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Authors
Ross, H.
Whalen, S.

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Howard Ross and Sue Whalen

August 1982

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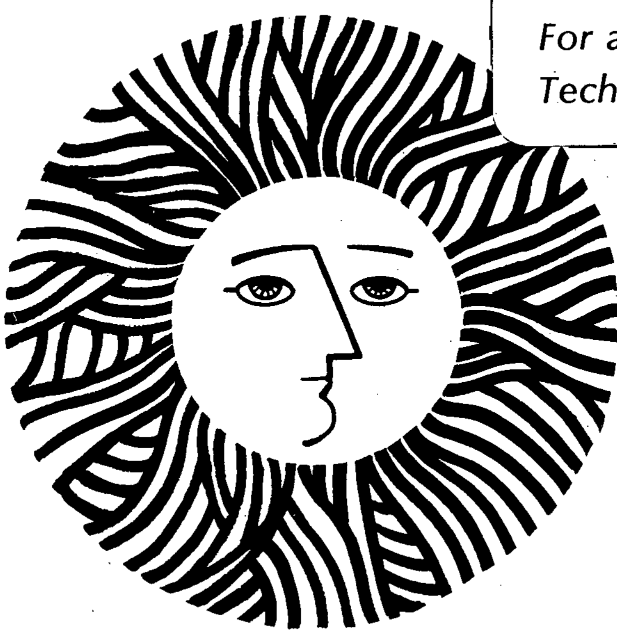

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BUILDING ENERGY USE COMPILATION AND ANALYSIS (BECA) PART C: CONSERVATION PROGRESS IN RETROFITTED COMMERCIAL BUILDINGS

Howard Ross and Sue Whalen

Buildings Division
U.S. Department of Energy
Washington, D.C. 20585

August 1982

The BECA series is available from the Buildings Energy Data group, Lawrence Berkeley Laboratory, and includes:
Part A = New residential buildings (published in Energy and Buildings 3 (1981) 315-332).
Part B = Retrofit residential buildings (Submitted to Energy and Buildings).
Part C = Commercial buildings (Submitted to Energy and Buildings).
Part D = Appliance energy use
Part V = Validation of computer programs

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

ABSTRACT

Data on actual energy use were compiled for 223 retrofitted U.S. commercial buildings and analyzed for several quantities of interest: average savings, average retrofit cost, correlation between cost and savings, type of retrofit attempted, etc. Dominant building types were schools and offices; nearly all buildings included operations and maintenance changes as part of the retrofit. Eighty-nine percent of the buildings which saved energy by retrofitting achieved a payback (simple) in less than 3 years. Nine percent of the buildings failed to save, (generally because of improper maintenance) indicating there is some risk in conservation investment. Average savings for the entire sample was 20 percent, at an average cost of $0.62 per square foot. On a more limited subsample, energy savings predictions made by the auditors prior to retrofit were compared to actual energy savings. About 60 percent of the time actual savings exceeded predictions. Data were available on 15 buildings for savings achieved over a number of years following the retrofit; in most cases the savings persisted, and even increased.

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1.0 INTRODUCTION

Of the recent attention to energy conservation, only small efforts have been placed in the commercial building sector. At this point in time, no accurate accounting is available for this sector's floor area, number of buildings, building type and functional energy use. Forecasting models, which predict future use are relying on rough estimates for these parameters[(1)] and have no actual data on the retrofit progress or potential in this sector. Also while many audits on commercial buildings have been performed and could yield estimates of energy saving potential, few studies have looked at actual savings. There is widespread skepticism of the common use of estimation techniques for many policy, marketing, and engineering-related issues. Measured data can be used more appropriately (1) to determine the energy-saving potential of various retrofits; (2) to evaluate the effectiveness of state and Federal energy conservation grant programs; (3) to determine the extent to which conservation can offset the need for new energy supplies or increased energy costs; (4) to present case studies to interested, but uncertain, potential investors in conservation; and (5) to redirect Federal and private research efforts.

