Energy Conservation in Multifamily Housing: Review and Recommendations for Retrofit Programs

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Energy use in multifamily housing has long been identified as a particularly challenging area for energy conservation efforts. Much work has been done on technical and programmatic issues in the past decade. There is now much experience in effective approaches for improving multifamily housing energy efficiency, based on the efforts of private, non-profit, utility, and governmental programs. A number of studies covered issues particular to this sector in the early 1980s, guidelines for multifamily housing audit and retrofit were developed, and aspects of the topic were presented in previous ACEEE Summer Studies and other forums. However, there has been no recent compilation of the accumulated experience and lessons learned from more than a decade of effort in the field.

This paper summarizes the findings of a project to review the state-of-the-art regarding sector characteristics, issues and barriers, technology, retrofit programs, financing, evaluation, and policy for implementing energy conservation in multifamily housing. The full project results will be published by ACEEE in early 1995 as a book on multifamily energy conservation. Here we preview key results from that project, with a focus on assessing the job yet to be done in improving multifamily buildings nationwide and providing recommendations for programs, policies and research needed to advance energy conservation in this critical and challenging sector.

Introduction

Over 30 million Americans live in multifamily housing. Most are renters, and a disproportionate number are poor, minority, single parents, and children. Because so many multifamily households are located in cities, their housing problems are often intertwined with the social and economic problems of cities. While the dream of single-family home ownership inspires each new generation, apartment buildings and other forms of multifamily housing will continue to provide shelter for millions of Americans.

The multifamily sector covers a wide range of building types, from duplexes and low-rise garden apartments to high-rise buildings that occupy entire city blocks. Because of this variety of building types, no single set of attributes suffices to characterize the multifamily sector. For our purposes, we define the multifamily sector to include all residential buildings having five or more dwelling units. This follows the usage of the U.S. Department of Energy's Residential Energy Consumption Survey (RECS), a principal source of statistics on energy use in housing. Our subject population of five-or-more unit buildings consists of 1 million buildings housing 15 million households, roughly 15% of the 94 million total U.S. households reported in 1990 by RECS (1992).

Multifamily housing has long been identified as a particularly challenging area for energy conservation. There are technical unknowns about what are the best retrofits and how to implement them. Financial motives for conservation are often absent because of the split incentives problem: tenants have no interest in investing in efficiency improvements because they do not own the building, typically have low incomes, and often have short periods of occupancy; landlords may not invest in efficiency improvements because they can often pass energy costs on to tenants and retrofits often appear risky or unprofitable. Many building owners and managers lack information about potential savings, how to implement efficiency improvements, and the available financial assistance and incentives. There can be institutional barriers, such as landlord-tenant mistrust, poor training and expertise of building staff and trades relating to energy-using systems. Tax structures may allow deduction of energy costs but require depreciation of energy-saving improvements. Obtaining assistance in paying utility bills is relatively straightforward but procedures for securing retrofit financing are more complex.

In the early 1980s, a number of studies identified the opportunities for and barriers to energy conservation in multifamily housing (OTA 1982; Bleviss and Gravitz 1984). Since then, much work has been done on both technical and programmatic aspects of the issue. While more remains to be learned, valuable experience regarding effective approaches to improve energy efficiency in multifamily buildings has been gained through the efforts of local, state, utility, and federal programs. Manuals and guidelines for audit and retrofit of multifamily housing have been developed by DOE, HUD, and a number of state and city organizations. Numerous papers and reports on many aspects of the issue have been published and presented in previous ACEEE Summer Studies and other forums. However, there has been no compilation and distillation of the accumulated experience and lessons learned from the past decade's efforts in this field.

This paper previews the results from a forthcoming book that will review and synthesize ways to effectively reduce energy consumption in multifamily housing. The book will cover sector characteristics, issues and barriers, technology, retrofit programs, financing, evaluation, and policy for implementing energy conservation in multifamily housing. These findings are briefly summarized here; however, the paper's main focus is on assessing the job yet to be done and providing recommendations for programs and policies to advance multifamily energy conservation. Following a brief overview of sector characteristics, we summarize what has been learned about multifamily technical issues and programs. We then present a set of recommendations organized by major actor (federal, state, local, utility, and non-profit) and a list of research needs.

Sector Overview

Many tend to think of multifamily buildings as old, high-rise apartment complexes. In fact, multifamily buildings are mostly less than 25 years old and contain 14 units on average.[1] Multifamily buildings of 5 or more units comprise 21% of housing in the Northeast, 19% in the West, and 14% of housing in the South and Midwest. Larger buildings tend to be in the Northeast, where 42% of buildings having 50 or more units are located. The South has the largest share (34 %) of smaller multifamily buildings (5-9 units). Multifamily buildings are located 53% in cities, 42% in suburbs, and only 5% in rural areas. While the geographic statistics are probably expected, the age statistics might be surprising. More than half of multifamily units are in structures built since 1970; less than 20% were built prior to 1950. The past two decades' building booms in the South and West greatly swelled the numbers of multifamily buildings in these regions, which became overbuilt in some areas by the late 1980s.

