LBL 14787
EEB-BED-82-07

Paper presented at the ACEEE 1982 Summer Study in Energy Efficient Buildings, Santa Cruz CA, August 22-28, 1982.

A SUMMARY REPORT OF BUILDING ENERGY COMPILATION AND ANALYSIS (BECA) PART B: EXISTING NORTH AMERICAN RESIDENTIAL BUILDINGS

Leonard W. Wall, Charles A. Goldman, and Arthur H. Rosenfeld

Energy Efficient Buildings Program
Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

AUGUST 1982

This work was supported by the Assistant Secretary for Conservation and Renewable Energy, Office of Building Energy Research and Development, Building Systems Division of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

A SUMMARY REPORT OF
BUILDING ENERGY COMPILATION AND ANALYSIS (BECA)
PART B: EXISTING NORTH AMERICAN RESIDENTIAL BUILDINGS*#

Leonard W. Wall, Charles A. Goldman, Arthur H. Rosenfeld

Energy Efficient Buildings Program

Lawrence Berkeley Laboratory

University of California

Berkeley, California 94720 U.S.A.

August 2, 1982

ABSTRACT

BECA-B assesses the technical performance and economics of energy conservation retrofit measures in houses. The data collected thus far represent measured energy savings and retrofit costs for over 65 North American residential retrofit projects. The sample size within each project ranges from individual homes to 33,000 dwellings participating in a utility-sponsored program. The median value of energy savings is 22%. For fuel-heated homes, the median cost of conserved energy is $3.86/MBtu, substantially less than the average 1981 prices for purchased energy of $4.50/MBtu for natural gas and $8.70/MBtu for fuel oil. For ten of the eleven electric heat retrofits the cost of conserved electricity is less than the 1981 average residential electricity price of 6.2c/kWh.

---

*Most of this article is excerpted from Building Energy Compilation and nalysis (BECA) Part B: Existing North American Residential Buildings, by L.W. Wall, C.a. Goldman, A.H. Rosenfeld, and G.S. Dutt, Lawrence Berkeley Laboratory LBL-13385, EEB-BED-82-05, July 1982.

#The work described in this report was funded by the Assistant Secretary for Conservation and Renewable Energy, Office of Buildings and Community Systems, Buildings Division of the U.S. Department of Energy under Contra t No. DE-AC03-76SF00098.

INTRODUCTION

BECA-B is a compilation and analysis of measured energy use by U.S. and Canadian houses before and after conservation retrofits. Our results are based on the experience of homeowners, government agencies, utilities, and private firms. This study is part of an ongoing project that collects and critically reviews measured data on the energy performance and cost-effectiveness of low-energy new homes (BECA-A), existing "retrofitted" homes (BECA-B), energy-efficient commercial buildings (BECA-C), appliances and equipment (BECA-D), and validation of computer programs (BECA-V).

The U.S. residential sector accounts for approximately one-fifth of the nation's energy consumption. Space heating and water heating dominate the residential energy demand and hence most initial conservation programs have focused on lowering those usages, especially in existing buildings. It should be of great interest to policy-makers, homeowners, utilities, and contractors to learn what fraction of residential energy use can be saved by retrofit measures, and at what dollar cost. This study presents an initial data base of actual energy savings from retrofitted residences.

One objective of BECA-B is to better understand the technical performance of residential retrofit measures and to evaluate their relative cost-effectiveness. Another goal is to examine the range of conservation savings and costs in order to identify technical, institutional, or programmatic factors associated with high or low levels of performance. The optimum level of conservation investments needs to be determined for the variety of conditions in the residential sector. Energy engineering estimation techniques can also be evaluated by comparing actual energy savings with predicted levels. Finally, we hope to encourage the exchange of documented conservation results and to help establish widely accepted standards for the collection and analysis of such data.

BRIEF DESCRIPTION OF DATA SOURCES AND METHODOLOGY

In this section we briefly present some of the characteristics of our data base, which is composed of almost 70 retrofit projects along with 25 control groups. We also discuss aspects of the methodological approach used in our compilation and analysis.

Data Sources

Classifying our data sources by fuel type, we find that a majority of them use natural gas (39 out of 68) with "mixed," fuel types, electricity, and oil following in that order. The relatively small number (only 6) of oil-heat retrofits reflects our lack of extensive data from the northeast section of the country. We also need more data from the southwest U.S. and California. This last statement is partially based on an examination of the number of heating degree days (HDD) for our 68 data sources: only 6 have less than 4000 HDD_{65}, 34 (50%) have HDD's in the range of 4000 to 5000, and the other 28 have more than 5000 HDD's.

The bulk of our retrofit data represent either research-type studies (e.g., Princeton, NBS, LBL, etc.) or government-sponsored programs (especially low-income weatherization). We list results from 11 utility-sponsored programs but have only 4 entries from private-sector firms. The sample size within a particular project is usually fewer than 20 homes (true for 43 of 68 projects), reflecting relatively small but carefully monitored research and government studies. We have 11 projects with sample sizes of larger than 100 homes, of which 7 are utility-sponsored.

Floor area data were available from roughly two-thirds of our data sources. Almost one-half of those data points lie in the 1000-1500 ft^2 range,typical of the existing stock. For those homes with known floor area, we calculated a thermal fuel integrity value expressed in units of Btu/ft^2-DD. We found that prior to retrofit a large majority of the homes had integrities greater than 12.7 - 15 Btu/ft^2-DD, which is about the U.S. average for single-family dwellings. This is an expected result since one would expect that the majority of homes being retrofitted would initially be energy-inefficient.

The average amount of money spent on conservation measures ranged from $213 to nearly $14,000 per home (expressed in '81$), reflecting the diversity in the number and types of measures carried out. The median cost of retrofits in our data base was $1082. Most of the projects were directed towards more efficient space heating, but 14 of them (out of 68) involved efforts to reduce both space and water heating consumption. The most popular retrofit measure was insulation (occurring in almost 80% of the projects) but caulking and weatherstripping, storm windows, and reduction of infiltration losses (located using blower door pressurization techniques) also appeared frequently (Col I.

Table 1).

Methodology

The two major adjustments to the data that concerned us were isolation of the space heating portion of the fuel bill (by subtraction of the baseload usage) and normalizing energy use before and after retrofit to a "standard" heating season (by scaling actual HDD's to the 30-year mean value for that location). We did not account for any possible changes in the amount of "free" heat (e.g., solar gains, appliance usage, etc.) nor for any changes in occupant behavior or management (e.g., thermostat settings). The assumption of no change in occupants' comfort levels or management of heating systems and appliances is an important limitation in our present data and conclusions, one which we hope to remedy in future analyses. However, where there was a known change in occupants the home was eliminated from the data set. In some cases we also had to estimate the equivalent contractor cost of the retrofit.

Control groups were used in many of the retrofit projects, particularly for the research-type studies. We list control group energy savings in Table 1, but most of our scatter plots reflect gross rather than net energy savings for each data point. Figure 4 is the one exception to this practice. In this case, we have subtracted energy savings by the control group from those achieved by the retrofit group, to suggest the net savings induced by participation in the conservation program.

Some of our sample homes are heated by fuel, others by electricity. We would like to evaluate energy savings on a comparable economic basis regardless of fuel type. Hence we convert electricity usage to resource energy using the conversion factor 11,500 Btu per kWh. (In resource energy units, electricity and fuel costs are roughly comparable.)

The basic investment framework for conservation measures involves an outlay of capital today resulting in future reductions in energy use and dollar savings. These investments can be evaluated using a variety of economic analysis tools. In our study, we use two simple measures, cost of conserved energy (CCE) and simple payback time. Both have the advantage of avoiding the need to guess future energy prices but both are conservative indices of cost-effectiveness if energy prices are expected to increase faster than general inflation. We use three different capital recovery rates (CRR) in our calculations (Table 1, Col. M1-M3) but our plots in Figures 1-8 reflect only the middle value (CRR=.110), based on 7% real interest rate for 15 year lifetime. All of our CCE values are expressed in 1981 constant dollars; we have converted all original retrofit costs into 1981 dollars using the GNP Implicit Price Deflators.

DATA IN TABLE 1

Table 1 has 94 samples, consisting of 69 retrofit projects and 25 control groups (whose labels end with an A for active controls and B for blind controls). Columns A through K2 (plus L) are input data, of which the most important are annual energy use (Cols. K1 and K2) and retrofit cost (Col. L). Columns K3 and K4 plus M through R contain derived results: Energy Savings, Cost of Conserved Energy, Simple Payback Time, Fuel Intensity, and Thermal (Fuel) Integrity.

The 94 samples are ordered by type of fuel used, in the sequence Gas, Oil, Mixed, and electricity. "Mixed" means that within a sample of homes, more than one fuel was used.

Note that a typical scatter plot has between 55-65 points, not 94. This occurs because we have excluded the 25 active and blind control groups and because, on several plots, a few points overflow the scales.

RESULTS

The results of this data compilation and analysis are discussed with reference to Figures 1 through 8. The discussion covers energy savings, subtraction of control group savings, simple payback periods, cost of conserved energy, and actual vs. predicted savings.

Energy Savings

Figure 1 shows the annual resource energy savings plotted against the contractor cost of the retrofit. The data show the expected overall trend of increased energy savings for larger values of retrofit costs, but there is a lot of scatter. For retrofit costs equal to or less than $2000, annual savings varies up to a factor of seven. The sloping reference lines represent prices of purchased energy. A conservation retrofit is cost-effective if its plotted point lies above the price line for the appropriate fuel. We see that a sizeable majority of the retrofits are cost-effective. The median value of energy savings is 28 MBtu; the median cost is $1082.

As noted, there is a large range in the energy savings and cost effectiveness of the retrofit projects. Although more work is needed to identify the factors associated with the highly successful and the not-so-successful projects, we note a few important factors in the following discussion. The data point labeled OA2.1 represents the Page Homes retrofit, a 1950's-style multi-family public housing complex in New Jersey that was retrofitted with a microcomputer-based boiler control system. The results were a noteworthy 50% energy savings (about 48 MBtu/year saved per apartment) after an investment of about $250 per apartment. Besides the fact that initially the apartment complex was an "energy guzzler,"with daytime inside temperatures averaging 82°F, this successful retrofit suggests that substantial savings may be possible by installing better heating control systems, even without changes to the building shell, in some large multi-family apartment buildings.

