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Measured Energy Savings from Residential Retrofits: Updated Results from the BECA-B Project*

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SUMMARY

This study summarizes measured data on energy savings from conservation retrofits in existing residential buildings. We have compiled building performance data on approximately 115 retrofit projects (almost twice the size of the initial study) that we put into four general categories: utility-sponsored conservation programs, low-income weatherization programs, research studies, and multifamily buildings. The sample size for each project varies widely, ranging from individual buildings to 33 000 homes. Retrofits to the building shell, principally insulation of exterior surfaces, window treatments, and infiltration-reduction measures, are the most popular, although data on various heating system retrofits are now available. The average retrofit investment per unit in multifamily buildings is approximately $695, far lower than the average of $1350 spent in single-family residences. The median annual space heat savings in the four categories range from 15 to 38 GJ. Savings achieved are typically 20% - 30% of pre-retrofit space heating energy use although large variations are observed both in energy savings and in costs per unit of energy saved. Even given the wide range in savings, most retrofit projects are cost-effective. Approximately 75% - 80% of the retrofit projects have costs of conserved energy below their respective space heating fuel or electricity prices.

INTRODUCTION

A recent Office of Technology Assessment (OTA) report has concluded that "despite considerable theoretical analysis and thousands of audits, there is still very little documented information on the results of actual retrofits on different types of buildings" [1]. The OTA report stresses that improved data on the results of individual retrofits, retrofit packages, and actual savings compared to predicted savings could help alleviate building owners' concerns regarding retrofit expense and outcome.

The BECA project addresses the lack of monitored building performance data by collecting and analyzing *measured* data that document the energy savings and cost-effectiveness of conservation measures and practices. This study focuses on retrofitted residential. buildings. Updated results from approximately 115 retrofit projects are presented, nearly twice as many as in the previous compilation [2].

Analysis of a large data base (totaling 60 000 households) provides a fairly broad picture of retrofit performance under varying conditions, although this compilation is not a representative survey of the fraction of the housing stock that has been retrofitted in recent years. In this study, we examine factors that account for variation in energy savings among households installing similar measures. We also report on those building types, specifically multi-unit buildings, for which there is now more detailed coverage. Finally, we identify major data gaps and suggest

*Initial results from the Buildings Energy Use Compilation and Analysis (BECA) project on existing retrofitted homes were published in *Energy and Buildings*, *5* (1983) 151 - 170. Other BECA studies published in *Energy and Buildings* include results from low-energy new homes (BECA-A), *3* (1981) 315 - 332, and retrofitted commercial buildings (BECA-CR), *5* (1983) 171 - 196.

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possible research that could provide an improved picture of the effects of conservation in occupied residential buildings.

DATA SOURCES

We obtained information on retrofit projects from research organizations, utilities and government agencies that sponsor conservation programs, and firms that provide building energy services. The data collected in these studies typically included metered energy consumption, installed retrofit measures and their cost, and, in some cases, a brief description of the physical characteristics of the buildings along with demographic information on the occupants. Each project was placed in one of four broad categories (utility-sponsored conservation programs, low-income weatherization programs, research studies, retrofits of multifamily buildings) to permit a consistent and useful treatment of results (see Appendix A, Summary Data Table).

Utility-sponsored conservation programs are mostly large-scale efforts that retrofit thousands of homes. They typically reach single-family, mostly middle-income homeowners whose homes are structurally sound. Utility programs usually offer low- or zero-interest loans to finance recommended conservation measures. Our sample has a distinct regional bias. Thirteen of the 19 conservation programs (approximately 68%) were sponsored by utilities located in the Pacific Northwest or California, and fourteen were directed at electrically-heated homes.

The Department of Energy (DOE) Low-Income Weatherization Assistance Program, the CSA/NBS Weatherization Demonstration Research Project, and pilot retrofit projects for oil-fired heating systems funded by the Low-Income Energy Assistance Program are included in the low-income weatherization category. Data from a number of the DOE Weatherization Program evaluations are of questionable quality. Often, only annual utility bills or energy data for a fraction of the heating season are available, and cost data include only the cost of materials, not labor. Despite these limitations, we include the results because of the program's scope (nearly one million homes have been weatherized) and because it targets a housing sector where potential increases in energy efficiency are great [3, 4]. The CSA/NBS project involved extensive retrofitting of 142 homes in 12 different locations with detailed monitoring of energy consumption and cost data [5].

Research studies often test innovative retrofit measures or strategies. For example, Claridge et al. examined results from 26 Colorado homes that participated in the 50/50 Program, a DOE-conceived effort to speed implementation of a large number of low-cost energy conservation measures by making them available as a package [6]. Sample size for research studies tends to be small (fewer than 25 homes) and a comparison or control group is usually employed as part of the experimental design. A few studies collected sub-metered end-use data in the post-retrofit period but most research projects relied exclusively on utility billing data.

Retrofit activity in multifamily buildings lags far behind retrofits of single-family homes for a variety of institutional and technical reasons. Almost 85% of multifamily housing units are renter-occupied, producing the problem of 'split incentives'. Landlords have little incentive to invest in energy-saving improvements in cases where tenants pay their own utility bills and tenants are seldom inclined to make investments in property they do not own. The U.S. multi-unit buildings included in the data base are all located in the Northeast or Midwest. The buildings range in size from 5 to 1790 units; 68% of the buildings are larger than 50 units. The inhabitants are mostly renters and are often low-income. Fifty percent of the buildings are part of public housing projects. Three buildings were retrofitted by energy service companies who contract with building owners to manage building energy systems [7].

METHODOLOGY

The installation of conservation measures is just one of many factors that affect a building's energy consumption. Some factors will have a small effect while others such as seasonal weather variation and occupancy changes, must be accounted for explicitly. The building energy data that we encountered typically consisted of utility bills that include heating energy usage along with other (baseline) uses of the same fuel. In research studies, the CSA/NBS weatherization project, and some utility program evaluations, the data were analyzed using a linear model [8 - 10]:

$$E_j = \alpha + \beta(DD_R)_j \qquad (1)$$

where E_j is the average daily energy consumption over period j, and DD_R is heating degree-days per day over period j (calculated using reference temperature R).

The regression was done using heating degree-days to either a fixed (base 18.3 °C) or variable reference temperature. The reference temperature represents the outside temperature below which the building's heating system is demanded. The parameter α (energy use/day) is an estimate of the weather-independent usage (i.e., baseload) while β, the heat-loss rate, gives the amount of energy required for each incremental drop in outside temperature below the reference temperature [8]. These parameters, together with the normal-year heating degree-days to the best-fit reference temperature, are used to calculate a weather-normalized annual consumption (NAC) for the pre- and post-retrofit periods.

In most cases we had to make one or more adjustments to reported consumption data. If monthly utility billing and local weather data were readily available, we did the analysis using the regression model with a variable reference temperature for each house. Some studies, however, used a different weather-adjustment procedure or reported only annual consumption data. In these cases, we corrected for the varying severity of winter in different years by scaling space heat energy use before and after retrofit by the ratio of normal-to-actual year heating degree-days. We also estimated the space heating portion of total usage for each project by subtracting an estimated baseload usage. The non-space heating portion was derived either from the regression coefficient (α), calculated by scaling summer fuel use to a full year, or estimated from regional and utility data.

Only 40% of the retrofit projects in this compilation included a control or comparison group (see Appendix A). Control groups also differed significantly between projects. For example, method of selection, knowledge of the experiment, and level of retrofit activity independent of a program varied widely. In almost all cases, control-group residents were not restricted to maintaining their homes at pre-retrofit status during the study. For these reasons, energy savings in a comparison group were not subtracted from savings achieved in the retrofit group in the energy and economic analysis.

Retrofit cost data were standardized based on the direct costs to the homeowner of contractor-installed measures. An equivalent contractor cost was estimated in cases where only materials costs were known. Costs at the time of retrofit were converted to constant dollars (1983$), using the GNP Implicit Price Deflators. Three economic indicators were calculated: simple payback time (SPT), cost of conserved energy (CCE), and internal rate of return (IRR) [11, 12]. A real (or constant dollar) discount rate of 7% is used in the economic analysis. For multifamily buildings, the present value of projected annual operations and maintenance costs is included in addition to the initial investment (except for the SPT calculation). In calculating IRR, we assume that residential energy prices escalate annually at a real rate of 4% [13]. The CCE formula assumes constant (1983$) energy prices. Conservation investments are amortized over the measures' expected physical lifetimes.

RESULTS

Retrofit strategies

At present, most residential retrofits are directed towards improving energy efficiency in the two largest end-use areas: space heating and domestic water heating. This overall pattern can be observed in three of our data subgroups (28 multi-unit buildings, 418 homes that participated in research studies, and 142 low-income homes from the CSA/NBS weatherization project), although there are some striking differences in the relative frequency of 'shell' vs. 'system' retrofits between the groups (Fig. 1). For example, virtually all of the CSA/NBS low-income homes received shell retrofits, yet these measures were installed relatively infrequently in multifamily buildings. Only 15% of the multi-unit buildings installed attic insulation. The low implementation rate is due, in some cases, to adequate pre-retrofit insulation levels (e.g.,

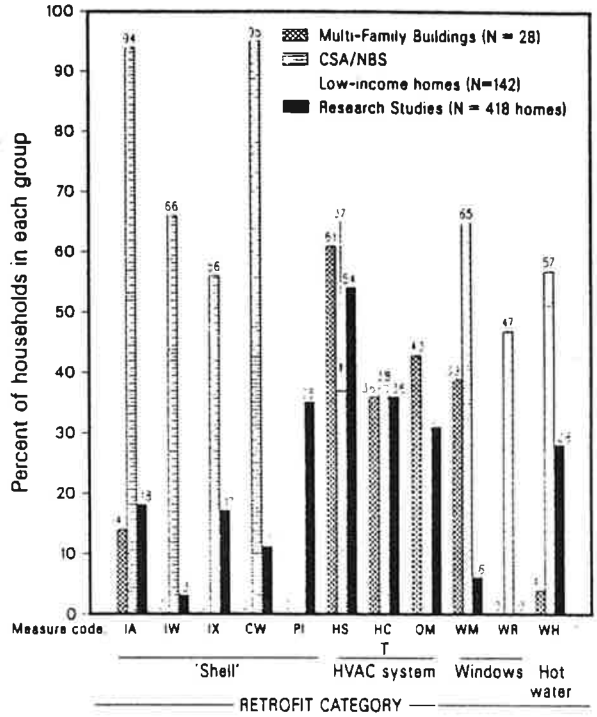

Fig. 1. Relative frequency with which retrofit measures were installed in research studies, multi-family buildings, and CSA/NBS low-income homes. The measure code key is: IA, attic insulation; IW, wall insulation; IX, insulation of miscellaneous areas or unspecified; CW, caulking and weatherstripping; PI, infiltration reduction using blower door pressurization; HS, heating system improvements; HC or T, HVAC controls or clock thermostats; OM, operations and maintenance actions; WM, window management; WR, window repair or replacement; WH, water heating.

in New York City Housing Authority buildings) or to structural characteristics that make installation exorbitantly expensive (e.g., flat roofs, either clad or masonry-bearing walls). In contrast, measures designed to improve the performance of existing heating systems (HS) either by modification/replacement of equipment (e.g., burners), altered operations and maintenance (OM) practices, or installation of control systems (HC) were popular retrofit strategies in multifamily buildings.