Perhaps the single most defining characteristic of multifamily households is that they are renters rather than owners. Ninety percent of multifamily households are renters, vs. thirty percent of all U.S. households. Multifamily households have lower-than-average incomes—over five million are eligible for means-tested federal assistance. Compared to single-family households, multifamily households spend higher fractions of their incomes for both housing (rent) and energy bills. Low-income multifamily residents face very tight household budgets, having to choose among paying for rent, food, medical expenses, and energy bills. While the ratio of single-to-multifamily housing has been stable nationwide, there has been a loss of low-rent multifamily housing stock. In particular, subsidized multifamily housing is being lost through disinvestment, abandonment, or conversion to higher-income units (Achtenberg 1992, NLIHPC 1988). Rehabilitation efforts that include energy conservation improvements are an important way to help preserve affordable housing.

What's Been Learned

Technical Issues

Lack of reliable technical information-what to do to improve energy efficiency-was identified as a major barrier to effective conservation in the early 1980s. By the end of the decade, technical know-how had become less of a limitation for some categories of buildings in several regions of the country. Of course, further dissemination of what has been learned is necessary, and much more work is needed in a number of technical areas. A recent summary of the topic was given by the "Multifamily Building Technology" panel of the 1988 ACEEE Summer Study (Vol. 2, summarized by Hewett 1988).

The broadest survey of multifamily energy conservation results is that of Goldman et al. (1988), who reported costs and energy savings for retrofits of 191 multifamily buildings (25,000 dwelling units). Median savings amounted to roughly 15% of pre-retrofit energy use, but there was substantial variation: savings were between 10% and 30% for 60% of the buildings surveyed. There were many outliers, including a few buildings where energy use increased after retrofit. High pre-retrofit consumption was a significant predictor of savings, confirming its usefulness as a screening tool for retrofit programs. The work reviewed by Goldman et al. was drawn from several leading energy conservation centers around the country.

Goldman et al. analyzed retrofit cost-effectiveness separately for fuel-heated (oil, gas) and electrically heated buildings. Fuel-heated buildings are amenable to mechanical system and control retrofits, which can be done at relatively low cost (median cost $370/unit with 6-year payback). Retrofits of most electric buildings necessarily emphasize shell measures, and have higher costs and longer payback (median cost $1600/unit with 20+ year payback). However, these results may be skewed due to a large portion of the sample being in the Pacific Northwest, which has low electricity prices and a moderate climate. More recent experience in the Northeast indicates that major retrofits of electrically heated buildings can have more favorable paybacks. Shell retrofits, such as window measures (which can be particularly costly), are valuable for bringing building loads into control and are often justified for other reasons, such as property value and aesthetics. Shell retrofits can enable more efficient mechanical-system upgrades and can therefore contribute to an attractive, cost-effective retrofit plan yielding substantial savings (e.g., 20% or more of pre-retrofit consumption) for either electrically heated or fuel-heated buildings. For example, a comprehensive retrofit of an all-electric apartment complex in Danbury, Connecticut, involved an investment of $3800 per unit, including low-emissivity replacement windows, and yielded 24% electricity savings with a 7-year simple payback (Kamalay 1992).

Boiler efficiency is a key determinant of energy use in the many multifamily buildings having some form of central steam or hydronic heat. Estimating boiler seasonal efficiency is important for planning retrofits and deciding whether to replace, derate, or convert the boiler or to add front-end equipment. Seasonal efficiency is determined not just by the boiler itself, but also by its interaction with the distribution system and building load. Retrofits can change these factors (e.g., shell measures which reduce thermal load can reduce seasonal efficiency, so that a boiler change may be needed to achieve the full conservation potential).

Progress in developing techniques for measuring in-situ boiler efficiency is featured in a recent issue of the ASHRAE Journal (Landry et al. 1993; Katrakis and Zawacki 1993). These techniques are not yet at the stage where they can be routinely used by conservation practitioners. Practically speaking, it is useful at least to be able to bracket boiler performance, based on experience with similar equipment in similar settings. This approach is possible in regions where field research has been conducted, but for many regions and systems, sufficient information is not yet available.

Boiler tune-up can provide savings even if the building and heating system are poorly optimized overall. With properly trained technicians and screening of candidate boilers, efficiency tune-ups yield cost-effective savings. Savings of 6% with 6-month paybacks have been demonstrated for conversion boilers, but this is generally a one-time opportunity. Other programs have shown that improvements of 2%-4% are achievable (Lobenstein 1989). A pilot project that combined professional tune-ups with on-site, boiler-specific operator training resulted in average energy savings of 10% (Norton & Lindberg 1992). Experience with vent dampers has been mixed. These were once a commonly recommended retrofit, but measured savings have been verified only for electronically controlled dampers which have been carefully installed or which are a factory-installed purchase option on new or replacement equipment (Goldman et al. 1988; Lobenstein et al. 1992).