The data points labeled E1.1, E1.2, and E6 represent conservation programs (mainly insulation) by TVA in the Southeast U.S. and Puget Power in the state of Washington. The energy savings are comparatively large (70-80 MBtu/yr per home) for the retrofit cost of $600-$1300. Both geographical regions represent locations which have historically enjoyed cheap hydroelectricity and for which there is considerable potential for buildings energy savings.

An example of a project with relatively poor results is the DOE Low-Income Weatherization Program in Minnesota, plotted as data points M10.1 and M10.3. Energy savings of only 7-11 MBtu/yr were achieved for retrofits estimated to cost $1000-1100. Since "free" CETA labor was used to install the retrofits, it is not certain whether poor workmanship or our possible overestimate of equivalent contractor costs is mainly responsible for the poor benefit-cost ratio.

Points M2 and G15 also represent low-income weatherization experiments, conducted in this case by the CSA/NBS Demonstration Program. The overall 12-city experiment achieved 31% annual energy savings, with retrofit measures, in the aggregate, proving to be cost-effective. However at several of the sites (e.g., Atlanta M2 and St. Louis G15) there were problems with the quality of the retrofit work and the data collection procedures, along with the failure to install the most effective retrofit options. Those points show annual savings of only 14-17 MBtu for investments of $1400-2000, and are not cost-effective.

In Fig. 2, the results are replotted in terms of percent energy savings versus contractor costs. The spread in results narrows slightly from Fig. 1. The curved line is based on a simple "eye-ball" fit and reflects a crude law of diminishing returns with increasing investment. The data suggest that a $1000 investment in conservation retrofits will, on the average, reduce a house's heating energy consumption by 25%; a $2000 investment will reduce consumption by roughly 40%. In Fig. 3, a histogram of the retrofit results expressed in percent fuel savings is presented. The median value of energy savings is found to be 22%.

<u>Subtraction of Control Group Savings</u>

Figure 4 illustrates the reduction in "program-induced" energy savings if control group savings are subtracted. For example, data point E5.1 shows the measured savings, 48 MBtu (resource units), from Seattle City Light's Residential Insulation Program. During the same period, average consumption per household decreased by 13% in the blind control group. Hence we show an arrow reducing the initial point E5.1 by 13% of the pre-retrofit usage or by 25.8 MBtu. Thus the energy savings attributable to the utility's conservation program are 22.2 resource energy MBtu or 1930 kWh per household. Similar subtractions are shown in Fig. 4 for nine other data points.

On the average (equal weighting for each site), the 14 active control groups in our study decreased their annual energy usage by 13.6 MBtu or 9.5 percent. Consumption also dropped approximately 9 percent in the 10 blind control groups, reflecting consumer response to higher fuel prices. In both cases, these changes probably indicate some combination of "independently"-installed retrofit measures, more energy-efficient operation of the home or appliances, and possibly reduced levels of occupant comfort.

Simple Payback Periods

Figure 5 shows the distribution of simple payback periods for the retrofit projects in our compilation. The median payback time is 7.9 years. A factor that partially accounts for the relatively high median value is the large number of research and demonstration projects in our data base. In research or demonstration studies, retrofit costs are often not the primary consideration. Consistent with this point is the lower median payback time of 5.7 years for conservation programs sponsored by utilities and private firms, where the cost-effectiveness of the individual retrofit measures are usually taken into account.

Cost of Conserved Energy

The relationship between the contractor cost for the retrofits and the cost of conserved energy is shown in Fig. 6. Reference prices of purchased electricity, gas, and oil are drawn as horizontal lines against which conservation retrofits for each fuel type can be compared. Including points that overflow the plotted axes, we find the following results: 72% (28 of 39) of the gas-heat projects have a cost of conserved energy below the reference gas price of 50c/therm; 82% (9 of 11) of the all-electric homes saved heating energy more cheaply than the electricity price of 5c/kWh; and 80% (4 of 5) of the oil-heat retrofits lie below the fuel oil price of $1.25/gal.

We observe that, for the homes in our data base, as long as a homeowner keeps his investment below $2500, he is almost sure to conserve energy at less than $5/MBtu, a result found in 46 of the 58 samples. Seven less successful retrofits invested between $500 and $2000 but had cost of conserved energy values ranging from $5.50 to $9/MBtu. For the six data sources with retrofit costs between $2500 and $4400, only one has a CCE of less than $5/MBtu; the other five CCE's ranged from $5-7/MBtu. The six least successful projects had CCE's from $11-16/MBtu, and are not shown in this figure as they overflowed the vertical scale. Fig. 6 also depicts the cost-effectiveness of "house doctoring" as is evidenced by the cluster of 7 gas-heat data points (from Princeton's Modular Retrofit Experiment) with cost of conserved energy values between $1-2/MBtu and retrofit costs of only $350.

Figure 7 shows the distribution of cost of conserved energy for the sample. The median cost of conserved energy is $3.80/MBtu (38c/therm).

The median CCE for electrically-heated homes is 3.1c/kWh (or $2.70/MBtu). We are also interested in possible explanations for the wide spread in CCE values. In Fig. 8 we test the hypothesis that there is a correlation between high original fuel intensity and low cost of conserved energy values. Homes that had high pre-retrofit fuel intensity values (i.e., had "leaky" thermal shells or are located in cold climates or a combination of the two factors) might be considered likely candidates for cost-effective retrofits. Despite the plausibility of this hypothesis, our plotted points show a lot of scatter and do not validate the correlation. At any of the plotted original fuel intensity values, the cost of conserved energy ranges from less than $1/MBtu to approximately $7/MBtu.

In this survey, the reporting of results by data sources is too aggregated to permit ordering individual options by return on investment. In cases where results can be disaggregated based on submetering, the data suggests that the most cost-effective sequence of retrofits includes attic insulation and measures that are part of the Princeton/LBL "house doctor" infiltration reduction program. At this time, our data indicate a high correlation between low retrofit costs and cost-effective CCE values.

Actual Savings vs. Predicted Savings

Millions of energy audits have been performed in U.S. residences for the purpose of estimating retrofit costs and savings to help guide homeowners' decisions on conservation investments. Comparison of actual vs. predicted savings is an important consideration in the evaluation of conservation programs -- an area in which little systematic work has been done. At present, we have limited data on this subject as shown in the following table.

Table 2. Comparison of Actual vs. Predicted Energy Savings

Label	Sponsor	Actual Savings	Predicted Savings
G1	NBS	59%	52%
M8.1	CSA/NBS Composite	31%	40%
E2	TVA	22%	25%
E4	Pacific Power and Light	20%	23%
E6	Puget Power	35%	26%
E7	Portland General Electric	32%	33%
E8.1	BPA/LBL	9%	4%
E8.2	BPA/LBL	16%	25%
E8.3	BPA/LBL	42%	36%

In over one-half of the above cases, actual savings fall slightly short of predictions. In our files, we have collected pre-retrofit predictions of savings on many new conservation programs. When these projects finally report their post-retrofit consumption, we hope to have enough data to permit further quantitative analysis of this subject.

CONCLUSIONS

Results from this study indicate that a conservation investment of $1000 will, on the average, reduce a house's space heating consumption by 25 percent while a $2000 investment will decrease usage by approximately 40 percent. The median value of energy savings for this data compilation is 22 percent.

Preliminary results reveal that attic insulation, sealing bypass and infiltration losses by pressurization techniques, and wrapping hot water heaters with an insulating blanket are very cost-effective retrofit measures.

Even though the data compilation contains a wide variation in the types of homes, the types of fuels, the locations and the types of retrofits, the overall results from aggregating thousands of individual cases show an attractive cost of conserved energy for residential retrofits. The median cost of conserved energy for our data points is an attractive \$3.80/MBtu, comfortably less than the average 1981 cost to residential customers for natural gas (\$4.50/MBtu) and for fuel oil (\$8.70/MBtu). In fact, 27 of the 39 gas-heat points fall below the natural gas price of \$4.50/MBtu and 4 of the 5 oil-heat points fall below the \$8.70/MBtu price for heating oil. Of the 11 electric heat data points, 10 of them show a cost of conserved electricity of less than 6.2c/kWh, the 1981 average price.

Our present version of BECA-B does not incorporate control group adjustments in the evaluation of cost-effectiveness of retrofit projects. First, control groups were not used in many of the projects; hence calculating net energy savings relative to a control group could not be uniformly implemented for the entire data compilation. Second, the present generation of control group data is not sufficiently detailed to enable us to separate energy savings into its principal components: savings due to improvements in the building's thermal shell and savings due to occupant management and adjustment of comfort levels. One goal for future editions of BECA-B is to make an accurate separation of these components. We solicit and encourage your help in this effort.

The absence of data on multi-family units and on the durability of energy savings from retrofits are worth noting. Thus, future additions to the BECA-B data base will emphasize multi-family retrofit projects and multi-year data on energy savings. We are also interested in obtaining more data on the results of low cost/no cost programs and from "failed" retrofit programs. This will allow us to describe the factors that account for successful and "failed" programs ad better explain the variation in predicted vs. actual energy savings.

Finally, we express the hope that as a result of this paper, potential contributors will contact us to begin sharing data, so that we can greatly increase the scope and accuracy of this compilation.

ACKNOWLEDGEMENTS

A number of persons contributed to this study, and the authors are grateful to all. Tom Borgers and Joe Costello collected some initial data for the 1980 Santa Cruz conference. Richard Crenshaw generously shared data and insight from the 12-city CSA/NBS study. Ender Erdem and Wolfgang Luhrsen contributed their computing expertise. Alan Meier and David Grimsrud helped us to interpret the data. Jeff Harris guided us with many helpful suggestions and critical comments. Jeana Traynor contributed her word processing skills. We also thank the many colleagues at other institutions who supplied us with data and answered our questions, especially Robert Dumont, at the National Research Center of Canada, who shared his Canadian files with us and Gautam Dutt at the Princeton University Center for Energy and Environmental Studies.