Conventional retrofits, particularly shell measures, window, and hot water retrofits, dominate utility-sponsored and DOE Low-Income Weatherization Programs (see Appendix A, column E). For example, attic insulation was the only measure implemented in six of 19 utility-sponsored programs and was an option in every program. Approximately 50% of the utility conservation programs financed floor insulation, storm windows and doors, and caulking and weatherstripping.

We believe that the savings from many shell measures are now well-documented for single-family homes, owing partly to the evaluation efforts and broad scope of these utility and low-income programs. Data are also increasingly available on heating system modifications for both single- and multifamily buildings although additional research is necessary on the optimal combination of shell and system measures for various structures and climates. We also need more empirical data on conservation measures at both extremes of the spectrum: performance data on 'super-retrofits' that approach the identified conservation potential as well as savings from low-cost measures.

Energy savings

There is substantial variation in annual space heat energy savings among single-family

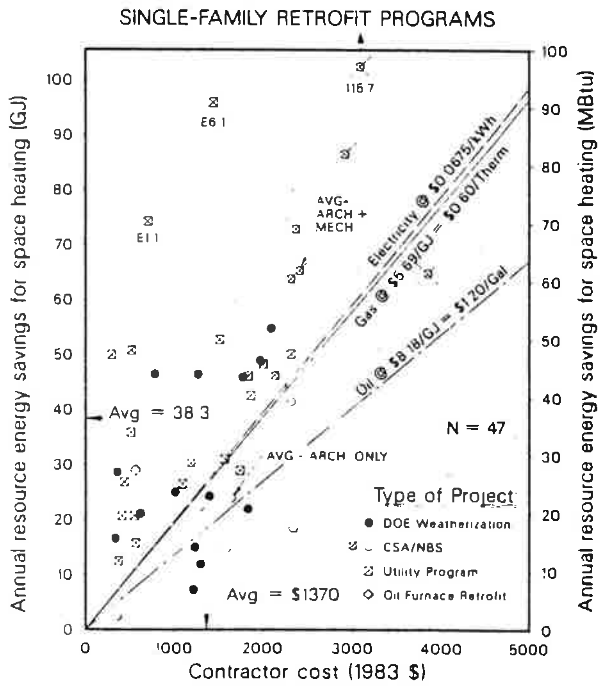

Fig. 2. Annual space heat energy savings are plotted against the first cost of the retrofit for utility-sponsored and low-income weatherization programs. The sloping reference lines show the minimum energy savings that must be achieved for each level of investment if the retrofit is to be cost-effective compared to national average fuel and electricity prices. This minimum is calculated as the present value of the energy purchases that would be necessary if the retrofit was not installed, assuming a 15-year lifetime, constant (1983$) energy prices, and a 7% real discount rate. Note, however, that there are regional variations in the prices of gas and electricity, so that the cost-effectiveness of specific projects may be different from that indicated here. Electricity is measured in resource units of 12.1 MJ per kWh.

retrofit projects at any given investment level (Fig. 2). For example, savings differ by a factor of four for an investment of $2400. Median space heat savings in 19 utility-sponsored conservation programs are 38.4 gigajoules (GJ) and 30.5 GJ in 27 low-income weatherization projects. The data points represent results from over 44 000 homes.

Conservation programs initiated by the Tennessee Valley Authority (TVA) and Puget Sound Power and Light (data points E1.1 and E6.1) achieved high energy savings (74 GJ and 96 GJ) relative to cost ($700 and $1450). The TVA pilot program specifically targeted low-income, high-energy consumers; hence significant improvements in building thermal performance were obtained at low cost.

Average space heating consumption was reduced by more than 20% in 27 of 45 (60%) single-family retrofit projects and 22 of 35 (63%) research studies (Figs. 3 and 4). Approximately 30% of the retrofit projects achieved average space heating reductions of 30% or more. Average savings were not strongly correlated with pre-retrofit consumption levels although this correlation was most

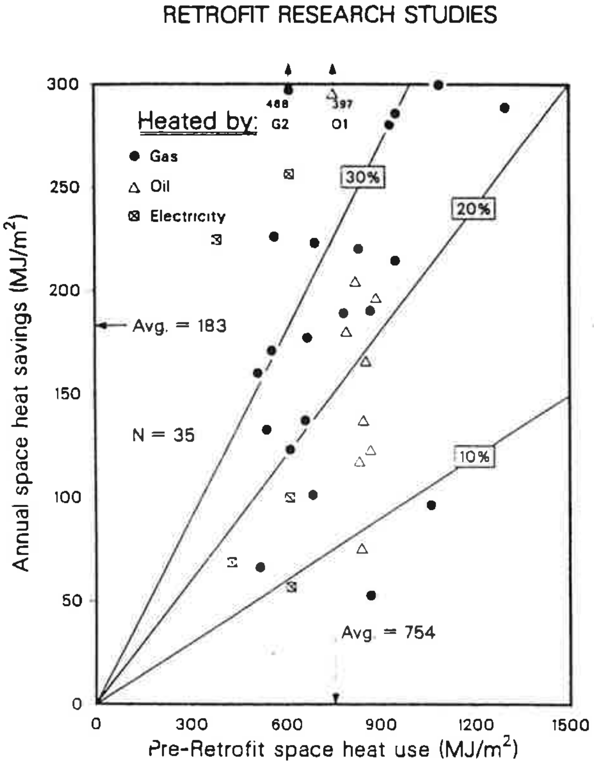

Fig. 4. Annual space heat energy savings in 35 research studies are plotted against pre-retrofit space heat consumption. Usage has been normalized by household floor area. Electricity use is expressed in terms of site energy (3.6 MJ per kWh).

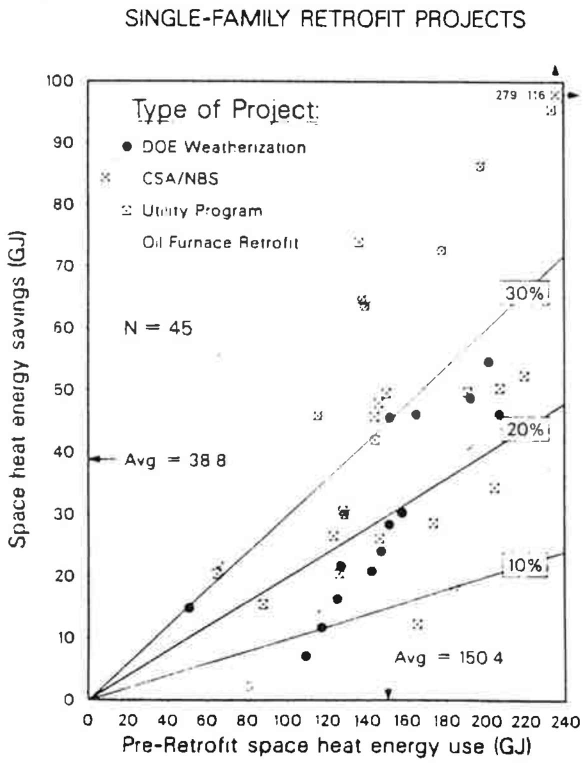

Fig. 3. Annual space heat energy savings as a function of pre-retrofit space heat energy use in 45 single-family retrofit projects. Electricity use is expressed in terms of site energy, 3.6 MJ per kWh (3413 Btu per kWh).

evident in results from the DOE Low-Income Weatherization Program. Choice of retrofit strategy clearly influenced savings obtained by residents who participated in the CSA/NBS Project. Median space heat savings were 42% of pre-retrofit levels in the 73 homes (located in 7 cities) that received heating and hot water system retrofits in addition to shell measures (see points with X printed over circle in Fig. 3), compared to median savings of 13% in the 69 homes that installed only shell measures.

Several retrofit strategies employed in multifamily buildings were very successful in reducing energy consumption (Fig. 5). For example, space heat and hot water usage declined by 44% at Page Homes, a 159-unit public housing complex in Trenton, New Jersey, after the installation of a microcomputer-based boiler control system. High inside temperatures (average 28 °C) and the buildings' relative energy-inefficiency before retrofit (a heating factor of 482 kJ/m^2 per DD$_C$ compared to the U.S. average of 318 - 353 kJ/m^2 per DD$_C$ for multi-unit buildings

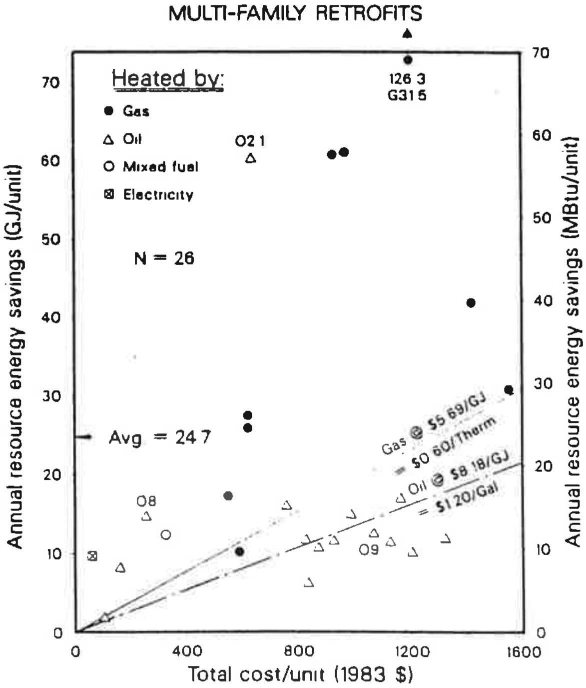

Fig. 5. Annual resource energy savings are compared to the total cost of the retrofit investment in 26 multi-unit buildings. Savings and costs are divided by the number of apartment units in that building. In most cases, the savings apply to space heat only, except for five buildings where the retrofit addressed both space heat and domestic hot water usage. In those five cases, we plot the combined savings. Estimated annual maintenance costs are included in the total cost. Price reference lines are defined as in Fig. 2. Electricity is measured in resource units of 12.1 MJ per kWh (12.1 MJ = 11 500 Btu).

with similar characteristics) help account for the impressive energy savings [14].

Annual space heat savings were between 26 - 61 GJ in six of eight gas-heated multi-unit buildings in Chicago that are cooperatively owned. Remarkable savings (126 GJ/unit) were obtained in another one of these buildings (data point G31.5), a 53% reduction from pre-retrofit levels, for an investment of $1200 per apartment. This building was extremely energy-inefficient before retrofit, with a heating factor of 586 kJ/m^2 per DD$_C$. Approximately 60% of the savings in the eight buildings were attributed to various heating system retrofits (e.g., de-rating burners in oversized heating systems, installing temperature-sensing burner controls, and balancing radiators and steam lines) [15]. Average space heat energy consumption declined by 14.7 GJ in four New York City Housing Authority (NYCHA) buildings retrofitted with thermostatic radiator valves (data point 08), another example of a successful heating system retrofit.

Lower energy savings per dollar invested were achieved in a NYCHA window retrofit project that installed double-glazed thermal-break aluminum windows in nine apartment complexes. Average savings in the nine buildings were 12.7 GJ for an investment of $1070 per apartment unit (data point 09). Pre-retrofit space heat levels were already fairly low in these buildings (65 - 75 GJ) as a result of NYCHA's ongoing energy conservation efforts. Their relative energy efficiency, compared to other multi-unit buildings in the data base, partially accounts for the lower return on investment.

