used to track programs often were not consistent across energy-efficiency technologies and programs. Several recommended establishing consistent measurement and reporting approaches so that different utilities and customers could develop a common level of understanding about measures of effectiveness and interpretations of program data.

The following specific data collection and tracking issues were identified: 1) The equipment being rebated and its location should be explicitly identified in the tracking database. 2) The Certificate of Compliance (or comparable record) generated for the building should be collected and retained in program records at the time of verification. 3) A simple database should be developed that can be easily understood and kept current by the people who are generating the information.

The issue of the data collection timing was also raised. One of the evaluations noted that participants interviewed a year or two after the program had started did not remember many details about the program, particularly process-related details. It was recommended that surveys and data collection be conducted early enough in a program that participants' recollections would be clear.

2.2.5 Program Marketing and Promotion

Both residential and commercial building program evaluations noted that poor program marketing diminished participation and effectiveness. Marketing can be used to target new participants while keeping current participants interested and committed to the program. Evaluators observed that understanding the attitudes of potential or current program participants was key in marketing energy-efficiency programs effectively. Productive marketing would utilize this information to focus on customers' needs and preferences. Facilitating continuous feedback from participants also was highly recommended.

Another important marketing step was to establish a reputation for a program with a distinctive logo. The Super Good Cents (SGC) program for residential buildings, for example, served as a good promotion and marketing tool for potential customers who were attracted by the quality of the product.

2.2.6 Program Cost-Effectiveness

The issue of program cost-effectiveness and ways to improve it were mentioned in a few evaluations. Because this issue arose more commonly in residential building program evaluations, it is discussed in detail in the subsequent section on residential programs.

2.2.7 Program Design and Implementation

Both residential and commercial building program evaluations identified the importance of sound program design, or opportunities to revise the program during implementation. It was noted that programs should be designed by taking into consideration the attitudes of participants toward energy-efficiency measures and then designing appropriate incentives and marketing and promotional strategies. Understanding stakeholders' awareness and attitudes was important in deciding how and when to demonstrate benefits of energy-efficiency measures to home owners and commercial building owners, developers, and design teams. Using this information to match program services and incentives to stakeholder needs was found to be critical in overcoming barriers to participation.

For the program design cycle, evaluations recommended adopting a comprehensive, long-term strategy of program design, feedback, and redesign. Feedback of implementation lessons into the process of designing and revising programs was highly recommended, particularly with regard to decisions about education, training, design assistance, financial and non-financial incentives, quality control, marketing and promotion, monitoring, and design tools.

Some evaluations emphasized the importance of keeping participants interested in energy-efficiency throughout program implementation so that energy-efficiency measures would continue to be adopted even after phasing out the program. This was directly related to concerns about the potential market transformation impacts of a program.

2.2.8 Cooperation and Coordination

For both commercial and residential building DSM programs lack of cooperation and collaboration among program stakeholders was responsible for waste due to duplication, scarcity of resources, and lack of lessons learned across participants. Cooperation and collaboration were encouraged for utilities to avoid additional costs, share resources to implement common goals, reduce the cost of program implementation, and share information and lessons learned for the design of future programs. Collaboration and interaction among the key players were recommended also for their benefits in supporting the creation or adoption of new codes.

One program evaluation specifically discussed the implications of new building construction DSM programs on the implementation of building energy codes. This study produced a number of findings related to collaboration: 1) utilities need to form working relationships with the building community; 2) utility collaboration can reduce costs and provide opportunities to reassess DSM programs to improve cost-effectiveness; and 3) utilities can work with state legislators to adopt energy codes. This study produced several recommendations for actions that DOE should take: 1) promote interaction between state energy offices (SEOs) and utilities; 2) identify opportunities for collaborative marketing programs; 3) promote SEO-utility collaboration on projects that combine energy efficiency and environmental concerns; and 4) help states identify ways to encourage local enforcement of energy codes.

2.3 FINDINGS SPECIFIC TO RESIDENTIAL BUILDING PROGRAMS

This section discusses findings that arose specifically or primarily in evaluations of residential building programs. Because they emerged primarily from residential building program evaluations did not mean that they were relevant only to residential building programs, but that they should be of special concern in such programs.

2.3.1 Incentives and Financial Assistance

There were no issues associated with incentives and financial assistance that were unique to residential building programs. See discussion in Section 2.2.1.

2.3.2 Training and Education

Six residential program evaluations raised the issue of home owner and builder education. They found that home owners were poorly educated on the characteristics of energy-efficiency measures for their homes or on the benefits of adopting energy-efficiency measures and this contributed to energy efficiency not being a major selection criterion for home buyers. The evaluations suggested that this might be changed through education activities in residential building programs. Specific education efforts mentioned included addressing perceived problems linked with energy efficiency measures, such as indoor air quality and moisture, and increased efforts to raise consumer awareness of incentives. One study highlighted the benefits of education in producing a small but important impact on the entire construction market and consumer behavior. Another study specifically noted that the SGC program was effective at creating region-wide awareness of energy efficiency.

Another study recommended increasing marketing to and education of home buyers and increasing incentive choice alternatives. It also recommended conducting builder training coupled with post-training follow-up to monitor training impacts. It advocated developing a simplified, prescriptive path for multi-family construction.

One study specifically explored the impacts of consumer education in a residential building program and found that the education component had a measurable effect. The study showed that education could affect consumer equipment choices and maintenance behavior, but that broader behavioral changes were harder to measure without a more complete experiment.

Other training needs mentioned included refresher training courses for builders and training of program staff, particularly to maintain program continuity when staff changed.

2.3.3 Design and Technical Assistance

There were minimal design and technical assistance issues raised in the utility residential program evaluations. See Section 2.2.3.

2.3.4 Data Collection and Tracking

There were no significant data collection and tracking issues raised in the utility residential program evaluations. See Section 2.2.4.

2.3.5 Program Marketing and Promotion

Inefficiencies in residential building program marketing were noted in some evaluations. One evaluation recommended ways to improve marketing cost-effectiveness of residential building programs: 1) target efforts at the obstacles facing home buyers desiring to purchase energy-efficiency products and 2) develop builder promotions highlighting consumer interest in energy-efficient homes.

Another evaluation stressed a similar need to tailor residential building program marketing to better meet the needs of the key stakeholders. This was felt to be a key to improving overall program cost-effectiveness.

2.3.6 Program Cost-Effectiveness

Although cost-effectiveness is a critical issue in utility DSM programs, few of the evaluations that we reviewed focused on this issue. Two studies did review the same 10 residential new construction programs (RNCPs) and highlighted issues of cost-effectiveness.

They concluded that program cost-effectiveness was reduced by several factors. Three major factors were the following: 1) increased tightening of state building standards that have improved the baseline against which DSM program cost-effectiveness is measured; 2) program marketing strategies that have often been incomplete or misdirected; and 3) energy savings estimates that often failed to include indirect savings induced by the program such as those from energy-efficiency improvements by non-participants who made the improvement because of the program. These indirect savings reflect the free driver and "market transformation" components of DSM program impacts (see Section 4.1).

These two studies recommended improving the cost-effectiveness of residential new construction programs by 1) promoting technologies and advanced building design practices that significantly exceed state and federal standards; 2) reducing program marketing costs and developing more effective marketing strategies; 3) recognizing the role of these programs in increasing compliance with existing state building codes; and 4) allowing utilities to obtain an "energy-savings credit" from utility regulators for program spillover (market transformation) impacts. The studies also noted that utilities can leverage their resources, thus improving cost-effectiveness, by forming strong and trusting partnerships with the building community and local and state governments.

2.3.7 Program Design and Implementation

The program design and implementation lessons from both commercial and residential DSM program evaluations were similar, but there were important differences in details and emphasis.

Several evaluations pointed out that there was a need in the residential building program design process to take a long-term, broad view. One study found that only a few programs were designed as part of a long-term strategy to promote energy-efficient construction. One study recommended focusing program enhancements in four areas: program goals, program features, program delivery and administration, and program implementation.

Successful programs often were designed and implemented to provide intervention early in the building design and planning process in order to minimize delays in the project design, approval, financing, and construction process. One residential building program evaluation pointed out the importance of designing the program to respond to builder and home owner attitudes and behavior. In particular, the study noted that installation of energy-efficiency measures, in general, was driven more by home buyers than builders or architects. The study also noted, however, that consumers vastly overestimated the costs of efficiency measures. This suggested that, while builder education was an important program component, program design also should incorporate steps to increase buyer awareness of costs and benefits.

Few programs, however, were designed to address issues later in the building life cycle. Recommended program steps later in the process included providing quality control support, conducting building rating and labeling, providing energy awards for buildings and building professionals, improving operations and maintenance activities, and performing building commissioning.

Several studies alluded to the need to monitor and evaluate program performance. Studies specifically found that if an evaluation strategy was not accounted for in the program design then evaluation of the program in the future often was impeded. Studies recommended, therefore, that provisions for monitoring and feedback be incorporated in the program design, and that process and impact evaluations of utility programs be conducted.

2.3.8 Cooperation and Coordination

Effective cooperation between residential building program planners and implementers was highlighted as a key necessity in one evaluation. The evaluation recommended that communications between planners and implementers be improved.

2.4 RESULTS SPECIFIC TO COMMERCIAL BUILDING PROGRAMS

This section discusses findings that arose specifically or primarily in evaluations of commercial building programs. As noted in the discussion of residential building programs, the information presented here should be of special concern in commercial building programs, but might be relevant to residential programs as well.

2.4.1 Incentives and Financial Assistance

There were no major issues associated with incentives and financial assistance that were unique to commercial building programs. One evaluation did stress, though, that incentives provided should be flexible enough to deal with different sub-markets and differing technical opportunities, and another stressed the need to make financial and non-financial incentives simple enough so that they could be explained easily and sold to commercial building design teams and their owners.

2.4.2 Training and Education

Some evaluations noted that commercial building owners were not very knowledgeable about the economic benefits of energy-efficiency measures but were very concerned with keeping construction costs down. Building design and construction professionals were found to not only lack adequate information, but were skeptical about the performance of new high-efficiency technologies. Because these technologies were unfamiliar to them, they often considered their performance claims to be unproven and financially risky. The Energy Edge program demonstrated that educational efforts paid off in increased building professionals' familiarity with energy-efficient design and an increased willingness to implement energy-efficiency measures in buildings starting from the early stage of the building process.

Other studies showed that educating building operators on energy-efficiency measures and practices was essential in efforts to reduce energy waste in commercial buildings. Education and training of building operators on the efficient use of lighting could significantly increase energy savings in commercial buildings.

In one evaluation, education and training were found to be most needed at the building conceptual design stage. The study recommended that utilities inform and train designers about incorporating energy conservation measures early in their designs. The study also noted that more efficiency measure cost information needed to be provided to educate owners and builders.

2.4.3 Design and Technical Assistance

Five commercial building program evaluations expanded on the issue of design assistance. Design assistance was needed to help building owners and designers meet a targeted energy performance level. Design assistance addressed two major needs similar to those targeted by education and training: reducing costs of energy-efficiency options in buildings and increasing owners' and builders' knowledge of new and innovative energy efficiency options. Design assistance aimed at eliminating difficulties in terms of time and expense of evaluating the costs and benefits of energy-efficiency options. It also reduced risks and increased the knowledge of the design team about efficient design approaches and technologies. One study specifically found that design assistance was a good investment because the cost was far less than the initial cost of retrofitting efficient equipment after a building was built.