Rosenfeld et al (Rosenfeld, 1980) attempted a very limited survey of actual case histories of commercial building retrofits, and used the most successful buildings in the data to predict the technically-feasible, economically-justified potential for energy savings in the sector. Misuriello and Bily (IEA, 1981) also collected some commercial building retrofit data on forty buildings by reviewing the last several years of "Energy User News," a trade publication.

The goal of this study was to expand the previous data collection efforts for this difficult sector, to determine any possible correlation between retrofit costs and actual savings, to examine the types and finances of retrofits, and to determine to what extent owners are investing in conservation. It is stressed that the only data which was accepted for inclusion in the study was actual metered energy use, for a period of at least one year before and one year after installation of the retrofit. Data herein is presented on two hundred and twenty-three (223) buildings, the majority of which are schools and offices.

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(1) The ORNL Model (ORNL, 1980) is felt by its developers to contain accurate figures for overall energy use, but the data for square footage and for energy use per square foot may be as much as 50% in error. Such discrepancies exist between (EIA, 1981) and (ORNL, 1980) according to Corum (Corum, 1981). The results of our survey lead us to believe the latter parameter used by ORNL for schools is too high; the schools in the most severe climates use less resource energy than that estimated by average in the model (See Figures 1A and 1B).

1.1 METHODOLOGY OF STUDY

The data sought for each building was: building type, annual energy consumption by fuel type before and after retrofit, retrofit description and cost, and year of the retrofit installation. Upon receipt of this data the following were calculated: site and source total energy consumption (kBtu/sq.ft/yr) before and after retrofit,(2) percent reduction in consumption, simple payback period, cost in 1980$/sq.ft. spent to retrofit and the cost of conserved energy in 1980$/MBtu saved in site and source energy.

Several tactics were employed to locate and collect this data. In addition to a literature search, all State Energy Offices were called for data on state-owned facilities and for other sources of retrofit data within the state. Several engineering consultants and trade associations known to be involved in building conservation were also contacted. Appendix A summarizes the data sources and Appendix B displays all calculated values.

The data was not normalized for varying weather conditions. Commercial building energy use has a diminished dependence on climate as the building size increases. The majority of the sample had a floor area over 50,000 square feet. In larger buildings lighting and other climate-independent energy uses predominate. Appendix C provides further discussion on this topic. All cost data has been normalized to 1980 levels by using the Gross National Product Price Deflators of the United States Bureau of Labor Statistics (BLS, 1980). Unfortunately, cost data was obtained on less than 30% of the sample. Frequently, only portions of the desired data were available. For this reason, the sample size differs between various calculated values of interest; the sample size is displayed on many of the figures and tables.

2.0 TYPES OF RETROFITS

Figure 2 shows the types of retrofits which were installed in the two hundred twenty-three (223) buildings in the sample. Interestingly, the frequency distribution of retrofits parallels that which most handbooks suggest as the typical prioritized order of retrofit of a single building, i.e., operations and maintenance efforts most frequent, then lighting, and mechanical system retrofits, etc; rarely can major architectural changes be justified on a cost-effectiveness basis, and do not appear in the sample. Thus, the sample has the appearance of a "statistical survey" though obviously it is not. It does provide some assurance that the correct retrofits are being installed with some frequency.

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(2) Site energy consumption (kBtu/ft^2 - yr) was calculated as follows: (Annual fossil fuel bill + Annual electric bill *3413)/Gross Floor Area. Source energy consumption was calculated as (Annual fossil fuel bill + Annual electric bill *3413 *3)/Gross Floor Area. The factor of 3 transforming site electric usage to source is to account for inefficiencies in generation and distribution of electricity.

The nomenclature of retrofit measures varied from one owner to another. What was simple operations and maintenance to one owner/operator was a capital investment to another. This can be seen in the wide range of costs associated with "operations and maintenance" measures. Our definitions are described in Table 1.

As can be seen from Figure 2 only a fraction of the buildings have been retrofitted in any extensive manner. No examples of a "solar" retrofit could be found which had pre-retrofit and post-retrofit data (although we know of two buildings in which such retrofitting has been done recently). When one excludes operations and maintenance, lighting(3) and caulking and weatherstripping measures, the number of buildings which have been retrofitted shrinks to seventy-nine or about one third of the sample.

