Retrocommissioning:
Program Strategies to Capture Energy Savings in Existing Buildings

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SUMMARY

Retrocommissioning (often abbreviated as *RCx*) is a systematic process for optimizing building performance. Through the RCx process, improvements to building systems and operations are identified. Recent experience in the United States has demonstrated that RCx can result in significant energy savings and improved building performance, while playing an important role in reducing peak electric demand. Field results have shown that proper RCx can yield cost-effective energy savings of 5% to 20% with a typical payback of 2 years or less.

A number of energy efficiency program implementers are focusing increasing attention on existing building commissioning. This attention is driven by the large potential for cost-effective energy savings, an opportunity to provide service to an important class of large customers, and a growing body of program experience in this area. Efforts to promote RCx to date have included several pilot projects to demonstrate the benefits of RCx, training for RCx providers, and education to increase building owner and operator awareness of RCx. Such programs have been offered in California, Colorado, Minnesota, New York, and Texas, and throughout New England and the Pacific Northwest. A few of these efforts are broad-scale programs that have already served dozens of buildings. The other programs are pilot, demonstration or start-up efforts, although several of these are expanding in 2003. In addition, several new pilot programs are also being planned for 2003.

In this report, we provide an overview of the RCx market and a brief review of RCx programs, how they operate, their results to date, and their near-term plans. Overall trends and recommendations to help program planners and implementers improve existing programs and design new programs are provided.

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TECHNOLOGY DESCRIPTION

In the United States, most new buildings are not commissioned during design, construction, and start-up. Furthermore, as buildings age, changes in their use and operation can lead to degraded building performance. Common problems in existing buildings include excessive equipment repair and replacement costs, high utility bills, indoor air quality concerns, high employee absenteeism, and increased tenant turnover. By returning buildings to optimum performance, RCx can address and eliminate many of these problems and can yield significant savings regardless of whether the building was commissioned as part of its construction. Specifically, RCx is a one-time event that applies a systematic investigation process for improving and optimizing building operations and maintenance (O&M) (Haasl and Sharp 1999). RCx typically focuses on energy-using equipment such as mechanical systems, controls, and lighting to ensure the functionality of system components as well as their combined functionality in order to reduce energy consumption and operating costs, and identify and fix existing problems within the facility. While RCx utilizes building diagnostics and O&M tune-ups in order to improve building performance, the process may also be used to identify potential capital improvements for additional performance gains.

Typically, RCx is implemented through a four-stage process as outlined in Table 1. Possible RCx tasks include the following:

- Analyzing utility bill data
- Examining building documents to identify original owner requirements
- Developing and documenting new operating criteria based on current facility use
- Testing and optimizing mechanical, control, and electrical equipment
- Adjusting and repairing poorly functioning equipment
- Recommending potential capital improvements
- Writing a formal retrocommissioning report

Table 1: Retrocommissioning Phases

Planning Phase	Decide which building systems should be analyzed and assign responsibilities
Investigation Phase	Determine how the selected systems are supposed to operate, measure and monitor how they operate, and prepare a prioritized list of the operating deficiencies found
Implementation Phase	Correct the highest-priority operating deficiencies and verify proper operation
Hand-Off Phase	Report improvements made and show the building owner/operator how to sustain proper operation. Put these ongoing actions in writing in case of staff turnover.

Source: Haasl and Sharp 1999

In addition to energy savings, RCx can yield numerous non-energy benefits. Examples include extended equipment life, improved indoor air quality, reduced O&M costs, improved comfort and worker productivity, more knowledgeable building staff, and increased net operating income and tenant retention (for investor-owners). In many buildings, changes in operation, occupancy, use, or the emergence of new problems may necessitate follow-up through re-commissioning or a continuous commissioning effort.

MARKET STRUCTURE

The RCx market can be split into demand- and supply-side actors, generally building owners and commissioning providers, respectively. The broad category of "building owners" is made up of such diverse actors as owner-occupants and investor-owners, public and private sector entities, owners' representatives, property management companies, facility or property managers, and other financial decision-makers. The large facilities that make ideal targets for RCx often have complex, multi-level management structures. In these environments, it is important that RCx is supported by decision-makers at all levels of the organization—from the facility manager or building operating staff to the owner or key executives. Previous studies show that among large building owners, the ones most interested in commissioning and other O&M services are owner-occupants and owners of Class A leased space. Chief concerns for these owners are operating costs and/or keeping occupants comfortable (RLW 1999).

