Panel 2 Overview:
Multifamily Building Technologies

Multifamily research has increased substantially since the first ACEEE Summer Study. The growth is most welcome, since this large sector (27% of the existing U.S. housing stock), which has a disproportionate share of low income households, was mostly neglected in the period immediately following the energy crisis. Multifamily research presented at the Summer Studies has focused primarily on low rise buildings in the 4 to 100 unit range.

MONITORING THE PERFORMANCE OF RETROFITS

This year's multifamily papers continue a solid emphasis on monitoring the actual performance of retrofits. This is of course the ultimate test of energy conservation, and provides real information that can be used by building owners, program managers and policy-makers. Single-family research has amply demonstrated the hazards of relying on engineering estimates alone. The research presented here ranges in scope from measurements in a single building to a compilation of data from nearly 200 projects, though most studies cover samples smaller than are typically found in single-family research. The sophistication of monitoring has increased, so that simple utility bill analysis is supplemented or even supplanted by detailed analyses of temperatures, run times, flows, etc. collected at short intervals by computerized data acquisition systems.

Several authors discuss the performance of retrofit packages. Goldman et al. give a comprehensive overview of documented multifamily research gleaned from published and unpublished sources. Their data base has been expanded since 1986 (Goldman and Greely, V. 3*), reflecting the growth in retrofit research in electrically-heated multifamily buildings. They find that in these buildings envelope measures are emphasized, with median costs of $1600 per unit and paybacks in the 20 to 25 year range. By contrast, retrofits of fuel-heated buildings commonly focus on mechanical system retrofits, with median costs of $370 per unit and paybacks in the 6 year range. Ivey et al. give results of shell retrofits on three electrically-heated buildings where end use data were collected hourly. Their findings illustrate the highly variable results that are often seen in small samples of real buildings, and that are complicated in multifamily buildings by vacancies and tenant turnover. Evens and Katrakis, building on the Center for Neighborhood Technology's earlier work (Katrakis, 1982, Katrakis et al., 1986, V. 2, Evens et al., 1986, V. 2), present results from nearly 50 steam-heated buildings in which packages of mechanical and shell retrofits reduced energy use by 30% with a cost to participants of $0.34 per therm conserved.

---

* All references to earlier work are to previous Proceedings of ACEEE Summer Studies.

Several authors document valuable new results for previously untested mechanical retrofits in central hot water heating systems and domestic hot water systems. Robinson et al. found 15 percent savings and a 10 year payback for highly efficient "front end" boilers installed to heat domestic hot water and provide base level space heating. This is a lower-cost alternative to the total modular replacement discussed by Gold in 1986 (V. 1). Robinson et al. also contribute to the very limited base of information on space heating and domestic hot water efficiencies in multifamily buildings. Ewing et al. add to the previous data base on outdoor reset controls (Hewett and Peterson, 1984, V. C, Peterson, 1986, V. 1). They show average savings of 7% in buildings smaller than those previously studied, and present illuminating information on the effect of reset control on indoor temperature and on the proportion of overall savings realized in each outdoor temperature bin. Nevitt and Stefanson provide the first data on field performance of a commercial water heater with a built-in flue damper, showing a 6% improvement over conventional commercial tank heaters and a 4 to 5 year payback on added cost at the time of replacement (for previous ACEEE work on domestic hot water, see DeCicco and Dutt, 1986, V. 2, and Englander and Dutt, 1986, V. 1).

AUDIT TOOLS, DIAGNOSTICS AND MODELLING

Multifamily researchers continue to develop and use more sophisticated tools for research and for energy auditting. These diagnostic procedures and analytical or computational models are extremely important to the long term success of multifamily energy conservation work. By helping us to understand and quantify the mechanisms responsible for retrofit performance, they provide a sound basis for estimating how retrofits will perform in different climates or in buildings with different characteristics. With this information, results from small samples can be extrapolated less expensively without endless replications, predictions can be developed to guide further field research, buildings can be diagnosed to identify those where particular retrofits will perform well, and performance can be measured more quickly based on short term data collection.

This year's research on steam-heated buildings emphasizes this more conceptual approach: not just what happens, but why and how. Katrakis builds on previous research on single pipe steam systems (Katrakis, 1982, Katrakis et al., 1986, V. 2, Peterson, 1984, V. C). He disaggregates the savings effects of thermostats, air venting, derating and vent dampers using both long term measurements of gas use and indoor temperatures and short term diagnostics such as boiler part-load efficiency and steam travel time. Based on the same previous research, Huang et al. develop modifications necessary to model the behavior of single pipe steam systems with the DOE-2.1C computer program. DeCicco uses a systems analysis to model the behavior of two pipe steam buildings controlled by an outdoor reset without space thermostats, a common building type on the East Coast. He demonstrates analytically the problems inherent in such open-loop control, and the savings possible if the system is controlled optimally and if thermostatic controls are added. Lobenstein and Peterson provide practical guidelines for selecting options and specifying and bidding conversions from two pipe steam to hot water heating, expanding on their previous work (Lobenstein et al., 1986, V. 1).