One major finding about design assistance was that it should be implemented in a flexible way. This involved providing exactly what was appropriate for a given customer, for a given project, within a given time constraint.

Another flexibility theme that emerged in different studies was the need to provide a broad range of services and making assistance available throughout the life of the project, not only at the design phase. As noted earlier, building operator training and building commissioning were recommended services.

One study examined the long-term effects of design assistance. It found that design assistance effectiveness was highly dependent upon factors such as the economics of the project, the openness of the design team to outside involvement, and the commitment of the building owner to lower operating costs. In projects where the owner had a high level of commitment to implementing energy-efficiency measures, they usually succeeded even without design assistance. However, even in these situations some projects failed because of a lack of cooperation among the building design team, and the study recommended using an integrated approach to building performance in new construction as an effective tool for communicating the practical benefits and investment opportunities of energy-efficiency measures to a building owner.

Other studies specifically highlighted the importance of technical assistance to building designers and owners. For example, in one program an energy specialist served as a resource and an ally to the utility, owner, and design team. The energy specialist devoted the necessary time and provided the expertise to develop energy conserving design improvements that were compatible with the building's design, as well as the project schedule and budget constraints.

Both design and technical assistance partially alleviated resource constraint concerns faced by design and construction professionals. They often felt burdened by the costs of the additional analyses required for energy-efficient design and, in general, owners and design teams lacked the time, budget, and sometimes the capability to analyze the options, to specify and procure unfamiliar equipment, and to ascertain proper performance. As noted earlier, the timing of design and technical assistance was critical: the window of opportunity for affecting decisions about the efficiency of building design and equipment was relatively small.

2.4.4 Data Collection and Tracking

There were no data collection and tracking issues identified in the evaluations that were unique to commercial building programs. See Section 2.2.4.

2.4.5 Program Marketing and Promotion

The utility building program evaluations identified a few findings and recommendations that were more suited to commercial building than residential building programs. First, marketing should target designers since they are involved with buildings in the early design stage. Second, a survey of businesses should be conducted to determine potential program participants. Third, some studies found that the professionals involved in commercial building design and construction not only lacked detailed knowledge about energy efficiency opportunities, but they also were unaware of utility programs. Thus, program marketing and promotion should target potential participants and employ intensive efforts to inform them about the program.

2.4.6 Program Cost-Effectiveness

No specific cost-effectiveness issues were highlighted in the commercial building program evaluations that we reviewed, although cost-effectiveness was clearly an important consideration.

2.4.7 Program Design and Implementation

As noted before, the program design and implementation lessons from both commercial and residential DSM program evaluations were similar, but there were important differences in details and emphasis.

One commercial building program evaluation recommended integrating a program redesign phase into the implementation process to form a continuing program design cycle. The study suggested conducting the following key steps: 1) form a Redesign Team with the original program designer and program manager as co-leaders and obtain their feedback on a regular basis in the form of a mini process evaluation to include group meetings, focus groups, and a review of processes and procedures; 2) continually channel all suggestions and input back into the program so that it is always evolving to reflect the ever-changing construction market; 3) ask questions such as "Are we satisfying customer needs?" as often as "Are we meeting our goal?"; 4) ask non-participants why they did not participate, and ask participants why they did; 5) continue to add new features to help sell the program; and 6) continue to add creative marketing techniques.

A key issue in the design of commercial building programs was how and when to demonstrate the benefits of energy-efficiency measures to building owners. Ensuring that this occurred early enough required development and implementation of an effective program marketing effort, including frequent communication with architects and engineers. Flexibility of the overall program design, as well as in the program components such as technical assistance, appeared to be important to the success of commercial building programs. To increase flexibility, utilities could offer a range of products and services including design analysis services, turnkey end-use services, equipment leases, or performance guarantees.

Another key to program success is designing the program in such a way that participation is simple. If potential participants perceive utility program participation as time-consuming or complicated, their interest and enthusiasm will be diminished.

2.4.8 Cooperation and Coordination

There were no issues of cooperation and coordination identified that were associated uniquely with commercial building programs. See Section 2.2.8.

2.5 UTILITY DSM PROGRAM EFFECTS ON CODE ADOPTION

Experiences with utility DSM programs are useful here to provide information about how to design, conduct, and evaluate code programs better. Evaluation methodology insights from utility programs are discussed along with those from code program evaluations in Chapter 4. In this section, we briefly discuss some of the relationships between utility building DSM programs and code programs.

Five of the utility program evaluations discussed linkages to code programs. Although such limited observations cannot be generalized, these studies established that utility DSM programs can facilitate the development, adoption, and implementation of new building energy codes. The efficiency requirements of utility programs often go well beyond those required by codes so they can provide a market pull for increased energy code requirements. Lessons learned and information from code programs, on the other hand, can be useful in designing utility building DSM programs.

Findings from one study confirmed that the success of a DSM program (in this case the residential SGC program) developed support for the Northwest Energy Code. Another study argued that a utility commercial building program paved the way for adoption of a new commercial building construction code. In another case, a utility (Ontario Hydro) put in place a new construction program that led to adoption of a revised version of ASHRAE 90.1[a] for commercial buildings. This evaluation revealed that the relationships and cooperation developed during utility programs were important factors in the successful adoption and implementation of a new code. Specific benefits included making the utility a knowledgeable stakeholder in the code development process, identifying and resolving quality control and evaluation issues, and improving energy savings analysis tools.

One study specifically examined lessons learned from a range of utility programs and their implications for the implementation of building energy codes. The study provided several useful findings: 1) DSM programs can be instrumental in improving building energy codes and standards; 2) utilities can become key players, working with state legislators to develop and adopt energy codes; and 3) energy codes are ineffective without adequate enforcement.

The relationship between utility programs and energy codes deserves further investigation because of increased interest in the market transformation impacts of utility programs. The market transformation approach has three main goals: 1) to change the market in fundamental ways, 2) to achieve widespread changes, and 3) to reduce costs to the utility. Energy codes meet these tests and constitute one key form of market transformation. To the extent that the building code produces energy savings, any associated costs are borne by the builder, designer, and owner; the utility typically has no direct costs. Utility programs, however, can accelerate the development of more stringent codes and some utilities have engaged in programs that have energy code upgrades as one of their goals. To reflect market transformation effects, utility program evaluations should account for any acceleration in the introduction, adoption, or penetration of energy-efficiency measures and any ultimate effects on the minimum efficiency levels mandated by resultant energy codes.

(a) The American Society of Heating, Refrigerating and Air-Conditioning Engineers standard for commercial buildings.

3.0 CODE PROGRAM EVALUATION FINDINGS

This chapter discusses the building code program evaluations that we reviewed. Building energy code programs can be described in terms of three stages: development, adoption, and implementation. The development phase involves the design of the code. The adoption phase deals with the passage of legislation for a code or standard and adoption of code language by a government agency. During this phase, different actors such as building owners, developers, architects, and local jurisdictions typically get involved in influencing the specifics of the code. The implementation phase of a building energy code involves compliance, monitoring, and enforcement. Although compliance is usually legally required by the code, buildings are not always constructed to the code and code officials do not always identify failures to meet the code and have them corrected. Lack of knowledge, lack of resources, and other constraints can contribute to inadequate compliance and enforcement.

The purpose of this chapter is to summarize findings and recommendations distilled from our review of code program evaluations. These findings and recommendations should prove informative to others interested in energy code programs and should be useful to future efforts to evaluate code programs.

3.1 APPROACH

A total of 46 code-related evaluations (including 8 that addressed both utility and code programs) were in the overall sample of 119 evaluations reviewed. Out of these 46, 15 were for residential building codes only, 9 were for commercial building codes only, and 22 related to both residential and commercial building codes.

We conducted a simplified content analysis to generate a list of issues to focus our review. We used prior experience to identify possible issues and then searched the evaluations to determine how often they appeared. Using this approach we identified the following issues: code and code process simplification (46), compliance and enforcement (38), training (24), education and awareness (17), review and field inspections (13), technical assistance (12), data and data collection (7), cooperation and coordination (6), design assistance (3), and utility DSM programs and codes (3). The numbers in parentheses indicate the number of documents (out of the 46 code-related evaluations reviewed) in which the issue was mentioned.

We then reviewed the issues and categorized findings and recommendations according to the stage of the code process to which they applied, i.e., code development, adoption, or implementation. We identified similarities across programs, as well as program-specific findings and recommendations. Most of the evaluations focused on the code implementation process so most of the findings and recommendations presented here address this phase.

Limitations in the code program studies available need to be recognized. Most of the evaluations we reviewed discussed the Washington State Energy Code (WSEC) and the Pacific Northwest Model Conservation Standards (MCS) programs.[a] Some of the programs were directly related to utility DSM programs or were programs to advance or ease the adoption of upgraded codes. Consequently, the lessons from these programs provided insights beyond those from programs strictly limited to traditional code adoption and implementation. Because of the relatively small number of evaluations available, unique features of the programs, and limited diversity, generalization of findings and recommendations must be done with care.

The code programs discussion is presented in three sections. The first discusses findings and recommendations applying across both residential and commercial building code programs. The second deals with results that appeared to be unique to residential building programs only. The last deals with results that were primarily for commercial building programs.

3.2 RESIDENTIAL AND COMMERCIAL BUILDING CODE PROGRAMS

This section discusses evaluation results that applied either explicitly or implicitly to both residential and commercial building energy code programs.

(a) The WSEC program was a supplemental effort to provide training and financial support to the code enforcement community. The program included a one-time start up payment, training allowances, technical assistance, and training on the code inspection procedures. Although implementation of the program was mandatory, participation was not. MCS was developed in 1983 by the Northwest Power Planning Council (NPPC) and adopted in 1989. Its goal was to ensure that all new electrically-heated buildings served by Bonneville utilities would be built to an energy-efficiency standard that was economically feasible to home owners and regionally cost-effective.

3.2.1 Code Development Phase

The most common theme that emerged from both residential and commercial building code evaluations was the need for *code simplicity*: code complexity reduced energy code effectiveness. Complexity created difficulty for designers, architects, and builders who sought to meet the code and made it more difficult for code officials who tried to enforce the code. A key lesson was that steps should be taken during the development phase to simplify the code in ways that would ease its interpretation and facilitate its enforcement. Some evaluations recommended on-going reviews of the code to pave the way for developing appropriate code updates, but reviews that were not so frequent that they would create confusion among code officials and the building community.

One study highlighted three recommendations best initiated during code development to enhance *compliance and enforcement*: 1) establish a partnership between the code regulatory agency and code enforcement agency, 2) establish a feedback loop among the designers, enforcement community, and the state code officials, and 3) create a process that allowed for exceptional methods and design so as to encourage creativity while maintaining a minimum standard of practice.

Some evaluations highlighted the need to initiate *training and education* of building professionals, subcontractors, building operators, and code officials during the code development phase. Early training and education could provide benefits in facilitating and implementing new or updated building codes.