Range of savings among households

Large variations in fuel savings are observed among households in the same geographic location that installed similar conservation measures (Fig. 6). Weather-adjusted energy consumption declined in almost 95% of the sample, increasing in only 17 of 376 homes. For the middle 50% of the homes, the spread in savings is typically ±70% of the median. The large range in savings suggests that more detailed monitoring is required if we are to fully understand the relative impact of key determinants. Efforts to interpret these results are hampered by data limitations. Inside temperatures are not available for any home and in a few cases, basic information, such as conditioned floor area, was not collected (e.g., G12, G30).

However, a few preliminary conclusions can be extracted from the data. Energy savings seem to be more variable with some measures than others. For example, the coefficient of variation (CV)* in energy savings is between 0.9 - 1.2 in four groups of homes in Long Island, New York, that retrofitted conventional burners with other options (Group 5 — vent damper, Group 6 — stack heat exchanger, Group 7 — double setback thermostat, Group 8 — thermostat and boiler temperature programmer). In contrast, savings were generally greater and more *uniform* in two similar groups that received retention head burners. The CV in energy savings is only 0.4 in homes

*The coefficient of variation is defined as the ratio of the standard deviation to the sample mean; a low CV means that there is less variability in savings.

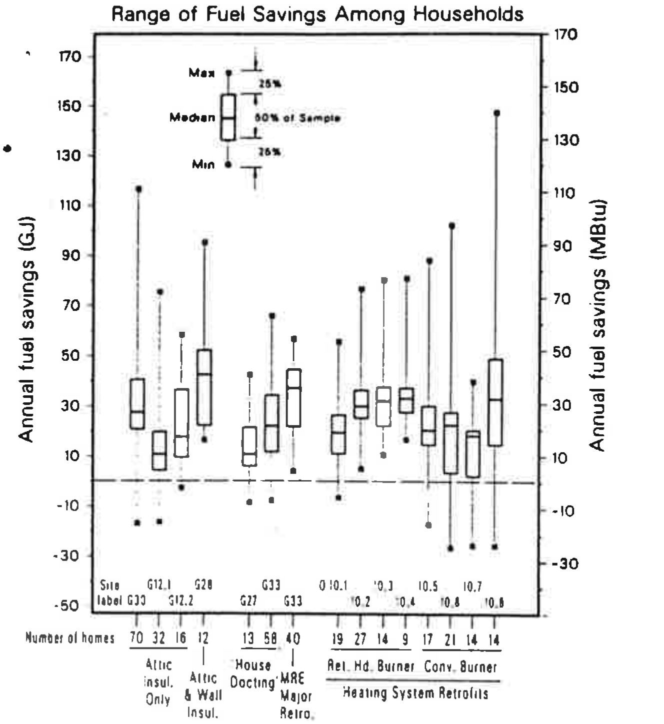

Fig. 6. Range in annual fuel savings among households installing similar measures. In most cases, the savings apply to space heat only, except for the heating system retrofits and the 'house-doctor' experiments where consumption includes all end-uses of the space heating fuel.

that received the energy-efficient burners with optimized installation techniques (Group 2) and 0.7 in homes where typical installation procedures were used (Group 1) [16].

Energy savings for an identical measure also appear to be more variable in mild than in harsh climates. For example, two utilities, Pacific Gas & Electric (PG&E) and Consolidated Gas of Michigan, evaluated conservation programs in which RSI 3.3 (R-19) attic insulation was installed in previously uninsulated homes [17, 18]. The PG&E single-family residences were located in the San Joaquin valley in California, a region with a relatively mild winter climate compared to that in Detroit, Michigan (1215 vs. 3477 annual heating degree-days, base 18.3 °C). At one PG&E site (G12.1), median savings were 10.8 GJ, though 50% of the homes saved less than 4.2 GJ or more than 18.8 GJ. In addition, space heating usage increased in four households during the heating season following the retrofit. The coefficient of variation (CV) is 1.07 in this group of homes. In contrast, the CV is 0.64 in the Michigan buildings, suggesting less variability in energy savings, even though the sample contained more varied building types (e.g., single-family, row houses, duplexes) than the California study. There is little information available on occupant behavior in either study but we suspect that differences in indoor temperature preferences contribute to the greater variability in energy savings in the mild climate.

Economic analysis

The prospects for significant retrofit investment in existing residential buildings hinge ultimately on the economic attractiveness of these investments to those responsible for building improvements. Homes in the nineteen conservation programs sponsored by utilities had a median simple payback time (SPT) of 5.7 years with a mean of 10.3 years (Fig. 7)*. The average payback period is greater than 15 years in four programs. Electricity prices at these utilities were extremely low ($0.01 - 0.02/kWh) at the time of retrofit. Price increases have far exceeded the general

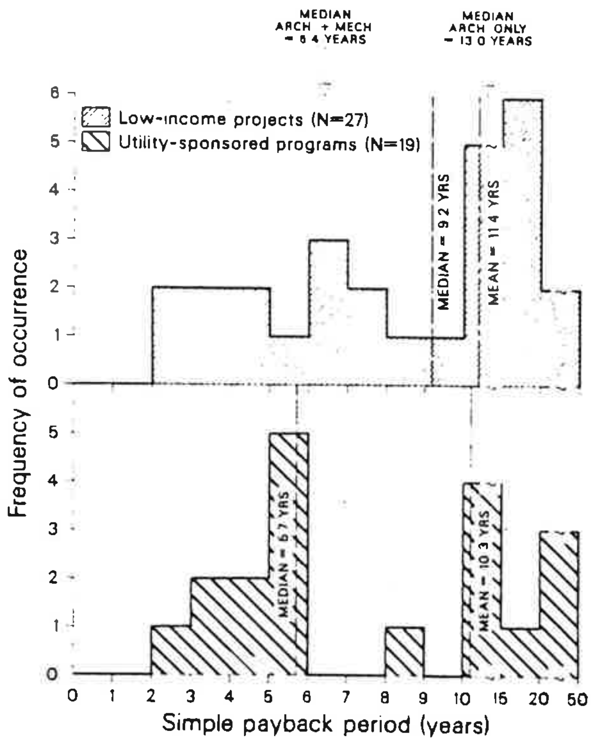

Fig. 7. Histogram of the simple payback period of 27 low-income weatherization projects (represents approximately 850 homes) and 19 utility-sponsored conservation programs (data from 43 730 homes).

*Every project is weighted equally in the calculation of mean and median values. Note that sample size varies within each project.

inflation rate in recent years, thus the payback period would be somewhat shorter at today's electricity prices. The mean and median payback periods are 9.2 and 11.4 years, respectively, for 27 low-income weatherization projects. The combination of heating system and shell retrofits was roughly two times more cost-effective than shell measures alone (6.4- versus 13-year payback period) for homes in the CSA/NBS Demonstration Project.

The cost of conserved energy (CCE) is defined as the ratio of annualized investment divided by annual energy savings, where annualized investment equals total investment multiplied by a capital recovery factor. The median and mean costs of conserved energy (CCE) in the 19 utility-sponsored programs ($2.71, 2.56/GJ) are significantly lower than those obtained in the 27 low-income weatherization projects ($4.33, 6.33/GJ). Key differences that may account for the varying levels of cost-effectiveness between these two groups include:

- poor workmanship and lack of quality control in homes that were retrofitted during the initial phases of the DOE Weatherization Program [19].
- systematic variations in the choice of retrofit options — for example, caulking and weatherstripping were installed in almost all low-income homes; energy savings from these measures are likely to be small and are directly related to the quality of workmanship.
- a fraction of the total investment in low-income homes, ranging from 0 to 25%, was often spent for energy-related structural repairs (e.g., broken window glass). These expenses raise the cost of conserved energy for these low-income homes relative to middle-income homes.
- possible overestimation of equivalent contractor cost for homes that used 'free' CETA labor in the DOE Low-Income Weatherization Program.

In most cases, retrofit measures that were installed in homes that participated in research studies also turned out to be attractive investments. The median cost of conserved energy for 38 research studies is $3.62/GJ (Fig. 8). Nineteen of 25 gas-heat data points have a CCE lower than $5.69/GJ, the national average price for gas, while all eight of the oil-heat data points have a CCE below the average price for oil. The cluster of gas-heat data points with a cost of conserved energy of only $2/GJ at a first-cost of $400 represent 'house-doctor' treatment results from six groups of New Jersey homes that participated in Princeton University's Modular Retrofit Experiment (MRE). This retrofit strategy was also evaluated in research projects conducted by the Bonneville Power Administration and Lawrence Berkeley Laboratory (E8.1 and G27.1). In these studies, the costs of conserved energy were $4 - 5/GJ. Researchers concluded that cost-effectiveness could be improved at these mild climate sites by focusing 'house-doctoring' efforts on homes with either high infiltration rates or those that could be retrofitted with low-cost non-infiltration measures such as intermittent ignition devices and hot water wraps.

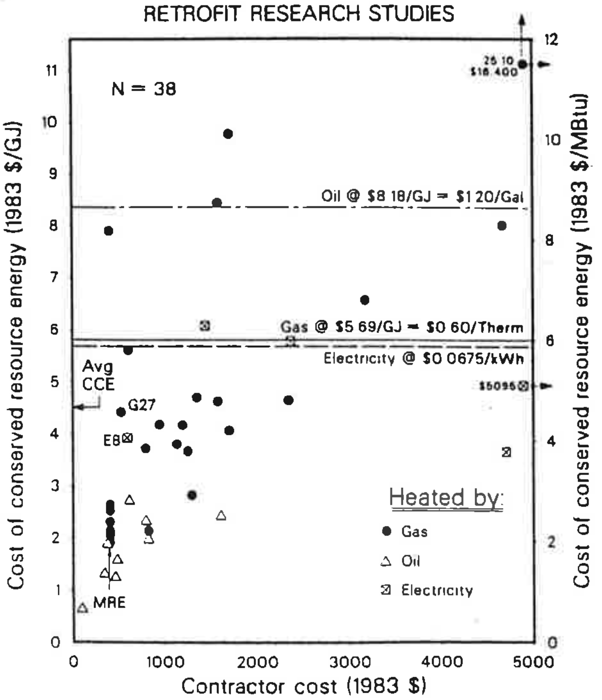

Fig. 8. The cost of conserved energy as a function of the contractor cost of the retrofit is shown for 38 *research studies*. The horizontal lines represent national average prices of purchased energy against which conservation retrofits can be compared. Electricity use is expressed in resource terms (12.1 MJ per kWh).

CONCLUSIONS

Key findings from this compilation of current retrofit experience in existing residential buildings are shown in Table 1. Energy

TABLE 1

Summary of key findings

		Utility programs	Low-income programs	Research studies	Multi-family buildings
1 Sample size		N = 19, comprising 43 730 homes	N = 30, comprising 938 homes	N = 38, comprising 352 homes	N = 28 bldgs.
2 Cost of retrofit (1983$)	Median	705	1370	824	533
	Average*	1044 ± 702	1578 ± 863	1685 ± 2747	695 ± 551
3 Space heat savings (GJ/yr)**	Median	38.4	30.5	27.8	15.1
	Average	40.3 ± 21.0	37.8 ± 26.2	34.3 ± 24.4	27.0 ± 27.4
4 Space heat savings (%)	Median	24%	22%	22%	22%
	Average	26 ± 11%	24 ± 12%	25 ± 14%	26 ± 14%
5 Simple payback time (yrs)	Median	5.7	9.2	6.4	4.7
	Average	10.3	11.4	9.5	7.9
6 Cost of cons. energy ($/GJ) D = 7% real	Median	2.71	4.33	3.62	5.03
	Average	2.56 ± 1.29	6.33 ± 4.63	4.34 ± 4.05	5.26 ± 3.31
7 Real rate of return (%)	Median	25%	6%	17%	11%
	Average	23 ± 15%	13 ± 14%	31 ± 35%	27 ± 31%

*Mean ± standard deviation.