Several authors discuss generally applicable diagnostic methods and results. Modera reviews the sparse and mostly very new data on the off-cycle losses and seasonal efficiencies of large central boilers and compares field measurements of stack losses to results from an analytical model. While the concept and general range of AFUEs have become familiar in the single-family sector, very little information has been available on multifamily boilers, although their efficiency relates directly to the performance of vent dampers, reset controls, front end boilers, replacment boilers, and other retrofits. Feuerman et al. present a method for measuring flow rates of clean water without cutting into pipes to install a flow meter. This potentially useful diagnostic and research tool currently has uncertainties on the order of 20%. Baylon and Heller give results of their efforts to develop a pragmatic air leakage test of multifamily buildings that can be conducted with a single blower door.

BUILDING PERFORMANCE

A relatively new area this year focuses not on retrofits but on the as-built performance of multifamily buildings. Considering that the existing national data base on energy use in multifamily buildings (EIA, 1986, 1987, see Goldman et al.) is over 80% based on imputed rather than measured energy use, such contributions are long overdue. Whole building performance is relevant to building code development, energy policy analysis, and utility planning. On an immediate level, it also provides a baseline for comparison in research and program work: Were buildings in which a certain retrofit was tested typical? Is this building being auditted already efficient or not, and hence is it a poor or a good candidate for further work? The only previous work presented at ACEEE in this area is Esterberg's end use monitoring of three buildings (1986, V. 2) and Vine et al.'s analysis of domestic hot water use (1986, V. 1).

Tonn and White compare energy use of 47 electrically-heated buildings in the Pacific Northwest built to the regional Model Conservation Standards with 30 buildings built to conventional codes. Stephens et al. provide data on the performance of several electrically-heated superinsulated multifamily buildings in southern Illinois. Fagerson et al. relate the energy consumption of 99 gas-heated multifamily buildings in Minnesota to envelope and equipment characteristics. Levin and Eriksson compare Swedish apartments with balanced ventilation and exhaust-only ventilation in terms of their sensitivity to wind and temperature driven infiltration.

WHERE DO WE GO FROM HERE?

The question of "What Works?", which was the focus of the 1982 Summer Study, is still being answered for multifamily buildings. Although much progress has been made in the past six years, many retrofits have been tested little, if at all. For example, ACEEE has seen little on central cooling, lighting, infiltration reduction, or high rise buildings. Many single family retrofits have been tested repeatedly in large samples in various locations (e.g., house doctoring, vent dampers). Most multifamily research has involved very small samples in a single city. Replicating these tests for different climates or building characteristics would begin to tell us how transferable the savings are to the multifamily stock as a whole.

Do savings persist from year to year? Very little has been done to address this question (although it is covered in an ACEEE workshop at this Summer Session). Do retrofits have a negative effect on air quality, moisture, the life expectancy of equipment and structures, or maintenance costs? Here again, little work has been done.

Diagnostic tools and modelling can be of great value in extrapolating savings, both to specific buildings being served by a program and to groups of buildings with different characteristics or locations. Multifamily diagnostics and models are still in their infancy, with much to be done in the areas of mechanical systems and controls, end use loads, and multizone infiltration. As an example, probably fewer than 10 field estimates of the seasonal efficiency of multifamily boilers or the service efficiency of domestic hot water systems have been made in the U.S., and most of these have been made in the past two years by ACEEE authors.

Real data on the overall energy use and end use profiles of new and existing multifamily buildings are just beginning to be compiled.

The multifamily sector presents some unique analysis issues. Turnover and vacancies, commonly eliminated from single family studies, are unavoidable in multifamily studies. Because of multiple zones, more complicated occupancy effects, and frequently small samples, multifamily studies present greater difficulties in weather-normalization than most large single-family studies, including problems of nonlinearities, outliers, and the visibility of savings that are small relative to the uncertainty of estimation. These analysis problems have vexed many a researcher, but have yet to be subjected to systematic study.

These many and varied issues should leave multifamily researchers laboring happily in the vineyards for years to come.

Finally, multifamily technologies do not exist in a vacuum, but are intimately related to behavior of occupants and operators, economic criteria of owners and funding sources, marketing approaches and other concerns. The reader is invited to explore other volumes from this and previous Summer Studies for insights into these areas.

Martha Hewett
Minneapolis Energy Office