One important message emerged across findings from a number of studies: code effectiveness depends to a large degree on how well compliance costs and complexity are balanced against energy savings during code development. The lesson was that codes designed to save large amounts of energy were unlikely to do so if they were either very complex (making compliance and enforcement difficult) or very costly to implement (providing an incentive to evade or not fully enforce them). The large number of studies that stressed the need to simplify codes either explicitly or implicitly recommended simplification as a means to increase compliance and enforcement, thus increasing overall code effectiveness. One study that reviewed several programs in California made a similar point by highlighting ways to offset the added costs imposed by codes at the same time significant efficiency improvements were achieved.

3.2.2 Adoption Phase

During the adoption phase, evaluations of both residential and commercial building code programs found that success increased with *education and awareness.* A clear understanding of the benefits and requirements of energy codes among the public, professionals, and code officials eased the adoption process.

Cooperation and coordination among the key stakeholders also facilitated adoption. Some evaluations noted the benefits of utility DSM programs in laying the groundwork for this cooperation and coordination.

3.2.3 Implementation Phase

One study provided an overview of code compliance studies conducted in several states. This was a very useful report because it identified many specific issues that were highlighted in other reports. Although the report was limited to residential code programs, its lessons were useful to both residential and commercial building code programs. The study's purpose was to expand the body of knowledge on code compliance and to capture critical factors that affected energy code compliance. Case studies reviewed included those in California, Florida, Oregon, Washington, Minnesota, Georgia, and Massachusetts. For each case the factors affecting energy code compliance were discussed and lessons were drawn to improve code compliance. The study identified several key areas for improving energy code compliance: *simpler* codes, *education* of members of the building community (architects, engineers, designers, builders owners) and code officials, development of improved *compliance and enforcement tools*, and coordination of energy code enforcement with other building activities such as financing, Home Energy Rating System (HERS) programs, and utility DSM programs.

As suggested earlier, *code simplicity* had its payoff in the implementation phase. Five evaluations expanded on the issue that complexity of the code led to poor compliance, wasted time and resources during implementation, and reduced willingness of designers and building owners to include code considerations in their designs.

Many studies cited the complexity of the code as one cause of low compliance. Codes that are too complex create three kinds of problems. First, they are too cumbersome for architects and engineers to accommodate in building designs. Second, a complex code diminishes understanding and interpretation by code officials. Third, a complex code limits the capacity of code officials to make required reviews and conduct enforcement in a timely manner with limited budget. One consequence is that building professionals tend to seek prescriptive paths for complying with codes, rather than taking more flexible, performance-based approaches. In addition, code officials seek simpler ways to verify compliance than demanded by performance-based compliance approaches.

Evaluations stressed the benefits of two kinds of simplification. First, simplification of the code itself was a frequent recommendation. Second, several evaluations noted that compliance would benefit from a more uniform code enforcement and compliance process backed up with adequate funding and tools for checking compliance. The tools needed to not only simplify the compliance and enforcement process, but needed to be simple to use themselves.

Many of the evaluations addressed *compliance and enforcement* issues. One study highlighted the fact that energy codes were often given less consideration by building professionals, building owners, and code officials than safety, health, and fire issues. Coupled with the perception that builders and owners were more concerned about potentially higher construction costs than about future higher operating costs, energy code enforcement and compliance faced special challenges.

As noted above, code complexity was one common contributing factor to implementation problems. Other contributing factors included lack of training and education of code officials and the building community, field changes, and frequent updates of the code. One study suggested that professionals from different disciplines be recruited as code officials to broaden code official expertise and improve review and inspections. The evaluations discouraged frequent updates of the code and a few evaluations recommended spacing updates in time in order to secure stability and credibility of code interpretations. Recommendations to address the other factors are discussed later.

Training and education during the implementation phase were recommended in six evaluations. It was found, in general, that architects, engineers, and builders were not adequately trained on the code. Therefore, they did not consider energy efficiency as a very important issue in their design compared with first cost. This reduced compliance in the buildings as built. Evaluations recommended educating these professionals so that energy-efficiency measures were integrated at the early stage of building design rather than being retrofitted in an existing building or home. Also, training home owners and building operators on energy-efficient building operation was found to have a significant impact on energy savings, particularly on lighting.

The evaluations also found that code officials generally were not adequately trained to understand and implement the code effectively. This affected the enforcement process and compliance. Studies of the WSEC particularly illustrated the benefits of training and educating code officials; these studies recommended that code officials be trained and educated specifically on code interpretation.

Development of better training tools was also recommended. Specific audiences noted were designers, code officials, professional trades, and subcontractors.

Nine evaluations specifically noted the importance of *increasing awareness* through education and training. To achieve this goal, better education packages and one-on-one training were recommended for building owners and builders. Also, some evaluations recommended that public education and education of building operators be conducted during code implementation to provide information about the code and energy efficiency and conservation measures.

Three evaluations specifically made recommendations involving *review and field inspections* as means to improve code implementation. It was found that a lack of plan review and field inspections could lead to neglect of energy efficiency or low code compliance, particularly in commercial buildings. Various recommendations were made including increasing plan review and field inspections, having the building owner hire a special inspector to oversee different construction operations, and, as noted before, expanding code official expertise by hiring experts with mechanical systems, electrical, and plumbing systems experience.

Although mentioned less often than in utility program evaluations, *design assistance* was mentioned occasionally in code program evaluations. Design assistance during code implementation was suggested as a means to reduce the number of field changes required by promoting more careful planning at the early stages of the building design.

3.3 RESIDENTIAL BUILDING CODE PROGRAMS

The number of residential building code program evaluations was relatively small; thus, the extent of results specific to residential programs was fairly limited. The evaluations in this category were dominated by programs in Washington state. As before, most of the findings applied to the implementation stage rather than the code development or adoption stages.

3.3.1 Code Development Phase

Compliance and enforcement issues related to the code upgrade process arose in two evaluations of residential building codes. In particular, the studies found that code changes often created confusion among code officials, designers, and owners leading to problems interpreting and enforcing new codes. As a result, code compliance tended to drop significantly during these transitional periods. The studies recommended limiting energy code changes so that they did not occur too frequently and coordinating them with the standard code revision cycles.

3.3.2 Code Adoption Phase

Two evaluations identified issues related to *compliance and enforcement* during the residential code adoption phase. One study noted that code officials were sensitive to the costs that a new code would impose on them and these costs should be addressed during the development and adoption phases. A second study highlighted the benefits of conducting voluntary code-related programs prior to full-scale implementation of a new code. In particular, the study noted that such programs could ease adoption of the new code.

3.3.3 Code Implementation Phase

Simplification was an especially important consideration in easing the implementation of residential building energy codes. The benefits of developing a simple code and simple-to-use tools for complying with and enforcing the code were highlighted in studies of the MCS.

Compliance and enforcement benefited from improvements to software tools such as WATTSUN. One study recommended devising such tools for use by residential building subcontractors, as well as code officials. Another study recommended developing software tools to assist with the tracking of reviews and inspections during enforcement.

In one study of the WSEC, it was suggested that qualitative measures could be used to evaluate code compliance and energy savings. Such measures could help simplify the compliance and enforcement processes.

One study examined the combined effect of education, training, and code enforcement support programs on energy code enforcement in Washington. It concluded that residential energy code compliance levels in Washington appeared to be higher than in other states as a result of these activities. The study noted that both builder and code enforcement support were important for making energy codes work over the long run.

Several specific *training and education* needs for residential building energy codes were identified. One evaluation noted that code officials mentioned four areas where improved training and education were needed: 1) better education packages for owners and builders, 2) increased radon monitoring and training, 3) better identification of window specifications, and 4) special training for subcontractors that would be available outside regular working hours. The development of special tools to meet the needs of subcontractor training was recommended.

Another study emphasized the need for continued training of code officials, builders, and subcontractors. This would help ensure that implementation continued smoothly and effectively.

One study of new residential construction compliance recommended conducting efforts to *increase awareness* about energy efficiency. Increased public and building community awareness of the benefits of and means to increase energy efficiency would improve compliance.

A few studies noted the importance of *review and field inspections* in the residential building energy code implementation process. In particular, there were recommendations for consistency in the review and field inspection processes and for ways to reduce duplication of efforts. As noted earlier, development of software for recording plan review and inspection activities was recommended.

In the studies we reviewed, *cooperation and coordination* were mentioned occasionally as important issues related to implementation of residential building energy codes. One study stressed the importance of learning from utilities that had participated in utility code-related programs and bringing their input into the code development and implementation processes.

3.4 COMMERCIAL BUILDING CODE PROGRAMS

This section discusses findings that focused on commercial building energy code programs. Only nine of the evaluations we reviewed addressed commercial building studies exclusively, so the breadth of information available was limited and its generalizability was questionable. As with the residential program evaluations, studies from the Pacific Northwest comprised the majority of the studies.

3.4.1 Code Development Phase

Simplification of the code during development was an important theme in several commercial building code program evaluations. In part because of the complexity of commercial buildings, the need for simplicity was more pronounced and harder to meet than for residential building codes. The studies usually focused on making the code less cumbersome for code officials to interpret and for architects and engineers to understand. One study noted that the existing code lighting requirements should be revised completely to permit a simpler compliance approach. Another study recommended development of easy-to-use enforcement tools for code officials.

Several specific steps during the development process were identified that could facilitate code *compliance and enforcement*. In one study of an Oregon code, two steps to ease compliance and enforcement were identified and both, consistent with the previous discussion, involved simplification. One step was to design lighting budget worksheets that each jurisdiction would use to increase compliance and minimize the effort required for code officials to verify compliance. Second, several code officials expressed the desire to simplify the code to make it more understandable and easier to comply with and enforce.

Several of the commercial building code program evaluations mentioned *training and education* during code development as important factors in program success. Training and education of design professionals and the building community were recommended along with design assistance, financial incentives, and quality control as part of a well-integrated package that would contribute to program success. One study noted that a training program should be developed for commercial building operators on efficient operation and maintenance of existing nonresidential buildings. This effort was expected to have a large payoff as a supplement to ever more energy-efficient building codes for new buildings.

One study recommended integrating into the code development process an on-going process of *data collection* on the new code. Information from this feedback could be inserted into the development process, hopefully leading to improvements to the existing code.

3.4.2 Code Adoption Process

Few issues were raised specific to the commercial building energy code adoption process. One issue that was brought up was the need for efforts to provide *education* and increase public *awareness* about energy efficiency. A few evaluations noted that these steps would help facilitate commercial building energy code adoption, but this would apply to residential building codes as well.

3.4.3 Code Implementation Process

The need for code *simplification* was a major issue associated with implementation of commercial building energy codes. The general lessons about the need for code simplification were amplified with commercial buildings because of the inherent complexity of the buildings themselves.

In some of the evaluations, officials complained that code language was complex and ambiguous, and hindered the inspection process. In some cases, the lack of understanding among the professional community and the lack of understanding and enforcement by building officials resulted in low compliance. Commercial building energy codes were reported to be too complex to be checked in a commercial building in the short time the building inspectors had available for each building. Generally, the recommendation was that either code enforcement should be enhanced with adequate resources and tools for reviewing commercial buildings or the code should be revised to make enforcement simpler and interpretation less difficult.

Compliance and enforcement were important implementation issues identified in many of the commercial building program evaluations. Recommended remedies for compliance and enforcement problems are discussed in the following paragraphs.