There are a number of other boiler-related topics on which progress has been made, largely through research done in conjunction with multifamily retrofit work by the Minneapolis Energy Office (now Center for Energy and Environment) and the Center for Neighborhood Technology (Chicago). More extensive review and discussion will be given in the book. Highlights of areas investigated include:

1. Use of front-end boilers, which can substantially raise overall seasonal efficiency in many situations;

2. Use of outdoor reset and cutoff controls, which lower heating distribution system temperature and cut the heating system off, respectively, resulting in higher seasonal efficiency;

3. Converting two-pipe steam to hydronic distribution, which can boost seasonal efficiency through lower distribution temperatures, provide better balance and control, and lower maintenance costs;

4. Balancing single-pipe steam, which can improve system efficiency but sometimes enhances tenant comfort with little energy savings.

Energy management systems (EMS) are appropriate for many multifamily buildings, but there has been variability with achieved savings. System control measures, including EMS, were found to provide a 12% median savings in the survey by Goldman et al. (1988). However, a large portion of savings may come from fixing broken controls or establishing thermostatic control where there had been none. Such basic measures are often part of EMS retrofit packages but can be carried out without installing an EMS. In any case, EMS installation must be accompanied by careful attention to thermostat type and location, proper setup and operation of controls, and other balance-of-system issues, such as building envelope integrity. As part of a performance contract retrofit package for a 150-unit electrically heated apartment building, an EMS contributed an estimated 13% toward a total 20% electricity savings (Kamalay 1992).

Comprehensive technical packages have been used in many performance contracting and energy service company (ESCO) arrangements. While measure-specific energy savings and cost-effectiveness breakouts are not readily available, overall savings results are impressive. The best ESCO efforts emphasize the building-as-a-system approach in the broadest sense of the term, addressing not only all the building's physical systems but also the situations of tenants and owners. Citizens Conservation Corporation (CCC) of Boston, MA, has completed comprehensive retrofits of thirty large multifamily developments in New England, covering a variety of fossil fuel and electrically heated buildings and including electric-to-gas conversions in high-rise buildings (CCC 1994). The average investment has been $3900 per unit (including administrative costs) with an average simple payback of less than 9 years (at current fuel and electricity prices). The retrofit packages typically include windows, other envelope measures, boiler repair or replacement, and other mechanical systems improvements. Five projects involved full conversion from electric to gas space heating. CCC provides resident education at all sites and includes it in program costs and payback estimates.

Forty-three percent of multifamily households use electricity as their primary source for space heating (RECS 1992). A major division is between systems with and without air ducts. Ducted systems include various forced warm-air designs, which may include air conditioning, as well as heat pumps, which provide both cooling and heating (generally with electric resistance as the second stage). While ducted systems account for 57% of electrically heated multifamily households, unfortunately they are the systems about which the least information is available on measured retrofit savings. More information is available about systems using some form of electric-resistance heat, which account for 42% of electrically heated multifamily buildings.

For non-ducted electric heating, the main energy-saving opportunities are improving controls and reducing building loads. Measures include thermostat replacements and setbacks; shell measures such as window retrofit, insulation, and air sealing; pipe and duct wraps, water heater insulation and water conservation devices; and lighting retrofits. Several programs targeting electrically heated multifamily buildings, such as those of Seattle City Light (SCL) and the Hood River Project, have successfully completed load-reduction retrofits.

The SCL program addressed low-rise (up to four-story) apartment buildings having five or more dwelling units and applied a comprehensive set of relevant shell, water heating, and lighting retrofits. Evaluating 95 buildings with 1,365 units covered by the program in 1986-87, Okumo (1991) found electricity savings of 4% - 9% (of 10 - 13 MWh/unit/yr pre-retrofit consumption) in low-income buildings and 13% - 18% (of 8 -9 MWh/unit/yr pre-retrofit consumption) in standard-income buildings. Window retrofits accounted for the largest portion of the savings. Compared to electricity costs in the SCL region, the 1986-87 retrofit program was cost-effective only for standard-income buildings. Higher costs of measure installation and administration made the program not cost-effective in low-income buildings. However, use of improved window technology is expected to move the program fully into cost-effectiveness (Tachibana 1993).

Roughly 3.5 million multifamily households have some form of ducted electric heat, either central air with resistance elements or heat pumps. Ducted systems can be problematic even under the best of circumstances; problems can be exacerbated in low-income settings. Proctor (1993) warns of many difficulties regarding misinstallation and poor performance of ducted systems in multifamily housing and advises that such designs be avoided when possible. Ductwork installed in attics or other effectively outdoor spaces is a serious problem that still occurs in new multifamily construction. In a sample of recently constructed buildings including several multifamily complexes, Hammarlund et al, (1992) found high incidence of below-specification air flows and refrigerant overcharge in heat pump systems, suggesting potential savings of 18% for cooling and 19% for heating; however, measured savings results are yet to be reported. Compared to detached single-family applications, problems are to some degree lessened when the HVAC equipment and ductwork are completely inside the apartment. In such cases, Modera (1993) points out, one can have a decently performing system with adequate routine maintenance (which is, of course, difficult to ensure in some settings). Moreover, duct systems are repairable and progress has been made in techniques for diagnosis and duct sealing (Home Energy 1993).