A range of building services professionals offers RCx services. The following entities often serve as primary commissioning authorities or as contributing members of the commissioning team: engineering firms; design professionals; general contractors; HVAC/controls contractors; commissioning specialists; testing, adjusting, and balancing (TAB) contractors; energy services firms; and O&M service contractors. Depending on the size and sophistication of the building O&M staff, owners may opt to have RCx measures implemented by in-house staff. In most parts of the country, there are few firms specializing in building commissioning; instead commissioning services make up a small portion of their overall business. To address the shortage of qualified commissioning providers, the Building Commissioning Association (BCA) has been established to promote commissioning practices and establish professional standards for service providers. Of the 340 members on the current BCA member list, 119 provider firms and 137 professional commissioning providers are included. Many of the provider firms have multiple regional offices around the country (BCA 2003).

MARKET BARRIERS

Despite the demonstrated energy savings achievable with RCx, the practice has gained limited acceptance in most parts of the United States. Recent surveys in Wisconsin, the Pacific Northwest, Massachusetts, and New York have identified a number of the key barriers to RCx (ECW 1998; RLW 1999; SBW 1998; Thorne, Baxter, and Irvine 2001). For building owners, barriers to greater adoption of RCx include:

- lack of awareness of the energy and non-energy benefits of RCx
- difficulty identifying qualified RCx providers
- perception that RCx is expensive with long-term paybacks
- lack of confidence in the anticipated results of RCx (results believed "too good to be true")
- misunderstanding of the types of building performance problems that RCx can address
- split incentives between owners and tenants in lease spaces
- internal accounting practices in owner-occupied spaces that do not return RCx savings to those who fund the services

On the supply side, a shortage of qualified RCx providers further hinders the development of a viable market for RCx. Among the building services professionals with some RCx experience, the majority have commissioned only limited building systems or energy conservation measures but have no experience with whole building commissioning.

ENERGY SAVINGS POTENTIAL AND ECONOMICS

Despite investment in increasingly complex building systems, studies show that problems are common and many building owners are not getting the specified performance out of their facilities. In a study of 60 commercial buildings, Lawrence Berkeley National Laboratory (LBNL) found that more than half suffered from control problems; 40% had problems with HVAC equipment; 30% had sensors that were not functioning properly; 25% had energy management systems, economizers and/or variable speed drives that did not operate properly; and 15% were missing equipment (Piette 1996). RCx addresses these problems through a systematic, documented process of assessment, diagnostic and functional testing, and implementation of improvements. A thorough RCx project involves building O&M staff and provides training and effective documentation to ensure the persistence of energy savings over time.

Retrocommissioning represents a tremendous opportunity for energy savings. A 2002 study estimated potential national primary energy savings from RCx of approximately 865 trillion Btu by 2020 (503 TBtu electricity and 362 TBtu gas). These savings were the second largest of the 38 different energy-saving technologies and practices in the residential and commercial sectors examined in the study (Nadel 2002). Experience with RCx from around the country consistently has shown energy savings of 5% to 20%, while demonstrating significant improvements in occupant comfort and reduced building operations problems.

A study of 44 retrocommissioned buildings conducted in 1996 found project costs ranging from \$10,000 to \$52,000. Investments of \$0.03 to \$0.43/ft^2 (average of \$0.19) yielded energy savings of 5% to 15% or more (median of 19%) and energy cost savings of 2% to 49%. The simple paybacks based solely on energy savings were typically less than 2 years, although the payback approached 4 years in a few instances (Gregerson 1997).[1] Table 2 summarizes projects included in the study by building type.

Based on these findings, if just half of the existing large commercial buildings in the United States were properly commissioned and electric savings averaged just 10% in each commissioned building, electricity savings would total approximately 17 billion kWh/year. RCx also contributes to significant peak demand reductions. In this example, peak demand savings would total about 8,700 MW.[2]

[1] Many of the projects included in this study were retrocommissioned by staff and students at Texas A&M University. Private projects relying solely on professional RCx providers are likely to cost more today.

[2] According to EIA (2002), U.S. buildings over 100,000 ft^2 consumed approximately 341 billion kWh in 1999. For peak demand savings, field data on RCx demonstrate an expected ratio of energy-to-peak savings of 1,950 kWh/kW (Nadel, Neme, and Gordon 2000).