As noted earlier, building energy codes in general had a lower compliance and enforcement priority than health, safety, and fire codes. One study pointed out factors related to this issue. It noted that lack of understanding of the energy code was a major barrier to enforcement and compliance. Most architects and engineers viewed energy codes as either a low priority or cumbersome to use. Second, field changes made by builders concerned with price or ignorant of energy code requirements undermined the code-compliance efforts. Between stages of the building process (plan reviews, calculations, and field inspection) many changes could occur which might affect compliance. Third, code officials often lacked training or the educational background required for understanding all code provisions. This often reinforced the tendency to focus on health and safety issues, leaving energy portions of the building code as "optional" or as a "guideline" rather than a minimum standard.

Another general compliance and enforcement process issue was identified. It was related to where the responsibility resided for code compliance. In general, commercial building designers, engineers, and architects did not believe that they were responsible for ensuring energy code compliance during either design or construction. In addition, subcontractors often were not very knowledgeable about code requirements or compliance and many commercial buildings were treated as a collection of subsystems. One study specifically recommended educating architects, designers, engineers, and subcontractors on code requirements. It also noted that the building prime contractor and owner needed to take responsibility for ensuring that the energy code was addressed by all members of the building and design team. In addition, it recommended providing adequate resources to code officials to enforce the code and modifying the code to simplify enforcement.

One study provided the following findings about commercial building energy code enforcement in Washington: 1) the insulation and glazing requirements were being enforced relatively well, but other parts of the code were not; 2) most jurisdictions reviewed the commercial building plans themselves; 3) the quality of the plans submitted was the most important factor in determining the amount of review time needed; 4) the costs of the current energy code enforcement averaged approximately 5% of the overall cost of building code enforcement; 5) more on-site training for officials would improve code compliance; and 6) code officials thought that Washington's Energy Hotline was a useful tool.

Another study of the Washington code provided several implementation findings. For code officials, it was found that 1) most people who were responsible for the commercial building energy code did not feel adequately trained or educated to enforce it; 2) most people involved in code enforcement had been in their position a long time and planned to stay until they retired; 3) most building enforcement personnel had had some college education, but only half had obtained a degree; 4) most building code officials had come from the construction trades; and 5) code officials enforcing the commercial energy code were a dedicated group of people who felt a great deal of responsibility toward their jobs.

Another evaluation recommended that each building owner hire an inspector with special expertise in areas such as concrete, ductile moment-resisting frames, and highstrength bolting, during specific construction phases to oversee code compliance. Experts with energy-efficiency and materials expertise could be included.

An evaluation of the Colorado commercial building energy code concurred with other studies in recommending ways to improve enforcement and compliance. They included 1) developing standard tools to be available to local building code officials for checking compliance, 2) reviewing and simplifying the lighting portion of the code to find ways to simplify checking compliance, and 3) continuing and improving the state training and technical assistance program for local enforcement officials.

One study specifically investigated the effect of field changes on compliance. In Washington and Oregon, large buildings had poor levels of envelope compliance because of the high amounts of glazing. Although lighting power densities (LPD) were regulated and reviewed in most jurisdictions, inspections were rare. Field changes that increased lighting levels were the largest single cause of lighting non-compliance. It was found that field changes were often carried out by building owners for budget or aesthetic reasons.

A study of the Minnesota State Building Code for Small Commercial Buildings also flagged compliance with lighting requirements of the code as a particular problem area. It was noted that the lighting portion of the code needed to be made simpler and clearer and that there was a need for more uniform enforcement supported by adequate funding.

Another evaluation pointed out that inadequate uniformity across code jurisdictions was a problem in commercial building energy code enforcement. Inconsistencies led to low compliance levels because of the uncertainties it created for builders. Additional funding was recommended by one study as a way to increase enforcement consistency. Another study recommended developing checklists for code enforcement so that the process could be more uniform and simpler for code officials, building owners, and their design teams.

Increased *training* was identified as a common need by many of the evaluations. Inadequate training of code officials on various aspects of the code and ways to administer enforcement was a problem noted in several studies. As noted earlier, inadequate training of architects and engineers on the commercial building energy code caused low compliance, in general, because these professionals did not take code compliance into account adequately in their designs. One study suggested the use of video tapes as a viable alternative method for training architects and engineers on code compliance.

Because of the significant energy impacts of lighting in commercial buildings and the frequent difficulty in understanding and implementing lighting code requirements, one evaluation focused on this topic. It recommended taking special steps to provide training and technical assistance on the lighting portion of the commercial building energy code.

Some evaluations noted that a lack of training of building professionals and code officials frequently impeded compliance when a new code took effect. It often took two to three years to overcome this initial difficulty. A thorough training program was recommended as a way to diminish the time required to successfully make the transition.

Specific issues involving *education and awareness* about commercial building energy codes were raised in a few evaluations. Several evaluations recommended providing broad education to code officials on the code itself and code-related issues.

Increasing public awareness about energy efficiency and building codes could create more informed demand on the part of commercial building owners. Several studies also suggested educating building operators on energy-efficiency requirements and efficient building operation. One study in Seattle, for example, found that operation was a major factor that impacted energy savings in large commercial buildings. Therefore, the study recommended educating building operators on monitoring and operating the systems installed in their buildings to provide maximum energy efficiency.

As mentioned earlier, weaknesses in the *review and field inspections* process could reduce actual energy savings realized from commercial building energy codes. Failure to conduct adequate plan reviews specifically led to lighting energy code compliance problems. Recommendations to alleviate these problems included training architects and engineers on the code, having the building owner hire a special inspector to oversee different operations, and increasing code official staff expertise to include experience in building trades, mechanical systems, electrical and plumbing systems. Another study recommended developing and implementing a standardized and well-defined process of review and enforcement that could deal with the issue of field changes. As noted earlier, field changes often increased the number of lighting fixtures in commercial buildings and they were found to be the major reason for non-compliance.

Technical assistance and design assistance were identified as important factors during code implementation in a few commercial building code evaluations. One study recommended funding lighting specialists at the state level to assist in the review of lighting system plans and in the inspection of installed lighting systems. To remedy the problem of field changes mentioned earlier, design assistance was recommended in one study as a way to help forecast field changes and incorporate them earlier in the design stage or at the early stage of the building process.

Finally, one study identified the need to establish *cooperation and coordination* among key stakeholders as a way to promote compliance. It was recommended that mechanisms be established to facilitate cooperation and coordination among code officials, building professionals, and trade allies. As noted in the discussion of residential building codes, another study emphasized the value of involving utilities in the entire code process, from development through implementation, to benefit from their expertise if they had engaged in DSM programs. It also recommended collaboration with state energy offices.

4.0 EVALUATION METHODOLOGY FINDINGS AND RECOMMENDATIONS

This chapter provides methodological findings and recommendations from the evaluations reviewed for this study. Because the code and utility program evaluation methods were often similar, this chapter does not distinguish between these two sets of evaluations. An overview of the approach is presented first, followed by sections discussing findings from residential building programs and then from commercial building programs.

4.1 INTRODUCTION

We used the same strategy as in the preceding chapters to identify methodology issues that appeared most frequently across the complete set of code and utility program evaluations. Prior research and experience helped guide the choice of issues to highlight. The selected methodology issues discussed here are the following, listed in order according to how often they appeared in the evaluations: 1) data collection, 2) evaluation design, 3) data analysis, 4) baseline and control group definition, and 5) costs and cost-effectiveness. Because the specific methodology issues raised differed between the residential and commercial building program evaluations, we report methodology findings separately by building type.

Across all the evaluations, 75 (63%) discussed data collection. They included different methods such as site interviews, follow-up consumer and builder surveys, focus groups, acquisition of billing data, and market research.

Evaluation design was addressed in 53 studies (44%). Data analysis techniques and issues were mentioned in 51 evaluations (43%). The most common generic energy analysis techniques used were econometrics methods, billing data methods, and engineering estimates. Some of the studies addressed analysis issues such as free ridership, free drivership, and market transformation.

- *Free riders* are energy-efficiency program participants who received a program incentive, but who would have taken the action even without the incentive. Free rider energy savings should not be attributed to the program. Accounting for free riders reduces the energy savings attributable to the program.

- *Free drivers* are program participants and non-participants who installed program efficiency measures or additional measures at no cost to the program. The free driver energy savings should be credited to the program. In a non-participant group used to estimate baseline energy efficiency levels, the free driver energy efficiency improvements should not be included in baseline energy efficiency changes because they are indirect impacts of the program. Accounting for free drivers increases the energy savings attributable to the program.
- As noted earlier, *market transformation* seeks to change the market in fundamental, long-lasting ways, achieve widespread changes, and reduce program costs. Free drivers are an important market transformation component.

Forty evaluations (34%) mentioned baseline and control group definition as a key methodology issue. In DSM program evaluations, buildings that do not participate in a program can often serve as the control group for estimating program effects. Because codes are intended to apply to all buildings of a certain type, however, code program evaluations typically lack a natural, non-participant group for comparison. Consequently, a baseline must be defined relying on conditions prior to the code and projected into the future. Because the baseline and control groups served similar purposes in the evaluations, defining them was considered as a single issue.

Finally, program cost and cost-effectiveness issues were discussed in 33 evaluations (28%).

4.2 FINDINGS BASED ON RESIDENTIAL BUILDING PROGRAM STUDIES

This section discusses the methodological findings and recommendations that emerged from our review of residential building code and utility program evaluations. They are presented in the order based on how often they appeared across all the evaluation studies (for both residential and commercial buildings) that we reviewed.

4.2.1 Data Collection

Fifty-seven percent of residential building program evaluations raised data collection issues. Data collection methodological concerns in residential building program evaluations related primarily to the collection of qualitative and descriptive information. Some issues arose about collecting energy consumption data, but these are discussed in subsequent sections. The major data collection issues involved the design and conduct of surveys, follow-up interviews, focus groups, and site interviews of home builders and program participants.

In one study, housing starts data were collected on a regular basis to permit analysis of the effects of the DSM program being evaluated. Similar data would be needed for most impact evaluations of residential building programs.

Some evaluations included a survey to assess participants' perceptions of the program and identify ways to improve future program participation. One study conducted a survey of home builders to develop an evaluation baseline, determine home builder perceptions regarding energy efficiency and their reaction to the DSM program (SGC), determine their willingness to participate, and develop suggestions on improving future participation.

One study collected billing history data and sub-metered site data to estimate space-heat performance of single-family homes using the Princeton Scorekeeping Method (discussed later). It found that reliability of the results depended on sample size and length of billing history. Another study focused on the need to screen data when using this method to derive estimates of weather-sensitive loads. As discussed later, the presence of heat pumps, air conditioning, and wood heating was problematic when using this method. To solve such problems, the study found that it was necessary to screen out households using such equipment or to conduct special analyses of them.

Other evaluations used on-site collection of both qualitative and quantitative data. Some conducted surveys and interviews of occupants. Some collected data pertaining to the physical characteristics of the home and equipment and appliances, equipment operating schedules, and occupancy. In some cases, the data were essential for calibrating models used to estimate energy savings.

Customer-specific consumption data were collected in one study to estimate average energy consumption using conditional demand analysis (CDA). In addition to actual customer-specific consumption information, the CDA technique required collecting weather data, customer-specific demographic information, dwelling unit characteristics, and DSM program implementation data to develop the conditional demand load impact estimates.