Leonard Wall wishes to thank Associated Western Universities for support during July-August 1981 when he worked on this project.

The work described in this report was funded by the Assistant Secretary for Conservation and Renewable Energy, Office of Buildings and Community Systems, Buildings Division, of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

REFERENCES

A complete listing of all the sources used in assembling the retrofit data base discussed in this article may be found in the following reference: Wall, L.W., Goldman, C.A., Rosenfeld, A.H., and Dutt, G.S. 1982. Building energy use compilation and analysis (BECA) part B: existing North American residential buildings. Lawrence Berkeley Laboratory LBL-13385, EEB-BED-82-05.

Table 1

A LABEL	B SPONSOR CAT.	C NUMBER OF HOMES	D LOCATION	E SPONSOR	F HDD	G YR OF RETRO FIT	H SQF	I RETROFIT TYPE	J HEATING OR HEAT+WATER	K1 ANNUAL ENERGY (MBTU) BEFORE	K2 AFTER	K3 SAVINGS (MBTU)	K4 PERCNT
G1	R	1	BOWMAN HOUSE,MD	NBS	4610	75	2054	I,W,C	H	125.6	52.1	73.5	59
G2	R	1	TWIN RIVERS,NJ	PRINCETON	4911	77	1500	I,W,C,P	H	81.0	19.2	61.8	76
G3	R	1	HS 11,NJ	PRINCETON	4911	79	1200	I,W,H,P	H	59.6	35.7	23.9	40
G4	R	1	HS 22,NJ	PRINCETON	4911	79	1560	I,D,H,P	H	114.4	84.1	30.3	26
G5.1	R/U	6	MRE/FREEHOLD,NJ	PRINCETON/NJNG	4911	80	2500	I,T,P	H,W	178.8	135.1	43.7	24
G5.2	R/U	12	MRE/FREEHOLD,NJ	PRINCETON/NJNG	4911	80	2500	T,P	H,W	171.9	142.9	29.0	17
G5.3B	R/U	6	MRE/FREEHOLD,NJ	PRINCETON/NJNG	4911		2500			184.0	174.9	9.1	5
G6.1	R/U	6	MRE/TOMS RIVER,NJ	PRINCETON/NJNG	4911	80	900	I,T,P	H,W	87.2	70.4	16.8	19
G6.2	R/U	12	MRE/TOMS RIVER,NJ	PRINCETON/NJNG	4911	80	900	T,P	H,W	99.2	92.4	6.8	7
G6.3B	R/U	6	MRE/TOMS RIVER,NJ	PRINCETON/NJNG	4911		900			98.0	98.0	0.	0
G7.1	R/U	6	MRE/OAK VALLEY,NJ	PRINCETON/SJG	4911	80	1200	I,T,P	H,W	116.3	88.9	27.4	24
G7.2	R/U	9	MRE/OAK VALLEY,NJ	PRINCETON/SJG	4911	80	1200	T,P	H,W	120.9	94.0	26.9	22
G7.3A	R/U	6	MRE/OAK VALLEY,NJ	PRINCETON/SJG	4911		1200			128.6	115.0	13.6	11
G7.4B	R/U	75000	MRE/OAK VALLEY,NJ	PRINCETON/SJG	4911								11
G8.1	R/U	5	MRE/WHITMAN SQ,NJ	PRINCETON/SJG	4911	80	1800	I,T,P	H,W	147.2	111.8	35.4	24
G8.2	R/U	9	MRE/WHITMAN SQ,NJ	PRINCETON/SJG	4911	80	1800	T,P	H,W	134.8	109.1	25.7	19
G8.3A	R/U	4	MRE/WHITMAN SQ,NJ	PRINCETON/SJG	4911		1800			133.8	112.4	21.4	16
G8.4B	R/U	75000	MRE/WHITMAN SQ,NJ	PRINCETON/SJG	4911								12
G24.1	R/U	6	MRE/EDISON,NJ	PRINCETON/ELIZ.GAS	4911	80	1550	I,T,P	H	163.4	124.8	38.6	24
G24.2	R/U	5	MRE/EDISON,NJ	PRINCETON/ELIZ.GAS	4911	80	1550	T,P	H	163.8	139.7	24.1	15
G24.3A	R/U	6	MRE/EDISON,NJ	PRINCETON/ELIZ.GAS	4911		1550			166.3	154.7	11.6	7
G24.4B	R/U	75000	MRE/EDISON,NJ	PRINCETON/ELIZ.GAS	4911								10
G25.1	R/U	6	MRE/WOODRIDGE,NJ	PRINCETON/PSEG	4911	80	1300	I,P	H	176.6	150.8	25.8	15
G25.2	R/U	6	MRE/WOODRIDGE,NJ	PRINCETON/PSEG	4911	80	1300	P	H	159.0	137.7	21.3	13
G25.3A	R/U	6	MRE/WOODRIDGE,NJ	PRINCETON/PSEG	4911		1300			147.8	131.2	16.6	11
G25.4B	R/U	550000	MRE/WOODRIDGE,NJ	PRINCETON/PSEG	4911								11
G26.1	R/U	5	MRE/NEW ROCHELLE,NY	PRINCETON/CONED	4911	80	1450	I,T,P,H	H,W	155.4	124.1	31.3	20
G26.2	R/U	5	MRE/NEW ROCHELLE,NY	PRINCETON/CONED	4911	80	1450	T,P,H	H,W	160.4	136.1	24.3	15
G26.3A	R/U	6	MRE/NEW ROCHELLE,NY	PRINCETON/CONED	4911		1450			158.9	138.3	20.6	13
G9.1	R	5	SASKATCHEWAN,CANADA	EN.CONS INFO C./NRC	10939	80	2157	I,C,P	H	177.1	123.8	53.3	30
G9.2	R	5	SASKATCHEWAN,CANADA	EN.CONS INFO C./NRC	10939	80	1752	C,P	H	163.5	148.6	14.9	9
G9.3	R	10	SASKATCHEWAN,CANADA	EN.CONS INFO C./NRC	10939	80		I,W,D,C	H	127.2	111.3	15.9	13
G10.1	R	1	BUTTE,MT	NCAT	9669	79	2300	I	H	269.2	243.0	26.2	10
G10.2	R	1	BUTTE,MT	NCAT	9669	80	2300	I,C,A	H	243.0	165.9	77.1	32
G11	U	84	RAMSEY COUNTY,MINN	NSP	8159	79	1900	I,C	H	156.7	144.9	11.8	8
G12.1	U	33	BAKERSFIELD,CA	PGE	2185	79		I	H	83.0	68.1	14.9	18
G12.2	U	16	FRESNO,CA	PGE	2650	79		I	H	61.5	42.0	19.6	32
G13	U	33000	COLORADO	PUB SERV CO	6016	77		I	H	119.2	99.6	19.6	16
G14.1	G	8	OAKLAND,CA	CSA/NBS	2909	79	1300	I,C	H	76.1	74.0	2.2	3
G14.2A	G	4	OAKLAND,CA	CSA/NBS	2909					116.9	128.4	-11.5	-9
G15	G	18	ST LOUIS,MO	CSA/NBS	4750	79	1355	I,W,C	H	174.7	157.3	17.4	10
G16	G	10	CHICAGO,ILL	CSA/NBS	6127	79	1464	I,W,C,H	H	264.8	155.1	109.7	41
G17.1	G	16	COLORADO SPRINGS	CSA/NBS	6473	79	998	I,W,C,H	H	132.0	71.6	60.4	46
G17.2A	G	4	COLORADO SPRINGS	CSA/NBS	6473					164.8	164.6	.2	0
G18.1	G	17	ST PAUL,MINN	CSA/NBS	8159	79	1421	I,W,C	H	180.9	141.6	39.3	22
G18.2A	G	5	ST PAUL,MINN	CSA/NBS	8159					286.1	262.7	23.4	8
G19	G	30	LUZERNE CTY,PA	DOE	6277	79		I,W,C	H	157.9	134.2	23.7	15
G20	G	89	LOUISIANA	DOE	1800	80			H	48.3	34.1	14.2	29
G21.1	G	21	KANSAS CITY,MO	DOE	5161	77		I,C	H	135.0	115.0	20.0	15
G21.2	G	45	KANSAS CITY,MO	DOE	5161	77		I,C	H	196.0	152.0	44.0	22