Domestic hot water (DHW) systems account for roughly 30% of energy use in multifamily housing, but the percentage among buildings depends greatly on the type of system. The wide variety of DHW systems installed in multifamily buildings makes for a wide variety of energy conservation opportunities. Low-flow showerheads and other end-use conservation devices have yielded cost-effective savings (Okumo 1991). There have been significant advances in water and energy conservation with new appliances such as dishwashers and washing machines (Wilson and Morrill 1992). There are clearly energy saving opportunities if efficient new appliances are specified when old ones need to be replaced. Setting controls to maintain the minimum hot water supply temperature necessary for utility and safety is basic and important; this can be 120°F for water heaters located in apartments, but Legionella concerns suggest higher settings may be needed for central systems.[2] Central circulation system DHW temperature setback during periods of low use was investigated by Lobenstein et al. (1992), who found seasonal DHW energy use savings of 10% to 16%, with a 2-year payback.

Other central DHW equipment measures have been investigated, but among these measures, retrofits known to be reliable and cost-effective are rare. Lobenstein et al. (1992) found that replacement with a high-efficiency condensing heater did save energy, but with 20+ year paybacks and some reliability problems. High-efficiency equipment of adequate capacity may not be available for large multifamily buildings. In buildings with a single central boiler supplying both heat and hot water, installing a smaller, appropriately sized boiler was found to be cost-effective (DeCicco & Dutt 1986; Robinson et al. 1988). However, variable results, including negative savings, were found in other situations (Englander & Dutt 1986). Improper DHW system sizing is a known problem in existing buildings (Goldner 1992). If replacement of decrepit equipment is needed, carefully sizing the new system would present energy saving opportunities. It is disappointing, however, that we cannot offer general guidance on central DHW equipment changes for energy savings alone on the basis of measured conservation results to date.

Recent years have brought increased activity to improve the efficiency of lighting and appliances in multifamily housing as part of utility conservation programs. Seattle City Light instituted a Multifamily Common Area Lighting Program in 1991, offering rebates for energy-efficient lighting retrofits in halls, utility rooms, parking lots, and other common areas of residential apartment buildings and condominiums. An evaluation of eleven buildings revealed electricity savings amounting to 50% of pre-retrofit lighting consumption or 11% of total house-meter consumption (Humburgs 1993). Multifamily lighting retrofits will be addressed further in the forthcoming book.

No matter what retrofit approaches are taken when attempting to improve multifamily building energy efficiency, a "solid emphasis on monitoring the actual performance of retrofits" (Hewett 1988) is crucial. For example, performance monitoring is effectively internalized through performance contracting arrangements and contributes to their success. Special efforts are needed to assure maintenance of energy savings in other programs which provide technical conservation services. The few studies that have tracked multifamily building energy savings for several years underscore the need for monitoring and follow-up. Greely et al. (1986) found that savings did not persist in a number of public housing projects examined; these findings were confirmed in a later study by Ritschard and McAllister (1992). They found that, while average savings in their sample remained positive, improper operation of equipment and lack of maintenance "drastically reduced the . . . savings from various equipment measures installed in public housing. " Because so much retrofit work has been done without ongoing monitoring, it is difficult to be confident that all multifamily programs which reported initial savings have indeed been cost-effective, since most conservation measures have multi-year payback times and so require persistent savings to realize a positive net benefit.

Programs

The initial drivers of energy conservation programs, including those which address multifamily buildings, were the energy crises of the 1970s, which prompted efforts to aid low-income households hard hit by rising energy costs. The federal Community Services Administration (CSA) Crisis Intervention programs were designed to provide weatherization and help pay bills. These programs evolved into the Department of Health and Human Services (HHS) Low-Income Home Energy Assistance Program (LIHEAP), which focuses on low-income utility bill assistance but permits states to devote up to 15% of their block grants to weatherization. Piloted at the end of the Carter Administration, the Department of Housing and Urban Development (HUD) Energy Block Grant program followed the prescriptions of the Community Development Block Grant program by providing grants or loans to low-income people. The Weatherization Assistance Program (WAP) specifically provides weatherization services for low-income households (below 150% of the poverty level) in privately-owned housing and about 17% of the eligible households live in 5-or-more-unit multifamily buildings (Brown et al. 1993). Following the CSA precedent, WAP is very decentralized. Funding passes through the states, which establish their own implementation plans, including audit procedures and allowable measures. Weatherization services are then managed locally by about 1,200 non-governmental, non-profit community action agencies across the nation (OTA 1992). About two-thirds of the 200,000 single-family plus 20,000 multifamily units weatherized annually are treated under the WAP rules.

Although many multifamily buildings qualify for assisted weatherization based on tenant income, they are inadequately reached. Public housing modernization efforts also provide opportunities to improve the efficiency of publicly owned stock. However, only a small share of such grants are used for energy-related improvements and this share has fallen over the past decade. The Commercial and Apartment Conservation Service (CACS) program established in 1980 required utility audit programs for small commercial buildings and centrally-heated 5-or-more-unit multifamily buildings. Of all the states, only Michigan submitted a CACS implementation plan. Federal back-up plans were drafted but the program was repealed in 1986 (OTA 1992). In short, federal programs have done a relatively poor job of reaching the multifamily sector.