Table 2: Summary of Results of 44 Retrocommissioning Projects

Building Type	# of Projects	Size (thousand ft^2)	RCx Cost Total $	RCx Cost $/ft^2	Energy Cost Savings $/year	Energy Cost Savings %	Pay-back (years)
Retail	4	107 to 170	11,000 to 52,000	0.09 to 0.31	8,000 to 42,500	3.1 to 12.8	0.8 to 1.9
Office—less than 100,000 ft^2	7	48 to 99	5,000 to 24,000	0.15 to 0.43	6,000 to 48,000	10.4 to 27.0	0.4 to 2.0
Office—100,000 ft^2 or larger	15	100 to 623	12,700 to 80,000	0.05 to 0.25	3,600 to 395,000	2.3 to 22.5	0.1 to 4.6
Medical institution	13	54 to 888	24,000 to 28,000	0.03 to 0.37	12,000 to 880,000	2.5 to 49.4	0.0 to 2.1
Library	2	67 to 120	20,000 to 24,000	0.20 to 0.30	9,900 to 36,000	21.0 to 22.5	0.6 to 2.4
Research	1	44	14,000	0.32	60,000	31.3	0.2
School district	2	62 to 93	20,000 to 24,000	0.26 to 0.32	11,800 to 14,300	9.0 to 29.0	1.4 to 2.0

Source: Gregerson 1997

The non-energy benefits of RCx are more difficult to quantify than the energy savings, but may be of greater importance to key decision-makers among building owners and managers. Building performance improvements can reduce the costs of employee absenteeism and other productivity losses related to worker discomfort and complaints. Numerous studies demonstrate that these costs are not trivial. According to the Building Owners and Managers Association (BOMA), payroll costs account for 92% of the cost of building ownership. The U.S. Environmental Protection Agency (EPA) estimates that increased productivity can result in revenues ten times higher than the energy costs savings. For investor-owners, EPA estimates that every dollar invested in energy upgrades yields $2 to $3 in increased asset value of the building (EPA 2002). Retrocommissioned lease properties can also be made more competitive by reducing the operating cost per square foot and lowering tenancy costs. Since the non-energy benefits of RCx can outweigh the energy cost savings, it is important that owners and managers are provided with sufficient information to appreciate all the contributions that RCx investments can make to their bottom line.

Past and Current Efforts to Promote Retrocommissioning

In recent years, a growing awareness of the benefits and energy-savings opportunities from RCx has led several utilities and other organizations to develop and implement programs to promote RCx to their customers and interested stakeholders. Results to date reveal substantial cost-effective energy savings and point to successful program approaches and strategies. Program elements include a mix of resource acquisition and market transformation activities, including:

- RCx demonstration projects
- Technical assistance
- Dissemination of educational and marketing materials such as case studies, RCx guidelines, and sample reports
- Training of RCx providers
- Building operator training
- Financial incentives

Several utilities have run or are currently operating RCx programs, including NSTAR (formerly Boston Edison), Commonwealth Edison, Portland General Electric, Sacramento Municipal Utility District, and Xcel Energy. Other organizations that have run programs or currently promote RCx include the Northwest Energy Efficiency Alliance, Texas A&M University, the Center for Energy and Environment in Minneapolis, and the New York State Energy Research & Development Authority. Other programs are just starting up. Details of some of the leading programs follow.

Portland General Electric

The Portland General Electric (PGE) Retrofit Commissioning Program targets large commercial and industrial facilities, particularly those with building energy management systems and other equipment that has not reached the end of its useful life (i.e., typically less than 12 years old). Through the program, customers work with a commissioning agent in four stages: an initial scoping study to identify suitability for RCx; RCx of the facility; implementation of RCx recommendations; and verification of energy savings. PGE provides a financial incentive to cover the cost of the scoping study and co-funding for RCx and implementation of recommended measures. Project funding is conditional on customer implementation of O&M projects with paybacks of 2 years or less. PGE reviews and verifies savings estimates (PGE 2002).

In its first year (1999), a total of five projects were completed, with total savings estimated at 5.4 million kWh (Dodds, Baxter, and Nadel 2000). Program savings have continued to grow each year along with the number of projects completed. In 2002, program savings totaled 6.6 million kWh from 27 projects, more than double the 3.1 million kWh savings in 2001 (Peterson 2002, 2003). As of 2003, the Energy Trust of Oregon began administering efficiency programs for PGE's customers as part of the state's utility restructuring process. The future of the Retrofit Commissioning Program in uncertain at this time.

