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ENERGY SAVINGS IN RETROFITTED MULTI-FAMILY BUILDINGS: NEW RESULTS FROM THE BECA-B PROJECT*

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ABSTRACT

We compile and analyze measured data on 141 retrofit projects in U.S. and Swedish existing multi-family buildings. We examine the costs of conservation measures and practices and the savings they generate. We also discuss the correlation between energy savings and initial pre-retrofit energy intensity, amount of investment, and choice of measures.

Various HVAC system retrofits (heating controls, equipment measures, and altered operation and maintenance practices) are the most popular conservation strategies in our sample of buildings. Most buildings in the data base are small to medium size multi-family buildings; 60 percent are between 10 and 50 units; only 10 percent are more than 100 units. Retrofit costs are less than $250/unit in 40 percent of the buildings, which suggests that many building owners confined their retrofit efforts to fairly low-cost measures. On average, initial retrofit costs are a lower fraction of annual energy expenditures in our sample of U.S. buildings than in our Swedish buildings (0.6 versus 2.1).

Median annual energy savings are 11 MBtu per dwelling unit, or 16% of pre-retrofit energy use. Energy savings are between 10 and 30 percent in 60 percent of the retrofit projects. We found that categorizing each retrofit project by strategy helped explain much of the variation in the amount invested; however, energy savings still varied widely among similar groups. Preliminary results for buildings in the data base suggest that some envelope measures (e.g., "shell" packages and window measures) have longer payback periods (12 and 16 years, respectively) than many of the heating system retrofit strategies (1-3 years). We also report on individual conservation measures that are particularly effective in specific building and heating system types (e.g., outdoor resets for cold-climate buildings with hydronic boilers).

INTRODUCTION

The multi-family sector, consisting of residential buildings with two or more units, comprises almost 27 percent of the U.S. housing stock (in terms of household units). Annual site energy use in these buildings is approximately 2.3 quads (1 quad = 10^{15}Btu) and directly or indirectly costs U.S. households almost $20 billion. Multi-family buildings vary widely in construction complexity, from single-family style to large office-building type structures. A recent Office of Technology Assessment study estimated the conservation potential in the multi-family sector at 1.0 quad per year by the year 2000 (43% of the sector's current energy use), although likely savings were only 0.3 quad, because of complex technical, information, institutional, and economic barriers (OTA, 1982). A 1985 survey of organizations concerned with multi-family retrofit activity highlighted some of these barriers:

- unwillingess on the part of building owners to invest in costly measures without guaranteed savings,
- problems related to split in economic interest between landlords and tenants,
- difficulty in obtaining financing for retrofits, and
- conflicting information on the performance and costs of retrofits (DOE, 1985).

The study and survey also found that documented information on the results of energy-efficiency improvements is not widely available. We attempt to address this problem by compiling and analyzing measured data on the costs of conservation measures and practices in multi-family buildings, and the energy savings they produce.* In this study, we examine the correlation between energy savings and initial pre-retrofit energy intensity, amount of investment, and choice of measures. We also identify individual measures that are effective for specific building and heating system types, and discuss limitations and gaps in the available data.

DATA SOURCES

We obtained information on retrofit projects from several data sources, including city energy offices [40], public housing authorities [40], research institutions and national laboratories [25], private building owners/managers [16], non-profit and for-profit energy service companies [14], and utilities [3].† The data collected typically included metered energy consumption, installed retrofit measures and their costs, the price of the space heating fuel the winter after retrofit, and a brief description of the physical characteristics of the building. In most cases, each data point represents one building, except in the case of public housing projects, which often have a number of buildings on one utility master meter.

BUILDING CHARACTERISTICS AND RETROFIT MEASURES

Most buildings in the data base are small to medium size multi-family buildings; 60 percent are between 10 and 50 units; only 10 percent are more than 100 units (Table I). Apartment size is comparable to the national multifamily stock; floor area per dwelling unit is between 500 and 1000 ft^2 in 70 percent of the buildings. Almost all of the buildings have central heating systems and are master-metered. Eighty-five percent are occupied by renters. Gas is the dominant space heat fuel (53%), followed by fuel oil (23%).

The sample of buildings in the data base is somewhat skewed with respect to geographic location, with clusters of buildings in a few cities/regions. For example, 40 buildings are located in the Minneapolis-St. Paul area, 50 retrofit projects are in the New York City-New Jersey area, and 11 projects are in San Francisco. Most of the U.S. buildings can be grouped into three categories:

* Results are drawn from the Buildings Energy Use Compilation and Analysis (BECA) residential data base at the Lawrence Berkeley Laboratory.

† Numbers in brackets represent number of data points obtained from each source.

- 10-30 unit, low-rise, wood-frame buildings built in the 1950's or 1960's with hydronic heating systems,
- steam-heated, low-rise buildings (typically 3-story walk-ups) with masonry bearing walls constructed between 1910 and 1940,
- high-rise public housing projects built in the 1940's or 1950's with 40 to 100 units in each building.

In general, multi-family retrofits were directed toward reducing consumption in the largest end-uses: space heating and domestic water heating. The most popular conservation strategies in our sample of buildings were various HVAC system retrofits including (Fig. 1):

- heating system controls, such as outdoor resets, high limit outdoor cutout, and thermostatic radiator vents,
- heating system equipment measures, including new burners and vent dampers,
- boiler replacements,
- altered operation and maintenance practices.

Window retrofits were common measures, usually either storm windows or double-glazed thermal break aluminum windows. Typically, the cost per dwelling unit for these measures was high ($500 - 1200/unit); building owners and tenants often justified the cost by citing additional benefits of these retrofits, including improved building appearance, increased security, and decreased maintenance expenses. In general, envelope measures were implemented far less frequently than heating system measures in U.S. buildings, in contrast to our small sample of retrofitted Swedish buildings, in which envelope and HVAC system measures were equally popular. Some shell measures (e.g., wall insulation) may be implemented less often because of the physical characteristics of many multi-family buildings (e.g., masonry walls), which make the measures difficult to install.

Initial retrofit costs were less than $250/unit in 40 percent of the buildings, which suggests that many building owners confined their retrofit efforts to fairly low-cost measures (Fig. 2). The median cost of the retrofits was $537/unit for all buildings in the data base; costs were much higher ($1100/unit) in the Swedish buildings. We calculated the ratio of retrofit costs to pre-retrofit energy expenditures (in local currency) in order to derive an indicator that was not influenced by exchange rates altering over time. For Swedish buildings, the median cost of the retrofit was 2.1 times greater than annual energy expenditures prior to retrofit, compared to a ratio of only 0.6 for U.S. buildings. Sweden's larger investment is not surprising since the retrofits were part of government-sponsored research projects designed explicitly to evaluate the savings and cost-effectiveness of combinations of retrofit measures.

APPROACH

In most cases, we (or our data source) used the Princeton Scorekeeping Method (PRISM) to analyze energy consumption data before and after retrofit.* PRISM estimates a weather-normalized annual energy consumption (NAC) from parameters obtained from a regression of either utility bill or meter readings of the space heat fuel and daily average outdoor temperature (Fels, 1986). The NAC represents consumption that would occur in a year with typical weather conditions.

We were not able to use PRISM in 50 projects because of data problems (e.g., insufficient number of actual meter readings, monthly energy data without billing dates, or only annual energy consumption data provided). In these cases, we corrected for the varying severity of winter in different years by scaling annual estimated space heat energy consumption using the ratio of normal-to-actual year heating degree-days (base 65^{o}F). Annual baseload energy use was calculated by scaling estimated summer fuel use to a

* LBL analyzed utility billing data (when available) in all projects except those conducted by the Minneapolis Energy Office and Princeton Center for Energy and Environmental Studies, who did their own PRISM analysis.

full year. In most of these cases, summer fuel use was estimated by building owners.

For purposes of comparison, energy use at each project is expressed on a per dwelling-unit basis. In multi-family buildings, tenant turnover is often high and occupancy rates vary greatly over time. Energy savings may be masked by increases or decreases in the number of occupied units after a retrofit. For example, it is reasonable to assume that increases in the number of occupied units (and presumably occupants) will cause an increase in hot water and appliance energy use as well as heating load (depending on heating system type, distribution and control system, and operation and maintenance practices). For the 35 buildings where we were able to obtain information on vacancy rates, we divided energy use during each billing period by the number of occupied units in that period to adjust for this effect.

Retrofit costs reported in this study reflect the direct costs to the building owner of contractor-installed measures. The costs are calculated in constant dollars (1985$). Costs and energy prices for European buildings were converted at 1981 exchange rates to U.S. dollars; U.S. inflation rates were used to convert to constant dollars.** We calculate two economic indicators: simple payback time (SPT) and internal rate of return (IRR). SPT is the period required for the undiscounted value of future energy savings (at today's energy prices) to equal the initial cost of the retrofit. The IRR is the rate of interest which, when used to discount the life-cycle costs and savings of an investment, will make the two equal. The IRR calculation includes estimated annual operations and maintenance costs. We also assume that residential energy prices will escalate annually at a real rate of 1 percent over the measures' expected physical lifetime, based on recent Energy Information Administration (EIA, 1986) forecasts of average residential energy price increases (weighted by consumption) over the next ten years.

RESULTS

Energy Savings

Median annual energy savings for buildings in the data base were 11.2 MBtu (10^6 Btu) per dwelling unit, or 16 percent of pre-retrofit energy use. Energy savings were between 10 and 30 percent of pre-retrofit use in 60 percent of the projects; weather-normalized consumption increased after retrofit in 5 percent of the buildings (Fig. 3). Prior to retrofit, annual consumption of the space heat fuel (adjusted for floor area) is noticeably higher in the sample of buildings owned and managed by public housing authorities (PH) compared to Swedish and other U.S. multi-family buildings (mostly privately owned). This trend is most evident in low-rise buildings and is rather pronounced when we note that the public housing projects in the data base are located in climates with fewer heating degree-days than other multi-family buildings (Fig. 4). Within each climate zone, most buildings in this study used more energy before retrofit than the respective stock average for U.S. gas- and oil-heated multi-family buildings.†

Energy savings are correlated more strongly with energy consumption before retrofit (r = 0.68) than with total cost of the measures (r= 0.37). We found that categorizing each retrofit project by strategy helped explain much of the variation in the amount invested; however, energy savings still varied widely among similar groups (Fig. 5). Various types of heating system controls were the most popular low-cost strategy, while structural renovation of the building envelope, boiler replacement/retrofit and heating distribution system conversions (both indicated by dark square) and window retrofits were the most costly (i.e., greater than $1000/unit). In most cases, investments in excess of $2000/unit do not save enough energy to justify the cost. The 22 projects that invested over $2000/unit had a median payback time of 20 years.

Results from buildings in the data base suggest that some envelope measures (e.g., shell packages and window measures) have much longer payback periods than many of the heating system retrofit strategies

** We used 1981 exchange rates because most experts believe that in more recent years the dollar has been overvalued with respect to other major currencies.

† We used the 1982 RECS public use data tape to calculate energy consumption/ft^2 of the space heat fuel for gas and oil-heated multi-family buildings with five or more units. To estimate a stock average, we weighted energy use/ft^2 in four climate zones by the number of households that heated with each fuel.

(see Fig. 6 and Table II). However, the apparently superior economics of heating system measures may not persist over time. Typically, the success of most of the heating system measures is more closely linked to ongoing operating and maintenance practices (which can be problematic over the long term) than envelope retrofits.* There are other important differences between these groups of buildings:

- median energy use before retrofit was lower in the group of buildings that received window and shell retrofits and heating controls (50-65 MBtu/unit) than in buildings that installed energy management control systems (EMCS) and heating system measures (90-110 MBtu/unit),
- the groups differ with respect to climate severity; buildings that received window and shell measures (5000 HDD) are located in milder climates than the buildings that received heating system measures (7000 HDD),
- individual unit electric resistance heaters were used in 25% of the buildings that received shell retrofits (thus precluding many of the system retrofits),
- all window retrofits were installed in high-rise buildings, while retrofits in the other four groups were implemented principally in low-rise buildings.

In summary, two of the groups of buildings which received heating system retrofits were also located in more severe heating climates and were relatively more energy-intensive before retrofit than groups that received shell and window measures; hence differences in cost-effectiveness are not attributable solely to choice of measures.

A more detailed comparison of groups of similar retrofits is shown in Table II. There is an element of subjectivity in the classification of many retrofit projects, in that sets of often widely assorted measures are implemented at the same time. In some cases, we grouped retrofit projects into one of three broad strategies: 1) heating and hot water system packages, 2) shell packages (e.g., various envelope measures), and 3) system and shell packages. Where possible, we classified a retrofit project into a more disaggregated group (e.g., window measures, heating controls, solar DHW). Energy savings are significant at the 90 percent confidence level for all strategies except energy management control systems (EMCS), boiler replacements and controls, and solar domestic hot water systems (DHW). The savings in buildings that received EMCS and boiler replacements were not significant at this confidence level because our sample was small (4-5 buildings), and savings varied widely.