Progressive state agencies have been able to mount a variety of valuable energy conservation efforts for rental housing. Again, however, multifamily participation rates have been disproportionately low. Early prescriptive programs, including mandatory or voluntary building and component standards, tended to focus on shell measures, and were not generally able to address the mechanical systems measures so crucial in most multifamily buildings (Hubinger 1984). A set of new building energy-efficiency standards are being tested in the Pacific Northwest. The multifamily buildings evaluated have not yet shown savings relative to a control group, although this appears to have been due to better-than-average efficiency in the control group units and use of air-to-air heat exchangers, which may have improved indoor air quality while increasing electricity use (Brandis et al. 1993). Some states emphasize informational approaches, such as obligating utilities to offer audits and certifications that specified energy-efficiency standards were met. Without financial incentives and technical assistance, however, it is difficult to accomplish widespread implementation of conservation retrofits.

Similarly, financial incentives alone cannot achieve high participation in multifamily weatherization programs, due to the split incentives problem and informational barriers endemic in the multifamily sector. Rebate programs fail to attract renters since they do not own the units being improved and may not (or may only partly) benefit from the energy cost savings; renters also may not own appliances eligible for rebates. Building owners may be unaware of incentives or lack the information to take advantage of them (Hewitt & Palermini 1989). Modest incentives may be insufficient to prompt investments by cash-strapped owners. This obstacle can be addressed by mandating free weatherization services to low-income customers, as done in California and Ohio, or offering substantial rebates coupled with information provision, as done by the City of Austin municipal utility multifamily program.

Program marketing, information provision, technical assistance, performance standards and ratings (mandatory or voluntary), and financial incentives must all work together in order to significantly improve energy efficiency in multifamily housing. Monitoring, program evaluation, and follow-up are needed to ensure that savings are achieved. These realizations have informed more recent state-led efforts, such as those of the Vermont Housing Finance Agency (VHFA). VHFA's multifamily energy-efficiency program, which assists with retrofit financing and engages energy service companies to provide comprehensive conservation work, illustrates some of the key characteristics of effective programs. Buildings are targeted on the basis of high per-unit energy costs; analyses of energy costs, retrofit costs, and cash-flow are performed; assistance is given in preparing work specifications and bid selection; and construction management, contractor supervision, and final inspection are provided.

The City of Portland, Oregon, after failing to politically sustain a regulatory approach to weatherization, drew on state incentives and utility audit capabilities to develop an effective marketing strategy for multifamily weatherization (Hewitt & Palermini 1989). Building owners were provided with information on benefits and available financial incentives, assistance in arranging a free audit, technical assistance in interpreting the audit, financial analysis, and financial planning. Within two years, 22% of Portland's multifamily building stock had enrolled in the program and nearly 4% had received retrofits. The need for program marketing, personal contact with owners, and "handholding" through the planning and implementation process—all in addition to financial incentives—is a recurrent theme for multifamily programs (Hammarlund 1991).

The Seattle City Light (SCL) multifamily conservation program, provides audits, technical assistance, financial incentives (including a grant program for low-income buildings), and post-retrofit monitoring (Okumo 1990). A driver of its success has been an aggressive implementation plan: there are annual quotas for the number of buildings serviced, targeted to reach two-thirds of the multifamily stock in the SCL service area by 2004.

Performance contracting is an effective approach for obtaining reliable energy efficiency improvements in multifamily housing and has been identified as a particularly promising way to overcome the challenges of retrofitting public housing (ORNL 1992). In the energy conservation context, performance contracting refers to arrangements in which payment for new energy-using equipment, utility services, or other energy-related improvements depends on the energy costs savings resulting from the improvements. The building's energy consumption "performance" is guaranteed by a contractor, usually an energy service company, to be sufficiently better than the existing performance so that over the term of the contract, total costs (of equipment, improvements, maintenance, monitoring, and energy bills) will be no greater than those expected if existing conditions had continued.

The previously mentioned Citizens Conservation Corporation (CCC) program has used performance contracts to address large (50 + unit), publicly-assisted buildings in the Northeast. CCC's approach includes extensive energy audits, detailed energy billing analysis, a planning analysis to determine the greatest opportunities for energy savings and enhancing tenant comfort, and development of a retrofit package that provides sufficient savings to pay for improvement costs under the performance contracting arrangement. CCC identifies two key factors that are important for achieving energy savings. One is a set of retrofit measures that will save energy without active tenant participation. The other is inclusion of tenants in the retrofit process, by providing information about the changes being made in the building and education about what they help do to reduce energy use and improve their comfort. These factors complement each other, helping to guarantee that the desired energy savings are achieved and maintained.

Programs providing at least some of the elements identified above are evolving in other regions as well. Nationwide, there may be as many as forty targeted multifamily conservation programs, inducing an annual $60-$90 million of investments in improving energy efficiency in multifamily housing.

Evaluation

Program evaluation is as crucial in the multifamily sector as it is in any area of energy efficiency work. Good evaluation results help break through the "confidence barrier" by countering building owners' and managers' skepticism about energy savings and the value of the investments involved. Evaluation findings are essential for researchers and practitioners to refine their methods. Evidence of success is important for persuading policy makers to commit the additional resources needed to improve efficiency in the majority of multifamily buildings still to be reached nationwide. Evaluation of multifamily retrofit programs is particularly challenging because of the greater complexity of the structure, air flows, space conditioning, water heating, and other energy-using components. Maintenance staff training and behavior, resident behavior, and occupancy changes further complicate the energy-use picture, making it a challenge to determine retrofit effectiveness.