**Electric space heat savings are measured in resource energy units, 12.1 MJ/kWh.

savings occurred after retrofit in almost all retrofit projects, with average annual savings ranging from 27 to 40 GJ in the four categories. Savings actually achieved were typically 20 - 30% of pre-retrofit space heating energy use. These results suggest that most efforts to date have fallen far short of estimates of the identified technical potential [20]. There seem to be few successful, cost-effective retrofits involving expenditures of more than $2500 per house. The average investment in multifamily buildings is approximately $695/unit with a maximum of $1650/unit, far lower than the average of $1350 spent in single-family residences.

There is substantial variation in energy savings for investments of the same magnitude, even after controlling for pre-retrofit energy intensity, building type (e.g., single- vs. multi-family), and climate. We suspect that the variance in savings is due mainly to differences in occupant behavior, physical differences among houses prior to retrofit, variations in product and installation quality, and to measurement error. It is difficult to accurately estimate space heat savings when given only total billed energy use before and after a retrofit. Program evaluations rarely relied on sub-metered heating energy use or monitoring of inside temperatures. The absence of such monitoring techniques means that changes in the household appliance stock, use of secondary heating equipment, or adjustments in occupant behavior might have gone undetected, masking the actual effect of the retrofit. At a minimum, program evaluations should include a telephone or on-site survey of occupants in order to obtain information on these issues, a technique used in only a fraction of the studies.

Particularly cost-effective retrofit strategies can now be verified based on actual metered consumption data*. The installation of attic insulation, particularly in homes with little or no insulation, resulted in cost-effective energy savings, irrespective of structural and demographic characteristics or climatic region. Conservation strategies designed to reduce domestic hot water usage, typically tank and pipe insulation and/or reduced-flow fittings, were also sound energy-efficiency investments. Varying packages of shell retrofit measures, typically including attic insulation, storm windows and, often, wall or floor insulation, were successful in most single-family electric-space heated homes. In low-income, single-family homes, retrofitting

*These conclusions are drawn primarily from projects where individual measures or sets of measures were installed in groups of homes with similar structural characteristics in the same geographic location.

existing gas or oil-fired heating equipment appeared to be a very cost-effective complement to shell weatherization measures. Results from several pilot programs (e.g., Philadelphia Oil Furnace Retrofit Project) indicate that the cost-effectiveness of low-income weatherization can be enhanced through the development of administratively simple programs that employ well-trained private contractors to install various heating system retrofits.

The conservation potential in multifamily buildings is large and barely tapped. Improvements in existing heating system performance using such techniques as improved controls, burner de-rating, duct insulation, and balancing distribution systems are attractive energy-saving strategies in multi-unit buildings. However, additional retrofit data are needed from multifamily buildings located in different climatic regions, and with varying physical characteristics and ownership patterns, to determine whether these preliminary results can be widely duplicated.

Many conservation measures are attractive economic investments from a homeowner's perspective, compared to either other investment possibilities or to maintaining present consumption levels at current residential fuel or electricity prices. The median real rate of return ranged from 6% in the 30 low-income weatherization projects to 25% in 19 utility-sponsored programs. These rates compare favorably with real rates of return from tax-free bonds (3 - 5%). Approximately 75 - 80% of the retrofit projects have costs of conserved energy below their respective space heating fuel or electricity prices.

Finally, this compilation highlights gaps or limitations in the data currently available on the measured performance of retrofits in existing residential buildings [21]:

- Measured data on retrofit performance in existing multifamily buildings, though increasing in number, are still inadequate. Successful retrofit strategies noted in this study must be tested in other climatic regions and in varying building types.
- Insufficient data are available on energy savings trends over multi-year periods. This information is needed to validate engineering estimates of retrofit lifetime, a factor that can be as crucial to cost-effectiveness as first-year savings. Long-term tracking of occupied buildings, however, magnifies the problem of accounting for changes in operating conditions, occupancy, or the effect of additional retrofits. Successful projects will need stable research funding and will almost surely require direct monitoring of major household end-uses and inside temperatures.
- Few data are available on the effect of retrofits on peak power and cooling energy requirements. We have had limited success obtaining data from regions of the country (i.e., Southeastern and Southwestern U.S.) where cooling accounts for a substantial portion of total residential energy use. There are also less data on retrofits directed at end-uses other than space heating. Studies of active and passive solar retrofits are not properly represented in the data base, often because of insufficient cost data.

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APPENDIX A

Summary Data Table

Explanatory notes on Table headings:

(A) Label is a project's identification number. An asterisk (*) indicates a new entry to the data base and a plus (+) denotes substantial revision to a previously entered project. The first letter indicates the principal fuel used for space heating ("G" = natural gas, "O" = fuel oil, "E" = electricity, "M" = mixed fuel — heating fuel differed from house to house within a study sample). The number after the initial letter is a counting index that identifies each retrofit project. The number after the decimal point indicates that groups of homes received different retrofit treatments at a particular site. The letter "A" or "B" at the end of the label signifies an "active" or a "blind" control group. Example: "G7.3A" signifies gas-heated homes which are part of an active control group at the 7th site.

(B) Number of homes in a retrofit project included in the database. The number of apartment units is indicated for each multi-family building.

(E) Retrofit measures — a two-character code used to identify measures installed. The measure must have been implemented in at least 20% of the homes in a project to be listed. The retrofit measure code key is: operations and maintenance (OM), heating system retrofits (HS), HVAC controls (HC), clock thermostats (T), heating system replacement (HR), insulation of walls (IW), attic (IA), or floor (IF), caulking and weatherstripping (CW), infiltration-reduction using diagnostic equipment (PI), window management (WM), water heating (WH), storm doors (DR), and lighting system (LS).

(F) Heating degree-days — the 30-year average of heating degree-days for the retrofit site(s).

(G) Year of retrofit — the actual year of retrofit or the median year in cases where a large sample of homes was retrofitted over several years.

(H) Floor area — average floor area for homes in the sample. In multifamily buildings, floor area per apartment unit is indicated. A missing value indicates that floor area was not available.

(I) Energy use code (EUC) indicates the end-uses included in adjusted total energy use (Col. J). The letter code is: "W" = space heating and domestic hot water heating; "F" = all end-uses of the space heating fuel (generally includes water heating, cooking, clothes drying, etc.); "B" = non-space heating consumption (baseload); "L" = lighting. The EUC also indicates the energy savings (Col. J2 or K2) used in the economic calculations; space heating ("H") or total usage (either "F" or "W").

(J1, J2, J3) Adjusted total energy use — the weather-adjusted annual consumption of the heating fuel. Yearly savings in absolute terms and as a percentage of pre-retrofit consumption are shown. Generally, the heating energy data are combined with other (baseline) uses of the same fuel. Missing values usually indicate that only space heating consumption was available (e.g. EUC = "H"). The space heat portion of consumption is normalized to the long-term average weather at that site. Units are gigajoules (GJ) for fuel-heat homes and kilowatt-hours (kWh) for electric-heat homes (1 GJ = 0.948 MBtu). Percent savings are calculated by taking the mean consumption before and after retrofit for homes in a retrofit project and calculating percent savings for the group as a whole.

(K1, K2 and K3) Adjusted space heat use — the weather-adjusted space heating usage. Yearly savings in absolute terms and as a percentage of pre-retrofit space heating consumption are shown. Percent savings are calculated using the method described in total energy use.

(L1 and L2) Heating factor is derived by dividing average space heat usage by the mean floor area and number of normal year heating degree-days (base 18.3 °C) at that site. Electricity used for space heating is converted into site energy and that value is divided by 0.67, the average assumed efficiency of existing gas or oil systems (i.e., 3.6 MJ/0.67 or 5.4 MJ per kWh). This adjustment is made to account for the higher site efficiency of electric heating systems, thus allowing rough comparisons of building shell performance between homes heated with gas and electricity. [$kJ/m^2\ DD_C \times 0.049 = Btu/ft^2\ DD_F$]

(M) Retrofit cost — the average first cost of retrofit (1983$).

(N) Simple payback time (SPT) in years.

(O) Cost of conserved energy (CCE) — in calculating the capital recovery rate, a real discount rate of 7% is used. Retrofit lifetime estimates (in parentheses) for various measures and programs are: attic insulation only (20), storm windows (15), caulking and weatherstripping (5), measures associated with 'house-doctor' treatment (10), storm doors (10), insulating blanket on hot water heater (10), thermostatic radiator valve (10), heating system improvements (15 - 20), energy management control system (10), lighting system changes (10), DOE and CSA/NBS low-income weatherization programs (15), utility-sponsored conservation programs (20). Units for CCE are $/GJ for fuel-heated homes and cents/kWh for electric-heat homes.

(Q) Net present value (NPV) of energy savings. Assumptions used in the NPV calculation include: 7% real discount rate; 4% real energy price escalation rate; 15% federal tax credit; expected retrofit lifetime (see Column O); salvage value and maintenance costs for single-family retrofit projects are assumed to be zero; estimated annual maintenance cost depends on measure in multi-unit buildings.

(R) Internal rate of return (IRR) — assumptions are the same as for NPV (except that the discount rate is not specified).

(S) Confidence level — assessment of overall reliability of results from a particular retrofit

project. Criteria used in ranking are explained below:

"A" = high confidence in the data. Consumption data for each house analyzed using linear regression model with variable reference temperature or sub-metered data was collected. Retrofit costs are also well documented Often, total costs are itemized by measure or divided into material and labor costs. The experimental design includes a control group.

"B" = medium high confidence. Consumption data analyzed using a regression model with reference temperature fixed at 65 °F. Baseload usage is determined from the fuel bills of the summer months. Space heating usage is scaled by the ratio of normal-to-actual heating degree-days (base 18.3 °C) at that site. Retrofit costs are fairly well documented. In some cases, a control group is employed.

"C" = average confidence. Often, only annual consumption data are available for each house and no weather or baseload corrections have been made by the original authors. A simplified baseload subtraction is made using either summer months' fuel bills or regional estimates. Retrofit cost data are barely adequate, in some cases consisting of only materials cost and labor hours.

"D" = low confidence. Energy consumption data used in the project evaluation are of poor quality. Retrofit measures and costs are often not indicated. Evaluation methodology is not explained.

"F" = no confidence. Very crude data with much missing information. Major flaws exist in the data, e.g., metered consumption data were not collected.

"I" = data are incomplete.

(No "F"-level data are included in this study. "D"-level data are shown in the Summary Data Table but are not included in the Figures.)

(Appendix A, Summary Data Table, overleaf.)