We believe that it is not appropriate to evaluate metering conversions and boiler replacements in the same context as the other strategies (hence they are separated at the bottom of Table II). Metering conversion projects in the data base involve changing from master metering to tenant metering systems (except for one project). A tenant metering system is not strictly a technical efficiency measure since reduction in energy use is due to changes in occupant behavior. The economics of tenant metering systems appear quite attractive from the perspective of the building owner, based on a sample of 10 low-rise Minnesota buildings which have hot water baseboard heating systems and individual zone control of the flow of hot water into each apartment (Hewett, 1986). Energy costs were included in the rent in these master-metered buildings prior to the installation of the new metering system. The new metering system divides the energy bill among individual apartments on the basis of use. After the new system was installed, gas energy use decreased by 15-18 percent compared to pre-retrofit levels. The effect of tenant metering on the individual tenants depends on whether or not the building owner reduces rents to account for his lower operating expenses. If this retrofit is implemented without a rent reduction, the tenant's total costs can increase significantly. From a public policy perspective, it is important to ensure that metering systems do not weaken the building owner's commitment to finance future efficiency improvements, and that energy costs are allocated equitably on the basis of actual use (e.g., accurate measurement of delivered heat, and accounting and billing for non-space heating and standby losses).

* See Greely et al., "Analyzing energy conservation retrofits in public housing " for discussion on persistence of savings.

Installing conservation measures in conjunction with equipment replacement tends to improve the economics of rehabilitating older multi-family buildings, however, this strategy makes it difficult for us to accurately assess the impact of boiler replacement on energy consumption. In most cases, the quality of reported cost and consumption data, makes it impossible to perform a cost/benefit analysis of the merits of boiler replacement versus other retrofit options. The incremental costs associated with installing a new energy-efficient boiler are typically not available, and we can not determine the magnitude of savings attributable to the new boiler because other measures (e.g., storm windows) are also installed. Not surprisingly, total costs are high for this group of buildings (over $2000/unit), thus payback times are long (12-17 years) despite significant energy savings (21 to 26 MBtu/unit).

Individual Measures

Typical retrofit practice is to install a set of measures concurrently, although we have compiled data for a subsample of buildings in which individual measures were implemented. For example, the Minneapolis Energy Office (MEO) monitored energy consumption in nine, low-rise apartment buildings with gas-fired hydronic boilers that received outdoor reset and cutout controls (Hewett, 1984). These three-story walk-ups are all master-metered, with wood-frame construction, lightly insulated walls and roofs, and double-glazed windows. Initial retrofit costs were quite low ($10-20/unit), space heat savings were significant (approximately 13 percent), and paybacks were very short (roughly one year). The results suggest that an outdoor reset is probably the most cost-effective retrofit for hydronically heated apartment buildings with cast-iron boilers.

The MEO also tested and monitored the effectiveness of a set of measures designed to balance the heat distribution system in buildings with single-pipe steam systems. Uneven heating is a common problem in steam-heated buildings and is caused mainly by large differences in steam arrival times among radiators in a building, excessively short boiler cycles, and the absence of individual unit temperature controls (Peterson, 1984).* The steam balancing techniques employed in this group of ten buildings included: 1) installation of larger main-line air vents (to reduce the differences between steam arrival times at near and far radiators), 2) new boiler controls which effectively lengthen the boiler cycle, and 3) thermostatic radiator vents (to improve individual space temperature control) (Peterson, 1986). Boilers were cleaned and tuned at three of the sites. Annual gas savings averaged 10 MBtu/unit among the 10 buildings, roughly six percent of pre-retrofit consumption. Improved comfort is often the primary motivation for this retrofit; therefore, it is not completely surprising that three buildings had negative energy savings (i.e., savings are only expected to occur if the indoor temperature averaged over all of the units decreases). Payback times ranged from one to five years for the seven buildings that realized savings.

DISCUSSION

The typical master-metered multi-family building has unique characteristics which pose challenges for analysts who wish to "keep score" of the effectiveness of conservation programs/measures. Turnover rates are high among U.S. renters (almost half of renters remain in their residences for only one year or less), and 85 percent of the multifamily stock is occupied by renters (DOE, 1985). Evaluations of retrofit programs directed at single-family homes generally exclude homes in which occupancy has changed; this approach is clearly not feasible in master-metered buildings. We do not account for changes in energy use due to possible differences in behavior patterns between occupants who moved into a building after a retrofit, and those who previously occupied the unit. With the current level of monitoring, secondary heating equipment use or occupant behavior changes might go undetected, masking the actual effect of retrofits.

We do normalize energy use by the number of occupied units before and after retrofit (when data are available), although this is at best a crude proxy in accounting for the impact of occupant density and amount of conditioned space on energy use. We assume that vacant units are unheated; this may not be

* High indoor temperatures are a by-product of uneven heating, which results in greater conduction and infiltration losses (opening windows to relieve overheating).

true. Other data reporting problems include missing information on key physical parameters, or inconsistencies in reported information, as is the case for conditioned floor area. A detailed building description and operating profile, possibly one specified by a protocol, would help overcome this problem.

With a few exceptions, retrofit projects in this compilation did not meter heating energy use separately or monitor inside temperatures. Energy savings are based in most cases on only one year of consumption data after a retrofit. Even when energy use data are available, long-term tracking of occupied buildings is difficult, because the problem of accounting for changes in operating conditions, occupancy, or the effect of additional retrofits is magnified as the monitoring period increases.

It is difficult to estimate space heat (or DHW energy) savings accurately when energy data are limited to utility bills from before and after a retrofit. We can, however, report on the overall quality of the PRISM estimates. The mean value of the relative standard error of NAC is roughly 4 percent for multifamily buildings that were analyzed with PRISM, while the standard error of the reference temperature is generally around 4°F.* In terms of quality of fit, the average coefficient of determination (r^2) is 0.95 for all buildings, although the average r^2 is lower (0.88) for buildings located in mild, coastal climates (e.g., San Francisco). It appears that the overall results are somewhat less robust compared to those obtained in gas-heated single-family houses (Dutt, 1986).

CONCLUSION

We found that energy savings are between 10 to 30 percent of pre-retrofit energy use in 60 percent of the buildings in our compilation. Large variations are observed in energy savings and in costs per unit of energy saved among similar measures. On average, initial retrofit costs are a lower fraction of annual energy expenditures in our sample of U.S. buildings than in Swedish buildings (0.6 versus 2.1). This difference can be partly attributed to two facts: Swedish buildings have lower pre-retrofit energy intensities than American buildings, and also receive relatively costly shell improvements more often than U.S. buildings. Many conservation investments are attractive from a building owner's perspective: the median real rate of return for buildings in this study is 14 percent, which compares quite favorably with real rates of return from tax-free bonds (3-5%). Preliminary results also suggest that, in our sample of multi-family buildings, some envelope measures (e.g., shell and window measures) have longer median payback periods than many of the heating system retrofit strategies.

We are beginning to compile evidence on the effectiveness of individual conservation measures in specific building and heating system types (e.g., outdoor resets for cold-climate buildings with hydronic boilers). There are several on-going research projects (e.g., DOE:LBL, Princeton CEES; Gas Research Institute: Center for Neighborhood Technology; Bonneville Power Administration's ELCAP project) in which detailed monitoring (i.e., energy end-use data and indoor temperature measurements) will be used to assess the performance of selected multi-family retrofits. We plan to use the data from these monitoring projects to improve our understanding of retrofits in which there is only whole-building energy data.

This study is part of an on-going project (BECA); data contributions from readers are welcomed.

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* The mean relative standard error of NAC is lower for gas-heated buildings compared to oil-heated buildings (3 vs. 5%).

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Table I. Building and demographic characteristics.

	No. of Projects[a]	*% of Total Projects*
• Building Type:		
High-Rise	52	37
Low-Rise[b]	82	58
• Heating System Type:		
Central	127	90
Individual Unit	7	5
• Space Heat Fuel:		
Natural Gas	75	53
Oil	33	23
Electricity	6	4
Mixed Fuel[c]	12	9
District Heating	15	11
• Size of Dwelling Units:		
< 500 ft^2/unit	2	1
500-750 ft^2/unit	28	20
750-1000 ft^2/unit	71	50
1000-1250 ft^2/unit	19	14
1250-1500 ft^2/unit	4	3
1500-1750 ft^2/unit	4	3
1750-2000 ft^2/unit	4	3

	No. of Projects	*% of Total Projects*
• Climate Zone:[d]		
1 (> 7000 HDD)	43	30
2 (5500-7000 HDD)	28	20
3 (4000-5500 HDD)	58	41
4 (<4000 HDD)	12	9
• Occupancy:		
Family	34	24
Senior	9	6
Adults Only	11	8
Mixed[e]	48	34
• Ownership:		
Renter-Occupied	118	84
Owner-Occupied	13	9
• Dwelling Units per Building:		
< 10	24	17
10-25	38	27
25-50	46	33
50-100	17	12
100-150	10	7
150-200	3	2
> 750	1	1

[a] Total number of projects is 141; information is not available on certain building characteristics.

[b] Low-Rise = 4 stories or less.

[c] "Mixed Fuel" means that either two fuels are used for space heating (typically gas and oil, depending on availability), or that fuel switching occurred after the retrofit.

[d] Climate zones as defined by the Residential Energy Consumption Survey (Energy Information Administration, *Housing Characteristics 1982*, 1984, p. 211).

[e] "Mixed" occupancy projects include a combination of the above categories.

Table II. Energy savings and cost-effectiveness of various retrofit strategies. [a]

Retrofit Strategy	Number of Projects [No. of Units]	Median Site Energy Savings (MBtu/ unit-yr.)	(%)	Median Total Cost (1985 $/ unit)	Median SPT (years)	Median IRR (%)
Heating Controls	18 [5268]	7 ±3	15 ±4	50 ±60	1.2 ±0.5	89 ±49
System Packages[b]	29 [2117]	11 ±4	13 ±3	170 ±100	1.8 ±1.0	37 ±74
EMCS[c]	5 [2874]	16 ±17	18 ±14	570 ±110	2.8 ±1.4	26 ±38
System and Shell Packages	18 [764]	17 ±9	26 ±5	1260 ±260	7.8 ±7.0	9 ±10
Distribution System Conversion[d]	7 [118]	24 ±13	25 ±5	780 ±1280	8.9 ±3.6	14 ±9
Shell Packages	12 [3840]	6 ±4	4 ±4	280 ±210	11.5 ±6.4	4 ±13
Window Measures	12 [11143]	11 ±2	16 ±2	1090 ±110	16.9 ±2.3	5 ±2
Solar DHW	6 [388]	2 ±4	6 ±6	570 ±20	36.5 ±57.0	0 ±0
Metering Conversion[e]	11 [2983]	11 ±4	18 ±3	230 ±10	1.4 ±0.3	53 ±27
Boiler Replacement & Controls	4 [474]	26 ±17	16 ±9	2430 ±1290	12.9 ±8.4	7 ±9
Boiler Replacement & Windows	7 [393]	21 ±5	18 ±3	2430 ±200	17.2 ±2.2	0 ±0

[a] Results given are median values plus standard error (se) of the sample median. Standard error of the sample median is computed from:

$$se\ [median\,(X)] = IQ\,(X)\ /\ N^{0.5}$$

where IQ is the interquartile range and N is the number of projects.

[b] "Packages" refer to sets of retrofit measures implemented at the same time, so that the savings attributable to individual retrofits cannot be determined. "Systems packages" are retrofits to space heat and hot water systems. "Shell packages" means that various envelope measures were implemented (e.g., insulation, caulking and weatherstripping, storm windows).

[c] EMCS refers to energy management control systems.

[d] At these projects, the heating distribution system was converted from steam to hot water.

[e] The category "Metering Conversion" includes conversion of electricity billing from master-metered to individual unit submetering and installation of tenant metering systems that divide total gas use in an apartment building on the basis of indicators that are proxies for the amount of heat delivered (e.g., number of hours that the thermostat calls for heat).

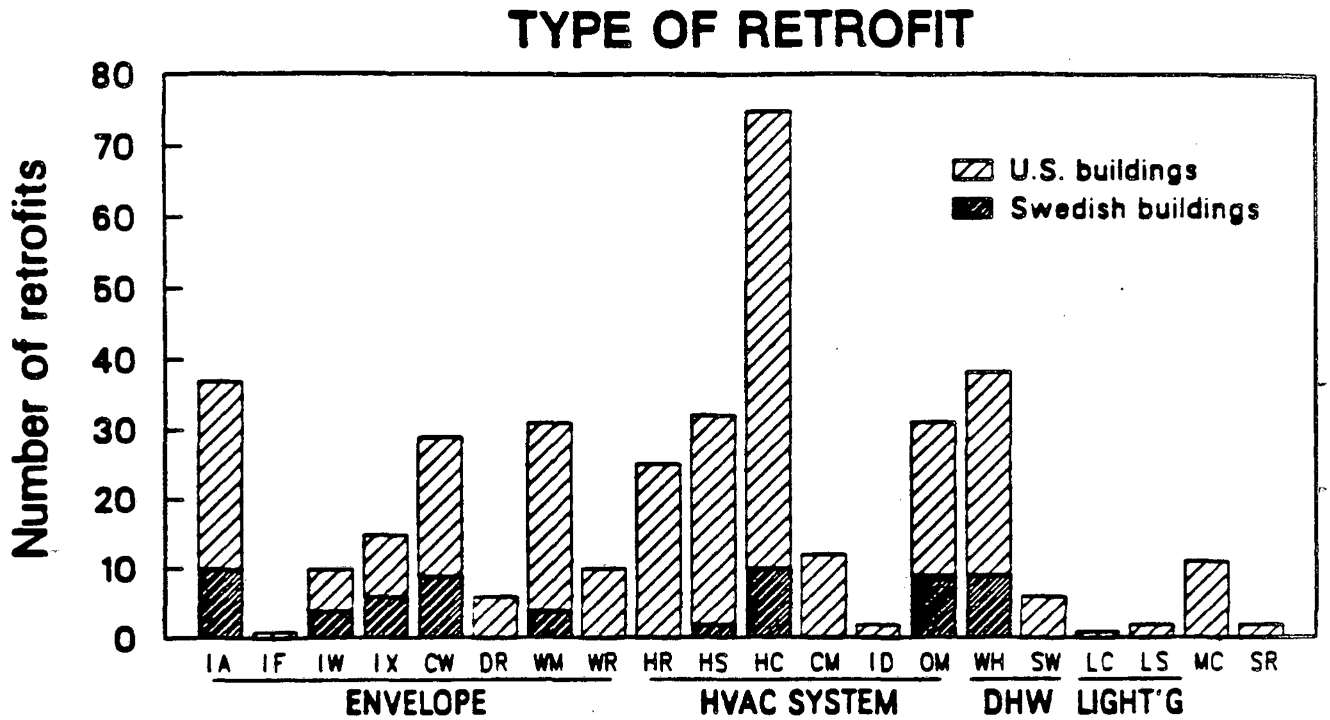

Fig. 1. Relative frequency with which retrofit measures were installed in multi-family buildings. Retrofit code is: IA, attic insulation; IF, floor insulation; IA, wall insulation; IX, general insulation; CW, caulking and weatherstripping; DR, storm doors; WM, window measures; WR, window replacement; HR, heating system replacement; HS, heating system retrofit; HC, heating controls; CM, computerized heating control system; ID, duct insulation, OM, operations and maintenance; WH, water heating retrofit; SW, solar domestic hot water; LC, lighting controls; LS, lighting retrofits; MC, metering conversion; and SR, structural renovation.