Evaluation tools include engineering analysis, statistical analysis of energy bills, instrument-based approaches, and surveys or site visits. Analysis of energy bills or fuel use measurements (e.g., oil burner run time) is essential, since it represents the "bottom line" for energy savings. Generally, the major challenge is the collection of adequate and reliable pre- and post-retrofit data. Engineering analysis (including computer modeling) is not a reliable predictor of multifamily building energy consumption and it should not be considered a stand-alone evaluation tool. Engineering analysis is important for interpreting billing data analysis results and as a foundation for instrumented analyses. Instrument-based evaluation is expensive and therefore primarily considered a research tool, but can be quite valuable for pilot programs. Surveys and site visits provide an important qualitative adjunct to energy-use measurements and are particularly important for assessing tenant, owner, and staff issues.

Generally, a combined approach to evaluation is most effective. Kushler et al. (1992) point out that the use of combined approaches is a growing trend in DSM evaluation. There are several statistical practices by which information from different evaluation approaches can be combined to yield more reliable and informative results than are obtainable from any single approach. While financial resources are always a constraint and can limit the extensiveness of evaluation, it is short-sighted to not plan for adequate evaluation as part of any multifamily conservation program. Planners and policy makers should not give in to the illusion that they might get more "bang" per program "buck" by shortchanging data collection and analysis efforts, which are essential for ensuring program effectiveness.

A model evaluation effort is the one conducted by Seattle City Light in support of its multifamily energy conservation program (Okumo 1991). Design of the evaluation program started with evaluation of the 1986-87 pilot phases of the conservation project: the lesson here is that provision for and refinement of evaluation became an essential part of the conservation program from its inception. SCL relied on billing and statistical analysis supported by data from site visits, audits, and inspections. SCL found that they could not use pre-existing evaluation methods developed for different regions and building types. Thus, the evaluation protocols were specifically designed to address the types of retrofits, types of buildings, and occupancy situations (e.g., low- vs. moderate-income) in the SCL area. The lesson here is that one cannot expect to pick up a "canned" evaluation methodology. Rather, one must study relevant efforts in order to design an evaluation around a given program's needs and resources.

Recommendations

Recommendations for enhancing energy conservation must consider the diversity of the multifamily sector in terms of physical building type, fuel use, geography, type of ownership, and the variety of institutions involved. Recommendations could potentially be organized in a number of ways. Here we find it useful to present recommendations by major actor: federal agencies, state and local agencies, and utilities. A final section addresses research needs. Our recommendations do not all flow from the preceding abbreviated review of multifamily energy conservation activities. Rather, they are drawn from the authors' experience and broader review work plus inputs from other individuals contacted during the course of the project.

Multifamily residential units remain underrepresented in government-funded and utility-sponsored conservation programs. In terms of resources, federal programs are still disproportionately focused on single-family and owner-occupied housing. State and local conservation programs have not met their potential for targeting the multifamily sector. Utility-based multifamily programs remain few in number and limited in scope. A greater commitment of resources to multifamily conservation is needed on all fronts. There are now a number of good models, highlighted above, for programs that can cost-effectively conserve energy in this sector.

Whether run by government agencies, utilities, or non-profit, multifamily conservation programs should include all of the key elements of success: targeted program marketing; information provision; thorough energy and cost analysis; technical assistance in retrofit planning (including oversight of bidding and contractor work); performance standards and other regulatory tools; financial incentives; education of tenants, staff, and management; monitoring; evaluation; and follow-up. Such a comprehensive approach is needed to ensure significant and persistent energy savings. Targeting is important because of the diversity of the multifamily stock: different approaches are needed for publicly owned, publicly assisted, and private buildings; for large and small buildings; different fuel types; and depending on the types of financial resources available. For a given target market, it is valuable for a program to set up a single point of contact for coordinating the various services, providing "one stop shopping" for building owners.

Federal Programs and Policy

Increased funding levels are needed for the existing DOE and HUD programs for improving energy efficiency in multifamily housing. HUD should provide a financing program for publicly owned and assisted housing and revive grant programs targeted to low-income housing. We recommend that the federal funding level for energy conservation retrofit of public housing be ramped up to $400 million per year. This is still modest relative to the more than $2 billion spent annually by HUD to subsidize energy bills and would be sufficient to reach the total federally assisted stock within 10-12 years. Generally, such grant programs should be utilized to leverage other financing, including debt financing, so as to provide greater market coverage and to enable more comprehensive investments per building. Monitoring and evaluation of energy-conserving grant components should always be required.

Performance contracting is a useful tool for public housing as well as HUD- and state-financed properties. A national energy-savings insurance pool would be a relatively inexpensive way to accelerate performance contracting. The insurance pool would be used to guarantee energy savings in performance contracts; in doing so, it would effectively reduce credit risk, thereby reducing the interest rate on loans for energy-efficiency improvements. Such a pool would need about $50 million and could be created off-budget by DOE or HUD (or both).