APPENDIX A

Summary Data Table

(A) LABEL	(B) NUMBER OF HOMES	(C) LOCATION	(D) SPONSOR	(E) RETROFIT MEASURES	(F) HDD (^{o}C)	(G) YR	(H) FLOOR AREA (M^2)	(I) EUC	(J1) ADJ. TOTAL ENERGY USE PRE-RETR. (GJ/YR)	(J2) SAVINGS (GJ/YR)	(J3) (%)
RESEARCH STUDIES											
O 1	1	NEW JERSEY	PU/CEES	IA,WM,OM,PI	2728	79	185	H			
• O 10 B	30	LONG ISLAND,NY	BNL		3056		145	W	156.5	18.5	12
• O 10.1	19	LONG ISLAND,NY	BNL	HS	3056	80	160	W	161.1	22.7	14
• O 10.2	27	LONG ISLAND,NY	BNL	HS,OM	3056	80	170	W	175.1	34.0	19
• O 10.3	14	LONG ISLAND,NY	BNL	HS,OM,T	3056	80	176	W	168.4	38.3	23
• O 10.4	9	LONG ISLAND,NY	BNL	HS,OM	3056	80	186	W	184.9	46.0	25
• O 10.5	17	LONG ISLAND,NY	BNL	HS	3056	80	175	W	179.6	29.0	16
• O 10.6	21	LONG ISLAND,NY	BNL	HS	3056	80	169	W	177.0	25.0	14
• O 10.7	14	LONG ISLAND,NY	BNL	HS,T	3056	80	178	W	179.6	16.1	9
• O 10.8	14	LONG ISLAND,NY	BNL	HS,T	3056	80	173	W	185.6	40.9	22
• M 13.1	130	SWEDEN	ROYAL INST	IW	4011	77	138	W	150.3	19.5	13
• M 13.2	106	SWEDEN	ROYAL INST	IA	4011	77	168	W	166.4	17.1	10
• M 13.3	105	SWEDEN	ROYAL INST	IW,IA	4011	77	142	W	159.4	18.1	11
• M 13.4	140	SWEDEN	ROYAL INST	IA,HS	4011	77	152	W	173.9	25.5	15
• M 13.5	111	SWEDEN	ROYAL INST	WM	4011	77	170	W	163.6	12.1	7
• M 13.6	17	SWEDEN	ROYAL INST	WM,IA	4011	77	144	W	149.9	14.9	10
• M 13.7	32	SWEDEN	ROYAL INST	HS	4011	77	180	W	182.8	22.3	12
• M 14.1	30	SWEDEN	ROYAL INST	IW	4011	77	64	W	68.1	9.5	14
• M 14.2	25	SWEDEN	ROYAL INST	IA	4011	77	71	W	83.0	7.0	8
• M 14.7	63	SWEDEN	ROYAL INST	HS	4011	77	75	W	80.9	6.2	8
G 2	1	TWIN RIVERS,NJ	PU/CEES	IX,WM,CW,PI	2728	77	139	H			
G 3	1	NEW JERSEY	PU/CEES	IA,WM,OM,PI	2728	79	112	H			
G 4	1	NEW JERSEY	PU/CEES	IA,DR,OM,PI	2728	79	145	H			
G 5.1	6	MRE/FREEHOLD,NJ	PU/NJNG	IX,IA,PI,WH,T	2707	80	232	F	188.8	46.4	25
G 5.2	12	MRE/FREEHOLD,NJ	PU/NJNG	PI,WH,T	2707	80	232	F	181.5	30.6	17
G 5.3B	6	MRE/FREEHOLD,NJ	PU/NJNG		2707		232	F	195.2	11.6	6
G 5.4B	140000	MRE/NJNG	PU/NJNG		2707			F			3
G 6.1	6	MRE/TOMS RIVER,NJ	PU/NJNG	IX,IA,PI,WH,T	2707	80	81	F	91.8	17.9	20
G 6.2	12	MRE/TOMS RIVER,NJ	PU/NJNG	PI,WH,T	2707	80	80	F	104.4	7.4	7
G 6.3B	6	MRE/TOMS RIVER,NJ	PU/NJNG		2707		84	F	103.4	0.0	0
G 6.4B	140000	MRE/NJNG	PU/NJNG		2707			F			4
G 7.1	6	MRE/OAK VALLEY,NJ	PU/SJG	IX,T,PI,WM	2707	80	130	F	122.4	28.5	23
G 7.2	9	MRE/OAK VALLEY,NJ	PU/SJG	PI,WH,T	2707	80	130	F	127.7	28.5	22
G 7.3A	6	MRE/OAK VALLEY,NJ	PU/SJG		2707		130	F	135.0	13.7	10
G 7.4B	75000	MRE/SJG	PU/SJG		2707			F			11
G 8.1	5	MRE/WHITMAN SQ,NJ	PU/SJG	IX,IA,PI,WH,T	2707	80	197	F	155.1	36.9	24
G 8.2	9	MRE/WHITMAN SQ,NJ	PU/SJG	PI,WH,T	2707	80	175	F	142.4	27.4	19
G 8.3A	4	MRE/WHITMAN SQ,NJ	PU/SJG		2707		186	F	141.4	23.2	16
G 8.4B	75000	MRE/SJG	PU/SJG		2707			F			12
G 9.1	5	SASKATCHEWAN,CAN.	ECIC/NRC	IA,IF,CW,PI	6077	80	200	H	221.4	56.2	25
G 9.2	5	SASKATCHEWAN,CAN.	ECIC/NRC	CW,PI	6077	80	163	H	209.6	15.4	7
G 9.3	10	SASKATCHEWAN,CAN.	ECIC/NRC	IA,IW,WM,DR	6077	80		H	159.1	16.7	10
G 10	1	BUTTE,MT	NCAT	IA,IW,CW,SH	5372	80	214	H			
G 24.1	6	MRE/EDISON,NJ	PU/E.G.	IX,T,PI	2707	80	165	F	172.0	40.1	23
G 24.2	5	MRE/EDISON,NJ	PU/E.G.	PI,T	2707	80	168	F	173.0	25.3	15
G 24.3A	6	MRE/EDISON,NJ	PU/E.G.		2707		167	F	175.1	11.6	7
G 24.4B	75000	MRE/ELIZ. GAS	PU/E.G.		2707			F			10
G 25.1	6	MRE/WOOD RIDGE,NJ	PU/PSEG	IX,PI	2707	80	125	F	186.7	27.4	15
G 25.2	6	MRE/WOOD RIDGE,NJ	PU/PSEG	PI,WH	2707	80	127	F	167.7	22.2	13
G 25.3A	6	MRE/WOOD RIDGE,NJ	PU/PSEG		2707		130	F	156.1	17.9	11
G 25.4B	550000	MRE/PSEG,NJ	PU/PSEG		2707			F			11
G 26.1	5	MRE/NEW ROCH.,NY	PU/CONED	IX,T,PI,OM	2707	80	121	F	163.5	32.7	20
G 26.2	5	MRE/NEW ROCH.,NY	PU/CONED	PI,WH,OM,T	2707	80	136	F	168.8	25.3	15
G 26.3A	6	MRE/NEW ROCH.,NY	PU/CONED		2707		130	F	167.7	20.0	12
• G 27.1	13	WALNUT CREEK,CA	PG&E/LBL	PI,HS,WH,OM	1611	80	208	F	135.3	17.3	13
• G 27.2A	6	WALNUT CREEK,CA	PG&E/LBL		1611		232	F	142.0	15.0	11
• G 27.3B	1800	WALNUT CREEK,CA	PG&E/LBL		1611			F	92.6	6.5	7
• G 28	12	CHAMPAIGN, ILL.	U. OF ILL.	IA,IW	3207	78	148	F	184.7	43.9	24
• G 29.1	25	DENVER,COL.	SERI/DOE	CW,OM,WH,IA,IX,ID,T	3342	81		F	162.0	31.0	19
• G 29.2A	25	DENVER,COL.	SERI/DOE		3342			F	143.0	20.9	15