A	L1	L2	L3	M1	M2	M3	N	O1	O2	P1	P2	Q	R
	AVG. RETRO COSTS			CCE=1981 COST OF			SIMPLE	FUEL INTENS.		THERMAL INT.		CONFI-	
			81 $/	CONSERVED		NERGY	PAYBACK	(MBTU/KSQFT)		(BTU/SQFTDD)		DENCE	
LABEL	ORIGS	81 $	KSQFT	8.3	11.0	13.2	(YEARS)	BEFORE	AFTER	BEFORE	AFTER	LEVEL	COMMENTS
-----	*****	*****	-----	-----	-----	-----	-------	-----	-----	-----	-----	******	----------
G1	2840	4202	2046	4.75	6.29	7.55	16.1	61.1	25.4	13.3	5.5	A	FIRST EXTENSIVE STUDY
G2	3000	4036	2690	5.42	7.18	8.62	16.2	54.0	12.9	11.0	2.6	A	TOWNHOUSE
G3	700	814	678	2.83	3.74	4.49	7.9	49.7	29.8	10.1	6.1	A	ELIMINATE BYPASS LOSSES
G4	1000	1162	745	3.18	4.22	5.06	8.9	73.3	53.9	14.9	11.0	A	ELIMINATE BYPASS LOSSES
G5.1	2562	2750	1100	5.22	6.92	8.31	13.0	71.5	54.0			A	H. D. AND CONTRACT RETR.
G5.2	325	349	140	1.00	1.32	1.59	2.5	68.8	57.2	---		A	H. D. ONLY
G5.3B								73.6	70.0	15.0	14.2	A	BLIND CONTROL GROUP
G6.1	1272	1365	1517	6.75	8.94	10.73	16.8	96.9	78.2			A	H. D. AND CONT. RET.
G6.2	325	349	388	4.26	5.64	6.77	10.6	110.2	102.7			A	H. D. ONLY
G6.3B								108.9	108.9	22.2	22.2	A	BLIND CONTROL GROUP
G7.1	911	955	796	2.89	3.84	4.60	6.2	96.9	74.1			A	H. D. AND CONTRACT RETR.
G7.2	325	341	284	1.05	1.39	1.67	2.2	100.8	78.3			A	H. D. ONLY
G7.3A								107.2	95.8	21.8	19.5	A	ACTIVE CONTROL GROUP
G7.4B												A	BLIND CONTROL GROUP
G8.1	664	696	387	1.63	2.16	2.60	3.5	81.8	62.1			A	H. D. AND CONT. RETR.
G8.2	325	341	189	1.10	1.46	1.75	2.3	74.9	60.6			A	H. D. ONLY
G8.3A								74.3	62.4	15.1	12.7	A	ACTIVE CONTROL GROUP
G8.4B												A	BLIND CONTROL GROUP
G24.1	1562	1677	1082	3.61	4.78	5.73	8.1	105.4	80.5	21.5	16.4	A	H. D. AND CONTRACT RET R.
G24.2	325	349	225	1.20	1.59	1.91	2.7	105.7	90.1	21.5	18.4	A	H. D. ONLY
G24.3A								107.3	99.8	21.8	20.3	A	ACTIVE CONTROL GROUP
G24.4B												A	BLIND CONTROL GROUP
G25.1	961	1032	794	3.32	4.40	5.28	7.4	135.8	116.0	27.7	23.6	A	H. D. AND CONTRACT RETR.
G25.2	325	349	268	1.36	1.80	2.16	3.1	122.3	105.9	24.9	21.6	A	H. D. ONLY
G25.3A								113.7	100.9	23.2	20.6	A	ACTIVE CONTROL GROUP
G25.4B												A	BLIND CONTROL GROUP
G26.1	1008	1082	746	2.87	3.80	4.56	6.4	107.2	85.6			A	H. D. AND CO NTRACT RETR.
G26.2	325	349	241	1.19	1.58	1.90	2.7	110.6	93.9			A	H. D. ONLY
G26.3A								109.6	95.4	22.3	19.4	A	ACTIVE CONTROL GROUP
G9.1	1976	2027	940	3.16	4.18	5.02	12.38	82.1	57.4	7.5	5.2	B	SEALED AND INSULATED
G9.2	514	527	301	2.94	3.89	4.67	11.58	93.3	84.8	8.5	7.8	B	SEALED ONLY
G9.3	1442	1479		7.72	10.23	12.28	30.28					C	INSULATED
G10.1	500	570	248	1.81	2.39	2.87	5.48	117.0	105.7	12.1	10.9	B	PHASE I
G10.2	13100	13738	5973	14.79	19.60	23.52	44.58	105.7	72.1	10.9	7.5	B	PHASE II, INCLUDES PASSIVE WALL
G11	290	325	171	2.28	3.03	3.63	8.4	82.5	76.3	10.1	9.3	B	LOW-INCOME WEATHERIZATION
G12.1	427	496		2.76	3.66	4.40	5.7					B	ATTIC INSUL PROG IN SAN JOAQUIN VALLEY
G12.2	417	485		2.06	2.72	3.27	4.3					B	ATTIC INSUL PROG IN SAN JOAQUIN VALLEY
G13	272	360		1.52	2.02	2.42	4.48					B	LOW INT LOANS FOR ATTIC INSUL
G14.1	274	312	240	12.01	15.91	19.10	18.9	58.5	56.9	20.1	19.6	A	DEMO PGM. LOW-INCOME WEATHERIZATION
G14.2A												A	ACTIVE CONTROL GRP.
G15	1781	2031	1499	9.69	12.84	15.41	43.6	128.9	116.1	27.1	24.4	A	DEMO PGM. LOW-INCOME WEATHERIZATION
G16	2347	2677	1828	2.03	2.68	3.22	7.3	180.9	105.9	29.5	17.3	A	DEMO PGM. LOW-INCOME WEATHERIZATION
G17.1	1765	2013	2017	2.77	3.67	4.40	12.0	132.3	71.7	20.4	11.1	A	DEMO PGM. LOW-INCOME WEATHERIZATION
G17.2A												A	ACTIVE CONTROL GROUP
G18.1	1761	2008	1413	4.24	5.62	6.75	15.7	127.3	99.6	15.6	12.2	A	DEMO PGM. LOW-INCOME WEATHERIZATION
G18.2A												A	ACTIVE CONTROL GROUP
G19	789	900		3.15	4.18	5.01	9.2					C	LOW-INCOME WEATHERIZATION
G20	1044	1071		6.26	8.30	9.96	17.9					C	LOW-INCOME WEATHERIZATION
G21.1	407	539		2.24	2.96	3.55	13.0					C	LOW-INCOME WEATHERIZATION
G21.2	525	675		1.27	1.69	2.03	7.6					C	LOW-INCOME WEATHERIZATION

Table 1 , continued

A	B	C	D	E	F	G	H	I	J	K1	K2	K3	K4
LABEL	SPONSOR CAT.	NUMBER OF HOMES	LOCATION	SPONSOR	HDD	YR OF RETRO FIT	SQF	RETROFIT TYPE	HEATING OR HEAT+WATER	ANNUAL ENERGY (MBTU) BEFORE	AFTER	S A V I N G S (MBTU)	PERCNT
G21.3	G	44	KANSAS CITY,MO	DOE	5233	78		I,C	H	191.0	139.0	52.0	27
G22	G	138	KENTUCKY	DOE	4729	79		I,W,D,C	H	118.5	102.8	15.7	13
G23	G	30	INDIANA	DOE	5577	78	1102	I,C,H	H	182.1	135.7	46.4	25
O1	R	1	HS 21,NJ	PRINCETON	4911	79	1990	I,W,H,P	H	132.0	62.5	69.5	53
OA2.1	G/P	159	PAGE APTS, NJ	HUD/TRENTON	4911	81	830	H,E	H,W	96.2	48.5	47.7	50
OA2.2B	R	1500	PAGE APTS, NJ	HUD/TRENTON	4911					116.7	98.3	18.4	16
OA3	P	521	MF COMPLEX,WASH DC	SCALLOP THERMAL MAN.	4211	78		H,E,O	H,W	116.3	108.4	7.9	7
OA4	P	752	MF COMPLEX,MD	SCALLOP THERMAL MAN.	4211	78		H,E,O	H,W	84.9	83.1	1.8	2
OA5	P	60	COOP BLDG,NYC	SCALLOP THERMAL MAN.	4848	78		H,E,O	H,W	167.3	152.1	15.2	9
O6	G	13	VERMONT	DOE	7876	80		I,W,D	H	143.5	100.0	43.5	30
M1.1	G	13	CHARLESTON,SC	CSA/NBS	2146	79	1111	I,C	H	62.5	41.4	21.1	34
M1.2A	G	5	CHARLESTON,SC	CSA/NBS	2146					36.3	30.7	5.6	15
M2	G	8	ATLANTA,GA	CSA/NBS	3095	79	1055	I,W,C	H	108.1	94.1	14.0	13
M3	G	4	WASH,DC	CSA/NBS	4211	79	915	I,W,C,H	H	130.5	69.1	61.4	47
M4.1	G	9	TACOMA,WA	CSA/NBS	5185	79	978	I,W,C	H	168.8	99.8	69.0	41
M4.2A	G	5	TACOMA,WA	CSA/NBS	5185					59.5	50.1	9.4	16
M5.1	G	13	EASTON,PA	CSA/NBS	5827	79	1334	I,C,H	H	121.7	93.1	28.6	24
M5.2A	G	3	EASTON,PA	CSA/NBS	5827					44.0	39.9	4.2	9
M6.1	G	14	PORTLAND,ME	CSA/NBS	7498	79	1008	I,W,C,H	H	187.3	105.4	81.9	44
M6.2A	G	4	PORTLAND,ME	CSA/NBS	7498					232.5	203.8	28.7	12
M7.1	G	12	FARGO,ND	CSA/NBS	9271	79	786	I,W,C,H	H	109.5	65.8	43.7	40
M7.2A	G	5	FARGO,ND	CSA/NBS	9271					145.1	131.3	13.8	10
M8.1	G	142	CSA/NBS	COMPOSITE		79	1168		H	146.7	101.9	44.8	31
M8.1A	G	41	CSA/NBS	COMPOSITE						145.2	138.7	6.5	4
M9	G	65	NW WISCONSIN	CSA	8388	76	1292	I,W,D,C	H	143.0	115.9	27.1	19
M10.1	G	59	MINNESOTA	DOE	8310	78	806	I,W,C	H	110.9	99.6	11.3	10
M10.2B	G	37	MINNESOTA	DOE	8310		1325			78.2	80.1	-1.9	-1
M10.3	G	19	MINNESOTA	DOE	8310	78	774	I,W,C	H	103.6	96.7	6.9	7
M11	G	13	WISCONSIN	DOE	8820	79			H	139.3	116.3	23.0	17
M12	G	86	ALLEGAN CTY,MI	DOE	6801	80			H	156.0	112.0	44.0	28
										(KWH)		(KWH)	
E1.1	U	69	TENNESSEE	TVA	4436	76	1013	I,C	H	11270.	5148.0	6122.0	54
E1.2	U	105	TENNESSEE	TVA	4421	76		I	H	12383.	8271.0	4112.0	33
E2	U	546	TENNESSEE	TVA	4010	78		I	H	10148.	7937.0	2211.0	22
E3.1	R/P	29	DENVER,COL	JOHNS MANVILLE	6016	78	1600	P	H	17615.	14779.0	2836.0	16
E3.2A	R/P	30	DENVER,COL	JOHNS MANVILLE	6016					20606.	17715.0	2891.0	14
E3.3B	R/P	30	DENVER,COL	JOHNS MANVILLE	6016					23886.	21034.0	2852.0	12
E4	U	1896	OREGON	PAC PWR LIGHT	4800	79		I,W,D,C	H	21305.	17044.0	4261.0	20
E5.1	U	133	SEATTLE,WA	SEATTLE CITY LIGHT	5185	79		I	H	17107.	12934.0	4173.0	24
E5.2B	U	551	SEATTLE,WA	SEATTLE CITY LIGHT	5185					16843.	14634.0	2209.0	13
E6	U	8802	WASHINGTON	PUGET POWER	5500	79		I,W	H	20000.	13070.0	6930.0	35
E7	U	161	OREGON	PORTLAND GEN ELEC	4792	78		I,W,D,C	H	13000.	8879.0	4121.0	32
E8.1	R/U	5	MIDWAY,WA	BPA/LBL	4760	80	1260	P	H	19984.	18138.0	1846.0	9
E8.2	R/U	5	MIDWAY,WA	BPA/LBL	4760	79	1253	I,C	H	19803.	16568.0	3235.0	16
E8.3	R/U	4	MIDWAY,WA	BPA/LBL	4760	79	1239	I,C,D,W	H	19649.	11445.0	8204.0	42