Northwest Energy Efficiency Alliance

In 1998, the Northwest Energy Efficiency Alliance launched an initiative to promote commissioning of public buildings in Idaho, Montana, Oregon, and Washington. The program includes training, education, case studies, development of commissioning services, and outreach to public officials about the benefits of commissioning. The program seeks to build support for commissioning in public policy as well as action in public facilities. Each state operates its own customized program. The original focus of the effort was on new building commissioning but has been expanded to include RCx. Through this project, 33 public buildings have been commissioned or are in the process and a variety of case studies are in preparation. Of these, 14 are RCx projects (Northwest Alliance 2003). A recent analysis of energy savings from eight of the 14 RCx projects found average savings of 125,734 kWh/year and 6,104 therms/year (or a total of $0.14/ft^2/year) with an average payback of 3.9 years (Tso, Skumatz, and Jennings 2003).

As a follow-up to this project, as well as to also reach privately owned buildings, the Northwest Alliance is launching a new program called the Building Performance Services Initiative. This will seek to improve the performance of existing buildings by conducting an initial screening study and then providing additional services as appropriate for each building. Four service packages are planned—premium O&M practices, building tune-up (sometimes called commissioning "lite"), comprehensive commissioning, and equipment replacement. Three project phases are planned—market infrastructure development, building performance services test, and a pilot program. Infrastructure development will include defining each of the services, developing technical support tools and guidelines, developing market support tools, and education and training. During the building performance services test, 10–15 buildings will receive services, an evaluation of these projects will be conducted, and recommendations for the pilot program will be developed. The pilot program will include delivery of services by 6–8 local utilities, each involving 20–30 buildings. These three phases will take place over the 2003–2005 period. The expectation is that a full-scale market transformation effort will take place starting in 2006 (Hermenet 2002).

Oakland Energy Partnership

The Oakland Energy Partnership is a multi-pronged effort to make the City of Oakland a model for energy efficiency. The program includes several components, including a Large Commercial Building Tune-Up program. The overall program is funded by the California Public Utility Commission using funds from California's Public Goods Charge, which is a small surcharge on electrical service used to fund energy efficiency, renewable energy, low-income, and research and development efforts in the state.

Through the Large Commercial Building Tune-Up program, medium- and large-size buildings in Oakland will undergo RCx. The 15-month program has a goal of achieving 16.7 GWh of energy savings from RCx of more than 10 million ft^2 of building floorspace. Buildings that qualify for the program receive RCx services at no cost to the building owner. The program also offers funding to offset the cost of implementation of the RCx recommendations; measures with a one-year payback are given full rebates, those with longer paybacks are eligible for partial rebates. In addition, customers are provided with recommendations for other energy-savings investments. At project completion, the building operators are supplied with a systems manual and training to help ensure persistence of the RCx measures. The program began in September 2002 and as of March 2003, 21 owners had been targeted with marketing and recruitment efforts. Of these, five buildings totaling 2.6 million ft^2 had signed on to the program and additional scoping audits were in progress (Jump et al. 2003).

Xcel Energy

Xcel Energy operates a Building Recommissioning program in Minnesota. The program pays 50% of the cost, up to $15,000, for a diagnosis of building mechanical systems and preparation of a set of recommendations. The customer selects a contractor and the customer or contractor submits an application to co-fund the study. Xcel staff review the application and approach, and if it fits their guidelines and the contractor appears to have the necessary experience, the application is approved. Incentives are also available to cover up to 50% of implementation costs. These incentives are based on peak demand savings. The program targets buildings over 100,000 ft^2 that are at least 5 years old, with large mechanical systems and controls that are not likely to be replaced soon. The program has prepared a list of local service providers but is also open to others. A case study of a completed local project was prepared and is available on the web. In addition to incentives, the program also provides education for building operation staff on maintaining mechanical system efficiency (Gauthier 2002; Xcel 2002).