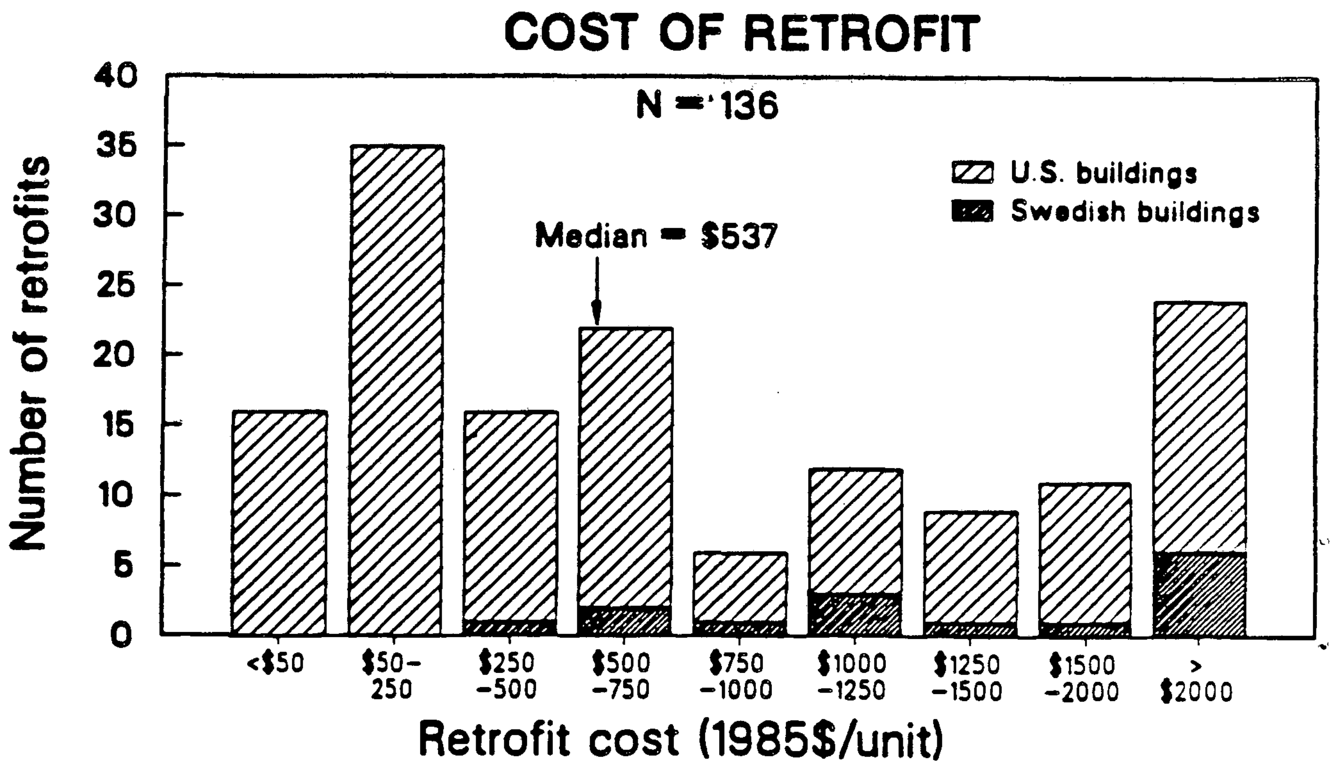

Fig. 2. Distribution of retrofit costs for buildings in the data base.

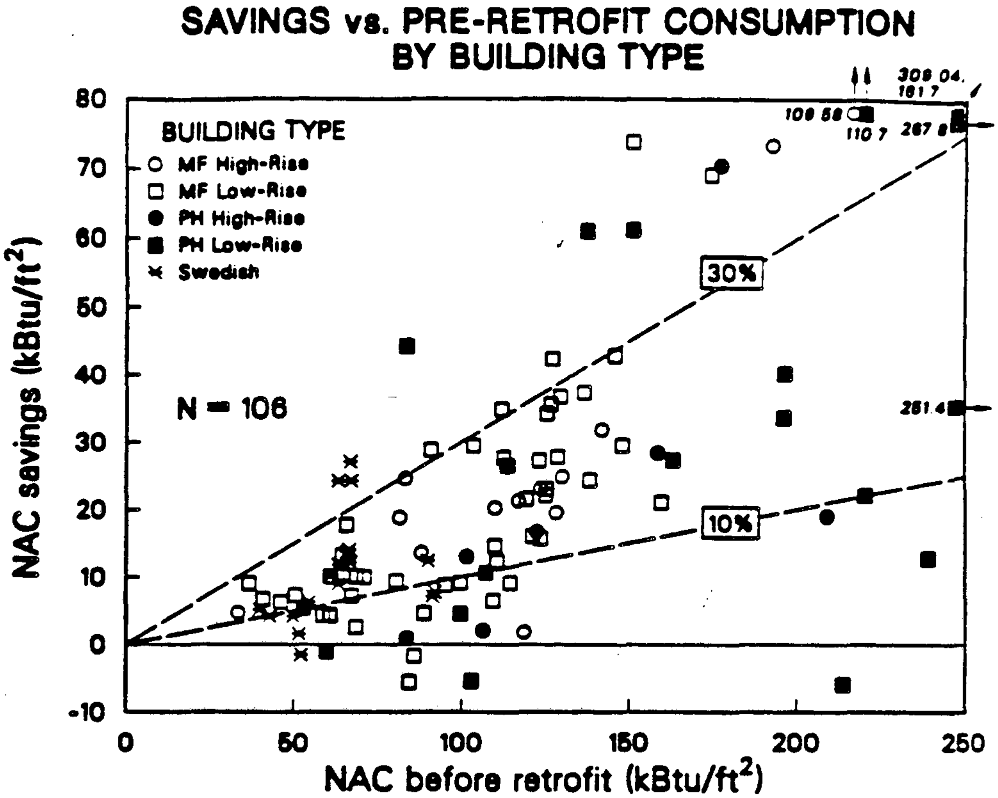

Fig. 3. Plot of energy savings as a function of pre-retrofit energy use, grouped by building type (low-rise versus high-rise) with public housing and Swedish buildings identified separately. Electricity use is expressed in terms of site energy, 3,412 Btu per kWh.

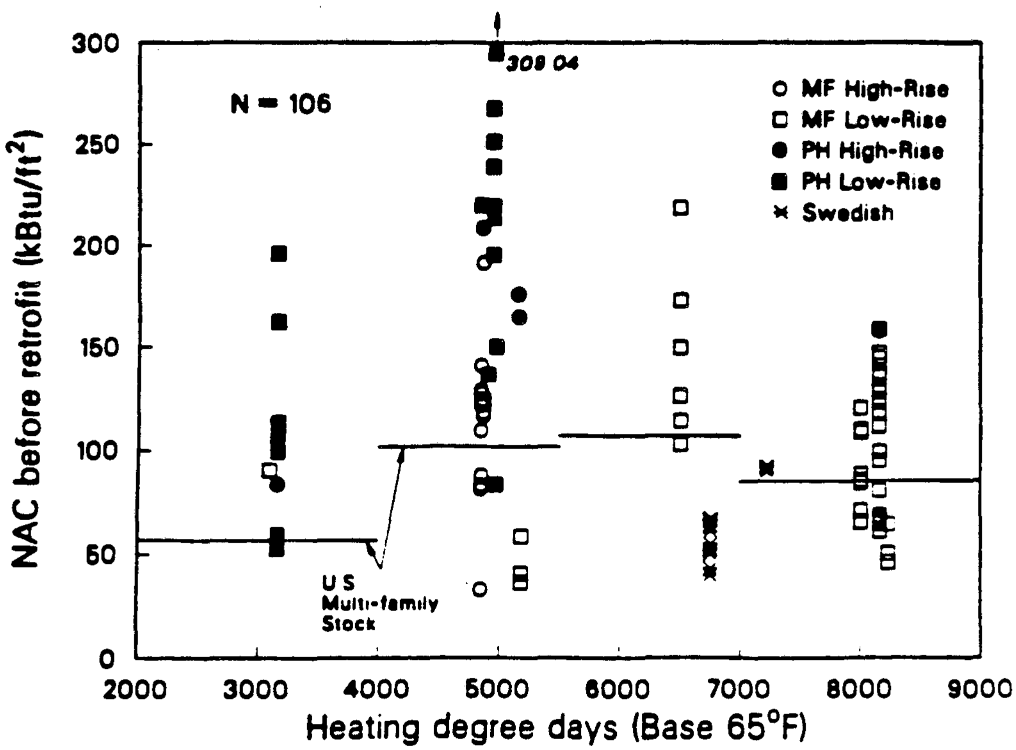

Fig. 4. Energy use before retrofit (NAC) is plotted against heating degree-days (base 65°F) for each retrofit project.

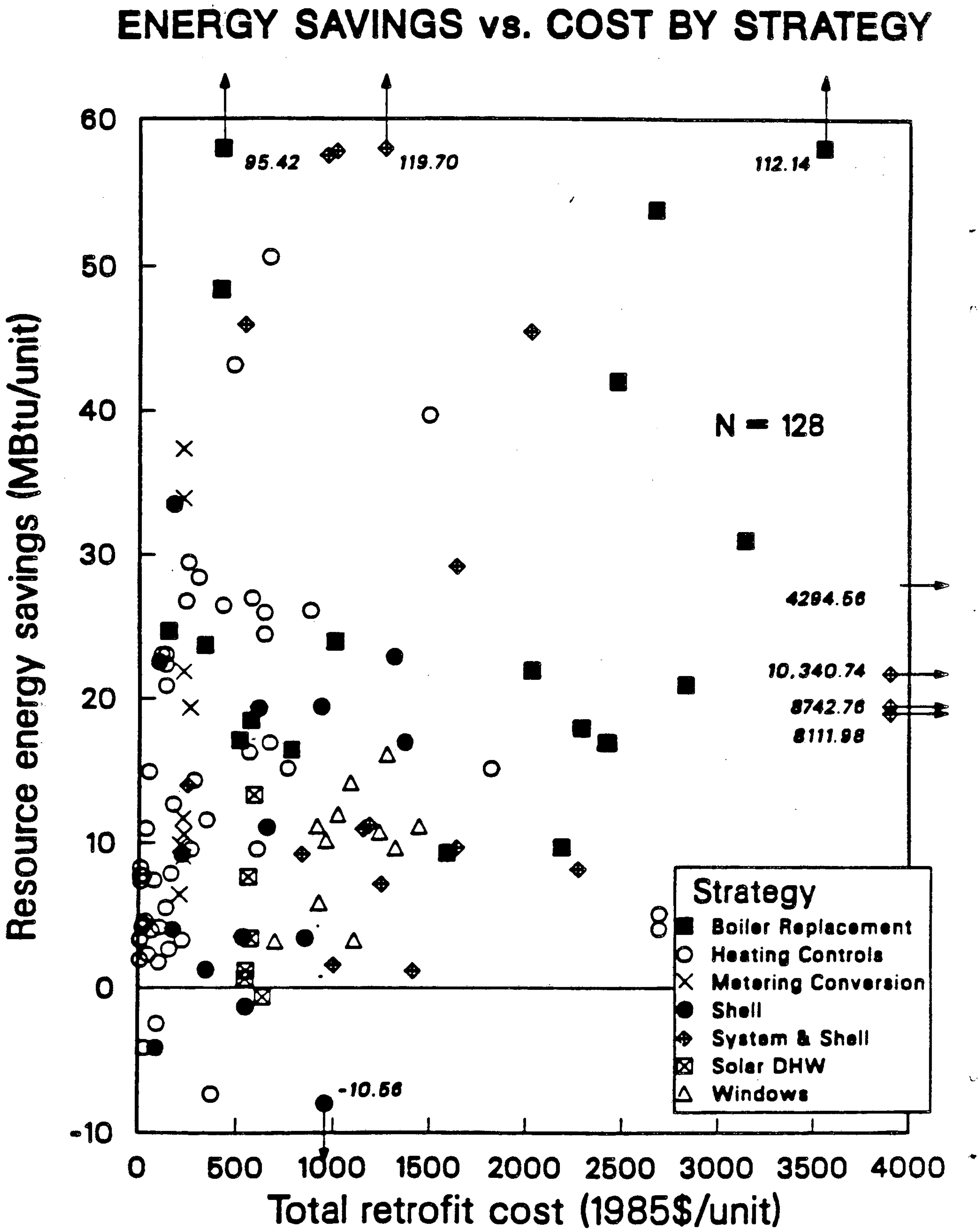

Fig. 5. Annual resource energy savings are compared to the total cost of the retrofit investment in 128 multi-family buildings. In most cases, the savings include changes in consumption for all end uses of the space heat fuel (i.e., domestic hot water, cooking). Electricity is measured in resource units of 11,500 Btu per kWh.