A	L1	L2	L3	M1	M2	M3	N	O1	O2	P1	P2	Q	R
	AVG. RETRO COSTS			CCE-1981 COST OF CONSERVED ENERGY			SIMPLE PAYBACK	FUEL INTENS. (MBTU/KSQFT)		THERMAL INT. (BTU/SQFTDD)		CONFI-DENCE	
LABEL	ORIG$	81 $	81 $/ KSQFT	8.3	11.0	13.2	(YEARS)	BEFORE	AFTER	BEFORE	AFTER	LEVEL	COMMENTS
	*****	*****										******	
G21.3	1494	1814		2.89	3.84	4.60	15.5					C	LOW-INCOME WEATHERIZATION
G22	254	290		1.53	2.03	2.44	4.6C					C	LOW-INCOME WEATHERIZATION
G23	1375	1700	1543	3.04	4.03	4.84	14.1C	165.2	123.1	29.6	22.1	B	LOW-INCOME WEATHERIZATION
O1	1200	1395	701	1.67	2.21	2.65	3.1	66.3	31.4	13.5	6.4	A	ELIM. BYPASS LOSSES
OA2.1	252	246	297	.43	.57	.68	.6	115.9	58.4	23.6	11.9	B	MULTI-FAMILY APT. RETROFIT
OA2.2B												B	BLIND CONTROL GROUP
OA3				3.45	3.56	3.68	9.0C					B	THERMAL SERVICES CONTRACT
OA4				9.00	9.36	9.59	23.6C					B	THERMAL SERVICES CONTRACT
OA5												I	THERMAL SERVICES CONTRACT
O6	1506	1579		3.01	3.99	4.79	4.1					C	LOW-INCOME WEATHERIZATION
M1.1	977	1114	1003	4.38	5.81	6.97	6.6	56.3	37.3	26.2	17.4	A	DEMO PGM. LOW-INCOME WEATHERIZATION
M1.2A												A	ACTIVE CONTROL GROUP
M2	1211	1381	1309	8.19	10.85	13.02	18.9	102.5	89.2	33.1	28.8	A	DEMO PGM. LOW-INCOME WEATHERIZATION
M3	2924	3335	3645	4.51	5.97	7.17	6.3	142.6	75.5	33.9	17.9	A	DEMO PGM. LOW-INCOME WEATHERIZATION
M4.1	1807	2061	2107	2.48	3.29	3.94	8.4	172.6	102.0	33.3	19.7	A	DEMO PGM. LOW-INCOME WEATHERIZATION
M4.2A												A	ACTIVE CONTROL GROUP
M5.1	905	1032	774	3.00	3.97	4.76	6.1	91.2	69.8	15.7	12.0	A	DEMO PGM. LOW-INCOME WEATHERIZATION
M5.2A												A	ACTIVE CONTROL GROUP
M6.1	2215	2526	2506	2.56	3.39	4.07	3.8	185.8	104.6	24.8	13.9	A	DEMO PGM. LOW-INCOME WEATHERIZATION
M6.2A												A	ACTIVE CONTROL GROUP
M7.1	1626	1854	2359	3.52	4.67	5.60	5.7	139.3	83.7	15.0	9.0	A	DEMO PGM. LOW-INCOME WEATHERIZATION
M7.2A												A	ACTIVE CONTROL GROUP
M8.1	1610	1836	1572	3.40	4.51	5.41	8.2	125.6	87.2			A	DEMO PGM. LOW-INCOME WEATHERIZATION
M8.1A												A	ACTIVE CONTROL GROUP COMPOSITE
M9	219	307	238	.94	1.25	1.50	2.4	110.7	89.7	13.2	10.7	C	LOW-INCOME WEATHERIZATION
M10.1	906	1120	1390	8.23	10.91	13.09	25.1C	137.6	123.6	16.6	14.9	C	LOW-INCOME WEATHERIZATION
M10.2B								59.0	60.5	7.1	7.3	C	BLIND CONTROL GROUP
M10.3	849	1050	1357	12.63	16.74	20.09	36.0	133.9	124.9	16.1	15.0	C	2 POST-RETRO YEARS SUBGROUP
M11	1088	1241		4.48	5.93	7.12	11.1					C	LOW-INCOME WEATHERIZATION
M12	1050	1101		2.08	2.75	3.30	3.9					C	LOW-INCOME WEATHERIZATION
					CENTS/KWH								
E1.1	440	610	602	.83	1.10	1.31	3.5	127.9	58.4	12.8	5.9	A	DEMO PROGRAM BY PRIVATE CONTRAC.
E1.2	154	213		.43	.57	.68	1.9					B	DEMO PROGRAM BY TVA PERSONNEL
E2	310	383		1.44	1.91	2.29	5.1					A	EARLY PART OF HOME INSUL. PROG
E3.1	1050	1245	778	3.64	4.83	5.80	7.78	126.6	106.2	9.4	7.9	A	STUDY OF AIR LEAKAGE
E3.2A												A	ACTIVE CONTROL GROUP
E3.3B												A	BLIND CONTROL GROUP
E4	1335	1523		2.97	3.93	4.72	13.6					C	ZERO INTEREST WEATH. PROGRAM
E5.1	399	455		.91	1.20	1.44	5.1					C	EARLY PART OF WEATH. PROGRAM
E5.2B												C	BLIND CONTROL GROUP
E6	1110	1266		1.52	2.01	2.41	6.88					C	ZERO INTEREST WEATH. PROGRAM
E7	1357	1609		3.24	4.30	5.15	9.4					C	EARLY PART OF WEATH. PROGRAM
E8.1	525	525	417	2.36	3.13	3.75	11.4	182.4	165.5	17.1	15.5	A	EXTENDED H. D.
E8.2	1860	2041	1629	5.24	6.94	8.33	23.0	181.8	152.1	17.0	14.2	A	ATTIC AND CRAWLSPACE INS.
E8.3	4023	4416	3564	4.47	5.92	7.10	19.6	182.4	106.2	17.1	9.9	A	INS. PLUS STORM DOOR,WINDOW