DOE should launch an urban energy-efficiency demonstration initiative, which would bolster efforts by the Urban Consortium and others by providing greater resources targeted to efficiency improvement of buildings in low-income urban areas. Such an initiative can be considered an energy/environmental adjunct to Enterprise Zones, with federal seed money being matched by private sector commitments. A version of this concept, entitled "Rebuild America," was included in the Clinton Administration's Climate Plan (White House 1993). Special efforts are needed to ensure that multifamily housing receives adequate attention when implementing these initiatives. DOE and EPA should develop an emissions reduction credit program for energy conservation efforts in buildings, both for meeting Clean Air Act targets and for achieving Climate Action Plan CO_2 emission-reduction goals. Stronger data gathering and evaluation efforts will be helpful for developing accurate tracking systems for emissions reductions achieved through energy conservation.

DOE should consider establishing an information clearinghouse network within DOE regional offices for effective multifamily programs. Such a network should coordinate with and facilitate similar state efforts; a federal role is desirable because many technical issues are common at the regional level and not all states have strong programs. This effort can be coordinated with bolstered sector characterization and evaluation data gathering efforts and provide a way to cross-fertilize successful programs as well as for implementing organizations to locate training and technical experts within their region. The regional multifamily retrofit information network can be tied together at the national level by reviving and expanding the multifamily energy conservation database (last reported by Goldman et al. 1988).

For allowable energy conservation measures (e.g., under WAP), DOE should develop a performance-based procedure for establishing and modifying the measures included. Some of the types of measures that should be considered for inclusion are: appliance replacement, large motor retrofits, mechanical ventilation retrofits, and expanded lighting retrofits. Consideration should be given to relaxing WAP restrictions on submetering, unit-level heaters, and fuel switching when there are clear cost savings and benefits to residents.

HUD should make an energetic effort to inform appraisers involved in conversion, disposition, and refinancing of subsidized housing about the opportunities afforded by the Community Preservation Act to achieve property value enhancements through energy-efficient retrofit and rehabilitation. There are substantial opportunities to preserve affordable housing by accounting for the added value due to the reduced net operating costs which follow from energy-efficiency improvements. However, opportunities are being lost because appraisers, owners, and financial entities involved in disposition and conversion are ill-informed about this potential. HUD needs to engage experienced organizations in an educational/marketing effort that would provide training and information about how to get the technical assistance needed to realize such property-value enhancements. HUD should also allow sufficient owner equity return, which would provide incentives for owners to keep apartments affordable and develop new affordable housing.

HUD guidelines should be amended to allow Public Housing Authority performance contracting arrangements to incorporate purchase of super-efficient ("Golden Carrot" qualified, see L'Ecuyer et al. 1992) refrigerators (and other relevant appliances, as these programs expand) under the Performance Funding System (described in ORNL 1992). Similar arrangements already exist for efficient heating and hot water equipment. The federal government subsidizes the purchase of roughly 100,000 refrigerators annually and also subsidizes the energy bills resulting from their use. It is therefore in the long-run financial interest of HUD for housing authorities to obtain the most energy-efficient equipment on the market. This measure would expand the "market pull" exerted by the "Golden Carrot" programs as well as provide residents with higher quality appliances.

A general federal policy recommendation is that a significant portion of the proceeds of any energy or carbon tax be directed to improving energy efficiency in buildings, particularly multifamily housing. In principle, energy price increases are helpful in providing a market signal to induce efficiency improvements. However, the same barriers to conservation that operate in the multifamily sector also obstruct an effective response to price increases alone. To both achieve significant efficiency improvements and offset the adverse equity consequences of higher taxation, it is imperative that pricing approaches to energy policy include provisions to devote additional resources to energy conservation programs for multifamily housing (and for low-income housing in general).

State Programs and Policy

Much program innovation occurs at the state level. States should be further encouraged to use their own resources, as well as federal sources which they manage, to explore new approaches to improving multifamily building efficiency. Ways to leverage private financing hold promise. A small fuel tax increase could help fund improvements in oil-heated buildings.

States should coordinate with regional federal offices in collecting and maintaining multifamily sector data and retrofit performance information. States should support technology transfer working groups to make better use of regional and state resources and to streamline implementation processes. The information gathering network should also reach out to utilities, fuel vendors, and local implementation agencies to enable routine gathering and sharing of energy use (billing) data for analysis, evaluation, and statewide trends tracking. The network should provide an automated degree-day reporting service for a representative set of locales throughout a state. State public service commissions should strongly encourage utilities' efforts to strengthen and expand multifamily audit services. Implementation can be strengthened with pilot retrofit programs and performance contracting arrangements. Monitoring and evaluation must be part of all efforts. More generally, states should strengthen technology-transfer efforts and the dissemination of successful program approaches, thereby providing a mechanism for sharing problems, solutions, and results among various implementing agencies within the state.