Issues about the timing of data collection arose in several studies. In one, builders suggested that surveys aimed at them would be best implemented during the slowest building season for optimal response. This study collected survey data, along with energy consumption data, to assess program implementation and administration issues, customer satisfaction, and program impacts. Three surveys were implemented to get billing data. The study noted that the survey did not cover specific areas such as supplemental heating fuel use.

One study noted a particular problem with data collected in new homes. Energy consumption data collected when occupancy begins may not reflect the long-term consumption habits and needs of the home owners. The study recommended revisiting the new homes after a year to revise energy consumption data.

One study made specific recommendations reflecting the types of data typically collected. It emphasized that it was necessary to collect data to establish a market baseline. Second, it recommended that data on attitudes and values be collected and assessed. Third, it noted that home sales data should be tracked.

4.2.2 Evaluation Design

About 29% of residential building program evaluations discussed evaluation design issues. Note that this proportion is considerably smaller than for commercial building program evaluations, reflecting the fact that analyses of residential buildings and programs are usually considered to be simpler than those for commercial buildings and programs. Most of the discussions addressed energy analysis methodologies and related findings, which are presented in a later section.

In one study, the small size of the sample hindered a statistical analysis to determine key determinants of program performance. It was recommended that a larger data set be used to learn more about the differences in results.

Several studies suggested using multiple analysis techniques and approaches. The study by Florida Power & Light (FPL), for example, reported on seven related evaluations as components of its overall evaluation design.

One study discussed a quasi-experimental design to evaluate a conservation program. A treatment group and a non- participant group were used. There were seven basic steps: 1) drawing a stratified sample of participants and non-participants, 2) designing and implementing a telephone survey, 3) performing a market penetration analysis, 4) weather-normalizing sample billing histories, 5) developing a multivariate regression model to estimate energy savings, 6) performing energy savings analysis, and 7) performing a cost-effectiveness analysis.

In another study, a comprehensive analysis plan was developed to guide the evaluation of the energy impacts of a model conservation standard. The plan included a set of generic procedures that addressed all aspects of the evaluation from experimental design, through data collection and analysis, to the evaluation of energy savings realized by the individual conservation measures in each building participant and non-participant pair. Emphasis was placed on the unique aspects of the analysis plan that included the calibration of the DOE-2 hourly simulation model used with the measured performance data under conditions with and without the energy-efficiency features.

4.2.3 Data Analysis

Issues related to data analysis methodologies were raised or implied in 38% of the residential building program evaluations. This section discusses the analytic techniques used in the studies and then summarizes recommendations for improving the analyses.

One of the most commonly used methodologies for analyzing residential energy use is the Princeton Scorekeeping Method (PRISM). This technique relies on the use of billing data acquired from samples of homes. The technique allocates energy consumption from the billing data by using weather data to estimate the temperature-dependent and independent portions of the consumption. The technique was originally devised to perform weather adjustments to measured energy consumption.

One study used PRISM to normalize electric utility bills to estimate weather-adjusted annual space heating electricity use. Occupant surveys were used to control for non-climate influences on energy use. Multivariate regression models were developed from these data to identify the amount of electric space heating savings that could be attributed to the MCS. It was found that PRISM overestimated space heating in the single-family residential (SF) sector, and that it also probably overestimated space heating among the multi-family residential (MF) buildings analyzed in this study, particularly when occupied units were losing heat to vacant units.

PRISM was used in another study to estimate total energy consumption and space-heating consumption for two sets of homes. To adjust for misallocations of energy use between the heating and baseload components of PRISM estimates, four alternative adjustment factors were developed and applied to PRISM estimates using all bills, only one year of bills, and one year of bills weather-normalized to the same time period. It was found that PRISM misallocated a large fraction of energy use between baseload and heating load, probably because some portion of baseload consumption was season-dependent. This finding was confirmed by two other studies. It appeared that this misallocation was higher for residences that were more energy-efficient and this resulted in an underestimate of energy savings. Further assessment was recommended.

Another evaluation presented findings about other limitations of using PRISM. First, the presence of heat pumps had the potential to introduce significant errors in the estimates from PRISM. Second, the use of PRISM in the presence of air conditioning was also problematic because, where such equipment was used, temperature-sensitive loads assumed a bimodal shape that violated the basic assumptions of PRISM. To resolve this problem, only non-summer consumption records were used in the PRISM models. Wood heating was problematic because it violated the linearity assumption of the PRISM model. A precaution was taken to exclude from the study sample all households that reported wood as their primary space heating fuel. It was recommended that consistent screening procedures be applied to all billing records before the application of PRISM.

One study was designed specifically to examine the feasibility and limitations of using an evaluation approach based on PRISM, as well as to provide a preliminary estimate of the performance of SGC residences. The study found that results were subject to uncertainty due to 1) small final sample size upon which the estimate of space heat consumption was based, 2) short billing histories (sometimes less than one year in length), 3) few sub-metered sites available for estimation of the adjustment model for SF homes, and 4) no sub-metered data available for estimation of an adjustment model for MF residences.

In another study using PRISM, submetering of unit end-use loads was recommended to facilitate the calibration of PRISM parameter estimates. Further study was recommended to synthesize the engineering and econometric approaches to savings analyses.

In other cases PRISM was used in combination with other analysis programs. One study started with a PRISM analysis of on-site survey and billing data. A parametric simulation using the CALPAS3 software was then done to estimate the appropriateness of the modeling assumptions.

Another study combined load research, billing data, and engineering estimates to evaluate a new home construction program. The study applied a quantitative program impact analysis involving the estimation of a discrete-choice participation model and a conditional demand model of home energy use to estimate program-induced energy savings. One phase involved estimating the discrete choice participation models and preliminary energy savings models, which used billing data. PRISM was used to normalize the billing data. The primary purpose of the discrete choice participation models was to control for self-selection and free ridership in the energy savings models.

A number of residential building program evaluations used more sophisticated techniques to analyze energy use and energy savings. They frequently combined analytic techniques. One study integrated several impact evaluation techniques using engineering estimates, load data, and billing analysis to produce a robust estimate of savings for a residential new construction program. This study found that it was difficult to differentiate the effect of equipment from the effect of building components on energy consumption.

Another study conducted an impact evaluation to measure the incremental cost, compliance, and electricity savings. Three primary methods of analysis were used in evaluating compliance: 1) physical data were collected from on-site inspections of selected housing units, along with data from the building plans and interviews of the building inspectors; 2) blower door tests were performed; and 3) energy-use simulations were performed for each of the housing units to determine estimated annual energy use for space heating. The SUNDAY computer model was used to estimate the effects of MCS-related measures on annual electricity consumption for space heating in individual housing units.

One study used extensive data collected from participants and non-participants including billing, site audit, tracking system, and end-use and whole-premise load data to develop baseline and energy-efficient home engineering simulation models. MICROPAS3 computer models were calibrated for both baseline and energy-efficient homes. Using these models, customer-specific engineering adjustment factors were developed by running minimum and maximum parameter values for key selected parameters. Combining the participant data with the adjusted factors allowed site-specific and measure-specific impacts to be calculated. Net-to-gross savings issues were also addressed. The statistically-adjusted engineering analyses were used to produce realization rates by customer segments and climate zone.

Another study used a CDA technique to estimate the load impacts. Using actual customer-specific consumption data, the CDA technique can statistically estimate average energy savings from specific conservation measures. In addition to actual customer-specific consumption information, the CDA technique utilizes weather data, customer-specific demographic information, dwelling unit characteristics, and program implementation data to develop the conditional demand load impact estimates. Corrections for serial correlation and heteroscedasticity were made to get consistent estimated standard errors of the coefficients. The model with no corrections for serial correlation and heteroscedasticity produced higher load impact estimates for high-efficiency space heaters and improved wall insulation when compared with the corrected model.

Another study applied a similar approach. It used a discrete-choice participation model and a CDA model of home energy use to estimate program-induced energy savings. PRISM was used to normalize the billing data. The primary purpose of the discrete choice participation models was to control for self-selection and free ridership in the energy savings models. The final phase of the project was still underway when the report was written; it involved the collection of additional information to be used in estimating energy savings resulting from the Good Cents Program, which incorporates information from energy audits performed by the evaluation team and a load research experiment being conducted by CMP.

Another study used building simulation models to evaluate the impact of an energy-efficiency program and an energy-efficiency rebate program. Several analyses were conducted in this MF building program evaluation. First was an implementation analysis and database review for program participants. Second was an impact evaluation including energy and electrical demand impacts. The primary analysis technique for the impact evaluation was building simulation modeling of participating new residential buildings and their heating, ventilation, and air-conditioning (HVAC) systems to estimate annual savings estimates for each year's program participants. Third, short-term lighting metering was conducted during site visits at participant sites. Fourth, a post-period billing analysis was conducted on a fossil-fuel-heated MF participant. This analysis had the advantage of being conducted at a site that had a very closely matched control group in a building in the same complex. Detailed engineering simulations were completed using MICROPAS 4.2, and savings estimates were then calibrated with DOE-2.1D using hourly regression calibration factors. Final savings estimates were disaggregated to the program year, residence type, and rate/revenue code. The simpler and less input-intensive simulation program, MICROPAS 4.2, enabled the evaluators to move beyond the use of "prototype" buildings, to a methodology where all program participants could be evaluated individually.

Another study compared statistical and engineering methods for evaluating residential programs. The study assessed the consistency of energy savings estimates between the two methods. Both statistical and engineering models were used to estimate weather-adjusted savings using energy bills for a sample of participant and non-participant customers. The engineering model used was CALRES, a residential building simulation software tool. The statistical model used regression analysis of actual customers' energy bills. The baseline used was a revised building code.

Another study combined three analysis methodologies: conditional demand analysis to estimate gross energy impacts, load analysis methodology to estimate gross load impacts, and builder survey analysis to estimate free rider and free driver rates for the program.

A study by FPL that reported on seven related evaluations described several different analysis methods:

- impact evaluation: Models were developed to estimate program impacts based on pilot program participation and a thorough evaluation of baseline home features. Impacts were calculated based on the difference in energy or demand between baseline and BuildSmart homes. Cooling and heating impacts were derived using DOE-2 model simulations and adjusted using statistical analyses of end-use metering (EUM) data. Domestic hot water (DHW) impacts were reevaluated using models designed specifically to identify heat recovery unit (HRU) energy and demand effects.
- market evaluation: Surveys of builders provided baseline information regarding building practices and self-reported willingness to participate in the BuildSmart program, and helped assess satisfaction levels of pilot program participants. Surveys of 950 occupants of new homes were used to assess new home buyers' awareness of energy-efficiency options and how this affected their home purchase decisions.
- inspection evaluation: Two data sets describing building characteristics from code compliance forms submitted to building departments were used to establish baseline building features.
- code and rating system evaluation
- cooling upgrade evaluation: Dwelling and occupant characteristics, such as the effect of glass-to-floor ratio, were statistically analyzed using the EUM data to isolate factors that affect cooling energy and demand.
- heating upgrade evaluation
- DHW evaluation.