After 2 years, the program has performed approximately 40 building analyses, and approximately 30 participants have implemented measures from completed studies. Peak demand savings have ranged from about 40–500 kW per project; data on average savings have not been compiled. In 2002, the program completed projects totaling 2.17 MW (Volkert 2003). One recent innovation is that the program is now assisting potential program participants to use the ENERGY STAR® Buildings benchmarking tool. Initial experience is that this benchmarking process is increasing customer interest in participating in the full program (Gauthier 2002).

Xcel Energy Colorado conducted a pilot Building Recommissioning program in 2002, modeled on the Xcel Minnesota program. Of the four projects participating in the pilot program, all have completed the building analysis study, one has completed implementation of recommended measures, and implementation of measures is underway for the other three. The program was expanded to a full-scale effort in 2003 with a goal of 25 projects yielding 2 MW of peak demand savings by the end of the year. As of early May, 18 projects have been awarded and eight service providers have been pre-certified for participation (Gruen 2003).

Commonwealth Edison

Commonwealth Edison ran the Maintenance, Operations, and Repairs (MORES) project during 1998–1999. This was a 2-year program to introduce RCx to its customers and to address the peak–period reliability problems facing the utility. The goal of MORES was to reduce peak demand by identifying and offering simple, low-cost or no-cost cooling system improvements. The utility collaborated with trade allies (i.e., commissioning providers) to target a wide variety of buildings with electric chillers and minimum-load profiles of 1,000 kW. Building types included hospitals, offices, university facilities, and retail establishments. The project consisted of two phases: a study phase where the commissioning provider would diagnose problems, recommend “spot” improvements, and write a detailed study; and an implementation phase where the improvements were carried out. Each study was reviewed by Com Ed to select measures for implementation that met kW reduction and cost goals, and could be implemented by the 1999 summer cooling season. To encourage participation, Com Ed matched building owner funds up to $8,000 for the study costs and up to $10,000 for implementation costs (Kessler et al. 1999).

Anecdotal evidence suggested that smaller facilities with less management bureaucracy had a higher rate of implementing all project recommendations. Larger facilities were more inclined to rectify only problems that had immediate benefits. Eleven buildings with almost 12 million ft^2 were surveyed and most received implementation incentives under the program guidelines. The program reduced peak demand by 840 kW and achieved energy savings of 1.6 million kWh/year (Philbrick 2000). The utility saw this program as low-cost demand reduction: $132/kW saved versus $300/kW for peaking gas-fired generation (Kessler et al. 1999).

New York State Energy Research & Development Authority

The New York State Energy Research & Development Authority (NYSERDA) offers financial support for RCx through its FlexTech and Technical Assistance Programs. In addition, NYSERDA has funded a market transformation program to promote commissioning of new and existing buildings since late 2000. The program offers education, training, and technical assistance to building owners and commissioning providers, and is developing a series of case studies on successful commissioning projects. In 2003, a second phase of the program will begin, with a specific focus on RCx. The project is designed to engage leaders in the building industry, demonstrate the opportunity RCx presents, and enlist industry leaders in promoting RCx to the commercial building industry. Through the program, building owners and managers will be eligible for a no-cost scoping study provided by trained RCx providers. Those interested in continuing on with a full-scale RCx project will be shepherded through the process of working with NYSERDA funding programs and their RCx provider. Case studies of completed projects will be developed and presented to key industry meetings and the relevant trade press. The program will target owners and operators of multiple large buildings in key markets throughout the state with customized outreach and marketing materials.

Texas A&M University: Continuous Commissioning^{SM}

The Energy Systems Laboratory at Texas A&M has pioneered development of the Continuous Commissioning^{SM} process. Like retrocommissioning, continuous commissioning is a systematic way of identifying and correcting building system problems and optimizing performance. A key difference is that continuous commissioning rigorously attends to the persistence of energy savings by continuously collecting and analyzing energy use data via permanently installed metering equipment. When changes are noted in building operations either from ongoing collection of monitored data or by facility operators themselves, the engineers will revisit the facility to determine what is causing the problems. The commissioning engineers and facility staff then work together to fix the problems. The goals of the continuous commissioning process are to optimize the operation of existing systems, improve comfort, solve IAQ problems, minimize energy retrofit costs, and guarantee continuous optimal performance in future years. Continuous commissioning tends to work most effectively on buildings several hundred thousand square feet and larger.