(A) LABEL	(K1) ADJ. SPACE HEAT USE PRE-RETR. (GJ/YR)	(K2) SAVINGS (GJ/YR)	(K3) (%)	(L1) HEATING FACTOR BEFORE (KJ/M²-DD)	(L2) AFTER	(M) RETRO-FIT COST (83$)	(N) SPT (YR)	(O) CCE d=7% ($/GJ)	(Q) NPV ($)	(R) IRR (%)	(S) CONFI-DENCE LEVEL	COMMENTS
RESEARCH STUDIES (cont.)												
O 1	139.3	73.3	53	276	131	1610	3.1	2.41	3432	38.2	A	ELIM. BYPASS LOSSES
O 10 B	129.9	15.3	12	293	259						B	CONTROL GROUP
O 10.1	133.7	18.8	14	274	235	383	1.9	1.85	1499	61.5	B	RET. HEAD BURNER (RHB)
O 10.2	145.4	28.2	19	281	226	483	1.6	1.56	2322	73.1	B	RHB W/ OPT INSTALLATION
O 10.3	139.8	31.8	23	260	201	799	2.4	2.29	2401	49.7	B	RHB W/ TEMP. PROGRAMMER
O 10.4	153.5	38.2	25	270	203	828	2.0	1.98	2996	57.6	B	RHB W/ VENT DAMPER
O 10.5	149.0	24.1	16	278	233	348	1.4	1.32	2038	86.7	B	DAMPER WITH CONV. BURNER
O 10.6	146.9	20.8	14	285	245	613	2.8	2.69	1490	42.2	B	FLUE HT. EXCH. W/ BURNER
O 10.7	149.0	13.4	9	275	250	94	0.7	0.64	1218	178.0	B	SETBACK W/ CONV. BURNER
O 10.8	154.0	34.0	22	292	228	465	1.3	1.25	2897	91.4	B	SETBACK+TEMP. PROG.
M 13.1											C	WALL INSUL.—SF AGG. RESULTS
M 13.2											C	ATTIC INSUL.- SF AGG. RESULTS
M 13.3											C	WALL+ATTIC INS.-SF RESULTS
M 13.4											C	WALL+ATTIC INS.+TRV- AGG.
M 13.5											C	TRIPLE GLAZING—AGG. RESULTS
M 13.6											C	TRIPLE GLAZING+WALL INS.- AGG.
M 13.7											C	TRV VALVE
M 14.1											C	WALL INSUL.- MF AGG. RESULTS
M 14.2											C	ATTIC INSUL.-MF AGG. RESULTS
M 14.7											C	TRV VALVE + VARIATOR EQUIP.
G 2	85.5	65.2	76	225	53	4667	16.2	7.86	-1340	1.1	A	EXTENSIVE RETR. AT TWIN RIVERS
G 3	62.9	25.2	40	207	124	939	7.9	4.09	282	12.2	A	RES. STUDY ON BYPASS LOSSES
G 4	120.7	32.0	26	305	224	1342	8.9	4.61	230	10.1	A	RES. STUDY ON BYPASS LOSSES
G 5.1	118.2	37.2	32	188	129	3164	12.9	6.44	- 099	6.5	A	HOUSE DOCTOR + CONTRACTOR RETR
G 5.2	119.5	15.4	13	190	166	401	2.5	1.87	791	46.2	A	HOUSE DOCTOR RETR. ONLY
G 5.3B	140.1	1.3	1	223	221						A	BLIND CONTROL GROUP
G 5.4B											A	UTILITY AGGREGATE
G 6.1	63.4	15.3	24	290	220	1571	16.6	8.27	- 334	3.6	A	HOUSE DOCTOR + CONTRACTOR RETR
G 6.2	69.4	4.2	6	321	301	401	10.3	7.74	- 068	2.5	A	HOUSE DOCTOR RETR. ONLY
G 6.3B	73.1	0.0	0	323	323						A	BLIND CONTROL GROUP
G 6.4B											A	UTILITY AGGREGATE
G 7.1	72.0	22.3	31	204	141	1125	6.2	3.73	951	18.2	A	HOUSE DOCTOR + CONTRACTOR RETR
G 7.2	69.8	17.3	25	198	149	401	2.2	2.01	924	52.0	A	HOUSE DOCTOR RETR. ONLY
G 7.3A	76.3	13.7	18	217	178						A	ACTIVE CONTROL GROUP
G 7.4B											A	UTILITY AGGREGATE
G 8.1	131.6	34.9	27	247	181	820	3.5	2.10	1776	33.4	A	HOUSE DOCTOR + CONTRACTOR RETR
G 8.2	106.9	21.5	20	226	180	401	2.3	2.08	877	49.9	A	HOUSE DOCTOR RETR. ONLY
G 8.3A	109.0	24.7	23	217	168						A	ACTIVE CONTROL GROUP
G 8.4B											A	UTILITY AGGREGATE
G 9.1	186.8	56.2	30	153	107	2329	14.2	4.55	- 217	5.2	B	GROUP #1—INSUL.+ INFIL. REDN
G 9.2	172.5	15.7	9	174	158	606	13.2	5.49	- 135	.0	B	GROUP #2—INFIL. REDN. ONLY
G 9.3	134.2	16.8	12			1699	34.7	9.56	- 833	.0	C	GROUP #3—INSUL. MAINLY
G 10	277.4	61.7	22	242	188	16398	70.1	25.08	-9998	.0	B	PASSIVE SOLAR WALL IN 2ND YR
G 24.1	114.6	36.9	32	256	174	1692	7.2	3.98	1048	15.4	A	HOUSE DOCTOR + CONTRACTOR RETR
G 24.2	111.0	23.1	21	244	193	401	2.7	2.26	700	42.2	A	HOUSE DOCTOR RETR. ONLY
G 24.3A	121.2	25.0	21	268	213						A	ACTIVE CONTROL GROUP
G 24.4B											A	UTILITY AGGREGATE
G 25.1	136.0	37.5	28	402	291	1187	7.4	4.08	692	14.9	A	HOUSE DOCTOR + CONTRACTOR RETR
G 25.2	120.9	27.3	23	351	272	401	3.1	2.58	570	36.3	A	HOUSE DOCTOR RETR. ONLY
G 25.3A	115.8	24.5	21	329	259						A	ACTIVE CONTROL GROUP
G 25.4B											A	UTILITY AGGREGATE
G 26.1	105.1	23.0	22	321	251	1245	6.5	3.59	970	17.4	A	HOUSE DOCTOR + CONTRACTOR RETR
G 26.2	92.8	13.7	15	253	215	401	2.7	2.26	700	42.2	A	HOUSE DOCTOR RETR. ONLY
G 26.3A	118.0	17.3	15	335	286						A	ACTIVE CONTROL GROUP
G 27.1						525	6.3	4.32	136	13.2	A	HOUSE DOCTOR ONLY
G 27.2A											A	AUDIT ONLY-ACTIVE CONTROL
G 27.3B											A	BLIND CONTROL-UTIL. AGGREGATE
G 28	141.1	42.4	30	297	207	1285	8.2	2.76	1282	20.0	B	INSUL. INSTALLED BY PRIV. FIRM
G 29.1						792	5.3	3.64	373	17.9	B	50/50 PROGRAM
G 29.2A											B	NON-PART. CONTROL GROUP

(continued overleaf)

Summary Data Table *(continued)*

(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J1)	(J2)	(J3)
									ADJ. TOTAL ENERGY USE		
	NUMBER						FLOOR	E	PRE-		
	OF			RETROFIT	HDD		AREA	U	RETR.	SAVINGS	
LABEL	HOMES	LOCATION	SPONSOR	MEASURES	(^{o}C)	YR	(M^2)	C	(GJ/YR)	(GJ/YR)	(%)
									(KWH)	(KWH)	
E 3.1	29	DENVER,COL	J-M CO.	PI	3342	78	149	H			
E 3.2A	30	DENVER,COL	J-M CO.		3342			H			
E 3.3B	30	DENVER,COL	J-M CO.		3342			H			
E 8.1	5	MIDWAY,WA	BPA/LBL	PI	2644	80	117	H			
E 8.2	5	MIDWAY,WA	BPA/LBL	IA,IX,CW	2644	79	116	H			
E 8.3	4	MIDWAY,WA	BPA/LBL	IA,IX,WM,DR,CW	2644	79	115	H			
+ E 10	1	BOWMAN HOUSE,MD	NBS	IA,IF,IW,WM,CW	2561	75	191	H			
UTILITY SPONSORED PROGRAMS											
E 1.1	69	TENNESSEE	TVA	IA,IF,CW	2464	76	94	H			
E 1.2	105	TENNESSEE	TVA	IA	2456	76		H			
E 2	546	TENNESSEE	TVA	IA	2228	78		H			
+ E 4.1	973	OREGON	PP&L	IA,IF,WM,DR,CW,WH	2725	79	138	F	25421.0	4461.0	18
+ E 4.4B	69337	SIX N.W. STATES	PP&L		2725			F	24386.0	869.0	4
E 5.1	133	SEATTLE,WA.	SCL	IA,IF	2881	79		H	30110.0	4180.0	14
E 5.2B	551	SEATTLE,WA.	SCL		2881			H	29843.0		
+ E 6.1	6289	WASHINGTON	PUGET PWR.	IA,IW,IF,WM,DR,T,WH	3056	80	155	F	32800.0	8575.0	26
+ E 7.1	300	PORTLAND,ORE	PGE	IA,IF,WM,DR,WH,CW	2662	78		F	23638.0	3937.0	17
+ E 7.2B	200	PORTLAND,ORE	PGE		2662			F	20177.0	8.0	0
• E 9.2	810	E. WASH./IDAHO	WWP	IA,IF,DR,WM	3797	79	116	H	30137.0	4349.0	14
• E 9.3B	251	E. WASH./IDAHO	WWP		3797		129	F	24794.0	1248.0	5
• E 11.1	195	ORE,WASH,MONTANA	BPA	IA,IF,IW,DR,WM,CW	2958	81	164	F	27200.0	4400.0	16
• E 11.2A	54	ORE,WASH,MONTANA	BPA		2958		123	F	22500.0	2200.0	10
• E 11.3B	200	ORE,WASH,MONTANA	BPA		2958			F	23000.0	1100.0	5
• E 13.1	183	SEATTLE,WA.	SCL	IA,WM,IF,WH,IW,ID,CW	2881	81	153	F	26320.0	2880.0	11
• E 13.2A	270	SEATTLE,WA.	SCL		2881		142	F	25320.0	-80.0	0
• E 13.3B	112	SEATTLE,WA.	SCL		2881		155	F	25690.0	-490.0	- 2
• E 14.1	293	SEATTLE,WA.	SCL	IA,IF,IW,WH,ID,CW	2881	81	118	F	21055.0	3039.0	14
• E 14.2B	208	SEATTLE,WA.	SCL		2881		122	F	21840.0	-299.0	- 1
• E 15.1	321	SEATTLE,WA.	SCL	WH		79		B	11249.0	465.0	4
• E 15.2A	124	SEATTLE,WA.	SCL					B	11894.0	-83.0	- 1
• E 16.1	208	PORTLAND,ORE	PGE	IA,IF,WM,DR,WH,CW	2662	79	147	F	24491.0	4243.0	17
• E 16.2A	105	PORTLAND,ORE	PGE		2662		145	F	23464.0	2899.0	12
• E 16.3B	91	PORTLAND,ORE	PGE		2662		134	F	21045.0	1763.0	8
• E 17.1	101	BOISE,IDAHO	IDAHO PWR	IA,IF,IW,WM,ID,CW	3241	81	123	F	23080.0	2180.0	9
• E 17.2B	48	BOISE,IDAHO.	IDAHO PWR		3241			F	20880.0	550.0	3
									(GJ/YR)	(GJ/YR)	
G 11	84	RAMSEY COUNTY,MINN	NSP	IA,CW	4533	79	177	H	206.6	12.4	6
G 12.1	33	BAKERSFIELD,CA	PG&E	IA	1214	79		H	123.0	15.7	13
G 12.2	16	FRESNO,CA	PG&E	IA	1472	79		H	100.4	20.6	21
G 13	33000	COLORADO	PSC	IA	3342	77		H	165.8	20.8	13
• G 30	71	DETROIT,MICH.	CONS. GAS	IA	3477	74		H	269.1	35.0	13
LOW-INCOME WEATHERIZATION PROJECTS											
O 6	13	VERMONT	DOE/LIW	IA,WM,DR	4376	80		H			
• O 7.1	47	PHILADELPHIA,PA.	ASE	HS,OM,T	2703	80		W	154.6	28.9	19
• O 7.2A	45	PHILADELPHIA,PA.	ASE		2703			H			
• O 11.1	42	MINNESOTA	LIEAP	HS	4991	83		H			
• O 11.2	29	MINNESOTA	LIEAP	IA,IW,CW,WM	4991	83		H			
• O 11.3	15	MINNESOTA	LIEAP	HS,IA,IW,CW,WM	4991	83		H			
• O 11.4A	32	MINNESOTA	LIEAP		4991			H			
M 1.1	13	CHARLESTON,SC	CSA/NBS	IA,IX,CW,WR,WH	1192	79	103	H			
M 1.2A	5	CHARLESTON,SC	CSA/NBS		1192			H			
M 2	8	ATLANTA,GA	CSA/NBS	IA,WM,IX,CW,IW,WR	1719	79	98	H			
M 3	4	WASH,DC	CSA/NBS	IA,IW,IX,CW,WM,HS,WH,T	2339	79	85	H			
M 4.1	9	TACOMA,WA	CSA/NBS	IA,IW,IX,WM,CW,WH	2881	79	91	H			
M 4.2A	5	TACOMA,WA	CSA/NBS		2881			H			
M 5.1	13	EASTON,PA	CSA/NBS	IA,IW,CW,WR,WH,T,HS	3237	79	124	H			
M 5.2A	3	EASTON,PA	CSA/NBS		3237			H			
M 6.1	14	PORTLAND,ME	CSA/NBS	IA,IW,IX,CW,WM,HS,T,WH	4166	79	94	H			
M 6.2A	4	PORTLAND,ME	CSA/NBS		4166			H			
M 7.1	12	FARGO,ND	CSA/NBS	IA,IW,IX,CW,WM,WH,HS,T	5151	79	73	H			
M 7.2A	3	FARGO,ND	CSA/NBS		5151			H			
M 9	65	NW WISCONSIN	CSA	IA,WM,DR,CW	4660	76	120	H			