An important conclusion drawn from the study was that the submitted energy performance index (EPI) alone could not be used effectively to determine the energy efficiency of the inspected home. When energy code forms submitted to local jurisdictions were compared with the inspected EPI's, nearly one-fourth resulted in utility-inspected EPIs that did not comply. Some inspected homes had construction features (such as ceiling insulation levels, glass-to-floor ratios, ceiling fan credits, and cross-vent credits) that were not accurately recorded on the submitted energy code forms. Many of these features would have increased the submitted EPI, at times leading to code violations.

One study described the development of a method used to extrapolate results from a survey-based engineering model and provided participant-specific engineering estimates, based on program participant information, for use in the building analysis. This approach maximized the use of available data for improving the impact estimate of residential new construction programs (RNCPs). The evaluation used three intermediate analysis steps to achieve the integrated impact analysis. The first was the Engineering Analysis, which estimated the energy and demand impacts in the absence of participants' behavioral responses to the program measures (such as snapback[a] and free-ridership effects). Second was the Statistical Billing Analysis, which produced estimates of kWh realization rates and accounted for participants' occupancy patterns and behavioral responses to program measures, as well as changes in baseline energy usage through the use of a comparison group of non-participants. Third was the Load Analysis. This step produced end-use-specific estimates of demand (kW) impacts and diversity factors. These estimates were used to calibrate the engineering models to better simulate actual usage patterns and estimate coincident system peak demand impacts. Finally, the Integrated Analysis combined outputs of the intermediate analyses to produce a comprehensive, systematic estimate of the energy and load impacts, by measure, for all program participants.

Several recommendations for improving the analyses were presented in the evaluations that we reviewed. Most of the recommendations focused on ways to improve the energy analysis techniques.

(a) Snapback, or takeback, refers to the often observed behavior of consumers to change their behavior in response to efficiency improvements in ways that increase comfort and other amenities but increase energy consumption, partially offsetting expected energy savings.

A study that used a discrete-choice participation model and CDA model recommended that 1) the survey instrument include more specific questions relating to supplemental heating fuel, 2) builder surveys be implemented during the slowest building season, and 3) data used in the statistical model include the average price of electricity across households.

One study recommended that future efforts focus on assessing the heating load differences caused by furnace, insulation, and window efficiency upgrades because the combination of these factors appeared to have produced an unrealistically low savings estimate for gas-heated homes.

One study that evaluated 10 residential new construction programs made six recommendations for data analysis activities that should be heeded in future studies: 1) model market processes so their role in energy-efficiency changes can be understood, 2) determine the relationship between attitudes and behavior and account for their effects, 3) compare pre-program and post-program market survey and billing data, 4) perform multivariate regression with control groups from outside the service area, 5) simulate market transformation effects so they can accounted for in the energy savings estimates, and 6) compare multiple methodologies.

An energy analysis methodology recommendation that was common to several studies was to apply and compare multiple methods. Generally, studies found that outputs from one analysis could be applied in other analyses, and multiple methods permitted triangulation to arrive at the best estimate of consumption and savings. One study specifically recommended considering use of 1) an enhanced PRISM model, 2) cross-sectional regression models, 3) combined cross-sectional regression and engineering simulation models, and 4) analysis of submetered data.

In a number of studies the issues of participation and free ridership/free drivership were considered in the analysis to evaluate program impacts. The issue of program participation came up in two studies. One study surveyed builders to determine their willingness to participate and suggested developing an appropriate strategy for stimulating future participation (for example, using focus groups). Another study applied a discrete-choice participation model to assess participation. The study applied a quantitative program impact analysis involving the estimation of a discrete-choice participation model and a conditional demand model of home energy use to estimate program-induced energy savings.

Three residential building program evaluations mentioned free ridership and free drivership. One study mentioned earlier used a discrete-choice participation model to control for self-selection and free ridership in energy savings analyses. One evaluation suggested that estimates of free ridership should be in either the process or impact evaluation, depending on whether the estimate was based on a comparison study or a survey, respectively. Another study used builder survey analysis to estimate free rider and free driver rates for the program. The study found that RNCPs can have important free driver effects. For example, by raising the energy efficiency levels home buyers demanded in new homes, the program could indirectly cause homes that did not qualify for the program to be built to higher energy efficiency levels than would have been achieved in the absence of the program.

Another study analyzed a home builder survey to estimate free rider and free driver effects of a residential new construction program for a utility company.

4.2.4 Baseline and Control Group Issues

About 34% of the residential building program evaluations mentioned issues related to baseline and control groups. The terms were not used consistently across the evaluations, but the studies were consistent in identifying the need to establish reasonable conditions against which program effects could be measured. Most of the studies recommended that the baseline energy consumption be determined accurately because inaccuracies would lead to incorrect estimates of energy efficiency gains for residential buildings. Different studies used different methods to determine the baseline.

One study used extensive data collected from program participants and non-participants including billing, site audit, tracking system, and end-use and whole-house load data to develop a baseline. Another study relied on interviews of code enforcement personnel in adopting and non-adopting jurisdictions to establish baseline values for enforcement and construction practice.

Another study assumed that the baseline costs, building practices, and energy efficiency found in pre-code homes would have continued in the absence of the code. This approach allowed the evaluator to use current-practice code enforcement costs, energy code compliance rates, and the energy consumption patterns of recently constructed homes as a baseline or control for the code impacts.

Another study found that baseline definition and tracking was very important to assess the impact of program spillover.[a] It was necessary to track changes in construction practices and the cause for the changes on a regular basis. The study recommended conducting quick builder surveys that addressed how current practices were changing and the motivations for these changes.

One study highlighted the difference between a baseline that reflected minimum code requirements and one based on current construction practices. In actuality, some houses are built below code requirements and some exceed the requirements. This study used these alternative baseline definitions as a key variable along with the number of housing units built and the energy savings per unit to estimate total energy savings.

One study assessed current market conditions and detailed baseline building practices. Part of the assessment included isolating factors that influenced energy efficiency choices by builders, architects, home buyers, and other major market participants. This study found that building codes were a good proxy for baseline building practices for all fossil-fuel heated homes and for electrically heated homes under 1,900 square feet.

4.2.5 Costs and Cost-Effectiveness Analysis

About 20% of residential building program evaluations addressed cost and cost-effectiveness issues. For most evaluations, the methodology used to assess cost-effectiveness was to estimate incremental time and cost requirements.

One study used an accounting cost approach to estimate the incremental time and cost of code enforcement. The incremental time of the enforcement personnel was measured and then multiplied by the cost of an energy-code specialist. However, because of limited resources available for this study, opportunity costs were not quantified.

One study relied on computer software to determine furnace and air conditioner characteristics. Outputs from the software provided the information needed to estimate expected energy costs for heating and cooling.

(a) Spillover refers to indirect effects of a program on non-participants. Usually such effects are positive, i.e., they produce indirect energy savings.

One study evaluated state energy efficiency standards. The study used a mail survey of home owners and site survey data in conjunction with a conditional demand analysis to provide mean estimates of end-use energy consumption. Cost-effectiveness calculations included estimated energy use and the incremental time and cost burdens arising from code enforcement activities.

In a related study, one of the objectives was to estimate the additional time and cost associated with code enforcement during plan reviews and inspections, as well as additional administrative time required by a new code. A combination of reporting and direct interviewing techniques was used to establish the effects of code implementation.

One study examined the economic costs and benefits of developing and implementing a residential energy code. The analysis was done in three investigative steps: 1) compiling data on development and implementation, 2) estimating energy savings, and 3) analyzing the cost per kWh of energy saved. Two methods were developed to calculate energy savings. One relied on the existing code level to determine a baseline. The second compared actual energy consumption for a sample of houses built to the new code with a sample of homes built where the new code was not in effect. Estimating the cost per kWh was done using three approaches: cost to the utility, total societal cost, and value of conserved energy. The first two relied on different assumptions about the discount rate. The third was estimated by running a model, the Integrated System for Analysis of Acquisitions (ISAAC).

4.3 FINDINGS BASED ON COMMERCIAL BUILDING PROGRAM STUDIES

This section discusses the methodological findings from our review of commercial building code and utility program evaluations. Findings are presented from evaluations that addressed only commercial building programs and studies that included both commercial and residential building programs. Findings are presented in the same order as in the discussion of residential building programs.

4.3.1 Data Collection

Issues related to data collection were mentioned in 50% of commercial building program evaluations.

On-site surveys were a common data collection procedure. One study that conducted surveys of new commercial buildings found that not all building data could be collected readily on-site (e.g., chiller efficiencies and glazing shading coefficients) and there was often an inadequate definition of some data before they were collected. This evaluation recommended that the data be verified through a post-survey follow-up with the project's architect or engineer. For some equipment, model numbers could be obtained and manufacturer catalogs used to obtain the required efficiency information. To ensure that the proper data were collected, the study recommended that data requirements be coordinated with proposed or existing program designs.

Another study used an integrated approach (billing data and engineering simulation) to evaluate new commercial buildings. On-site surveys were conducted and the collected data were fed into the engineering analyses. Another study found that on-site surveys were important to improve estimates of energy savings from engineering estimates and econometrics estimates. Using data collected on-site, simulations could be used to compare as-built conditions with as-occupied conditions.

One study stressed the need to improve data quality. The study suggested including data collection site visits, one-time measurements, and controlled testing. In addition, the study noted that documentation of building features and operating characteristics should be a continual process and not a one-time effort. Finally, the study recommended that the data be promptly and continually reviewed rather than having lengthy delays before review.

A study of a utility commercial building new construction program used participant and non-participant data. Mismatches between the participants and non-participants limited the study results, leading to the recommendation to choose a larger sample as well as improve the non-participant selection process.

A similar study collected data from a statistically derived sample of participants using a telephone survey of decision-maker organizations and on-site surveys to collect detailed information about the sample buildings. On-site data collection permitted verification that specific measures were installed. Among other recommendations, the study noted that non-participants needed to be included in such evaluations, short-term end-use data should be collected and used, provisions should be made for the cleaning and maintenance of data, and sample selection should be done taking into account the types of measures installed and their distribution.

In one study, unique types of data were collected to assess the compliance and enforcement processes. First, mail surveys of design professionals and code officials were used to determine their opinions, knowledge, and practices regarding the energy code program. Second, design professionals were asked how they implemented the energy code, and enforcement officials were asked how they enforced it. Personal characteristics (title, job experience, and jurisdiction), opinions of services provided by other organizations, and knowledge of specific energy code provisions were examined. Members of each group were asked to assess their colleagues' understanding of key provisions. Third, on-site inspections were undertaken to see how the energy code was being implemented in the field.

Another code program evaluation revealed that interviews and surveys of people involved with the program administration and implementation provided key information to understand program functioning and effectiveness. A related study found that follow-up telephone calls combined with key informant interviews were a strong strategy to supplement data previously collected by mail surveys. This helped fill any gaps that might have occurred in the survey.

A progress evaluation of a code program revealed that interviews and surveys of people involved with the program administration and implementation could be key sources of information for understanding the program. These data helped identify means to improve the program's operation.

Another study addressed a comprehensive approach that collected participant and non-participant building data. It found that the non-participant buildings did not closely match the participant buildings by type, size, and other energy-related characteristics. This diminished the ability of the study to interpret and attribute results. The study recommended choosing a larger sample as well as improving non-participant selection. The study also suggested including greater detail in the collected data.