As of 1998, the measured savings resulting from Texas A&M continuous commissioning projects had reached nearly $14 million. The program has consistently produced energy savings equivalent to traditional audit/retrofit types of projects (e.g., savings of 20%) at one-third of the cost. Project effectiveness is very dependent on a high level of support from the facility administration. Continuous commissioning must be part of an institution's long-term strategic plan (Liu, Claridge, and Turner 1999). The maintenance staff must be able to work with the facility engineers to learn how to incorporate this energy management methodology into their daily routines. For continuous commissioning to be cost-effective, the educated maintenance staff must eventually be weaned from constantly using the outside consulting engineers for minor adjustments. The Energy Systems Laboratory is continuing to update its training processes to find better methods to cost-effectively train maintenance staff (Dodds, Baxter, and Nadel 2000).

Other Programs

NSTAR (formerly Boston Edison) has undertaken several pilot projects and is planning to expand its pilot effort into a full program in 2003. The company surveyed programs around the country to help identify the most effective approaches. The program will place a strong emphasis on obtaining buy-in and support from key senior managers on the customers' staff and include a facility staff training component. A process for selecting projects has been developed; other details for this program will be worked out after this report is written (McGlynn 2003). United Illuminating, based in Connecticut, has also recently proposed to start a pilot program in 2003, although as of this writing, funding for this effort is uncertain due to the possibility of diverting energy efficiency funds to help address the state's budget crisis.

Pilot programs have also been run by the Sacramento Municipal Utility District (SMUD) and the Center for Energy and Environment in Minneapolis (CEE). Each of these programs retrocommissioned four buildings. Funding came from electric rates for the SMUD program and from a DOE grant for the CEE program (Dodds, Baxter, and Nadel 2000).

Beyond these programs, RCx is increasingly recognized as an important component of other efforts to reduce energy consumption in existing buildings. For example, in New York State, Governor Pataki issued Executive Order 111 in 2001 calling for all state agencies to cut energy consumption in their facilities by 35% by 2010 (relative to 1990 levels). RCx is highlighted as a key strategy for meeting the energy reduction targets.

The U.S. Green Building Council is about to start a certification program for existing buildings through its Leadership in Energy and Environmental Design (LEED) program. RCx will be a required element in this program. The program is currently in the pilot phase, with a formal release anticipated by 2004.

Efforts to train RCx providers and building O&M staff also play an important part in developing a strong market for RCx. Training for RCx providers is now offered through a number of training outlets and specialized courses. The University of Wisconsin and Texas A&M regularly offer continuing education workshops and courses on many aspects of building commissioning and related O&M issues. The Association of State Energy Research and Technology Transfer

Institutions (ASERTTI) and the Building Commissioning Association (BCA) have developed curricula for introductory workshops on building commissioning, as well as more in-depth, hands-on technical training. The curricula can be used to teach courses on-demand; a number of leading commissioning providers have experience teaching the courses. The National Conference on Building Commissioning, organized by Portland Energy Conservation, Inc., offers additional opportunities for training as well as networking and further development of the commissioning profession.

For building staff, Building Operator Certification (BOC) is a professional development program developed by the Northwest Energy Efficiency Council. Since 1995, more than 1,000 building operators in the Northwest have completed the program. The program has since expanded into the Northeast under sponsorship of the Northeast Energy Efficiency Partnerships. The Midwest Energy Efficiency Alliance is slated to offer BOC in the Midwest in 2003.

OTHER MEASURE SCREENING DATA

Energy Savings

As discussed above, experience with RCx has demonstrated energy savings of 5% to 20%. Savings vary depending on the size, condition, and complexity of the building as well as the extent of RCx and implementation of recommended improvements. For most buildings, a realistic estimate of energy savings probably is on the order of 10%. According to the Energy Information Administration (EIA), the average U.S. commercial building over 100,000 ft^2 consumes 15.8 kWh/ft^2 and 0.37 therms of gas/ft^2 (EIA 2002). Thus, for a 200,000 ft^2 building, typical savings from RCx will be about 316,000 kWh and 7,400 therms.

Measure Costs

Just as expected energy savings vary with building size and system complexity, so do the costs of RCx. The study of 44 buildings cited above (Gregerson 1997) found RCx costs ranging from \$0.03 to $\$0.43/ft^2$, with an average of \$0.19. Based on these data and the results of RCx programs, an average estimate of $\$0.20/ft^2$ is reasonable. This represents the cost of RCx and implementation of low-cost recommendations. The cost of RCx for smaller buildings, particularly those less than 75,000 ft^2, may be higher. Experience to date reveals typical costs per kWh saved of \$0.011 to \$0.02 (Nadel, Neme, and Gordon 2000).

