AN OVERVIEW OF THE BUILDING ENERGY RETROFIT RESEARCH PROGRAM

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ABSTRACT

This research update presents the status of a U.S. Department of Energy program that addresses the technical, financial, and behavioral barriers to improving the energy efficiency of existing buildings. The program is implemented with expertise from four national laboratories, Princeton University, and the Alliance to Save Energy in cooperation with a large number of state, utility, and local agencies.

The remaining potential for energy savings from cost effective retrofit measures in existing buildings is impressive, but a variety of barriers have been identified that reduce conservation investment. One significant barrier that the program can address is the large uncertainty about savings. Average savings for a large sample of retrofit homes is generally lower than expected, and savings in individual buildings varies unpredictably from negative to very high positive values. Our approach has been to provide reliable information on the performance and cost-effectiveness of energy conserving technologies and practices. Field performance monitoring is in progress in each building sector and development of diagnostic techniques and monitoring protocols is in progress.

INTRODUCTION

Improving energy efficiency of existing buildings through retrofit measures offers the largest potential for energy savings in the next 10 to 15 years in the United States. Replacement of some 90 million buildings by more energy-efficient ones is slow; consequently, most of the existing stock will remain in use for the next 30 to 40 years. It is estimated that almost 90% of the 1985 stock of residential buildings will still exist in the year 2010.

Energy retrofits of existing structures include improving the building's thermal envelope to minimize heat losses and improving or replacing mechanical equipment to reduce the use of energy for heating, air conditioning, and domestic water heating. Widespread use of retrofits for residential buildings could save 2.6 quadrillion Btu's (quads) per year and reduce annual energy costs by $17 billion. Full penetration of energy retrofits into the commercial building stock, for which initial costs are paid back by energy savings in three years of less, could save 2.5 quads per year and $15 to $20 billion per year.

However, to increase the rate of adoption of building energy conservation measures, a variety of barriers to retrofitting buildings must be overcome. The following factors are among those that limit achievable and cost-effective energy savings:

- Division of financial benefits for retrofits of rented buildings leads to potential problems for both landlords and tenants, and neither group perceives clear incentives to proceed
- Retrofit investments are risky because energy savings are less than expected on the average and difficult to predict for individual buildings
- Recent fluctuations in natural gas and fuel oil prices have reduced interest in conservation
- Most conservation programs only apply cold-climate retrofit measures to the building envelope without consideration of mechanical system retrofit, different measures for hot climates, and operation and maintenance.

Risk can be substantially reduced by providing the private sector with research results and predictive tools to help in the selection and installation of appropriate retrofits. This program within the Office of Buildings and Community Systems of the U.S. Department of Energy (DOE), is proceeding with research toward this long-term goal by focusing on four technical objectives:

- Provide reliable data on retrofit performance and the means of collecting such data
- Maintain the national capability for analyzing and updating retrofit performance data
- Measure and analyze the influence of human and other factors on the effectiveness of retrofits and post-retrofit operations and maintenance

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- o Make the results of retrofit research widely available to the building industry through technology transfer activities.

Research is being conducted on three building sectors: single-family and commercial buildings by Oak Ridge National Laboratory (ORNL), and multi-family buildings by Lawrence Berkeley Laboratory (LBL). Other participants include the Solar Energy Research Institute (SERI), Princeton University, the Alliance to Save Energy (ASE), and Pacific Northwest Laboratory (PNL).

SINGLE FAMILY BUILDINGS

The single family research program has developed a guideline, or protocol, that specifies the minimum data required for monitoring the performance of energy conservation retrofit measures. The protocol helped establish consistency of quality, completeness, and comparability between field tests and initiated American Society For Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) activities to improve all aspects of building monitoring.

The approach to developing credible retrofit information has been to monitor performance in homes in cooperation with state and local agencies with mutual interest. Field monitoring projects completed or in progress include combined envelope and equipment retrofit measures selected by an audit in Wisconsin and New York, air conditioner replacement in Texas and Oklahoma, foundation insulation retrofit in Minnesota, air duct leakage repair in Oregon, and attic radiant barrier installation in Oklahoma and Tennessee.

The effectiveness of improved infiltration control techniques was evaluated by monitoring energy use in twenty mobile homes. The location of major infiltration sites was found to be far different from those treated by normal caulking and weatherstripping and use of a blower door to locate them was essential. The average reduction in infiltration rate for this sample was 40%, resulting in a heating energy savings of 15%.

MULTIFAMILY BUILDINGS

The protocol for monitoring retrofit performance in multifamily buildings was field tested in Chicago and Minneapolis/St. Paul and submitted to the American Society for Testing and Materials (ASTM) as a draft standard for residential building monitoring. Development of short-term diagnostic tests to characterize the building shell and mechanical systems and an audit to identify appropriate retrofits for specific buildings were also under way. Diagnostic tests included boiler efficiency distribution losses, outside and inter-apartment air exchange, and appliance efficiency.