Utility Programs

Utilities need to become much more active in providing electricity and gas demand-side management (DSM) conservation services to multifamily customers, who are probably not receiving a due portion of utility DSM investments. For utility programs, we recommend that DSM benefit/cost calculations incorporate social externalities-this helps to strengthen the case for energy efficiency. To advance multifamily building efficiency in particular, calculations should include the benefits of arrearage reduction, community economic development, job creation, and public relations, as well as the benefits of avoided environmental externalities. The value of such benefits has been estimated and applied to calculate the cost-effectiveness of a utility-sponsored weatherization program in the Northeast (Ellison et al. 1988). Benefit/cost calculations should reflect the reduced maintenance expenses associated with energy-efficient retrofits. Aesthetics and safety benefits should be excluded from the benefit/cost test formula but included in cost-share arrangements, since they are an important factor for many building owners.

As is recommended for public funding, utility funding should be used to leverage other forms of financing, and to provide debt servicing, so as to address a larger market and allow more comprehensive investments per building. In order to attract multifamily building owners, loans should carry low-interest rates whenever justified.

Research Needs

More information is needed on the energy consumption and building characteristics of the multifamily sector in general as well as in particular subsectors, such as newer housing in the Sunbelt and suburban multifamily housing nationwide. This characterization will enable better estimates of program needs, financial needs, and the overall multifamily energy conservation potential.

More extensive evaluation research is needed for the sector, where a relative lack of information about energy conservation program effectiveness remains an issue. Evaluation research must be organized to reflect the diversity of the multifamily housing stock, providing separate coverage according to geographic region, building type, and system type. The variety of institutional and program delivery situations (public, publicly-assisted, or private; small or large buildings; utility, state/local, or community-based) must also be considered. Evaluation methodologies appropriate for each institution and region should be developed and incorporated as an inherent part of future programs.

The ongoing WAP review was scaled down from a full survey to case studies of five multifamily programs (in Chicago, New York, Seattle, Springfield, and St. Paul). While these case studies will provide valuable snapshots of the sector, a more detailed and representative look at what works and what is cost-effective is needed. Ongoing energy-consumption data gathering and evaluation analyses for multifamily WAP efforts should be built into future funding cycles. Monitoring and evaluation should be required for government-funded retrofit programs by all agencies. DOE should provide an information clearinghouse service, linked to national-laboratory based and other analysis programs, for multifamily retrofit evaluation results, organized to account for the geographic, physical, and institutional diversity of the multifamily stock.

The fragmentation and small-business basis of the building technical services sector has long provided a compelling rationale for a strong federal R&D role. The need is particularly urgent for multifamily buildings because of their greater complexity and the woeful lack of private expertise that has been reported by conservation practitioners. Suggestions include expanding national laboratory-based programs to better address the multifamily sector and providing federal assistance for the R&D efforts of state and local conservation organizations. Research sponsored by utilities and utility organizations has greatly contributed in the multifamily arena. These efforts should be expanded. Concerted federal/state research efforts are needed for oil heated buildings, in which there is not a utility interest. Good coordination of government and utility research programs will help insure appropriate targeting and timely transfer of research results to practitioners in the field.

Technical topics needing further research in the multifamily sector include: mechanical systems; ventilation, infiltration, internal gains, and building mass dynamics (especially the interactions among various components of a multi-unit structure); moisture and air quality; building shell heat loss; and energy use by appliances and ancillary equipment (elevators, etc.). Also, there is a need for refinement and validation of computer-based tools for auditing multifamily buildings and analyzing the performance of retrofits.

Coincident with the decline of federal energy-efficiency R&D throughout the 1980s, there was growing recognition of the importance of research to state economies. By 1992, eight states having energy-efficiency R&D programs were spending $39 million per year, equal to one-fifth of DOE's total conservation and renewable energy budget (Harris et al. 1992). New York State in particular has devoted considerable effort to energy-use research and conservation-program development for multifamily buildings. Such state efforts should be supported and expanded, and DOE can assist through coordination and co-funding. A collaborative approach to federal R&D is being taken in many areas of technology, e.g., Cooperative Research and Development Agreements (CRADAs) established with many high-tech, and energy-supply industries. For example, the California Institute for Energy Efficiency (CIEE) is a cooperative research arrangement oriented to improving energy efficiency.

Cooperative R&D arrangements, with perhaps a larger federal share, should be further explored for the "appropriate technology" being pursued by multifamily energy conservation researchers at state and local levels. Many of the technical people in state, municipal, non-profit and utility programs have the skill and desire for research as an adjunct to their retrofit work, but rarely have the time and money to do much of it; a large part of that which does get done is through their individual dedication. A relatively few federal dollars (compared to what is being spent in other sectors) could go a long way toward delivering valuable research results. Cooperative R&D arrangements also facilitate "technology transfer," provide ready feedback from field trials to federal researchers, and help expand the nationwide pool of energy-efficiency researchers and practitioners.

Endnotes

1. Statistics reported here on multifamily sector characteristics and energy use are drawn from RECS (1992) and AHS (1989) unless otherwise noted.

2. ASHRAE (1991) notes that systems must be kept above 115°F to avoid Legionella problems, so there is a need to insure that no part of a central DHW system stagnates at or below this temperature; no clear recommendation has been made for multifamily building systems, so this is a worthy topic for research.

3. The Urban Consortium Energy Task Force is a program for coordinating the use of resources from DOE and municipalities to demonstrate energy end-use projects which improve local government services or the revenue base of participating cities (Norton & Lindberg 1992).

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