(A) LABEL	(K1) ADJ. SPACE HEAT USE PRE-RETR. (GJ/YR)	(K2) SAVINGS (GJ/YR)	(K3) (%)	(L1) HEATING FACTOR BEFORE (KJ/M²-DD)	(L2) AFTER	(M) RETRO-FIT COST (83$)	(N) SPT (YR)	(O) CCE d=7% ($/GJ)	(Q) NPV ($)	(R) IRR (%)	(S) CONFI-DENCE LEVEL	COMMENTS
	(KWH)	(KWH)						(¢/KWH)				
E 3.1	17615.0	2836.0	16	192	161	1438	8.9	7.22	333	12.6	A	AIR INFIL. REDUCTION STUDY
E 3.2A	20606.0	2891.0	14								A	ACTIVE CONTROL GROUP
E 3.3B	23886.0	2852.0	12								A	BLIND CONTROL GROUP
E 8.1	19984.0	1846.0	9	349	317	603	11.4	4.65	- 140	.0	A	EXTENDED INFILTRATION REDN.
E 8.2	19803.0	3235.0	16	348	291	2356	23.0	6.87	- 917	.0	A	ATTIC AND CRAWLSPACE INS.
E 8.3	19649.0	8204.0	42	349	203	5095	19.6	5.86	-1578	1.8	A	INSUL.+ STORM WINDOW & DOOR
E 10	20330.0	11906.0	59	225	93	4709	8.0	4.34	1391	12.2	A	FIRST EXTENSIVE RES. STUDY
UTILITY-SPONSORED PROGRAMS (cont.)												
E 1.1	11270.0	6122.0	54	263	120	705	3.5	1.26	1762	37.5	C	DEMO PGM. BY PRIVATE CONTRAC.
E 1.2	12383.0	4112.0	33			296	2.2	0.68	1729	58.4	C	DEMO PGM. BY TVA PERSONNEL
E 2	10148.0	2211.0	22			443	5.1	1.89	906	27.1	A	EARLY STAGE OF HOME INSUL. PGM
E 4.1	12060.0	3980.0	33	173	116	2007	10.5	4.25	2012	17.8	C	GROUP 1—WEATH. + HTR.WRAP
E 4.4B											C	CONTROL GR.-ALL SF NON-PARTS.
E 5.1	17110.0	4180.0	24			525	5.1	1.18	1124	28.0	C	INSUL. PGM.-EARLY RESULTS
E 5.2B	16843.0	2209.0	13								C	BLIND CONTROL GROUP
E 6.1	19336.0	7903.0	41	220	130	1444	5.1	1.59	2971	27.2	C	ZERO-INT. LOAN WEATH. PGM.
E 7.1	11900.0	3500.0	29			1863	12.8	4.47	606	10.9	B	EARLY PARTS. IN WEATH. PGM.
E 7.2B											B	BLIND CONTROL GR.- NON-PART.
E 9.2	18137.0	4349.0	24	222	169	1515	17.2	3.29	38	7.3	B	ZERO-INTEREST WEATH. PGM.
E 9.3B											B	CONTROL GROUP
E 11.1	15740.0	4130.0	26	176	130	2312	25.9	4.96	- 653	2.9	A	WEATH. PILOT PGM.- AUDIT+LOAN
E 11.2A	14400.0	1410.0	10	215	194						A	WEATH. PILOT PGM.- AUDIT ONLY
E 11.3B	12750.0	850.0	7								A	WEATH. PILOT PGM.- NON-PART.
E 13.1	14320.0	2380.0	17	176	147	1743	28.1	5.71	- 547	2.3	B	HELP PGM.- AUDIT+LOAN
E 13.2A	13720.0	-80.0	- 1	181	182						B	HELP PGM.- AUDIT ONLY
E 13.3B	14090.0	-490.0	- 3	171	177						B	HELP PGM.- NON-PART.
E 14.1	10555.0	2555.0	24	167	127	1569	23.4	4.87	- 327	4.1	C	LOW-INC ELEC. PGM.-AUDIT+LOAN
E 14.2B											C	LOW-INCOME ELEC.PGM.- CONTROLS
E 15.1						39	3.8	1.18	55	33.6	C	AUDIT PGM.-HOT WATER RETR.
E 15.2A											C	AUDIT PGM.-NO HOT WATER ACTION
E 16.1	11880.0	3800.0	32	165	112	1841	11.8	4.10	784	12.0	A	ZIP WEATH. PGM.—AUDIT+LOAN
E 16.2A	11240.0	2500.0	22	157	122						A	ZIP WEATH. PGM.- AUDIT ONLY
E 16.3B	9340.0	1340.0	14	141	121						A	ZIP WEATH. PGM.- NON-PARTS.
E 17.1	12080.0	2180.0	18	164	134	1096	14.3	4.75	211	9.4	C	ZERO-INTEREST LOAN PGM.
E 17.2B	9880.0	550.0	6								C	BLIND CONTROL GROUP
	(GJ/YR)	(GJ/YR)						($/GJ)				
G 11	165.3	12.4	8	207	191	374	8.4	2.83	355	17.3	C	UTILITY LOW-INCOME WEATH. PGM.
G 12.1	87.6	15.7	18			573	5.7	3.44	1015	24.8	B	ATTIC INSUL. PGM.
G 12.2	64.9	20.6	32			560	4.3	2.56	1500	32.5	B	ATTIC INSUL. PGM.
G 13	125.8	20.7	16			416	5.1	1.90	1528	40.7	C	ATTIC INSUL. LOW-INT. LOAN PGM
G 30	204.4	34.5	17			521	4.2	1.43	1477	33.8	C	ATTIC INSULATION PROG.
LOW-INCOME WEATHERIZATION PROJECTS (cont.)												
O 6	151.4	45.9	30			1770	4.1	4.24	- 959	.0	D	LOW INCOME WEATHERIZATION
O 7.1	123.6	23.1	19			575	2.5	2.18	1573	46.2	C	OIL FURNACE PILOT RETR. PGM.
O 7.2A	157.6	4.1	3								C	ACTIVE CONTROL-OIL FURN.RETR.
O 11.1			22			565					I	GR. I—OIL FURNACE RETROFIT
O 11.2			12			1350					I	GR. II—WEATHERIZATION ONLY
O 11.3			29			1915					I	GR. III-OIL FURN. RETR.+WEATH.
O 11.4A			0								I	GR. IV—ACTIVE CONTROL
M 1.1	65.9	22.3	34	536	355	1285	6.6	6.34	682	15.9	A	LIW RESEARCH DEMO. PGM.
M 1.2A	38.3	5.9	15								A	ACTIVE CONTROL GROUP
M 2	114.0	14.8	13	677	589	1592	18.9	11.84	- 586	.0	A	LIW RESEARCH DEMO. PGM.
M 3	137.7	64.8	47	692	367	3845	6.3	6.52	2291	16.9	A	LIW RESEARCH DEMO. PGM.
M 4.1	178.1	72.8	41	680	402	2376	8.4	3.58	559	11.1	A	LIW RESEARCH DEMO. PGM.
M 4.2A	62.8	9.9	16								A	ACTIVE CONTROL GROUP
M 5.1	128.4	30.2	24	320	245	1190	6.1	4.33	766	17.6	A	LIW RESEARCH DEMO. PGM.
M 5.2A	46.4	4.4	9								A	ACTIVE CONTROL GROUP
M 6.1	197.6	86.4	44	507	285	2913	3.8	3.70	4508	30.4	A	LIW RESEARCH DEMO. PGM.
M 6.2A	245.3	30.3	12								A	ACTIVE CONTROL GROUP
M 7.1	115.5	46.1	40	307	185	2138	5.7	5.09	1600	19.2	A	LIW RESEARCH DEMO. PGM.
M 7.2A	153.1	14.6	10								A	ACTIVE CONTROL GROUP
M 9	150.9	28.6	19	270	219	355	2.4	1.36	1047	48.9	C	LOW-INC. WEATH.- REGIONAL EVAL.

(continued overleaf)

Summary Data Table *(continued)*

(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J1)	(J2)	(J3)
									ADJ. TOTAL ENERGY USE		
LABEL	NUMBER OF HOMES	LOCATION	SPONSOR	RETROFIT MEASURES	HDD (°C)	YR	FLOOR AREA (M^2)	EUC	PRE-RETR. (GJ/YR)	SAVINGS (GJ/YR)	(%)
M 10.1	59	MINNESOTA	DOE/LIW	IA,CW,DR,WR,WM,IW	4617	78	75	H	146.2	14.9	10
M 10.2B	37	MINNESOTA	DOE/LIW		4617		123	H	169.5	-4.2	- 2
M 10.3	19	MINNESOTA	DOE/LIW	IA,CW,DR,WR,WM,IW	4617	78	72	H	136.6	9.1	7
M 11	13	WISCONSIN	DOE/LIW		4900	79		H			
M 12	86	ALLEGAN CTY.,MICH.	DOE/LIW		3778	80		H			
• G 1	11	WISCONSIN	DOE/LIW	IA,IF,CW,WM,WR,WH	4221	81	84	H	151.6	21.6	14
G 14.1	8	OAKLAND,CA	CSA/NBS	IA,CW,WR	1616	79	121	H			
G 14.2A	4	OAKLAND,CA	CSA/NBS		1616			H			
G 15	18	ST LOUIS,MO	CSA/NBS	IA,CW,WM,IW,IX	2639	79	126	H			
G 16	10	CHICAGO,ILL	CSA/NBS	IA,IW,WM,CW,WR,HS,WH,ID	3404	79	136	H			
G 17.1	16	COLORADO SPRINGS	CSA/NBS	IA,IW,IX,CW,WM,WR,HS,WH	3596	79	93	H			
G 17.2A	4	COLORADO SPRINGS	CSA/NBS		3596			H			
G 18.1	17	ST PAUL,MINN	CSA/NBS	IA,IW,CW,WR,WM,IX	4533	79	132	H			
G 18.2A	5	ST PAUL,MINN	CSA/NBS		4533			H			
G 19	30	LUZERNE CTY,PA	DOE/LIW	IA,CW,WM	3487	79		H	218.4	30.5	14
G 20	89	LOUISIANA	DOE/LIW		1000	80		H	76.3	15.0	20
G 21.1	21	KANSAS CITY,MO	DOE/LIW	IX,CW	2867	77		H	184.6	21.1	11
G 21.2	45	KANSAS CITY,MO	DOE/LIW	IX,CW	2867	77		H	249.0	46.4	19
G 21.3	44	KANSAS CITY,MO	DOE/LIW	IX,CW	2907	78		H	243.7	54.9	23
G 22	138	KENTUCKY	DOE/LIW	IX,WM,DR,CW	2627	79		H	150.8	16.6	11
G 23	30	INDIANA	DOE/LIW	IA,IF,CW,HS,WH	3098	78	102	H	218.4	30.5	14
MULTI-FAMILY BUILDINGS											
+ O 2.1	159	TRENTON,NJ	THA/HUD	HC,HS,WH	2727	81	77	W	120.1	53.4	44
O 2.2B	1500	TRENTON,NJ	THA/HUD		2728			W	123.1	19.4	16
O 3	521	WASHINGTON,D.C.	SCALLOP	HS,HC,OM	2339	78		W	122.7	8.3	7
O 4	752	MARYLAND	SCALLOP	HS,HC,OM	2339	78		W	89.6	1.9	2
O 5	60	NEW YORK CITY,NY	SCALLOP	HS,HC,OM	2693	78		W	176.5	16.0	9
• O 8	277	NEW YORK CITY,NY	NYCHA	HS	2667	77	81	H			
• O 8 A	277	NEW YORK CITY,NY	NYCHA		2667			H			
• O 8.1	42	NEW YORK CITY,NY	NYCHA	HS	2667	77	83	H			
• O 8.1A	42	NEW YORK CITY,NY	NYCHA		2667			H			
• O 8.2	98	NEW YORK CITY,NY	NYCHA	HS	2667	77	79	H			
• O 8.2A	98	NEW YORK CITY,NY	NYCHA		2667			H			
• O 8.3	56	NEW YORK CITY,NY	NYCHA	HS	2667	77	77	H			
• O 8.3A	56	NEW YORK CITY,NY	NYCHA		2667			H			
• O 8.4	81	NEW YORK CITY,NY	NYCHA	HS	2667	77	86	H			
• O 8.4A	81	NEW YORK CITY,NY	NYCHA		2667			H			
• O 9	10959	NEW YORK CITY,NY	NYCHA	WM	2667	80	76	H			
• O 9.1	1444	NEW YORK CITY,NY	NYCHA	WM	2667	80	79	H			
• O 9.2	1338	NEW YORK CITY,NY	NYCHA	WM	2667	80	72	H			
• O 9.3	1791	NEW YORK CITY,NY	NYCHA	WM	2667	80	75	H			
• O 9.4	1310	NEW YORK CITY,NY	NYCHA	WM	2667	80	75	H			
• O 9.5	1229	NEW YORK CITY,NY	NYCHA	WM	2667	81	78	H			
• O 9.6	1084	NEW YORK CITY,NY	NYCHA	WM	2667	80	71	H			
• O 9.7	1246	NEW YORK CITY,NY	NYCHA	WM	2667	80	77	H			
• O 9.8	786	NEW YORK CITY,NY	NYCHA	WM	2667	81	79	H			
• O 9.9	733	NEW YORK CITY,NY	NYCHA	WM	2667	81	79	H			
• M 15	503	ST. PAUL,MINN.	SPHA/HUD	HC,LC	4533	81		W	68.4	12.2	18
• G 31.1	19	CHICAGO,ILL.	CNT	IA,HC,HS,OM	3611	81	88	H	150.8	74.0	49
• G 31.2	22	CHICAGO,ILL.	CNT	IA,HS,OM	3611	81	96	H	188.5	74.9	40
• G 31.3	25	CHICAGO,ILL.	CNT	IA,HC,HS,WM,OM	3611	81	97	H	138.8	38.9	28
• G 31.4	7	CHICAGO,ILL.	CNT	HC,HS,OM,ID	3611	81	89	H	115.9	9.2	8
• G 31.5	6	CHICAGO,ILL.	CNT	IA,WM,HS,OM	3611	81	112	H	277.1	138.7	50
• G 31.6	6	CHICAGO,ILL.	CNT	HS,OM	3611	81	108	H	127.0	36.1	28
• G 31.7	4	CHICAGO,ILL.	CNT	HS,OM	3611	81	119	H			
• G 31.8	13	CHICAGO,ILL.	CNT	HS,HC,OM	3611	81	71	H	102.3	34.1	33
• G 32	530	NEWARK,NJ	NHA/HUD	HC,OM,HS	2698	82	69	H	171.4	17.2	10
									(KWH)	(KWH)	
• E 12	159	NEW YORK CITY, NY	NYCHA	LS		79	80	L	1285	793	62