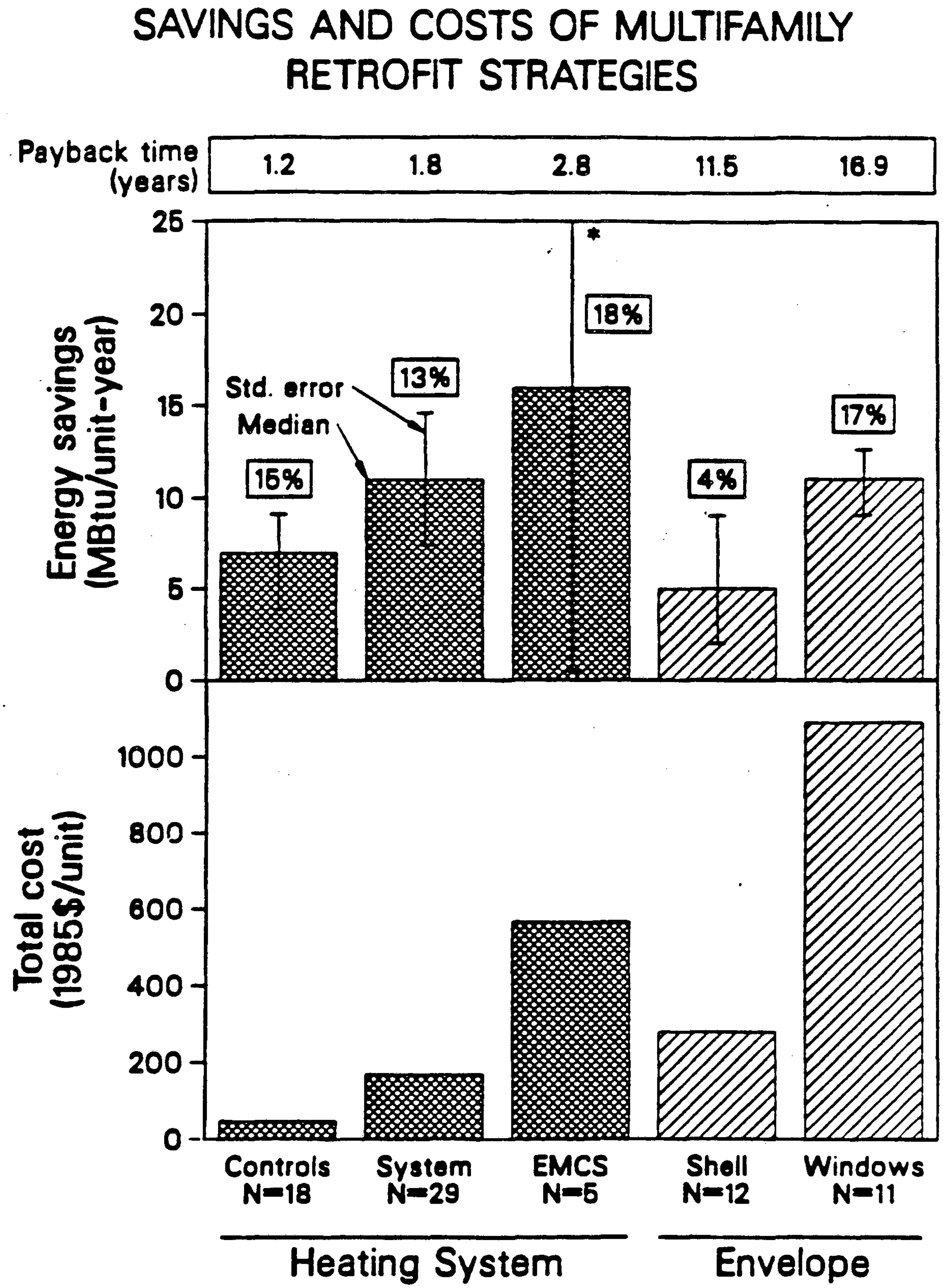

Fig. 6. Energy savings and costs of heating system and envelope retrofits in multi-family buildings. "System" refers to groups of measures that affect the heating or hot water systems. "EMCS" are energy management control systems. "Shell" includes combinations of retrofits which reduce heat loss through the building shell.

* The upper bound for one standard error is at 33 MBtu/unit-year.

Multifamily Retrofit Database

The following tables contain results from the analysis of multifamily retrofits implemented at throughout the U.S. and in Sweden. Each retrofit is uniquely identified by a label. (If more than one separately analyzed retrofit is carried out at a property, the same label, appended with an asterisk(s), is used for each successive retrofit package(s).)

The following terms and abbreviations are used in the tables:

TABLE I:

Label:	The first letter in each label stands for the fuel used for the end-use affected by the retrofit. 'E'=electricity, 'G'=natural gas, 'M'=mixed, 'O'=oil, 'X'=other.
Building Type:	'CO'=combination of types, 'HR'=high-rise, 'LR'=low-rise (4 stories or less).
Meter Type:	'IM'=individually metered, 'MM'=master-metered.
Ownership:	'OW'=owned by occupant, 'RE'=rented by occupant.
Type of Tenants:	'AO'=adults only, 'FM'=family, 'MX'=mixed, 'SN'=senior.
Number of Occupants Pre:	The number of occupants per dwelling unit before the retrofit.
Wall Type:	'BR'=brick, 'CB'=concrete block, 'FR'=frame, 'MA'=masonry.
No. of Glazing Layers:	Number of glazing layers in windows prior to retrofit (averaged if number varies throughout building).
Heat System Type:	'C'=central (one boiler room per project), 'B'=building (one boiler room per building), 'G'=group (one boiler room for a group of buildings, but not for whole project), 'I'=individual (one heater per dwelling unit).
Heat Distribution Type:	'D'=double-pipe steam, 'S'=single-pipe steam, 'W'=water,
Domestic Hot Water (DHW) Fuel:	'E'=electricity, 'G'=gas, 'M'=mixed, 'O'=oil, 'X'=other.

TABLE II:

End Uses:	'F'=all end uses of space heat fuel, 'H'=space heat, 'L'=lighting, 'W'=space heat and hot water.
Floor Area:	Total or conditioned floor area for all of the analyzed units.

Energy Use Data: All numbers are ***per dwelling unit***; electricity use is reported as kWh/dwelling unit, consumption at fuel-heated projects is expressed in MBtu/dwelling unit (1 MBtu=10^6 Btu). Oil and gas consumption converted to MBtus using the following conversion factors: #2 oil=0.139 MBtu/gallon, #4 oil=0.145 MBtu/gallon, #6 oil=0.150 MBtu/gallon, gas=0.102 MBtu/ccf=0.100 MBtu/therm.

NAC: Weather-normalized annual consumption, for the end-uses specified in the 'End Uses' field.

Space Heat: Separately metered space heat consumption, or weather-dependent portion of consumption estimated in PRISM analysis.

Analysis Method: 'R'=regression (PRISM) with variable reference temperature, 'S'=scaling of space heat data by annual or monthly HDD.

Confidence Level: 'B+'=PRISM analysis (variable reference temperature), 'B'=regression analysis of energy data with fixed reference temperature or accurate baseload determination from summer months' bills, 'C'=annual consumption data that is weather-corrected by scaling space-heat fraction by ratio of actual to normal HDD.

HDD: Long-term average heating degree-days to base 65°F.

Heating Factor: Space heat use divided by floor area and long-term average heating degree-days, base 65°F.

TABLE III:

Retrofit Measures: 'CM'=computerized energy management system, 'CW'=caulk and weatherstrip, 'DR'=door replacement, 'HC'=heating controls, 'HR'=heating system replacement, 'HS'=heating system retrofit, 'IA'=attic insulation, 'ID'=duct insulation, 'IF'=floor insulation, 'IW'=wall insulation, 'IX'=general insulation, 'LC'=lighting controls, 'LS'=lighting system retrofit, 'MC'=metering change, 'OM'=operations and maintenance, 'SR'=structural renovation, 'SW'=solar hot water, 'WH'=water-heating retrofit, 'WM'=window management, 'WR'=window replacement.

Heat System Measures: 'BTC'=boiler temperature/pressure control, 'CLT'=automatic setback or clock thermostat, 'CUT'=high limit outdoor thermostat, 'EMC'=energy mangement system with microcomputer, 'EMR'=remote computerized HVAC control, 'FD'=full furnace derating, 'FEB'=addition of front-end boiler, 'HRE'=heating plant replacement with high-efficiency boilers/furnace, 'HRM'=replace heating plant with modular boilers, 'HWR'=hot water boiler replacement, 'IHW'=insulating water heater blanket, 'IPI'=insulation on hot water pipes, 'LFS'=low-flow showerhead, 'MSB'=Minneapolis steam balancing, 'OMC'=operations and maintenance on heating controls, 'OMP'=operations and maintenance on heating plant, 'RES'=outdoor reset controls, 'RHB'=flame retention head burner, 'SET'=hot water temperature setback, 'SHT'=separate DHW heater, 'SHW'=steam to hot water conversion, 'TRV'=thermostatic radiator vents, 'TU'=furnace tune-up, 'TUR'=turbolators, 'VDE'=electric vent dampers, 'VDT'=thermal vent dampers.

Economic Indicators: All costs are in 1985 $/dwelling unit. In the following definitions, I=capital cost of retrofit, P=local price of energy (adjusted by an energy escalation rate=4%), ΔM=change in annual operations and maintenance costs, ΔE=change in annual energy use (normalized, in MBtu), d=real discount rate (= 7%), n=retrofit lifetime (years).

Simple Payback Time: $SPT = I/(\Delta E * P)$ The period required for the undiscounted cumulative value of future energy savings (at today's energy prices) to equal the initial cost of the measure in question.

Internal Rate of Return: The rate of interest which causes the discounted life-cycle costs and savings from an investment to be equal. It is useful for comparing the relative efficiency of energy conservation measures with other types of investments.

Net Present Value: The difference between the present value of the benefits resulting from a retrofit's lifetime energy savings and the present value of the lifetime costs of the retrofit. The best conservation investment has the highest NPV.

Cost of Conserved Energy: $CCE = [I/\Delta E] * \{d/[1-(1+d)^{-n}]\}$ The ratio of the annualized investment in a retrofit to the annual energy savings caused by it. An efficient investment is one whose CCE is less than the cost of fuel.

Confidence Level Cost: 'B'=documented cost data, contractor cost of retrofit, estimated O&M costs, 'C'=adequate cost data, aggregate cost data for group of buildings or buildings that have only materials cost plus labor hours, 'F'=no retrofit cost data.