To address the problem of infiltration control, air leakage was measured in six apartment buildings in Minnesota, California, Illinois, and Massachusetts using multiple blower doors. Specific air flows between units and to the outside was identified. Leakage between units was found to account for as much as 40% of the total leakage, and there was a ten-fold
variation in the amount of outdoor air entering up-wind versus down-wind apartments.

The previous year's monitoring work in multifamily buildings in Chicago and St Paul, Minnesota, has provided a large source of data on the energy characteristics of these buildings. The work this year has been to develop models that can use these data to evaluate the performance of the retrofits. The first model characterizes air flow through combustion appliances that vent through a common chimney to predict savings of vent dampers and flow restrictors. The second model estimates seasonal efficiency of multifamily boilers.

Two studies were conducted to determine the effect of occupant, owner, and manager behavior on building energy use. The first surveyed managers and building organizations to determine the effectiveness of actions taken to improve energy efficiency through improved operation and maintenance. The second evaluated the effect of improved information about energy use and savings on the attitudes of homeowners and renters.

FEDERALLY-ASSISTED HOUSING

The Department of Housing and Urban Development (HUD) is America's largest landlord and spends over $2 billion per year to pay all or part of the energy bills for about 3.6 million units of Federally-assisted housing. This sector consists of 1.75 million units of Section 8 (Low-Income Rental Assistance Program) housing, 1.25 million public housing units, 0.16 million units of Section 202 (Housing for Elderly or Handicapped) housing, and 0.5 million units covered under other HUD programs. The Lawrence Berkeley Laboratory initiated work in 1985 to identify and address the energy-related needs of the federally-assisted housing sector. The goals of this project are to address current energy issues in federally-assisted housing, improve the energy efficiency of the public housing stock, and provide technical assistance to HUD and local housing agencies to overcome barriers to meeting the conservation potential.

Information was compiled on building characteristics, energy use patterns, conservation potential, and barriers to conservation and a long-term research agenda was developed with an initial emphasis on the public housing sector. Development of analysis methods began by assessing existing, simplified, analytical tools (with particular emphasis on PC-based methods) available through previous DOE programs that evaluate the energy and cost savings of multifamily retrofit measures. A preliminary baseline energy analysis (using utility bills) of 91 public housing projects across the U.S. was performed to determine which specific factors contribute to the overall energy use of a public housing building. A generic utility accounting system, that allows local housing agencies to track their utility usage over time and prepare appropriate HUD reporting forms, was designed to increase the potential for improved operational efficiency and energy conservation at the Public Housing Authority (PHA) level. In an initial evaluation of retrofit performance, existing utility data (pre-and post-retrofit analysis) of 43 public housing retrofits were analyzed. The analysis showed a median savings of 14% (range of-6% to 62%) and a median payback of 12 years compared with about 15% median savings and a 3 year payback in private multifamily buildings.

COMMERCIAL BUILDINGS

Obtaining performance data that aids in selecting the appropriate retrofits for buildings is the program approach to reducing the barriers to adoption of efficiency measures. A major hurdle to obtaining useful performance data that is being addressed in the commercial program is the problem of understanding the variations in performance of the wide diversity of buildings and possible efficiency measures. As the program develops methods for dealing with the diversity and data to describe the variations in performance that can be expected for specific classes of retrofits in different building types, the motivational barrier to investment will be reduced.

The monitoring protocol sets up a framework for conducting field monitoring projects and obtaining retrofit performance data that provides some structure for understanding the diversity of buildings and how retrofits would perform in other buildings. The commercial protocol differs from the residential protocol in the emphasis placed on defining the uses, activities, schedules, and diverse systems associated with commercial buildings. A draft protocol was developed in 1987, and a published document is scheduled to be completed in 1988.

Initial retrofit performance monitoring efforts included installation of a "smart" thermostat to control three separate heating and air conditioning systems in a small bank in Tennessee and lighting retrofits in a small retail shop in Colorado. The next important task is to obtain and organize data on retrofit performance to use and test the monitoring protocol.

The development of analysis methods for estimating retrofit performance is an important part of the overall process. Analysis provides the answers that determine how effective different retrofits are and monitoring methods are influenced by the types of analysis that will be performed. A "power signatures" concept was developed which uses time series energy consumption to develop a characteristic, normalized profile of the power densities (typically Watts per square foot) for different time intervals. The power signature represents "energy characteristics" of a building that become part of the overall building description. Development has begun of an analysis tool that performs energy tracking and definition of energy indicators (energy use indices or EUIs) for baseline, weather adjusted, and building use adjusted values. This tool is a first step toward having a common method for classifying building energy performance relative to other buildings. Initial results are expected late in 1988 or early in 1989.