One study that used an integrated approach (billing data and engineering simulation) to evaluate new commercial buildings included site surveys to collect on-site data. Engineering analyses were conducted then using the data collected on-site.

4.3.2 Evaluation Design

About 45% of evaluations in this category mentioned or alluded to evaluation design issues. As noted earlier, this high proportion, compared with residential building program evaluations, probably reflects the relative complexity of analyzing commercial buildings and associated programs.

One study of a state code program analyzed interview and on-site inspection data to determine the degree to which actual construction reflected energy code requirements. Attitudinal information about the energy code was collected from design professionals and code officials. Qualitative data from design professionals and enforcement officials were used to assess code compliance and enforcement. Finally, on-site inspections provided quantitative and qualitative data on how the energy code was being implemented in the field.

One study made a useful recommendation regarding evaluation design. It noted that efforts should be made to persuade non-participants to participate in the study because their information can be used to better understand program participation and penetration rates. To promote their cooperation, it is necessary to explain to non-participants the benefits of data collection and the program analysis.

One study provided a useful evaluation design framework to evaluate design assistance programs for new commercial buildings. The framework used case studies and included the following steps: 1) contact participants and collect utility data, 2) review the utility data and the energy-efficient measures installed in the buildings, 3) conduct on-site visits to compare the design energy-efficient measures with what was actually installed, 4) conduct as-built computer simulation analyses, 5) interview the project participants, 6) estimate program impacts and assess important process issues identified for each case study. This methodology allowed evaluators to judge the cost-effectiveness of energy conservation measures delivered in the program, attitudes of participants, and the value of providing the building client with economic information on energy-efficiency improvements early in the building design phase to ensure building energy efficiency.

A study of commercial new construction practices in one state produced several key findings: 1) it is difficult to generate a stratified sample for new construction surveys since buildings are usually not operating at capacity, 2) not all building data can be collected readily on-site (e.g., chiller efficiencies and glazing shading coefficients), and 3) these data must be clearly defined before they are collected. The study recommended that the data should be verified through a post-survey follow-up with the project's architect or engineer.

A study that used the ASHRAE 90.1 standard as a baseline for evaluating commercial building new construction programs produced several findings. First, a second simulation analysis should be completed as end-use data become available. Second, standardization of documentation for end-uses is essential to determine the actual savings realized by a given building. Third, use of a sophisticated computer model, such as DOE-2, should be considered due to the complexity of modern commercial building designs.

Another study compared evaluations with resource planning. Evaluations generally focus on program-level effectiveness issues, whereas resource planning models focus on all savings from measures in buildings. Evaluations often use aggregate data analysis, whereas resource planning models are built on engineering simulations. Process evaluations look at how programs are operated. The study found that while many evaluations present data in a useful form for planning, absence of context, unclearly defined units, and, in some cases, absence of fundamental information limit the usefulness of many other evaluations. However, the study noted, many recent evaluations have begun to escape these pitfalls. The study presented many evaluation design and methodology recommendations including these: 1) document the context for the program, 2) document the context for the market, even if it sometimes requires borrowing data from customer surveys, resource studies, etc., 3) where practical, synchronize process and impact evaluations, 4) where engineering analysis is part of an evaluation, summarize and show the detailed performance parameters, and 5) in process evaluations, describe the success of the program in delivering technologies effectively.

4.3.3 Data Analysis

About 34% of the commercial building program evaluations discussed data analysis issues, particularly energy data analysis. The analysis techniques tended to be more complex than those used in residential building program evaluations because of the inherent relative complexity of commercial buildings.

One study used billing data for 26 program buildings and compared them with simulation model predictions. The billing data were also compared with the corresponding data for other, non-program buildings. Performance and cost-effectiveness of the first four buildings were analyzed in detail. The DOE-2 simulation model was used and calibrated using consumption data for each of the four buildings. The calibrated model was then used to compare a program building with one built to meet the energy standards to estimate energy savings. The study suggested that a calibrated, or tuned, model was advantageous for gaining experience in all aspects of the design since the model allowed one to see if the design was suitable for the application as well as identify problems that were not predicted at the design stage. Yet, the study commented, if on-site testing were not integrated with the model, it could have serious limitations. The main limitation noted was in assessing future design modifications. The study recommended that the specific approach of using a tuned model be refined with additional steps to validate the tuned model with a separate subset of data, use actual hourly values for loads and scheduled input to the model, and incorporate improved measurements for critical parameters in each building. The study also suggested that the model parameters be changed so that the model calculates savings for each measure and for various combinations of measures. The evaluation recommended that future studies include comparing simulation models with design predictions to determine the effect of changed input assumptions, model accuracy, and other factors. The evaluation also recommended data collection steps discussed earlier.

Another study offered an approach that integrated several types of data analysis. The first step was conducting site surveys of program participants. Engineering analyses were then conducted, using the survey data, etc. The engineering analyses results were used to conduct an economic analysis of the billing data. Finally, end-use data were generated by monitoring energy use. This approach provided a framework for integration of the different modes of analysis of energy consumption data. Integration of multiple methods helps remedy problems with engineering estimates that do not account for energy use variations due to occupant behavior, billing data that do not account for variations in energy-efficiency technology, and econometrics analyses that provide little illumination of consumer behavior or energy-efficiency improvements due to technology.

One study evaluated the net impact of a new construction program in the Pacific Northwest. The main strategy for the study was to compare the energy use of samples of program participants and non-participants. The participant data were used to estimate gross program savings through DOE-2 simulations, which were based on on-site survey data. The net-to-gross ratio, which is a measure of naturally occurring conservation, was used to adjust gross savings for estimating net program savings. This net-to-gross ratio was estimated through a telephone survey of building construction decision-makers and verified through an economic analysis. Three methodology recommendations arose from this study. First, time lags in construction and market changes should be accounted for when considering the timing of program evaluation. Second, end-use monitored data could be used selectively to increase the accuracy of key simulation input data, including utilization factors, off-hour operation, and installed load. Third, for addition and renovation projects, project documentation must identify new and existing building areas, rebated measures, and the areas they affect. The study recommended that the decision-maker analysis be extended to include non-rebated measure savings for program participants and free-driver effects for non-participants.

Another study conducted a combined engineering simulation and statistical billing analysis to estimate the reduction in energy consumption for a building program. The analysis used on-site surveys conducted with program participants and non-participants. The study found that non-participants were key in determining an appropriate baseline. The study recommended that statistical billing analysis play an integral role in evaluating new construction programs, but caution should be used in automatically scaling engineering estimates as a result of estimated realization rates. The study noted that the relative uncertainty of engineering estimates versus the uncertainty of regression results should be compared, as well as the sources and direction of potential bias associated with each method.

One study drew lessons from using building simulation analysis as an evaluation technique. The study produced three main methodological findings: 1) incompleteness of the documentation of pre-construction analyses and assumptions can hinder the efficiency and accuracy of post-construction evaluation analyses, 2) new construction savings analyses are very sensitive to differences between pre-construction assumptions and as-built conditions, and 3) the quality and accuracy of information used for the evaluation is greatly improved by on-site observations and monitoring of key operating parameters such as operating schedules. An important recommendation made by this study was that evaluation costs can be reduced by selecting impact analysis techniques that are measure-specific.

One study of an incentive program used a statistically derived sample of participants and a baseline to estimate energy savings based on calculations of free ridership. Several recommendations were made for future analyses: 1) time lags need to be recognized for non-residential new construction, 2) a definition of "Building" needs to be established, and 3) adequate time needs to be allowed for the evaluation.

One study that determined load impacts using CDA found that the savings estimates were not very reliable for a couple of reasons. This technique uses a separate equation for each end use. The CDA equations were estimated on a sample of customers that participated in the program through at least one end use. Participants who did not install a particular end use were used as a control group. Statistical information from these equations was used to construct confidence intervals. The study found that parameter estimates were much more sensitive than initially thought. Survey data were found to be inconsistent and unreliable in some cases. In addition, the survey data collected were not always compatible with the data needed for the analysis. The study recommended that data be collected from the appropriate decision-maker as close to the point of specific decisions about the building as possible. Also, it was recommended that the survey be limited to key questions and, to maintain consistency between survey data and program files, the same questions should be posed to all participants and non-participants.

One study addressed critical factors that affect compliance (complexity of the code, education of members of the building community and code officials, and development of improved compliance and enforcement tools). It recommended improving methods for analyzing compliance and enforcement to enhance understanding an individual jurisdiction's problems more thoroughly.

Only one commercial buildings program evaluation we reviewed discussed free ridership and drivership issues. The study used estimates of free ridership to calculate net energy savings for a commercial new construction incentive program. Gross energy savings were calculated for the actual measures and efficiencies compared with a baseline. The baseline was the state building standard. Results for the sample were projected back to the participant population to determine program impacts. The study was based on a statistically derived sample of participants.

4.3.4 Baseline and Control Group Issues

About 24% of commercial building program evaluations mentioned baseline and control group issues. Defining a baseline for comparison of energy use was an important and problematic methodological issue in the commercial building program evaluations. In particular, the lack of a "before" condition with new construction projects necessitated the creation of a suitable energy use baseline for comparison with the usage associated with the program.

A study of one energy-efficiency program presented three important methodological findings related to baseline issues. First, difficulties in matching control buildings with program buildings made it more difficult to document energy savings than energy use. Second, the building code did not provide a consistent baseline from which to calculate the savings of individual measures because of variations in compliance with the code. Third, as a consequence it was difficult to compare predicted and actual savings. One recommendation regarding the baseline was that construction trends should be closely tracked and the performance of other buildings examined to establish baselines.

Another study of the same program used alternative methods to estimate energy savings associated with different baseline buildings. One used monitored end-use data to compare program buildings with other buildings in the region. Another compared actual energy consumption with the estimated consumption of a building representing the code baseline. It was found that the lack of standard definitions for a baseline building made it difficult to compare the buildings. The modeler was forced to make several assumptions to describe baseline buildings and there were ambiguities because the code did not apply to all end uses.

An evaluation of one state's programs compared three studies using the building standard as a baseline in commercial new construction. The study recommended the following characteristics for developing an appropriate baseline: 1) clear definitions of the participant and non-participant populations, 2) good record-keeping to keep the populations separate, and 3) careful analysis of installed measures.

One study provided useful insights into the process of defining a baseline, particularly when there is a lack of knowledge about construction practices before a new code or DSM program goes into effect. The study found that interviews with design professionals and on-site surveys were two useful methods. Although interviews with design professionals were promising, responses tended to be less quantitative than expected. On the other hand, on-site surveys offered the greatest degree of analytical rigor and accuracy, but they were usually very costly. The study recommended considering using either local building codes or national standards as the baseline.

Another study addressed the lack of a "before" condition with new construction programs that necessitated the creation of a suitable baseline. Four evaluations were conducted using two alternative baselines. One was defined by the level of energy efficiency established by existing building energy codes. The second method used participant and non-participant buildings to determine characteristics of new buildings in the study area. This study observed that building standards had several characteristics that made them useful as a baseline:

- program planners had used the code during program design to estimate the energy efficiency of typical new construction

- building standards provided implementers and building designers with a familiar, common language to understand ways of improving upon minimum efficiency building practices
- familiarity with code requirements helped builders, designers, and building owners identify the costs and benefits of incremental measures to improve the building energy efficiency.