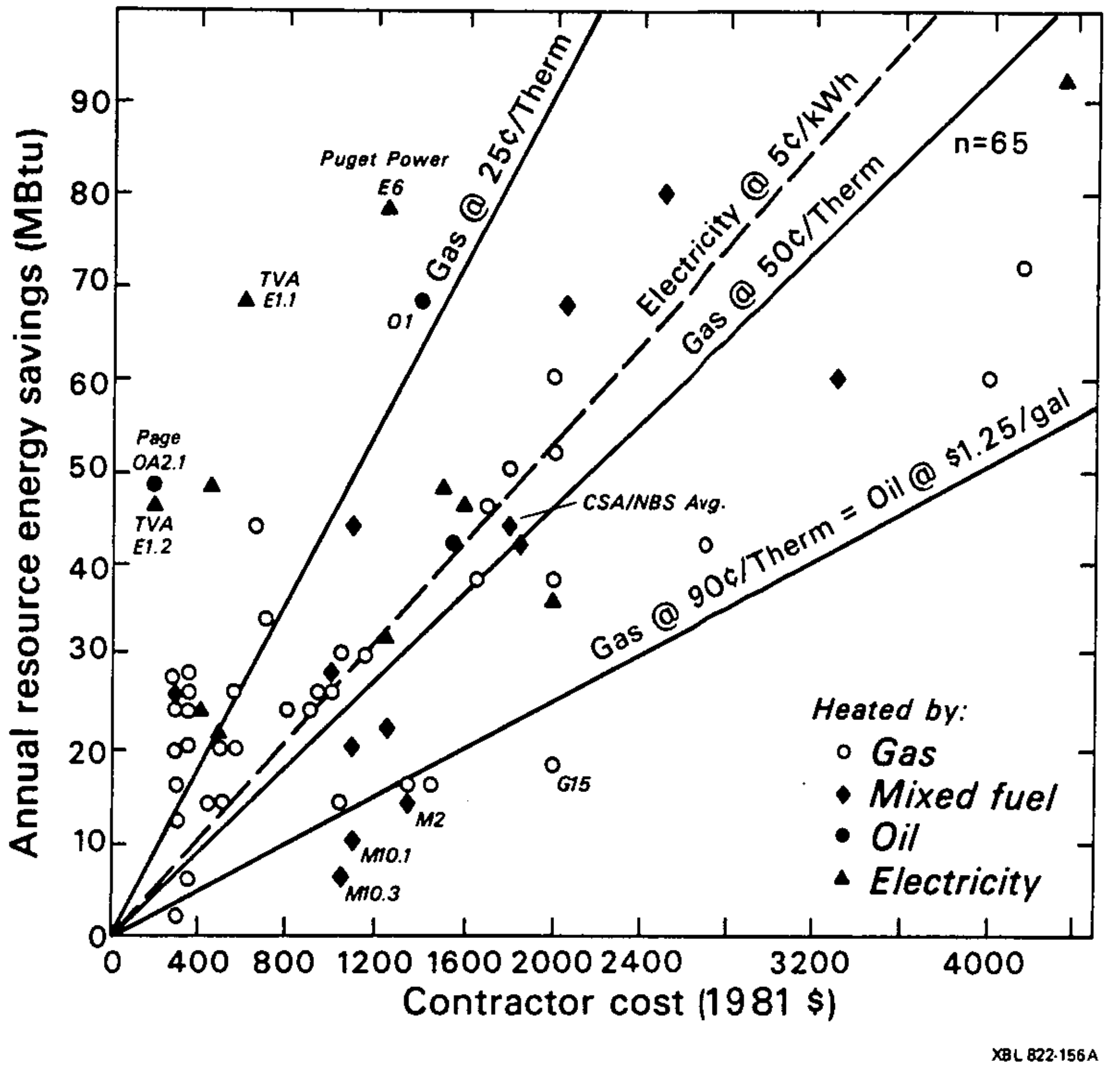

Fig. 1. Annual resource energy savings vs. Contractor cost. Annual savings, in resource energy, after retrofit are plotted against the contractor cost of retrofits for 65 data sources. The sloping reference lines represent the boundary of cost-effectiveness for typical residential energy prices. Since conservation investments are typically "one-time," the future stream of energy purchases for 15 years is converted to a single present value, assuming a 7% real discount rate. The conservation retrofit is cost-effective if the data point lies above the purchased energy line for that fuel. In most cases the plotted savings apply to space heat only, except for 14 samples which addressed both hot water and heating (shown in Table 1, Col. J as H,W). In those 14 cases, we plot the combined H + W savings. Electricity is measured in resource units of 11,500 Btu per kWh sold.

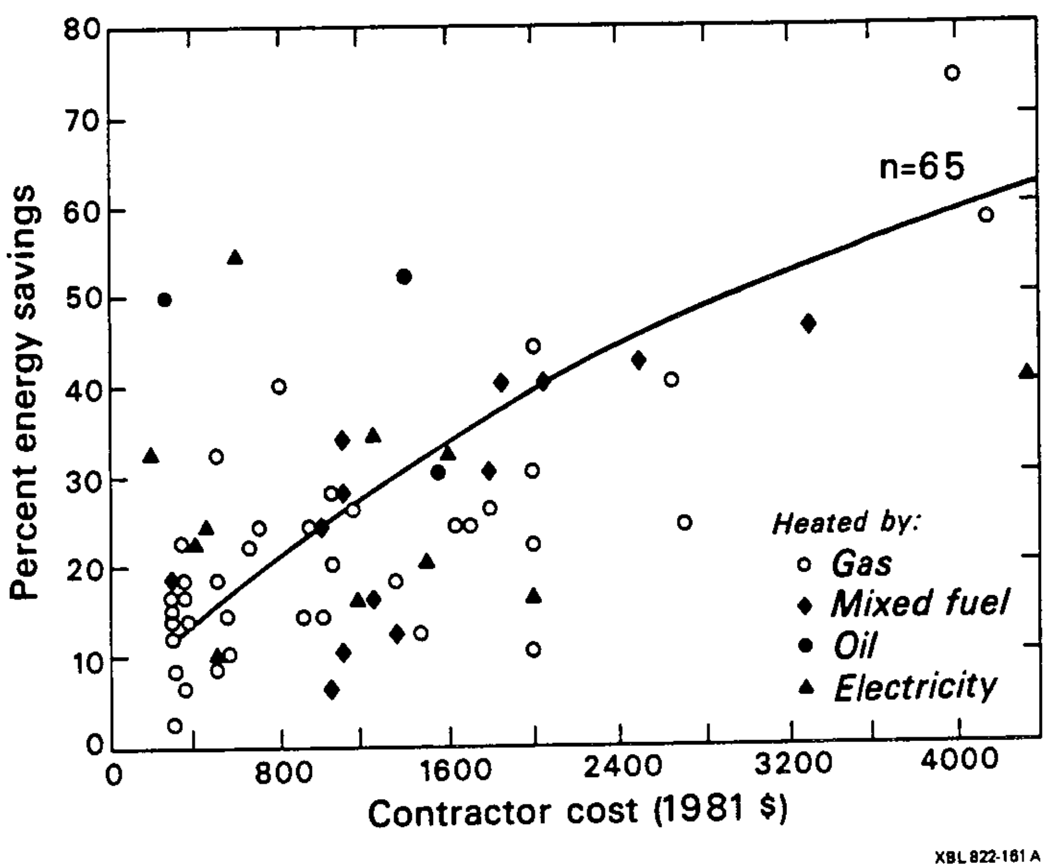

Fig. 2. Percent energy savings vs. Contractor cost for 65 entries in Table 1. The curved line is an "eye-ball" fit of the data, suggesting approximate energy savings of 25% for $1000 and 40% for a $2000 conservation investment.

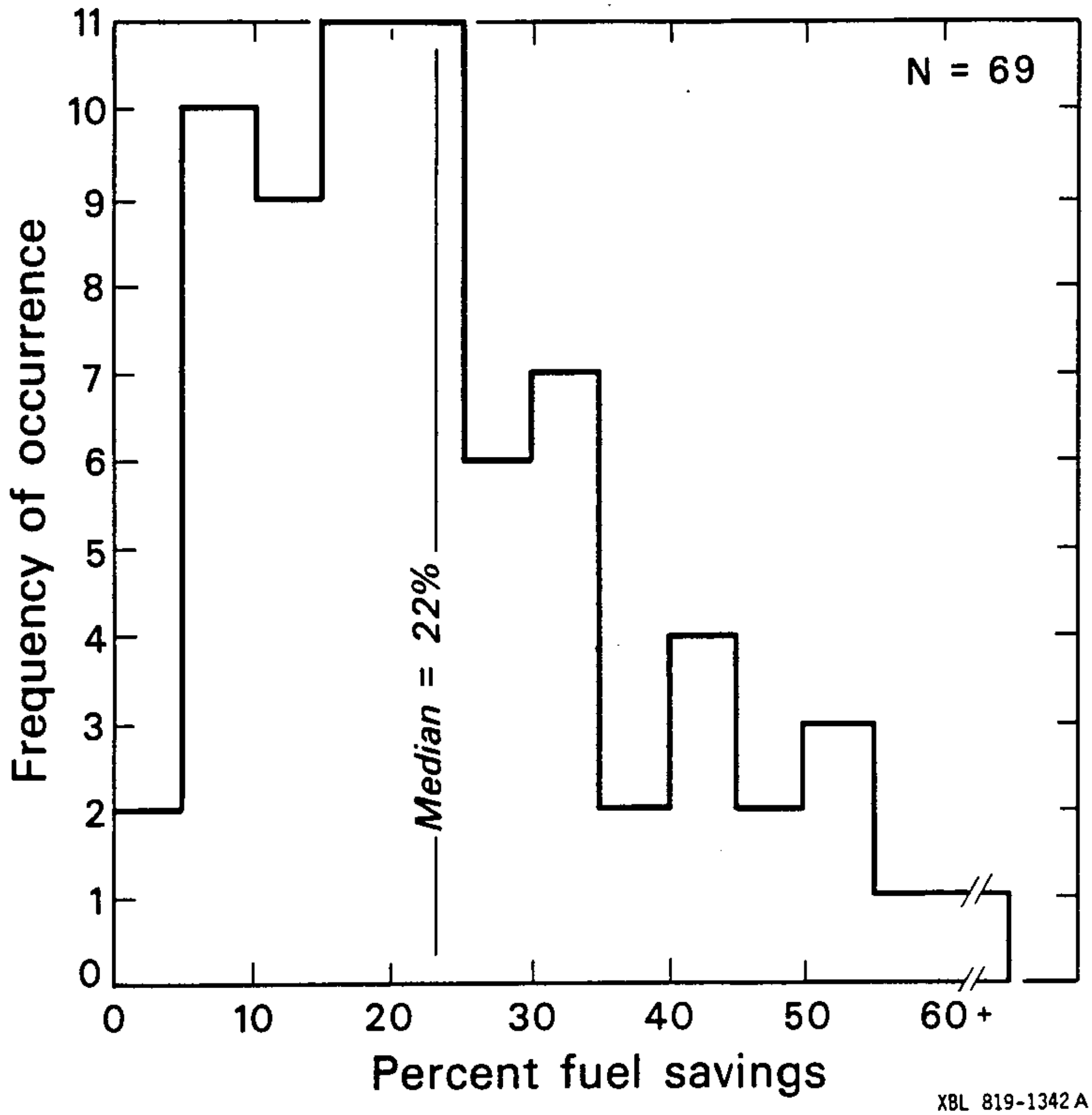

Fig. 3. Histogram of the energy savings data shown in Figure 2. The median energy savings is 22%.