Table I

BLDG. LABEL	LOCATION		NO. OF APT. UNITS	NO. OF BLDGS	YEAR BUILT	BLDG. TYPE	METER TYPE	OWNER-SHIP	TYPE OF TENANT	NO. OF OCCUP. PRE	WALL TYPE	NO. OF GLAZING LAYERS	HEAT SYSTEM TYPE	HEAT DIST. TYPE	DHW FUEL
E012	NEW YORK	NY	159	1	1965	HR	MM	RE	FM	2.8	MA		C	S	
E019.1	SEATTLE	WA	21	1	1963	LR	IM	RE	MX	2.0	FR		I		E
E019.2	SEATTLE	WA	17	1	1928	LR	IM	RE	MX	1.4	FR		I		E
E019.3	SEATTLE	WA	21	1	1968	LR	IM	RE	FM	1.5	FR		I		E
E021	NEW YORK CITY	NY	1666	2	1977	HR	MM	RE	MX		MA	2.0	I		
E022	NEW YORK	NY	2820	15		HR	MM	RE		2.3					
G031.1	CHICAGO	IL	19	1	1910	LR	MM	OW			MA	2.0	B	S	G
G031.2	CHICAGO	IL	22	1	1910	LR	MM	OW			MA	2.0	B	S	G
G031.3	CHICAGO	IL	25	1	1910	LR	MM	OW			MA	1.0	B	S	G
G031.4	CHICAGO	IL	7	1	1910	LR	MM	OW			MA	2.0	B	S	G
G031.5	CHICAGO	IL	6	1	1910	LR	MM	OW			MA	1.0	B	S	G
G031.6	CHICAGO	IL	6	1	1910	LR	MM	OW			MA	1.8	B	S	G
G031.7	CHICAGO	IL	4	1	1910	LR	MM	OW			MA	2.0	B	S	G
G031.8	CHICAGO	IL	13	1	1910	LR	MM	OW			MA	1.7	B	S	G
G032	NEWARK	NJ	530	12	1940	LR	MM	RE	FM		MA		C	S	G
G035.1	SAN FRANCISCO	CA	772	91	1942	LR	MM	RE	FM	3.7	CB		I		G
G035.11	SAN FRANCISCO	CA	107	5	1970	HR	MM	RE	SN		CB		C	W	G
G035.12	SAN FRANCISCO	CA	108	1	1972	HR	MM	RE	SN		CB		C		G
G035.13	SAN FRANCISCO	CA	22	1	1971	LR	MM	RE	SN		FR		C		G
G035.14	SAN FRANCISCO	CA	40	1	1971	LR	MM	RE	SN		FR		C		G
G035.15	SAN FRANCISCO	CA	75	1	1973	HR	MM	RE	SN		MA		C		G
G035.16	SAN FRANCISCO	CA	36	1		LR	MM	RE	SN		FR		C		G
G035.2	SAN FRANCISCO	CA	469	38	1942	LR	MM	RE	FM	3.3	CB		C	W	G
G035.4	SAN FRANCISCO	CA	258	41	1962	LR	MM	RE	FM	4.8	FR		C	W	G
G035.5	SAN FRANCISCO	CA	158	24	1956	LR	MM	RE	FM	4.0	FR		I		G
G035.6	SAN FRANCISCO	CA	170	10	1963	LR	MM	RE	FM	2.6	FR		C	W	G
G036.1	HIGHTTOWN	NJ	32	1	1965	LR	MM	RE	MX	2.0	MA	1.0	G	W	G
G036.2	HIGHTTOWN	NJ	32	1	1965	LR	MM	RE	MX	2.0	MA	1.0	G	W	G
G036.3	HIGHTTOWN	NJ	32	1	1965	LR	MM	RE	MX	2.0	MA	1.0	G	W	G
G036.4	HIGHTTOWN	NJ	16	1	1965	LR	MM	RE	MX	2.0	MA	1.0	G	W	G
G036.5	HIGHTTOWN	NJ	16	1	1965	LR	MM	RE	MX	2.0	MA	1.0	G	W	G
G037.1	ST. PAUL	MN	17	1	1900	LR	MM	OW	MX	1.9	MA	2.0	B	S	G
G037.2	MINNEAPOLIS	MN	25	1	1920	LR	MM	RE	MX	1.6	MA	2.0	B	S	G
G037.3	ST. PAUL	MN	16	1	1938	LR	MM	RE	MX	1.5	MA	2.0	B	S	G
G037.4	ST. PAUL	MN	10	1	1890	LR	MM	RE	MX	1.4	MA	2.0	B	S	G
G037.5	ST. PAUL	MN	6	1	1920	LR	MM	OW	FM	2.0	MA	2.0	B	S	G
G037.6	MINNEAPOLIS	MN	18	1	1929	LR	MM	RE	MX	1.6	MA	2.0	B	S	G
G037.7	ST. PAUL	MN	26	1	1916	LR	MM	RE	MX	1.5	MA	2.0	B	S	G
G038.1	MINNEAPOLIS	MN	33	1	1972	LR	MM	RE	AO		FR	2.0	B	W	G
G038.2	MINNEAPOLIS	MN	22	1	1971	LR	MM	RE	AO		FR	2.0	B	W	G
G038.3	MINNEAPOLIS	MN	12	1	1967	LR	MM	RE	AO		FR	2.0	B	W	G
G038.4	MINNEAPOLIS	MN	45	1	1971	LR	MM	RE	AO		FR	2.0	B	W	G
G038.5	MINNEAPOLIS	MN	27	1	1972	LR	MM	RE	AO		FR	2.0	B	W	G
G038.6	MINNEAPOLIS	MN	24	1	1972	LR	MM	RE	AO		FR	2.0	B	W	G
G038.7	MINNEAPOLIS	MN	20	1	1973	LR	MM	RE	AO		FR	2.0	B	W	G
G038.8	MINNEAPOLIS	MN	21	1	1971	LR	MM	RE	AO		FR	2.0	B	W	G
G038.9	MINNEAPOLIS	MN	23	1	1973	LR	MM	RE	AO		FR	2.0	B	W	G
G039	ASBURY PARK	NJ	60	2	1963	HR	MM	RE	SN	1.3	CB	1.0	C	S	G
G039 *	ASBURY PARK	NJ	60	2	1963	HR	MM	RE	SN	1.3	CB	1.0	C	S	G
G040.1	MINNEAPOLIS	MN	4	1	1964	LR		RE				2.0	B	W	
G040.10	ST. PAUL	MN	5	1	1966	LR		RE				2.0	B	W	

Table I (continued)

BLDG. LABEL	LOCATION		NO. OF APT. UNITS	NO. OF BLDGS	YEAR BUILT	BLDG. TYPE	METER TYPE	OWNER-SHIP	TYPE OF TENANT	NO. OF OCCUP. PRE	WALL TYPE	NO. OF GLAZING LAYERS	HEAT SYSTEM TYPE	HEAT DIST. TYPE	DHW FUEL
G040.2	ST. PAUL	MN	16	1	1957	LR		RE				2.0	B	W	
G040.3	MINNEAPOLIS	MN	4	1	1927	LR		RE				2.0	B	W	
G040.4	MINNEAPOLIS	MN	24	1	1971	LR		RE				2.0	B	W	
G040.5	ROCHESTER	MN	30	1	1975	LR		RE					B	W	
G040.6	ROCHESTER	MN	30	1	1978	LR		RE					B	W	
G040.7	ROCHESTER	MN	30	1	1978	LR		RE					B		
G040.8	ST. PAUL	MN	19	1	1966	LR		RE				2.0	B	W	
G040.9	ST. PAUL	MN	5	1	1966	LR		RE				2.0	B	W	
G041.1	CHICAGO	IL	6	1		LR	MM	RE	FM	3.3	MA		B	W	G
G041.2	CHICAGO	IL	6	1		LR	MM	RE	FM	3.5	MA		B	S	G
G041.3	CHICAGO	IL	12	1		LR	MM	RE	FM	4.0	MA		B	W	G
G041.4	CHICAGO	IL	31	1		LR	MM	RE	FM	4.0	MA		B	W	G
G041.5	CHICAGO	IL	27	1		LR	MM	RE	FM	2.7	MA		B	W	G
G042.1	MINNEAPOLIS	MN	32	1	1920	LR	MM	RE	AO		MA		B	S	G
G042.2	MINNEAPOLIS	MN	7	1	1910	LR	MM	OW					B	S	G
G042.3	MINNEAPOLIS	MN	30	1	1968	LR	MM	RE				2.0	B	W	G
G042.4	MINNEAPOLIS	MN	17	1	1963	LR	MM	RE				2.0	B	W	G
G043	ATLANTA	GA	16	1	1922	LR	MM	OW	AO	2.0	BR	1.0	B	S	G
G044.1	PHILLIPSBURG	NJ	150	24	1951	LR	MM	RE	FM		BR		C		G
G044.2	PHILLIPSBURG	NJ	222	49	1942	LR	MM	RE	MX				I		G
G045.1	MINNEAPOLIS	MN	11	1	1925	LR	MM	RE	MX		FR	2.0	B	S	G
G045.10	MINNEAPOLIS	MN	11	1	1930	LR	MM	RE	MX		MA	2.0	B	S	G
G045.11	MINNEAPOLIS	MN	25	2	1915	LR	MM	RE	MX		FR	2.0	B	S	G
G045.12	MINNEAPOLIS	MN	26	1	1924	LR	MM	RE	MX		MA	2.0	B	S	G
G045.13	MINNEAPOLIS	MN	14	1	1922	LR	MM	RE	MX		FR	2.0	B	S	G
G045.2	MINNEAPOLIS	MN	32	1	1914	LR	MM	RE	MX		FR	2.0	B	S	G
G045.3	MINNEAPOLIS	MN	17	1	1913	LR	MM	OW	MX		FR	2.0	B	S	G
G045.4	MINNEAPOLIS	MN	20	1	1924	LR	MM	RE	MX		FR	2.0	B	S	G
G045.5	MINNEAPOLIS	MN	45	1	1924	LR	MM	RE	MX		FR	2.0	B	S	G
G045.6	MINNEAPOLIS	MN	6	1	1911	LR	MM	RE	MX		FR	2.0	B	S	G
G045.7	MINNEAPOLIS	MN	6	1	1911	LR	MM	RE	MX		FR	2.0	B	S	G
G045.8	MINNEAPOLIS	MN	40	1	1914	HR	MM	RE	MX		BR	2.0	B	S	G
G045.9	MINNEAPOLIS	MN	10	1	1930	LR	MM	RE	MX		FR	2.0	B	S	G
G046	ASBURY PARK	NJ	126	12	1941	LR	MM	RE	FM		BR		C	S	G
G047.1	ST. PAUL	MN	10	1	1940	LR	MM	RE	AO	1.4	FR	2.0	B	W	G
G047.10	ST. PAUL	MN	17	1		LR	MM	RE							G
G047.11	ST. PAUL	MN	5	1	1930	LR	MM	RE	AO		FR	2.0	B	D	G
G047.12	ST. PAUL	MN	165	14	1954	LR	MM	RE	AO		MA		B	W	G
G047.2	ST. PAUL	MN	33	1	1910	LR	MM	RE	AO	1.2	BR	2.0	B	D	G
G047.2 *	ST. PAUL	MN	33	1	1910	LR	MM	RE	AO	1.2	BR	2.0	B	W	G
G047.3	ST. PAUL	MN	19	1	1940	LR	MM	RE	AO	1.1	BR	2.0	B	W	G
G047.3 *	ST. PAUL	MN	19	1	1940	LR	MM	RE	AO	1.1	BR	2.0	B	W	G
G047.4	ST. PAUL	MN	14	1	1920	LR	MM	RE	AO	1.1	BR	2.0	B	S	G
G047.5	ST. PAUL	MN	52	2	1920	LR	MM	RE	AO	1.5	BR	2.0	B	S	G
G047.5 *	ST. PAUL	MN	26	1	1920	LR	MM	RE	AO	1.5	BR	2.0	B	S	G
G047.6	ST. PAUL	MN	6	1	1920	LR	MM	RE	AO	1.5	BR	2.0	B	S	G
G047.7	ST. PAUL	MN	17	1	1930	LR	MM	RE	AO	1.1	FR	2.0	B	D	G
G047.7 *	ST. PAUL	MN	17	1	1930	LR	MM	RE	AO	1.1	FR	2.0	B	W	G
G047.8	ST. PAUL	MN	25	1	1964	LR	MM	RE	AO	1.2	FR	2.0	B	W	G
G047.9	ST. PAUL	MN	24	2	1930	LR	MM	RE	AO	1.4		2.0	B	D	G
M014.1	SWEDEN		453	30	1940								B	W	
M014.2	SWEDEN		1429	25	1960								B	W	
M014.7	SWEDEN		3470	63	1953								B	W	
M015	ST. PAUL	MN	503	3	1964	HR	MM	RE	SN		BR		B	W	M
M016	TRENTON	NJ	112	14	1954	LR	MM	RE	FM		MA	1.0	C	W	O
M016 *	TRENTON	NJ	112	14	1954	LR	MM	RE	FM		MA	1.0	C	W	O
M017.1	NEW YORK	NY	91	1	1941	HR	MM	RE	FM	3.0	MA	1.0	B	S	M
M017.1 *	NEW YORK	NY	91	1	1941	HR	MM	RE	FM	3.0	MA	1.0	B	S	M
M017.1 **	NEW YORK	NY	91	1	1941	HR	MM	RE	FM	3.0	MA	2.0	B	S	M