Measure Life

RCx typically yields energy savings of 5% to 15% during the first year of post-RCx building operation, but it is difficult to predict the lifetime of the savings. Estimates range from less than 1 year for projects where little or no maintenance is performed or where there are drastic changes in building use and occupancy to as long as 15 years for projects with adequate training of building operations staff and appropriate ongoing maintenance. An average measure life of 7 years has been used in previous analyses (Suozzo and Nadel 1998).

Eligible Building Stock

The size of the market for RCx is dependent on the building stock. Opportunities for energy savings are largest in larger buildings—those over 100,000 ft^2—and owners of this size of building are typically more interested in investing in RCx. In the United States, there are approximately 89,000 commercial buildings over 100,000 ft^2 and 402,000 buildings between 25,000 and 100,000 ft^2 (EIA 2002). RCx of the packaged HVAC systems common in buildings under 100,000 ft^2 is receiving increased attention by service providers and the energy efficiency community as an emerging savings opportunity.

RECOMMENDED PROGRAM STRATEGIES

Experience to date demonstrates the significant opportunities for cost-effective energy savings and improved building performance resulting from RCx. Furthermore, RCx can yield substantial peak demand reductions. Based on this review of opportunities and current program offerings, a number of important RCx program features emerge.

- Educate building owners and operators on the energy and non-energy benefits of RCx for their businesses. Case studies (particularly those highlighting local RCx projects) and tools to help assess the costs and paybacks can be very helpful in selling RCx to decision-makers. Recent research with building owners reveals that the key factors in their decisions regarding energy efficiency are financial performance, perceived effects on occupant comfort, and technology track record (IMT 2001). Given these considerations, owners may be reluctant to invest in a new practice such as RCx without credible evidence of its potential payoffs. Effective education and marketing can provide the evidence needed to make the case for RCx. In conducting education and marketing activities, program operators should target owners and operates who are involved in multiple buildings, and also work through local organizations to which owners and operators of large buildings are members.

- Offer site-prescreening as part of the marketing strategy. For owners who are still unsure about proceeding, an initial scoping study may be offered at no cost to the building owner in order to help determine which facilities are best suited for RCx, identify key areas for improvement with a thorough RCx process, and provide owners with an estimate of potential energy savings. This process has worked well for the Portland General Electric Program and Xcel Energy and will soon be implemented by NYSERDA. In Minnesota, the ENERGY STAR Buildings benchmarking tool is used. In New York, a set fee of approximately $3,000 will be paid by NYSERDA directly to the RCx provider to cover the cost of the scoping study.

- Incentives can play an important role in attracting owners to RCx. Cost-sharing for RCx studies is the most popular type of incentive. Currently, a number of programs cap incentives at $15,000 or $20,000. Assuming an average study cost of $0.25/ft^2$, this structure covers 50% of study costs for buildings up to 150,000 or 175,000 ft^2. But for larger buildings, these incentives will cover a progressively smaller share of the study cost. One way to offer additional support for larger buildings is to provide higher cost caps, with a reduced cost-share for these higher expenses (e.g., pay 30% of study costs between $30,000 and $100,000).

- Incentives for implementing RCx recommendations can also be helpful. Program incentives should be structured to encourage measures that result in both peak demand savings, electricity savings, and (when feasible) gas savings. Some program implementation incentives are now limited only to measures that result in peak demand savings. Yet RCx can yield substantial savings through improved part-load performance of building systems that do not have as much of an impact in on-peak operation. Program operators should consider also offering incentives for kWh savings (with the amount of the incentive based roughly on the value of the kWh savings). In gas service territories, rebates on gas savings can encourage efforts to capture thermal energy savings as well as electricity savings.

- Consider engaging an experienced RCx provider to provide technical assistance to local RCx providers and to review initial RCx studies. Such technical assistance can improve the quality of initial work and help local providers learn more quickly. The technical assistance provider may need to come from outside the region so as not to be a competitor with local firms.

- Encourage building owners and operators to take advantage of the Building Operator Certification (BOC) program if offered in the region. If not, explore the option of establishing a local BOC program. Owners will benefit from in-house staff with up-to-date training in O&M procedures and practices.

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