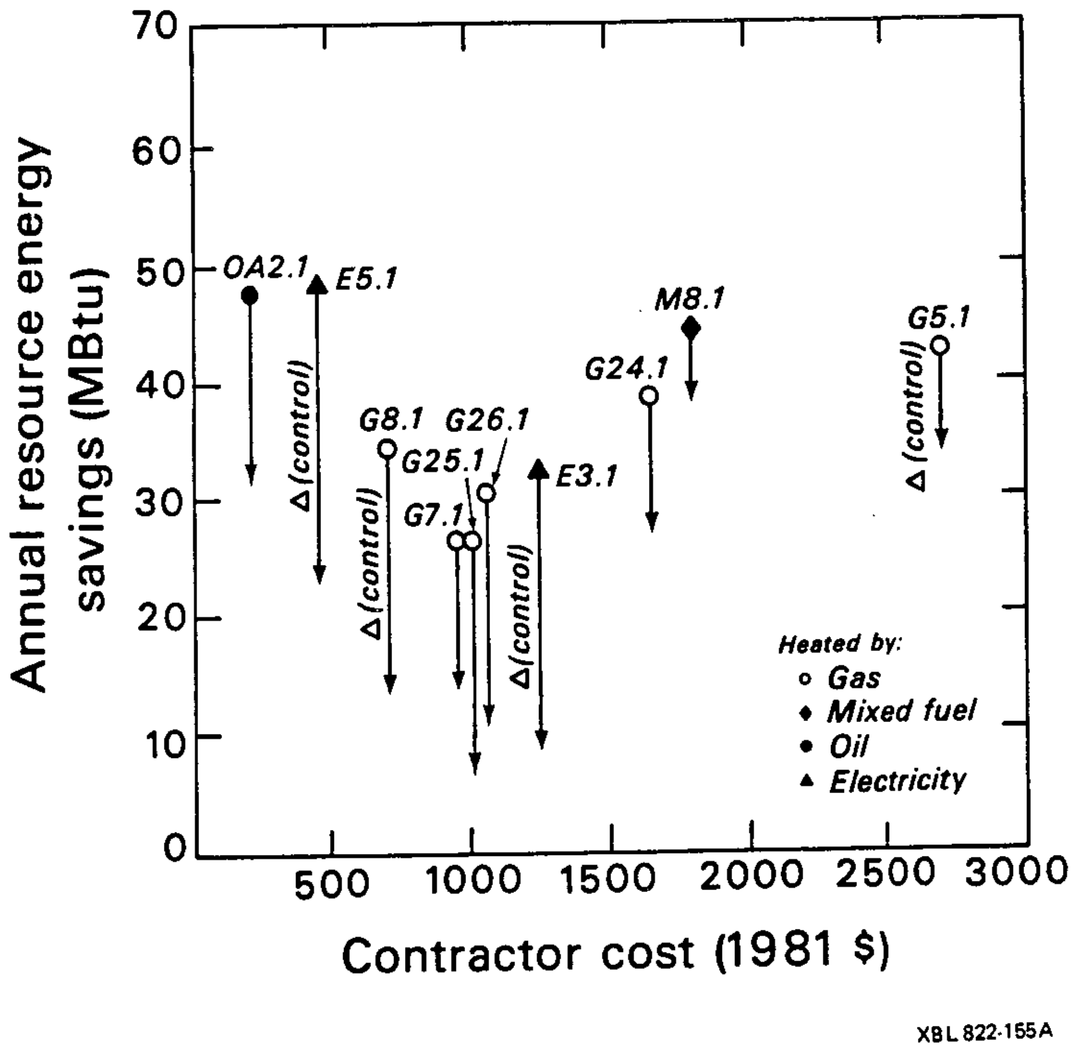

Fig. 4. This figure shows the reduction in "program-induced" savings when control group energy savings are subtracted. The scatter plot illustrates the reduction in savings (drawn from the initial data point by an arrow) for 10 of 24 samples that employed a control group. The points not included either overlap those shown or were active control groups from the individual cities in the CSA/NBS Demonstration Program (whose results are aggregated in M 8.1A).

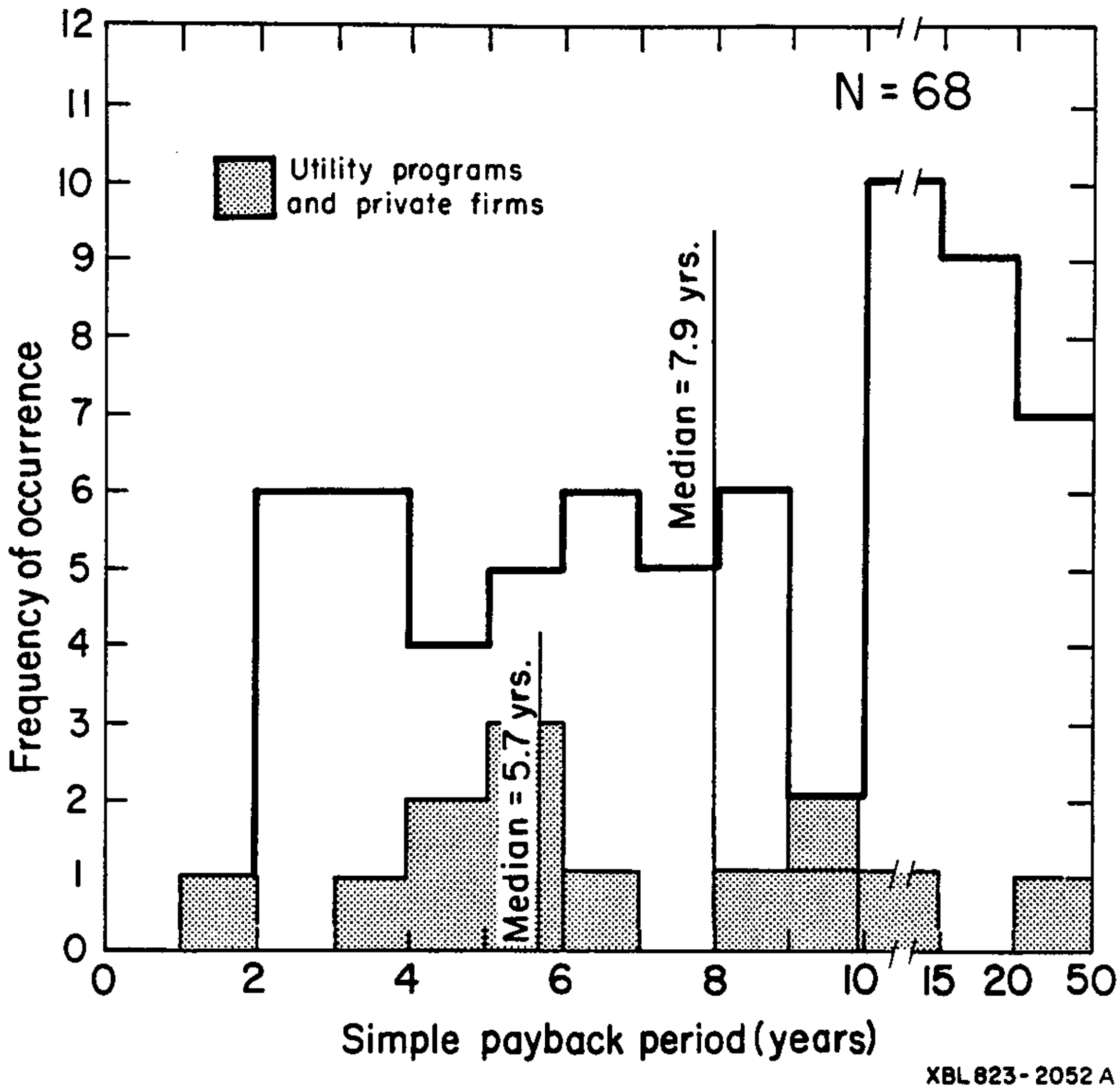

Fig. 5. Histogram of the simple payback time distribution of the data. For 68 studies, the median payback time is 7.9 years. Results for utility-sponsored programs and private firms are shown in the shaded area. Utility and privately-sponsored conservation programs had a median payback time of 5.7 years.