BLDG. LABEL	LOCATION		NO. OF APT. UNITS	NO. OF BLDGS	YEAR BUILT	BLDG. TYPE	METER TYPE	OWNER-SHIP	TYPE OF TENANT	NO. OF OCCUP. PRE	WALL TYPE	NO. OF GLAZING LAYERS	HEAT SYSTEM TYPE	HEAT DIST. TYPE	DHW FUEL
M017.2	NEW YORK	NY	112	1	1939	HR					MA		B	S	M
M017.2 *	NEW YORK	NY	112	1	1939	HR					MA		B	S	M
M017.3	NEW YORK	NY	55	1	1937	HR					MA	2.0	B		M
O002.1	TRENTON	NJ	159	3	1954	LR	MM	RE	FM		MA	1.0	C	W	O
O002.2B	TRENTON	NJ	1500	3	1954	LR	MM	RE	FM						O
O003	WASHINGTON	DC	521				MM								O
O004		MD	752				MM								O
O005	NEW YORK	NY	60	1			MM	OW							O
O008.1	NEW YORK	NY	42	1	1952	HR	MM	RE	FM		MA		C	S	O
O008.1A	NEW YORK	NY	42	1	1952	HR	MM	RE	FM		MA		C	S	O
O008.2	NEW YORK	NY	98	1	1955	HR	MM	RE	FM		MA		C	S	O
O008.2A	NEW YORK	NY	98	1	1955	HR	MM	RE	FM		MA	1.0	C	S	O
O008.3	NEW YORK	NY	56	1	1958	HR	MM	RE	FM		MA		C	S	O
O008.3A	NEW YORK	NY	56	1	1958	HR	MM	RE	FM		MA		C	S	O
O008.4	NEW YORK	NY	81	1	1968	HR	MM	RE	FM		MA		C	S	O
O008.4A	NEW YORK	NY	81	1	1968	HR	MM	RE	FM		MA		C	S	O
O009.1	NEW YORK	NY	1444	15	1955	HR	MM	RE	FM	3.0	MA	1.0	C	S	O
O009.2	NEW YORK	NY	1338	27	1948	HR	MM	RE	FM	3.2	MA	1.0	C	S	O
O009.3	NEW YORK	NY	1791	15	1950	HR	MM	RE	FM	3.0	MA	1.0	C	S	O
O009.4	NEW YORK	NY	1310	10	1948	HR	MM	RE	FM	2.8	MA	1.0	C	S	O
O009.5	NEW YORK	NY	1229	9	1950	HR	MM	RE	FM	3.0	MA	1.0	C	S	O
O009.6	NEW YORK	NY	1084	13	1948	HR	MM	RE	FM	2.8	MA	1.0	C	S	O
O009.7	NEW YORK	NY	1246	13	1958	HR	MM	RE	FM	2.7	MA	1.0	C	S	O
O009.8	NEW YORK	NY	786	7	1951	HR	MM	RE	FM	2.5	MA	1.0	C	S	O
O009.9	NEW YORK	NY	733	6	1950	HR	MM	RE	FM	2.5	MA	1.0	C	S	O
O013	TRENTON	NJ	376	85	1939	LR	MM	RE	FM		MA	1.0	C	S	O
O014.1	TRENTON	NJ	102	5	1953	LR	MM	RE	FM		MA	1.0	C		O
O014.2	TRENTON	NJ	81	3	1953	LR	MM	RE	FM		MA	1.0	C		O
O014.3	TRENTON	NJ	219	8	1954	LR	MM	RE	FM		MA	1.0	C		O
O015	PHILADELPHIA	PA	886	30	1963	CO	MM	RE	MX		MA		C	S	O
O016.1	NEW YORK	NY	72	1	1935	HR	MM	RE	MX		BR	1.0	B	S	O
O016.2	NEW YORK	NY	48	1	1938	HR	MM	RE	MX		BR	1.0	B	S	O
O016.3	NEW YORK	NY	110	1	1922	HR	MM	RE	MX			1.0	B	S	O
O016.4	NEW YORK	NY	48	1	1936	HR	MM	RE	MX		BR	1.0	B	S	O
O016.5	NEW YORK	NY	24	1	1936	HR	MM	RE	MX			1.0	B	S	O
O016.6	NEW YORK	NY	72	1	1929	HR	MM	RE	MX		BR	1.0	B	S	O
O016.7	NEW YORK	NY	49	1	1933	HR	MM	RE	MX		BR	1.0	B	S	O
O016.8	NEW YORK	NY	42	1	1930	HR	MM	RE	MX		BR	1.0	B	S	O
O017.1	PHILADELPHIA	PA	6	1		LR					BR				G
O017.2	PHILADELPHIA	PA	6	1		LR					BR				G
O018	NEW YORK CITY	NY	139	1	1968	HR	MM	RE	FM		BR	1.0	B	S	O
X001.1	SWEDEN		36	1		HR	MM	RE	MX	1.8	CB	2.0	G	W	X
X001.1 *	SWEDEN		36	1		HR	MM	RE	MX	1.8	CB	2.0	G	W	X
X001.2	SWEDEN		34	1		HR	MM	RE	MX	1.8	CB	2.0	G	W	X
X001.2 *	SWEDEN		34	1		HR	MM	RE	MX	1.8	CB	2.0	G	W	X
X001.2 **	SWEDEN		34	1		HR	MM	RE	MX	1.8	CB	2.0	G	W	X
X001.3	SWEDEN		36	1		HR	MM	RE	MX	1.8	CB	2.0	G	W	X
X001.4	SWEDEN		38	1		HR	MM	RE	MX	1.8	CB	2.0	G	W	X
X001.4 *	SWEDEN		38	1		HR	MM	RE	MX	1.8	CB	2.0	G	W	X
X001.5	SWEDEN		38	1		HR	MM	RE	MX	1.8	CB	2.0	G	W	X
X001.6	SWEDEN		38	1		HR	MM	RE	MX	1.8	CB	2.0	G	W	X
X001.6 *	SWEDEN		38	1		HR	MM	RE	MX	1.8	CB	2.0	G	W	X
X001.7	SWEDEN		38	1		HR	MM	RE	MX	1.8	CB	2.0	G	W	X
X001.8	SWEDEN		38	1		HR	MM	RE	MX	1.8	CB	2.0	G	W	X
X001.9	SWEDEN		36	1		HR	MM	RE	MX	1.8	CB	2.0	G	W	X
X001.9 *	SWEDEN		36	1		HR	MM	RE	MX	1.8	CB	2.0	G	W	X

Table I
(continued)

Table II

BLDG. LABEL	END USES	FLOOR AREA (SQ.FT.)	NAC BEFORE (MBTU OR KWH)	NAC SAVINGS (MBTU OR KWH)	NAC SAVINGS (%)	SPACE HEAT BEFORE (MBTU)	SPACE HEAT SAVINGS (MBTU)	ANALYSIS METHOD	CONFIDENCE LEVEL	HDD (F)	HEATING FACTOR BEFORE	HEATING FACTOR AFTER
E012	L	865	1285.0	793.0	62			S	C			
E019.1	F	756	13061.6	963.5	7	5898.3	987.4	R	B+	5185	7.7	6.4
E019.2	F	757	8151.6	1992.9	24	5366.2	1652.0	R	B+	5185	7.0	4.8
E019.3	F	759	9122.0	1478.1	16	5026.6	1402.9	R	B+	5185	6.5	4.7
E021	F	1060	10380.0	1475.0	14			S	C	4848		
E022	L		5674.0	638.0	11			S	C	4800		
G031.1	H	950	142.9	70.1	49	111.8	57.8	S	C	6500	18.2	8.7
G031.2	H	1030	178.7	71.0	40	139.7	57.5	S	C	6500	20.9	12.3
G031.3	H	1040	131.6	36.9	28	97.1	29.2	S	C	6500	14.3	10.0
G031.4	H	960	109.9	8.7	8	85.8	9.6	S	C	6500	13.7	12.2
G031.5	H	1200	262.7	131.5	50	227.4	119.7	S	C	6500	29.2	13.8
G031.6	H	1165	120.4	34.2	28	89.7	24.5	S	C	6500	11.8	8.6
G031.7	H	1280				108.8	39.7	S	C	6500	13.1	8.3
G031.8	H	765	97.0	32.3	33	84.9	26.0	S	C	6500	17.1	11.8
G032	H	738	162.4	16.3	10	116.8	16.3	S	C	4857	32.6	28.0
G035.1	F	869	93.2	9.2	10	15.5	-5.3	R	B+	3161	5.0	7.6
G035.11	W	554	58.8	1.1	2	16.1	0.8	R	B+	3161	8.8	8.7
G035.12	W	632	52.9	0.6	1	13.2	-7.2	R	B+	3161	6.4	10.2
G035.13	W	619	32.9	3.4	10	8.6	-0.8	R	B+	3161	4.2	4.8
G035.14	W	607	36.2	-0.6	- 2	1.2	-4.4	R	B+	3161	0.6	2.9
G035.15	W	587	59.5	7.6	13	7.3	0.5	R	B+	3161	3.9	3.7
G035.16	W	503	57.1	13.3	23	5.2	-5.5	R	B+	3161	3.1	6.7
G035.2	F	828	134.7	22.6	17	25.4	2.1	R	B+	3161	8.1	8.9
G035.4	F	836	164.1	33.5	20	11.2	-18.6	R	B+	3161	3.2	11.3
G035.5	F	870	86.6	4.0	5	21.1	-7.2	R	B+	3161	7.4	10.3
G035.6	F	771	79.4	-4.1	- 5	4.7	-9.5	R	B+	3161	0.9	5.8
G036.1	W	950	118.6	20.9	18	79.3	-15.5	S	C	4872	17.1	13.8
G036.2	W	850	104.5	23.1	22	72.2	19.8	S	C	4872	17.4	12.6
G036.3	W	975	122.0	22.4	18	83.1	17.6	S	C	4872	17.5	13.8
G036.4	H	945				66.3	14.9	S	C	4872	14.4	11.2
G036.5	H	945				61.8	2.3	S	C	4872	13.4	12.9
G037.1	F	1529	208.2	56.9	27			F	B	8159		
G037.2	F	582	85.9	17.1	20	72.5	20.0	R	B+	8159	15.3	11.1
G037.3	F	554	80.7	23.7	29	63.6	14.4	R	B+	8159	14.1	10.9
G037.4	F	680	93.8	16.5	18	81.3	16.2	R	B+	8159	14.7	11.7
G037.5	F	1800	202.4	49.6	25	179.1	49.2	R	B+	8159	12.2	8.8
G037.6	F	711	79.4	24.7	31	72.0	27.6	R	B+	8159	12.4	7.6
G037.7	F	446	71.0	9.3	13	58.1	7.7	R	B+	8159	15.3	13.8
G038.1	H	767				28.9	7.4	E	A	8159	4.6	3.4
G038.2	H	764				28.5	4.2	E	A	8159	4.6	3.9
G038.3	H	792				28.8	4.6	E	A	8159	4.5	3.8
G038.4	H	842				36.8	4.0	E	A	8159	5.4	4.8
G038.5	F	833	51.0	8.3	16	38.1	7.3	R	B+	8159	5.6	4.5
G038.6	F	771	47.1	3.3	7	38.5	3.2	R	B+	8159	6.1	5.6
G038.7	F	770	46.9	3.4	7	37.6	2.6	R	B+	8159	6.0	5.6
G038.8	F	757	49.1	7.8	16	40.3	10.3	R	B+	8159	6.5	4.9
G038.9	F	783	53.7	2.0	4	43.4	1.5	R	B+	8159	6.8	6.6
G039	F	653	107.8	-7.3	- 7	63.4	-31.8	R	B+	5034	19.3	28.9
G039 *	F	653	115.1	45.9	40	95.2	69.8	R	B+	5034	28.9	7.7
G040.1	F	700	89.9	19.4	22	66.0	10.8	R	B+	8159	11.6	9.7
G040.10	F	1020	121.4	21.9	18	81.1	11.7	R	B+	8159	9.8	8.3

Table II (continued)

BLDG. LABEL	END USES	FLOOR AREA (SQ.FT.)	NAC BEFORE (MBTU OR KWH)	NAC SAVINGS (MBTU OR KWH)	NAC SAVINGS (%)	SPACE HEAT BEFORE (MBTU)	SPACE HEAT SAVINGS (MBTU)	ANALYSIS METHOD	CONFI-DENCE LEVEL	HDD (F)	HEATING FACTOR BEFORE	HEATING FACTOR AFTER
G040.2	F	630	77.8	9.9	13	66.6	12.4	R	B+	8159	13.0	10.5
G040.3	F	994	124.5	33.9	27	85.7	18.0	R	B+	8159	10.6	8.3
G040.4	F	888	58.8	10.6	18	40.8	8.6	R	B+	8159	5.6	4.4
G040.5	F	889	57.4	11.7	20	41.4	11.8	R	B+	8227	5.7	4.0
G040.6	F	889	45.1	6.5	14	31.9	5.8	R	B+	8227	4.4	3.6
G040.7	F	1026	47.5	6.4	13	33.2	8.0	R	B+	8227	3.9	3.0
G040.8	F	993	98.9	9.0	9	79.7	10.6	R	B+	8159	9.8	8.5
G040.9	F	1020	131.7	37.3	28	95.8	27.0	R	B+	8159	11.5	8.3
G041.1	W	504	49.7	3.4	7			R	C	6497		
G041.2	W	1560	241.3	3.5	1			R	C	6497		
G041.3	W	1125	283.7	-10.6	- 4			R	C	6497		
G041.4	W	1050	74.6	19.5	26			R	C	6497		
G041.5	W	533	159.2	19.3	12			R	C	6497		
G042.1	H	644				49.6	5.0	E	A	8159	9.5	8.5
G042.2	H	1909				139.7	11.5	E	A	8159	9.0	8.2
G042.3	H	605				32.1	3.3	E	A	8159	6.5	5.8
G042.4	H	679				36.9	2.3	E	A	8159	6.7	6.2
G043	W	1500	136.1	43.2	32	115.6	52.0	R	B+	3095	24.9	13.7
G044.1	F	1103	166.2	67.5	41	139.3	72.7	R	B+	4972	25.4	12.1
G044.2	F	1524	127.3	67.4	53	85.5	51.8	R	B+	4972	11.3	4.5
G045.1	F	859	94.0	5.5	6	86.6		F	B	8007	12.6	
G045.10	F	1309	86.1	14.1	16	82.2		F	B	8007	7.8	
G045.11	F	801	122.1	15.1	12			R	B+	8007		
G045.12	F	1086	89.1	13.6	15			R	B+	8007		
G045.13	F	847	112.6	22.6	20			R	B+	8007		
G045.2	F	736	62.2	1.8	3	51.9		F	B	8007	8.8	
G045.3	F	1477	74.0	-10.7	-15			F	B+	8007		19.5
G045.4	F	963	85.4	4.4	5	74.1	4.9	R	B+	8007	9.6	9.0
G045.5	F	1116	79.4	11.0	14	61.9	12.2	R	B+	8007	6.9	5.6
G045.6	F	1840	222.5	29.5	13	203.8	37.4	R	B+	8007	13.8	11.3
G045.7	F	1840	202.2	26.8	13	187.8	42.9	R	B+	8007	12.7	9.8
G045.8	F	630	87.0	2.7	3			F	B	8007		
G045.9	F	1385	119.0	30.1	25			F	B	8007		
G046	F	708	211.0	110.6	52	153.0	94.3	R	B+	4972	43.5	16.7
G047.1	F	792	80.2	35.6	44	64.3	32.5	R	B+	8007	10.1	5.0
G047.10	D		9.7	3.0	31			E	B+	8007		
G047.11	F	912	126.5	70.9	56	108.9	65.3	R	B+	8007	14.9	6.0
G047.12	H	741	84.3	27.7	33	84.3	27.7	R	B+	8007		
G047.2	W	976	98.3	28.4	29	90.0	34.9	R	B+	8007	11.5	7.0
G047.2 *	W	976	73.5	4.8	7	53.6	0.3	R	B+	8007	6.9	6.8
G047.3	F	674	72.1	19.0	26			R	B+	8007		7.4
G047.3 *	H	674	37.8	5.7	15	37.8	5.7	R	B+	8007	7.0	6.0
G047.4	F	883	71.9	17.5	24	63.3	18.7	R	B+	8007	9.0	6.3
G047.5	F	737	77.5	16.6	21	67.2	10.5	R	B+	8007	11.4	9.6
G047.5 *	H	737	49.6	4.0	8	49.6	4.0	R	B+	8007	8.4	7.7
G047.6	F	1080	166.3	34.3	21	158.5	32.0	R	B+	8007	18.3	14.6
G047.7	F	669	62.2	35.0	56	50.9	32.7	R	B+	8007	9.5	3.4
G047.7 *	H	669	17.7	1.1	6	17.7	1.1	R	B+	8007	3.3	3.1
G047.8	F	765	49.1	3.8	8	39.5	6.5	R	B+	8007	6.5	5.4
G047.9	F	699	93.8	39.8	42	81.3	39.9	R	B+	8007	14.5	7.4
M014.1	W	689	62.0	8.5	14			F	C	7220		
M014.2	W	764	70.5	5.9	8			F	C	7220		
M014.7	W	807	73.8	5.7	8			F	C	7220		
M015	W	410	64.8	11.6	18			S	C	8159		
M016	F	862	184.4	-5.1	- 3	130.6	-6.1	R	B+	4952	30.6	32.0
M016 *	F	862	189.4	95.4	50	136.8	77.7	R	B+	4952	32.0	13.9
M017.1	W	659	126.6	48.4	38			S	C	4868		
M017.1 *	W	659	78.2	1.2	2			S	C	4868		
M017.1 **	W	659	77.0	14.0	18			S	C	4868		