Disadvantages to using the building code to define baseline conditions included the following:

- the assumption that buildings were built to just meet the code might be flawed (some buildings probably were built to exceed the code, while some probably did not meet the code)
- the building code offered building designers several approaches to compliance, but these approaches would not necessarily produce the same efficiencies when applied to a particular building
- certain building types might be exempt from the code.

As noted earlier, one study applied the ASHRAE 90.1 standard as a baseline for evaluating commercial building new construction programs.

4.3.5 Costs and Cost-Effectiveness

Program cost-effectiveness was mentioned or discussed in 26% of commercial building program evaluations. However, only two of those studies discussed methodological aspects of evaluating cost-effectiveness for commercial building programs.

One of the studies provided details of its cost-effectiveness analysis. This study of a building standards program calculated the cost-effectiveness of the new code using the energy savings, incremental capital cost, incremental operations and maintenance (O&M) cost, and measure lifetime estimates. The provisions of the code selected for analysis included all elements that saved electric energy. The incremental capital cost was estimated for the individual provisions of the new code using primarily vendor quotations. The lifetime of the measures was also estimated. The DOE-2.1D model was used to compute energy savings for the package including the interactive effects between provisions.

5.0 EVALUATION IMPLICATIONS

This chapter summarizes what we learned from reviewing the evaluations of code and utility new buildings programs. We focus on information that should be useful in designing and conducting an evaluation of the BSGP. We present general information about program findings that could help improve the success of future program activities. Because we found significant differences between the approaches, effort required, and measures used for residential and commercial building program evaluations, we present findings and implications separately for these two types of buildings.

5.1 GENERAL IMPLICATIONS

Several guidelines emerged from the evaluations that suggested ways to conduct successful building energy-efficiency programs. Some of them were most relevant to programs for upgrading building efficiency beyond code requirements, but these also could have implications for the success of code programs as well. These guidelines included the following:

- *Simplicity is probably the most important characteristic that should be considered in developing building energy-efficiency codes and programs, and all tools and materials associated with the codes and programs.*
- *Risks and additional costs of installing additional efficiency measures are major concerns of building owners and professionals.*
- *Incentives, both financial and non-financial, can be effective tools to address risk and added costs.*
- *Education and training can be effective tools for facilitating energy-efficiency improvements.*
- *Education and training should be directed at owners, building professionals, building operators, and code officials.*
- *Intervention early in the building design process can have considerable impact on actual energy efficiency.*
- *On-going consumer awareness and "brand" identification of energy-efficient buildings can increase consumer acceptance.*

- *DOE can play a significant role in facilitating energy-efficiency improvements by providing coordination across states and among building professionals and code officials.*
- *Energy-efficiency codes and programs should incorporate processes to accommodate innovative methods and designs so that innovation is not inhibited.*
- *Code and tool development should be done with input from building professionals and code officials.*
- *Code development can be improved by conducting voluntary demonstration code programs before full-scale adoption.*
- *Early training of building professionals and code officials can ease the transition to a new efficiency code.*
- *Tools and training should be targeted at key needs of the compliance and enforcement process.*

General lessons about evaluating programs that have implications for future evaluations included the following:

- *Data tracking and monitoring should be built into building code and energy-efficiency programs from the outset, and ways to achieve consistency should be implemented.*
- *Program assessment should be conducted on an on-going basis to flag potential problems and provide the basis for continuous program improvements.*
- *Both process issues and outcomes should be addressed in building energy-efficiency code and program evaluations.*

5.2 RESIDENTIAL BUILDING PROGRAM EVALUATIONS

The evaluations that we reviewed provided the basis for developing an effective evaluation approach for residential building energy-efficiency codes and other energy-efficiency programs. We summarize the key evaluation methodology implications in the following areas: data collection, evaluation design, evaluation analysis, baseline and control sample issues, and cost and cost-effectiveness analysis.

An effective **data collection process** for evaluating residential building programs should be based on the following guidelines:

1) *Both qualitative and quantitative data should be collected to permit assessment of the program's processes and outcomes. Appropriate data should be collected from consumers, code officials, and builders.*
2) *Qualitative data collected should include attitudes and perceptions of building professionals, consumers, and code officials.*
3) *Quantitative data collected should include baseline information on the housing market, utility bills, weather, demographics, construction costs, program or code administrative costs, building characteristics, and submetered energy usage.*
4) *Information should be collected that documents the processes in all phases of the program. Knowledgeable experts should be interviewed as soon as practicable.*
5) *Data should be collected that would allow the energy analysis to account for different types of heating systems and confounding factors such as use of wood heat.*
6) *Timing of data collection should take into account seasonality of the construction industry.*

An appropriate **residential building program evaluation design** should be based on the following guidelines:

1) *A comprehensive evaluation plan should be developed before the evaluation starts. The design should include approaches for addressing process issues and program outcomes.*
2) *Samples of program and non-program homes should be large enough to permit accurate detection and measurement of program effects, given the uncertainties inherent in the analysis methods and expected effects.*
3) *Multiple energy consumption data collection and analysis techniques should be incorporated in the approach to address uncertainties and increase confidence in the results.*

A number of guidelines emerged for a productive residential program evaluation **data analysis approach** including these:

1) *Building occupant data should be used in the analysis to account for household differences that might explain differential energy consumption.*
2) *The housing market should be analyzed to assess the effects of market processes on energy efficiency. Energy prices should be included as a factor in the analysis.*

3) *Techniques should be used that permit analysis of the energy use effects of different building components such as windows, envelope insulation, and ventilation.*
4) *Several energy data analysis techniques should be considered and multiple techniques should be applied. Potential techniques to be considered include PRISM analysis of billing data, analysis of submetered energy use data, parametric simulations, engineering models, regression and cross-section regression models, and conditional demand analysis.*
5) *The limitations of selected energy analysis methods should be recognized and appropriate steps should be taken to minimize their consequences. For example, homes with wood heat or heat pumps should be screened properly if PRISM is applied.*
6) *Detailed building characteristics data should be obtained and used in the analyses. Audit data should be used to verify as-built characteristics. Models should be calibrated with program and non-program homes.*
7) *The analysis should account for free rider and free driver effects in program impact estimates.*

Guidelines for establishing the **baseline** or **control** conditions included the following:

1) *Baseline data should include not only construction characteristics, but construction and enforcement costs too.*
2) *For programs such as state codes that will change the general baseline, data should be gathered before the program starts if possible.*
3) *Perceptions of both builders and code officials on construction trends should be documented to establish baseline conditions.*
4) *Actual construction practices should be documented rather than assuming that baseline construction is simply the code level.*
5) *In programs that cover a limited geographic area (e.g., code demonstrations), effects that spill over into housing outside the program area should be accounted for when establishing the baseline.*

Only a few lessons and insights about **cost** and **cost-effectiveness** analysis were highlighted in these studies. In particular, they included the following:

1) *Program costs should include incremental administrative enforcement time. Cost reporting and interviews should be included as data sources.*
2) *Software analysis may be required to estimate incremental material and equipment costs of complying with energy-efficiency requirements.*

3) *It may be appropriate to analyze cost-effectiveness from different perspectives including the consumer and society.*
4) *Costs and energy savings should properly account for the effect of free riders, free drivers, and market transformation.*

5.3 COMMERCIAL BUILDING PROGRAM EVALUATIONS

This section summarizes our key findings and implications for evaluating commercial building energy-efficiency codes and programs. As noted before, the complexity of commercial buildings generally requires a more complicated evaluation approach relative to the approach used to evaluate programs for residential buildings. Our findings are grouped in the same topic areas as those for residential building programs: data collection, evaluation design, evaluation analysis, baseline and control sample issues, and cost and cost-effectiveness analysis.

The **data collection process** for evaluating commercial building programs should reflect the following findings and guidelines:.

1) *Building professionals and code officials should be interviewed to document attitudes, behavior, and building practices.*
2) *Collection of process information should be an integral component of data collection.*
3) *Data should be collected on buildings as-built rather than relying on design-phase data. Data on building operations should be collected after the building has been occupied and "broken in."*
4) *On-site audits should be conducted to verify building characteristics. For equipment, it may be necessary to consult data from manufacturers or other sources because information on equipment may be incomplete.*
5) *Sampling and sample sizes should be based on statistical techniques for ensuring adequate data quality.*
6) *Short-term end-use energy monitoring should be implemented to supplement billing data. End-use data collection should be designed carefully to allow measurement of all key factors affecting energy consumption.*
7) *Quality assurance should be built into the data collection process through means such as continual data review and on-going surveys to improve data collection procedures.*

An effective **commercial building program evaluation design** should be based on the following guidelines:

1) *Both qualitative and quantitative data should be collected to permit assessment of the program's processes and outcomes.*
2) *The design should reflect the complexity of the buildings being studied.*
3) *The types of data needed should be defined carefully before data collection occurs, taking into account the key factors to be analyzed and the requirements of the analysis method(s).*
4) *Qualitative data collected should include attitudes and perceptions of building professionals, building owners, and code officials.*
5) *Documenting the characteristics of the market and the context in which the program occurs should be a component of the evaluation design.*
6) *An approach for characterizing non-program buildings (see baseline or control discussion below) should be incorporated in the design.*
7) *The design should reflect the fact that commercial buildings are very diverse and it will probably be difficult to develop a stratified sample.*
8) *A case study design should be considered in which specific buildings are analyzed in detail.*

Guidelines for an effective **data analysis approach** that emerged from the studies we reviewed included the following:

1) *The analysis approach(es) selected should guide the data collection plan.*
2) *The building and compliance process should be well studied to provide insights on how compliance and enforcement can be enhanced.*
3) *Multiple energy analysis techniques should be employed to permit calibration and verification of energy consumption and savings estimates. One approach that should be investigated is a detailed engineering analysis, with a program such as DOE 2, calibrated with billing and end-use data.*
4) *Effects on specific end use consumption should be analyzed using models and monitored end-use data.*
5) *Uncertainties associated with different analysis techniques and their results should be investigated and documented.*
6) *The analysis should account for free rider and free driver effects in program impact estimates.*

Guidelines and insights for establishing **baseline** or **control** conditions for commercial building program evaluations included the following:

1) *Design professionals and code officials should be interviewed to establish baseline conditions, although the results may be relatively inaccurate.*
2) *On-site surveys should be conducted selectively to improve baseline construction information, although such surveys tend to be costly.*
3) *Construction trends should be determined as part of the process of defining the baseline.*
4) *The definition of program and non-program buildings should be established very clearly because characteristics of commercial buildings can vary widely.*
5) *Program buildings should be matched as closely as possible with baseline or control buildings, although this can be difficult to achieve.*
6) *The pre-existing code may not be an appropriate baseline because actual compliance with the code varies. On the other hand, the code is familiar to building professionals and code officials so it provides a common starting point.*
7) *Both end-use and billing data for program and non-program buildings should be compared.*

Finally, only a few guidelines emerged from these studies regarding costs and cost-effectiveness for commercial building energy-efficiency programs. The primary guidelines were the following:

1) *Cost-effectiveness analysis should include estimated energy savings, changes in all costs (including incremental administrative and compliance and enforcement costs), changes in operations and maintenance costs, and measure lifetimes.*
2) *Costs and energy savings should properly account for the effect of free riders, free drivers, and market transformation.*