(A)	(K1)	(K2)	(K3)	(L1)	(L2)	(M)	(N)	(O)	(Q)	(R)	(S)	
	ADJ. SPACE HEAT USE			HEATING FACTOR		RETRO-						
	PRE-			BEFORE	AFTER	FIT		CCE			CONFI-	
	RETR.	SAVINGS		(KJ/		COST	SPT	d=7%	NPV	IRR	DENCE	
LABEL	(GJ/YR)	(GJ/YR)	(%)	M^2-DD)		(83$)	(YR)	($/GJ)	($)	(%)	LEVEL	COMMENTS
M 10.1	117.0	11.9	10	338	304	1295	13.4	11.93	- 218	3.7	B	LOW-INC. WEATH.- STATE EVAL.
M 10.2B	135.6	-3.4	- 2	239	244						B	BLIND CONTROL GROUP
M 10.3	109.3	7.3	7	329	307	1214	20.5	18.30	- 492	.0	B	SUB-GROUP W/ 2 POST-RETR. YRS
M 11	147.0	24.3	17			1390	11.1	6.29	- 041	6.5	D	LOW-INC. WEATH.- STATE EVAL.
M 12	164.6	46.4	28			1266	3.9	2.99	1881	29.6	D	LOW-INC. WEATH.- COUNTY EVAL.
G 1	126.9	21.9	17	360	297	1829	15.8	9.15	- 503	1.4	C	LOW-INC. WEATH.- STATE EVAL.
G 14.1	80.3	2.3	3	411	400	360	18.9	17.36	- 129	.0	A	LIW RESEARCH DEMO. PGM.
G 14.2A	123.3	-12.1	-10								A	ACTIVE CONTROL GRP.
G 15	184.3	18.4	10	555	500	2342	43.6	14.01	-1501	.0	A	LIW RESEARCH DEMO. PGM.
G 16	279.4	115.7	41	603	353	3086	7.3	2.93	1239	13.9	A	LIW RESEARCH DEMO. PGM.
G 17.1	139.3	63.7	46	418	227	2321	12.0	4.00	- 215	5.2	A	LIW RESEARCH DEMO. PGM.
G 17.2A	173.9	0.2	0								A	ACTIVE CONTROL GROUP
G 18.1	190.8	41.5	22	319	250	2316	15.7	6.13	- 627	1.5	A	LIW RESEARCH DEMO. PGM.
G 18.2A	301.8	24.7	8								A	ACTIVE CONTROL GROUP
G 19	157.3	30.5	19			1038	7.5	3.74	143	9.6	C	LOW-INC. WEATH.- COUNTY EVAL.
G 20	51.0	15.0	29			1230	17.9	9.02	- 421	.0	D	LOW-INC. WEATH.- STATE EVAL.
G 21.1	142.4	21.1	15			623	13.0	3.24	- 092	4.1	C	LOW-INC. WEATH.-0CITY EVAL.
G 21.2	206.8	46.4	22			780	7.6	1.85	271	13.0	C	LOW-INC. WEATH.- CITY EVAL.
G 21.3	201.5	54.9	27			2092	15.5	4.19	- 550	1.7	C	LOW-INC. WEATH.- CITY EVAL.
G 22	125.0	16.6	13			334	4.7	2.21	370	24.3	C	LOW-INC. WEATH.- STATE EVAL.
G 23	192.1	49.0	25	606	451	1965	14.1	4.41	- 398	3.0	C	LOW-INC. WEATH.- STATE EVAL.
MULTI-FAMILY BUILDINGS (cont.)												
O 2.1	87.6	53.2	61	416	164	459	1.0	1.69	2704	112.8	C	PAGE HOMES PUBLIC HOUSING RETR.
O 2.2B	123.1	19.4	16								C	BLIND CONTROL GROUP
O 3						24	0.7	2.81	13	19.5	C	ENERGY SERVICES CONTRACT
O 4						14	1.9	7.90	- 087	.0	C	ENERGY SERVICES CONTRACT
O 5						56	0.9	6.73	- 588	.0	C	ENERGY SERVICES CONTRACT
O 8	66.6	14.7	22	309	241	187	3.4	2.50	114	20.8	B	TRV DEMO -COMPOSITE
O 8 A	65.1	10.4	16								B	TRV CONTROLS-COMPOSITE
O 8.1	115.8	30.0	26	525	389	219	2.0	1.37	485	50.4	B	BREUKELEN—TRV DEMO PROJECT
O 8.1A	116.4	18.0	15								B	BREUKELEN CONTROL BLDG
O 8.2	41.0	10.1	25	195	147	185	4.9	3.60	3	6.6	B	CYPRESS HILLS—TRV DEMO PROJ.
O 8.2A	38.4	8.9	23								B	CYPRESS HILLS CONTROL BLDG
O 8.3	51.2	3.5	7	249	232	145	11.2	8.76	- 142	.0	B	MARLBORO—TRV DEMO PROJECT
O 8.3A	48.0	-2.3	- 5								B	MARLBORO CONTROL—TRV DEMO
O 8.4	58.4	15.1	26	256	190	199	3.5	2.53	117	20.3	B	OCEAN HILLS—TRV DEMO PROJECT
O 8.4A	57.7	16.9	29								B	OCEAN HILLS CONTROL BLDG
O 9	71.1	12.6	18	350	288	1385	15.5	8.02	144	8.5	C	NYCHA WINDOW RETR.—COMPOSITE
O 9.1	70.9	12.7	18	337	277	1244	13.8	6.91	191	9.3	C	CYPRESS HILLS WINDOW RETR.
O 9.2	67.3	10.2	15	351	297	1523	21.4	11.12	- 177	5.2	C	BROWNSVILLE WINDOW RETR.
O 9.3	77.1	17.1	22	384	299	1483	11.9	6.44	441	11.2	C	PATTERSON WINDOW RETR.
O 9.4	70.9	11.8	17	353	294	1640	19.1	10.56	- 099	6.1	C	JOHNSON HOUSE WINDOW RETR.
O 9.5	78.9	11.4	14	379	324	1447	19.9	9.35	- 124	5.7	C	ALBANY I&II WINDOW RETR.
O 9.6	72.6	15.0	21	385	306	1308	12.3	6.24	392	11.3	C	AMSTERDAM WINDOW RETR.
O 9.7	63.4	10.8	17	310	258	1190	15.5	7.65	174	9.1	C	CARVER WINDOW RETR.
O 9.8	66.1	11.8	18	316	260	1146	14.6	6.61	209	9.7	C	SEDGWICK WINDOW RETR.
O 9.9	65.8	6.2	9	313	283	1156	29.1	12.72	- 227	3.9	C	GUN HILL WINDOW RETR.
M 15						325	4.5	3.78	226	22.5	C	MGMT CONTROL SYS FOR PHA
G 31.1	117.9	61.0	52	370	179	650	2.1	1.74	2275	56.1	C	COOP APT. RETR.—MONROE 19
G 31.2	147.4	60.7	41	427	251	606	2.0	1.67	2295	59.9	C	COOP APT. RETR.—MADISON 22
G 31.3	102.4	30.8	30	294	205	1232	7.8	5.53	204	10.0	C	COOP APT. RETR.—REBA 25
G 31.4	90.5	10.1	11	281	250	268	5.2	6.36	- 056	2.9	C	COOP APT. RETR.—ALBANY 7
G 31.5	239.9	126.3	53	596	282	878	1.4	1.04	5490	91.7	C	COOP APT. RETR.—REBA 6
G 31.6	94.6	25.8	27	242	176	301	2.3	2.63	736	42.3	C	COOP APT. RETR.—MONROE 6
G 31.7	114.8	41.9	36	267	170	1098	5.1	3.71	897	20.2	C	COOP APT. RETR.—ELMWOOD 4
G 31.8	89.6	27.4	31	349	242	301	2.1	2.48	819	45.9	C	COOP APT. RETR.—MONROE 13
G 32	123.2	17.2	14	666	573	266	2.8	4.53	166	21.0	C	PUBLIC HOUSING—HT. CONTROLS
								(¢/KWH)				
E 12						95	1.4	1.07	457	94.8	C	FLUOR. LITE RETR-830 AMSTERDAM