Table II (continued)

BLDG. LABEL	END USES	FLOOR AREA (SQ.FT.)	NAC BEFORE (MBTU OR KWH)	NAC SAVINGS (MBTU OR KWH)	NAC SAVINGS (%)	SPACE HEAT BEFORE (MBTU)	SPACE HEAT SAVINGS (MBTU)	ANALYSIS METHOD	CONFI-DENCE LEVEL	HDD (F)	HEATING FACTOR BEFORE	HEATING FACTOR AFTER
M017.2	W		111.8	27.0	24			S	C	4868		
M017.2 *	W		84.8	1.6	2			S	C	4868		
M017.3	W		113.6	18.5	16			S	C	4868		
O002.1	W	830	113.8	50.6	44	83.0	50.4	S	C	4908	20.4	8.0
O002.2B	W		116.7	18.4	16	116.7	18.4	S	C	4911		
O003	W		116.3	7.9	7			S	D	4211		
O004	W		84.9	1.8	2			S	D	4211		
O005	W		167.3	15.2	9			S	D	4848		
O008.1	H	890				109.8	28.4	S	B	4800	25.7	19.0
O008.1A	H	890				110.3	17.0	S	B	4800	25.8	21.8
O008.2	H	850				38.8	9.6	S	B	4800	9.5	7.2
O008.2A	H	850				36.4	8.5	S	B	4800	8.9	6.9
O008.3	H	830				48.5	3.3	S	B	4800	12.2	11.3
O008.3A	H	830				45.5	-2.2	S	B	4800	11.4	12.0
O008.4	H	920				55.4	14.4	S	B	4800	12.5	9.3
O008.4A	H	920				54.6	16.0	S	B	4800	12.4	8.8
O009.1	H	850				67.2	12.0	S	C	4800	16.5	13.5
O009.2	H	775				63.8	9.7	S	C	4800	17.2	14.5
O009.3	H	810				73.1	16.2	S	C	4800	18.8	14.6
O009.4	H	810				67.2	11.2	S	C	4800	17.3	14.4
O009.5	H	840				74.8	10.8	S	C	4800	18.6	15.9
O009.6	H	760				68.8	14.2	S	C	4800	18.9	15.0
O009.7	H	825				60.1	10.2	S	C	4800	15.2	12.6
O009.8	H	845				62.7	11.2	S	C	4800	15.5	12.7
O009.9	H	850				62.4	5.9	S	C	4800	15.3	13.8
O013	F	779	152.5	26.1	17	118.8	34.5	R	B+	4952	30.8	21.9
O014.1	F	700	187.5	53.8	29	164.2	52.6	R	B+	4952	47.4	32.2
O014.2	W	790	198.6	27.9	14	167.1	27.8	R	B+	4952	42.7	35.6
O014.3	W	760	181.7	9.8	5	163.5	29.6	R	B+	4952	43.4	35.6
O015	F	1003	209.2	19.0	9	146.4	24.7	R	B+	4865	30.0	24.9
O016.1	W	1038	128.0	24.0	19			S	C	4848		
O016.2	W	1038	114.0	21.0	18			S	C	4848		
O016.3	W	1705	142.0	42.0	30			S	C	4848		
O016.4	W	1015	124.0	17.0	14			S	C	4848		
O016.5	W	975	138.0	31.0	22			S	C	4848		
O016.6	W	1250	110.0	17.0	15			S	C	4848		
O016.7	W	957	78.0	18.0	23			S	C	4848		
O016.8	W	1126	144.0	22.0	15			S	C	4848		
O017.1	H					97.3	45.4	S	C	4865		
O017.2	H					65.0	15.2	S	C	4865		
O018	W	1066	138.3	26.5	19	80.5	-12.9	R	B+	4848	15.6	18.1
X001.1	F	802	53.9	19.3	36			R	A	6750		
X001.1 *	F	802	34.6	3.3	10			R	A	6750		
X001.2	F	788	50.0	9.2	19			R	A	6750		
X001.2 *	F	788	40.7	1.2	3			R	A	6750		
X001.2 **	F	788	39.5	3.2	8			R	A	6750		
X001.3	F	810	51.4	7.2	14			R	A	6750		
X001.4	F	807	54.0	9.7	18			R	A	6750		
X001.4 *	F	807	44.3	5.1	12			R	A	6750		
X001.5	F	807	51.2	19.4	38			R	A	6750		
X001.6	F	807	53.2	11.0	21			R	A	6750		
X001.6 *	F	807	42.2	-1.3	- 3			R	A	6750		
X001.7	F	807	49.4	8.2	17			R	A	6750		
X001.8	F	807	53.7	11.3	21			R	A	6750		
X001.9	F	807	54.0	21.7	40			R	A	6750		
X001.9 *	F	807	32.2	4.1	13			R	A	6750		

Table III

BLDG. LABEL	RETROFIT MEASURES	HEAT SYSTEM MEASURES	YR OF RETRO FIT	RETRO. COST (85$)	MAINT. COST ($/UNIT)	SIMPLE PAYBACK (YEARS)	IRR (%)	NPV ($/UNIT)	CCE	LOCAL ENERGY PRICE	RETR. LIFE TIME	CONF. LEVEL COST
									(CENTS/KWH)			
E012	LS		79	102	-5	1.4	0.87	594.9	0.01	.070	10	C
E019.1	IX,WH,WM	IHW,SET,IPI	81	651	0	15.7	0.03	-175.8	0.06	.038	20	A
E019.2	IX,WH,WM,IA,CW,LS	SET,IPI	81	1313	0	15.3	0.04	-329.3	0.06	.038	20	A
E019.3	IX,WH,WM	IHW,SET,IPI	81	1370	0	21.5	0.00	-640.3	0.09	.038	20	A
E021	HC	EMR	80	479	18	3.3	0.26	925.8	0.04	.074	20	C
E022	MC		80	94	2	1.9	0.53	458.9	0.02	.060	20	B
									($ / MBTU)			
G031.1	IA,HC,HS,OM	TU,FD,TRV,CUT,OMP	81	699	35	2.2	0.49	2561.1	1.93	5.400	15	A
G031.2	IA,HS,OM	TU,FD,TRV,CUT,OMP	81	652	35	2.1	0.52	2589.2	1.85	5.400	15	A
G031.3	IA,HC,HS,WM,OM	TU,FD,TRV,CUT,OMP	81	1326	35	8.4	0.08	130.4	6.19	5.400	15	A
G031.4	HC,HS,OM,ID	TU,FD,TRV,VDE,OMP	81	288	35	5.6	0.03	-67.3	6.94	5.400	15	A
G031.5	IA,WM,HS,OM	TU,FD,CUT,OMP,VDT	81	945	35	1.5	0.80	6218.6	1.16	5.400	15	A
G031.6	HS,OM	TU,FD,TRV,CUT,OMP,VDT	81	324	35	2.5	0.37	836.2	2.88	5.400	15	A
G031.7	HS,OM	TU,TUR,FD,RHB,TRV,CUT	81	1181	35	5.5	0.18	937.2	4.15	5.400	15	A
G031.8	HS,HC,OM	TU,RHB,TRV,CUT,OMP	81	324	35	2.3	0.41	930.8	2.72	5.400	15	A
G032	CM,OM,HR	SHW,EMC	82	286	40	2.8	0.24	297.6	4.95	5.800	10	B
G035.1	IA,WH,CW	IHW	82	218	0	4.3	0.24	220.6	3.37	5.100	10	B
G035.11	SW		84	539	2	108.1	0.00	-510.4	71.54	4.400	10	B
G035.12	SW		84	535	2	196.6	0.00	-525.7	130.19	4.400	10	B
G035.13	SW		84	562	2	36.5	0.00	-444.6	24.14	4.400	10	B
G035.14	SW		84	623	2		0.00	-660.9		4.400	10	B
G035.15	SW		84	549	2	15.9	0.00	-267.9	10.55	4.400	10	B
G035.16	SW		84	577	2	9.5	0.04	-70.5	6.33	4.400	10	B
G035.2	IA,WH,CW,HC	LPS,CLT	82	100	0	0.8	1.34	976.8	0.63	5.100	10	B
G035.4	IA,CW,HC	CLT	82	178	0	1.0	1.13	1419.0	0.75	5.100	10	B
G035.5	IA,WH,CW	IHW	82	172	0	7.7	0.09	18.6	6.12	5.100	10	B
G035.6	IA,CW,HC	CLT	83	88	0		0.00	-281.3		5.100	10	B
G036.1	WH	SHT,SET	82	141	0	1.2	0.85	1202.8	0.64	5.000	20	C
G036.2	WH	SHT,SET	82	141	0	1.1	0.94	1344.3	0.57	5.000	20	C
G036.3	WH	SHT,SET	82	141	0	1.1	0.91	1299.3	0.59	5.000	20	C
G036.4	HC	RES,BTC	82	34	3	0.4	2.34	539.1	0.52	5.000	10	C
G036.5	HC	RES,BTC	82	34	3	2.7	0.26	35.3	3.39	5.000	10	C
G037.1	HR,HC,WH	SHW,RES,CUT,HWR	83	4052	-20	11.5	0.09	667.2	5.76	5.733	25	B
G037.2	HR,HC	SHW,RES	82	749	-20	6.9	0.18	881.8	2.59	5.733	25	B
G037.3	HR,WH,HC	SHW,RES,CUT,SHT	81	568	-20	3.7	0.32	1662.8	1.21	5.733	25	B
G037.4	HR,HC	SHW,TRV,RES	81	1013	-20	8.9	0.14	720.1	4.06	5.733	25	B
G037.5	HR,HC,IA	SHW,RES,HRE	83	3947	-20	13.2	0.07	97.0	6.43	5.733	25	B
G037.6	HR,HC	SHW,RES,CUT	83	383	-20	2.5	0.46	1776.6	0.52	5.733	25	B
G037.7	HR,HC	SHW,RES	81	1824	-20	28.8	0.02	-742.8	14.68	5.733	25	B
G038.1	HC	RES,CUT	82	14	0	0.3	3.30	328.7	0.28	5.733	10	B
G038.2	HC	RES,CUT	82	22	0	0.8	1.22	172.7	0.75	5.733	10	B
G038.3	HC	RES,CUT	82	41	0	1.4	0.72	172.5	1.26	5.733	10	B
G038.4	HC	RES	83	70	0	2.9	0.34	108.7	2.49	5.733	10	B
G038.5	HC	RES	83	11	0	0.2	4.81	360.2	0.18	5.733	10	B
G038.6	HC	RES	83	11	0	0.5	1.92	136.8	0.46	5.733	10	B
G038.7	HC	RES	83	13	0	0.7	1.52	138.1	0.58	5.733	10	B
G038.8	HC	RES	83	13	0	0.3	3.77	335.7	0.23	5.733	10	B
G038.9	HC	RES	83	12	0	1.0	1.06	77.7	0.83	5.733	10	B
G039	HC,WH	RES, SHT	82	377	0		0.00	-930.5		5.600	15	B
G039 *	WM,HS	OMP,OMC	84	545	0	2.0	0.45	681.0	2.90	5.600	5	B
G040.1	MC		82	136	18	1.1	0.76	615.7	1.93	5.733	10	B
G040.10	MC		82	101	18	0.7	1.27	945.7	1.48	5.733	10	B

Table III (continued)