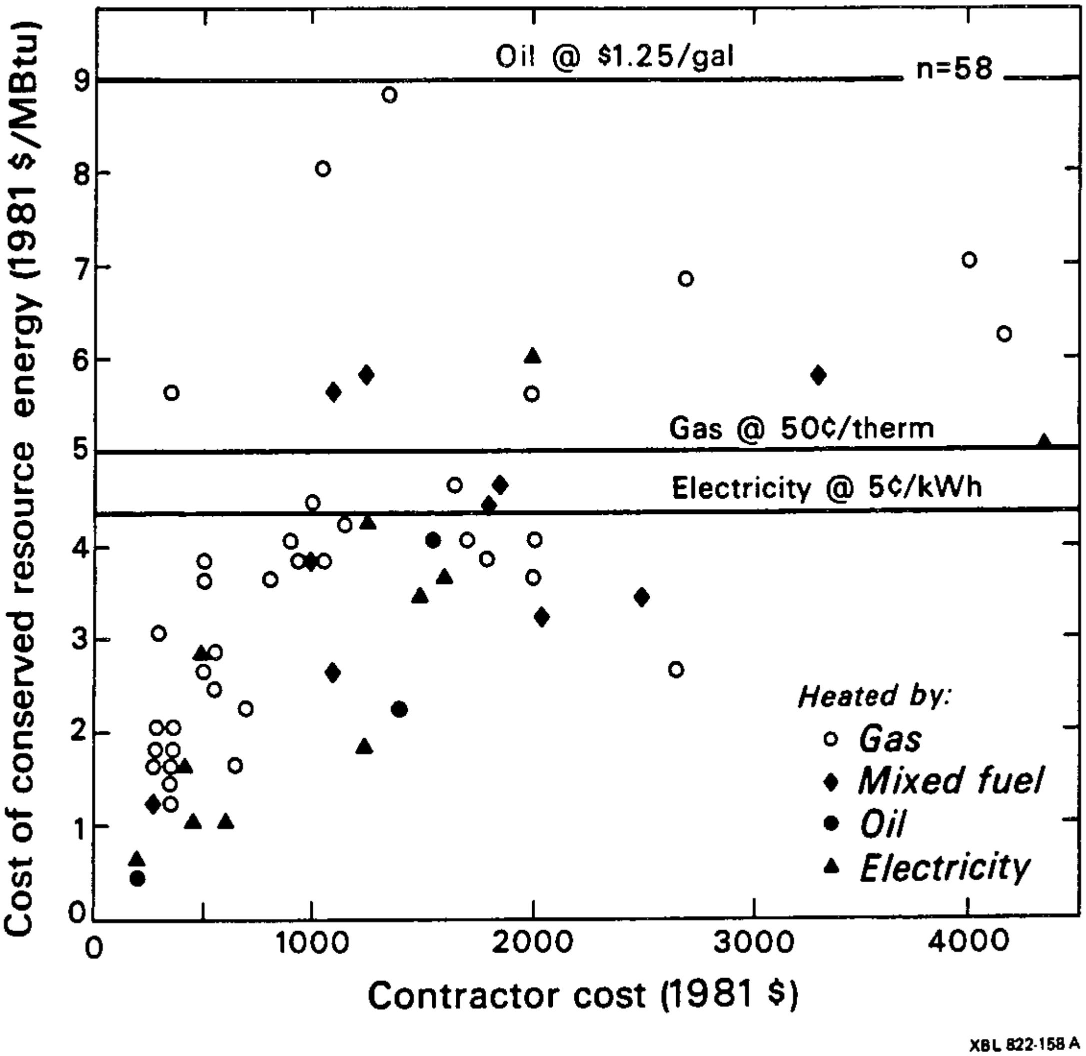

Fig. 6. The scatter plot shows the relationship between the cost of conserved energy and the contractor cost for the measures. The cost of conserved energy equals the ratio, total investment over annual savings, multiplied by the capital recovery factor (.11, assuming a 7% real discount rate and 15-year amortization period). The horizontal lines represent prices of purchased energy against which conservation retrofits should be compared. Of the 58 sources, 46 invested less than $2500 per home, and obtained CCE's of less than $5/MBtu. The 7 gas data points clustered between $1-2/MBtu represent the results of the Princeton house-doctoring experiments. Electricity is measured in resource units of 11,500 Btu per kWh sold.

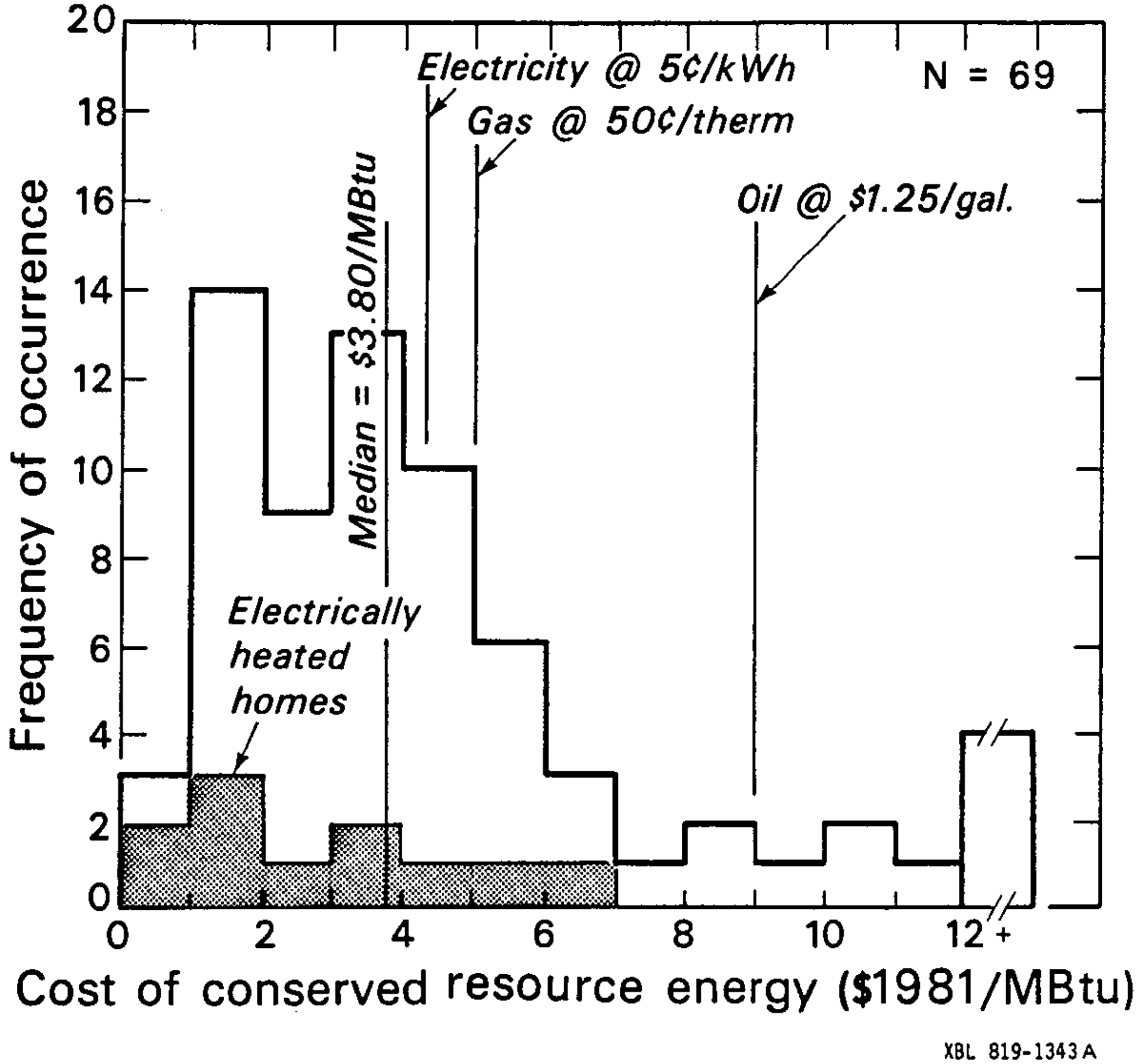

Fig. 7. Histogram of the distribution of cost of conserved energy (CCE) for the sample. CCE values for electrically heated homes (converted to MBtu at 11,500 Btu/1 kWh) are shown in shaded area with a median of 3.1¢/kWh (or $2.70/MBtu).
Overall, the 69 entries obtained a median cost of conserved energy of $3.80/MBtu (38¢/therm).

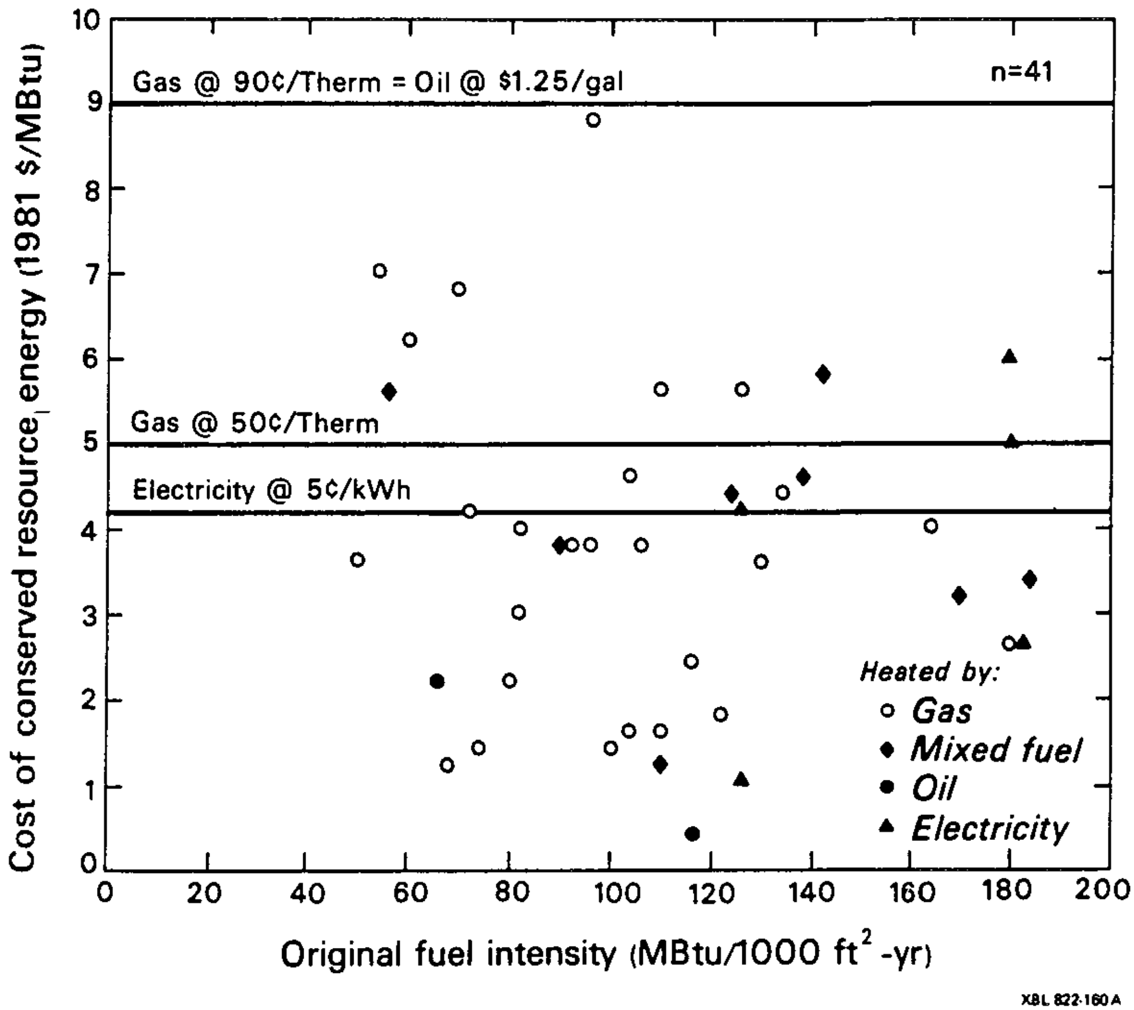

Fig. 8. Cost of conserved energy (CCE) vs. Original fuel intensity. The 41 data points are drawn from Table 1 samples that included average square footage data. There is no correlation observed between houses with high pre-retrofit fuel intensity ("leaky" thermal shells) and low CCE values. The CCE is amortized over 15 years at a real interest rate of 7%. In this plot, as throughout the paper, electricity is measured in resource units of 11,500 Btu per kWh sold. The horizontal lines represent various prices of purchased energy.