BLDG. LABEL	RETROFIT MEASURES	HEAT SYSTEM MEASURES	YR OF RETRO FIT	RETRO. COST (85$)	MAINT. COST ($/UNIT)	SIMPLE PAYBACK (YEARS)	IRR (%)	NPV ($/UNIT)	CCE	LOCAL ENERGY PRICE	RETR. LIFE TIME	CONF. LEVEL COST
G040.2	MC		82	87	18	1.4	0.49	229.1	3.07	5.733	10	B
G040.3	MC		82	101	18	0.5	1.99	1362.3	0.96	5.733	10	B
G040.4	MC,IA		83	105	18	1.6	0.44	237.2	3.11	5.733	10	B
G040.5	MC		82	100	18	1.4	0.55	303.0	2.76	5.733	10	B
G040.6	MC		82	84	18	2.0	0.24	78.5	4.60	5.733	10	B
G040.7	MC		82	84	18	2.1	0.23	73.8	4.67	5.733	10	B
G040.8	MC		82	101	18	1.8	0.36	176.7	3.60	5.733	10	B
G040.9	MC		82	101	18	0.4	2.16	1488.6	0.87	5.733	10	B
G041.1	CW,WM		81	851	0	40.5	0.00	-648.1	27.50	5.210	15	C
G041.2	CW,IA,WM,DR		81	532	0	24.6	0.00	-323.1	16.70	5.210	15	C
G041.3	WM,DR,CW		82	958	0		0.00	-1408.5		5.210	10	C
G041.4	WM,DR,CW		82	935	0	8.3	0.05	-105.5	6.83	5.210	10	C
G041.5	WM,DR,CW		82	609	0	5.4	0.14	211.8	4.50	5.210	10	C
G042.1	HS	VDE	84	54	3	1.9	0.49	198.2	1.78	5.700	15	A
G042.2	HS	VDE	84	123	6	1.8	0.51	465.1	1.69	5.700	15	A
G042.3	HS,WH	VDE	84	92	2	4.8	0.18	73.9	3.67	5.700	15	A
G042.4	HS,WH	VDE	84	131	3	12.6	0.00	-57.8	7.59	4.500	15	A
G043	CM	EMC	82	136	50	0.7	1.08	932.6	1.61	4.200	10	C
G044.1	WM,IA,DR,IW,IF,HC,SR	OMC	83	13767	0	29.2	0.03	-5437.9	17.50	6.500	25	B
G044.2	WM,DR,IA,HR,HC,IW,SR		82	12766	0	25.9	0.04	-4076.2	16.26	6.500	25	B
G045.1	HS,HC	TRV,MSB	84	142	0	4.5	0.19	88.4	3.67	5.586	10	A
G045.10	HS,HC	TRV,MSB	84	116	0	1.4	0.75	573.1	1.17	5.586	10	A
G045.11	HS,HC	TRV,MSB	84	29	0	0.3	3.05	603.3	0.27	5.586	10	A
G045.12	HS,HC	TRV,MSB	84	72	0	0.9	1.09	496.7	0.76	5.586	10	A
G045.13	HS,HC	TRV,MSB	84	78	0	0.6	1.68	868.2	0.49	5.586	10	A
G045.2	HS,HC	TRV,MSB	84	36	0	3.5	0.27	39.6	2.82	5.586	10	A
G045.3	HS,HC	TRV,TU,MSB	84	122	0		0.00	-570.1		5.586	10	A
G045.4	HS,HC	TRV,MSB	84	29	0	1.1	0.89	155.6	0.92	5.586	10	A
G045.5	HS,HC	TRV,MSB	84	40	0	0.6	1.60	420.5	0.51	5.586	10	A
G045.6	HS,HC	TRV,TU,MSB	84	254	0	1.5	0.67	980.5	1.23	5.586	10	A
G045.7	HS,HC	TRV,TU,MSB	84	242	0	1.6	0.64	879.7	1.28	5.586	10	A
G045.8	HS,HC	TRV,MSB	84	27	0	1.7	0.59	86.5	1.40	5.586	10	A
G045.9	HS,HC	TRV,MSB	84	98	0	0.6	1.78	1161.6	0.46	5.586	10	A
G046	HR,WH,HC	HRM,SHT	83	3341	0	5.1	0.24	6437.1	2.85	5.600	20	B
G047.1	HC,HR,IA,IW,DR,CW,WH	CLT,HRE	85	1066	30	5.6	0.15	809.0	3.67	5.390	20	A
G047.10	WH	HWR	85	206	0	12.7	0.07	-0.2	5.89	5.390	25	A
G047.11	HS,HC,IA,IW,CW,WH	SHW,CLT,VDT	85	2165	60	5.7	0.15	1566.4	3.73	5.390	20	A
G047.12	HS,HC,CW	FEB,RES,CUT	85	640	2	4.3	0.24	1045.0	2.25	5.390	20	A
G047.2	HC,HS,WM,CW,WH	SHW,FEB,CLT	85	677	9	4.4	0.22	976.9	2.57	5.390	20	A
G047.2 *	HS,WH	FEB	85	167	0	6.5	0.16	162.3	2.99	5.390	25	A
G047.3	HC,HS,IA,CW,WH	VDE,FEB,CLT	85	594	16	5.8	0.15	406.8	3.79	5.390	20	A
G047.3 *	HS,WH	FEB	85	316	0	10.3	0.09	75.0	4.76	5.390	25	A
G047.4	HC,IA,WM,CW,WH,HS	CLT,MSB	85	391	21	4.1	0.18	331.1	3.65	5.390	15	A
G047.5	HS,HC,IA,CW,WR,WH	CLT,VDE,MSB	85	707	6	7.9	0.09	104.8	5.04	5.390	15	A
G047.5 *	HS	VDE	85	17	0	0.8	1.29	191.8	0.47	5.390	15	A
G047.6	HS,HC,IA,WM,CW,WH	CLT,MSB	85	1020	50	5.5	0.11	314.8	4.72	5.390	15	A
G047.7	HR,HC,IW,CW,WH	SHW,FEB,RES,CUT,HRE	85	981	18	5.2	0.18	984.1	3.16	5.390	20	A
G047.7 *	HC	CUT	85	7	0	1.2	0.86	36.5	0.91	5.390	10	A
G047.8	CW,HC,HS,WH	RES,CUT,VDE,FEB	85	261	12	12.7	0.00	-154.1	9.64	5.390	20	A
G047.9	HC,HR,IA,CW,WH	RES,CUT,FEB,SHW	85	1480	13	6.9	0.13	833.8	3.84	5.390	20	A
M014.1	IW		77		0							
M014.2	IA		77		0							
M014.7	HC	TRV,RES	77		0							
M015	CM,LC	EMR	81	350	0	4.5	0.22	310.5	4.29	5.500	10	C
M016	WR		83		0						15	B
M016 *	HR	HRM	84	547	10	0.8	1.30	11072.3	0.39	6.700	25	F
M017.1	HR		80	419	0	1.2	0.88	3716.6	0.82	5.896	20	B
M017.1 *	WH,ID,WR	SHT	82	1416	0	171.3	0.00	-1321.5	111.38	6.255	20	B
M017.1 **	IA,CM	EMC	84	251	0	2.7	0.42	855.6	1.97	6.327	15	B

Table III (continued)

BLDG. LABEL	RETROFIT MEASURES	HEAT SYSTEM MEASURES	YR OF RETRO FIT	RETRO. COST (85$)	MAINT. COST ($/UNIT)	SIMPLE PAYBACK (YEARS)	IRR (%)	NPV ($/UNIT)	CCE	LOCAL ENERGY PRICE	RETR. LIFE TIME	CONF. LEVEL COST
M017.2	HR,WH	SHT	81	578	0	2.8	0.37	1817.3	2.02	6.830	20	B
M017.2 *	CM,WR	EMC	83	1003	0	88.3	0.00	-873.0	59.16	6.759	20	B
M017.3	HR		83	573	0	4.8	0.22	799.2	2.93	6.183	20	B
O002.1	HC,HS,WH		81	494	25	1.0	1.04	3623.6	1.89	8.269	10	B
O002.2B					0							B
O003	HS,HC,OM		78	26	20	0.7	0.21	21.5	2.99	2.960	10	D
O004	HS,HC,OM		78	15	13	1.9	0.00	-93.7	8.41	2.960	10	D
O005	HS,HC,OM		78	60	100	0.9	0.00	-620.8	7.14	2.960	10	D
O008.1	HC	TRV	77	236	10	2.0	0.49	673.2	1.54	2.517	10	B
O008.1A					0							B
O008.2	HC	TRV	77	199	10	4.9	0.10	30.3	4.00	2.517	10	B
O008.2A					0							B
O008.3	HC	TRV	77	156	10	11.2	0.00	-153.9	9.75	2.517	10	B
O008.3A					0							B
O008.4	HC	TRV	77	214	10	3.5	0.22	188.8	2.81	2.517	10	B
O008.4A					0							B
O009.1	WR		80	1339	-30	13.8	0.11	521.5	8.03	6.370	20	C
O009.2	WR		80	1639	-30	21.4	0.06	-96.5	12.86	6.370	20	C
O009.3	WR		80	1596	-30	11.9	0.12	830.2	7.45	6.370	20	C
O009.4	WR		80	1765	-30	19.1	0.07	39.8	12.20	6.370	20	C
O009.5	WR		81	1557	-30	19.9	0.07	-20.1	10.84	6.370	20	C
O009.6	WR		80	1408	-30	12.3	0.12	720.3	7.24	6.370	20	C
O009.7	WR		80	1281	-30	15.5	0.10	361.2	8.91	6.370	20	C
O009.8	WR		81	1233	-30	14.6	0.11	415.9	7.72	6.370	20	C
O009.9	WR		81	1245	-30	29.1	0.05	-241.1	14.83	6.370	20	C
O013	HC	RES	81	458	40	2.1	0.44	2307.3	3.19	7.020	20	B
O014.1	HR,HC	RES	80	2039	60	5.5	0.19	2778.3	4.69	5.599	20	B
O014.2	HR,HC	RES	80	3818	45	20.3	0.02	-1606.3	14.53	5.199	20	B
O014.3	HR,HC	RES	82	1556	60	22.7	0.00	-1217.8	21.10	6.415	20	B
O015	HC	RES	81		0						20	F
O016.1	HR,CM	OMP,EMC	80	973	4	5.2	0.18	779.5	4.62	5.968	15	C
O016.2	HR,WR,CM	OMP,EMC	80	2798	4	17.2	0.00	-1270.5	14.82	5.968	15	C
O016.3	HR,WR,CM	OMP,EMC	80	2441	4	7.5	0.11	661.7	6.48	5.968	15	C
O016.4	HR,WR,CM	OMP,EMC	82	2398	4	22.0	0.00	-1385.0	15.72	5.752	15	C
O016.5	HR,WR	OMP	83	3107	4	14.6	0.01	-1092.0	11.13	6.399	15	C
O016.6	HR,WR,CM	OMP,EMC	81	2384	4	20.3	0.00	-1290.0	15.63	5.824	15	C
O016.7	HR,WR,CM	OMP,EMC	83	2258	4	18.3	0.00	-1104.4	13.99	6.399	15	C
O016.8	HR,WR,CM	OMP,EMC	82	1997	4	14.4	0.01	-692.1	10.15	5.680	15	C
O017.1	HC,WH,IA,WM	CLT,RES	84	2030	0	5.2	0.19	1779.0	4.91	8.412	15	B
O017.2	HC,WH,HS	CLT,RHB,OMB,RES,TU,VD	84	1823	0	13.8	0.02	-547.8	13.17	8.412	15	B
O018	HC,OM,HS	RHB,CUT,OMC,OMP,TUR	84	334	14	2.2	0.42	699.4	2.32	5.659	10	B
X001.1	IA,OM,CW,WH,HC,IX,IW	OMC,LFS,TRV	83	7934	17	31.9	0.00	-5281.9	39.69	12.277	20	A
X001.1 *	WM		84	1108	0	26.0	0.00	-621.7	31.69	12.635	20	A
X001.2	IA,OM,CW,WH,HC	OMC,LFS,TRV	83	692	16	5.8	0.13	300.6	9.99	12.055	15	A
X001.2 *	IX		83	343	0	22.2	0.00	-166.6	27.01	12.277	20	A
X001.2 **	WM		84	698	0	16.9	0.03	-226.4	20.58	12.635	20	A
X001.3	IA,OM,CW,WH,HC	OMC,LFS,TRV	83	1100	16	11.9	0.01	-357.3	19.00	12.055	15	A
X001.4	IA,OM,CW,WH,HC,IX	OMC,LFS,TRV	83	1470	17	11.8	0.05	-230.2	16.06	12.277	20	A
X001.4 *	HS		84	1865	91	28.4	0.00	-2073.5	57.98	12.635	15	A
X001.5	IA,OM,CW,WH,HC,IX,IW	OMC,LFS,TRV	83	8565	17	34.3	0.00	-5898.2	42.56	12.277	20	A
X001.6	IA,OM,CW,WH,HC	OMC,LFS,TRV	83	1010	16	7.1	0.10	206.7	11.54	12.055	15	A
X001.6 *	IX		83	546	0		0.00	-737.5		12.277	20	A
X001.7	IA,OM,CW,WH,HC,WM	OMC,LFS,TRV	84	2094	17	19.8	0.00	-1069.1	26.17	12.635	20	A
X001.8	IA,OM,CW,WH,HC	OMC,LFS,TRV	83	1042	16	7.2	0.10	212.0	11.54	12.055	15	A
X001.9	IA,OM,CW,WH,HC,IX,IW,WM	OMC,LFS,TRV	83	10163	17	36.3	0.00	-7157.5	45.00	12.277	20	A
X001.9 *	HS		84	1865	91	35.3	0.00	-2198.3	72.13	12.635	15	A

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