No "innovative" retrofits--night insulation, passive solar additions, automatic daylighting control systems, significant waste heat recovery--were described. The only cases of wall insulation were in a series of schools in Maine, where frequently windows were boarded and replaced by insulated opaque wall sections; in addition some of these schools also retrofitted their walls with insulation. This retrofit is normally considered expensive and thus it is surprising that the payback period for these schools was so rapid (about 3 years). It was also surprising to note that despite the reduction in available daylighting, few of these schools increased their use of electricity. In the entire sample, lighting retrofits were dominated by delamping, although twenty-five (25) buildings in the sample did replace tubes with more efficient ones. Only three building owners installed task lighting, although this can be a large energy saver. Again, no building in the sample substituted a dimming system for perimeter lighting or other daylighting systems.

2.1 RETROFIT SAVINGS

Figure 3 shows the amount of energy saved as a function of the buildings' energy use before retrofit. There is the general expected trend of increased savings with increased energy use. However, savings varied over a wide range - where the original energy use varied from building to building by a factor of ten (10), savings differed by a factor of fifty (50). Lines of 5% through 40% savings are shown on this graph. At any particular level of energy use (e.g., 200,000 Btu/sq.ft/yr), savings varied by an order of magnitude, even when excluding the failed retrofits (those which did not save energy).

For the one hundred eighty-four (184) buildings for which data could be obtained and which successfully retrofitted, the average savings of resource energy was 23 ± 15%; when failed retrofits are included, savings shrink to 17 ± 17%. Figures 5A & B show little difference in representing this data as site or source. There was little variation

(3) This includes light bulb removal, the most frequently occurring lighting retrofit by far.

between building types with most types averaging between twenty (20) and thirty (30) percent. (See Table 2).

Savings in fossil fuel frequently exceeded electricity savings. On the average, 26% (N=156) was saved in fossil fuel, while only 19% (N=127) of electricity was saved when excluding failed retrofits or 24% (N=169) was saved in fossil fuel, while only 8% (N=177) of electricity was saved when including failed retrofits. One of the postulates of Rosenfeld et al was that equal percentage savings could be obtained economically in existing commercial buildings; in their very limited sample, savings were 47% and 30% respectively. While equal savings may be economically justifiable over the long term, such proportionality does not seem to occur in the first 25% savings. It is apparently more economical to save fossil fuel than electricity.[4] These results are similar to those shown in Hirst et al (Hirst, 1981) with a survey of forty-eight (48) hospitals.

The maximum savings of any building was seventy-five percent (75%): however, this building on the Ohio State University Campus, prior to retrofit, used twice the national average of fossil fuel and electricity. The greatest failure to save occurred in a community center where thirty-one percent (31%) more energy was used after retrofit.

2.2 COSTS AND PAYBACK PERIODS

Similar to the above data, retrofit costs varied over a wide range without a simple distribution (Figure 4). The average costs were $0.62 per square foot ± $0.51 per square foot. There was no significant difference due to building type.

A comparison was made between the cost of the retrofit and both the amount and percentage of energy saved. As can be seen from Figures 6A and 6B, no simple correlation exists. When certain buildings are excluded as possibly anomalous,[5] some of the data scatter disappears but not to acceptable levels. The general trend of diminished returns may be observed. Above $0.40 per square foot of investment, savings per dollar invested are between 5% and 10%; a linear regression of this data gives the following relation: Percent Saved = 22 + 10 x Dollar invested. However, this relation remains statistically poor (R squared is 0.52). As can be seen, at investment levels below $0.40 per square foot, no simple cost-savings trend can be found.

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(4) Rosenfeld et al did show a much greater savings in fossil fuel in new office buildings.

(5) The Ohio State University Buildings (#90, #91, #92 & #95) were operated 24 hours per day with reheat type mechanical systems, where large savings are abnormally cheap. Excluded also are those buildings which spent more than $0.10 per square foot but saved less than 10%, and the European Buildings.

Figure 7 shows the simple payback period distribution of the sample. As expected, almost 90% of the sample achieved payback periods of three (3) years or less. Long term investments were rare. Based on conversations with those building owners who found actual paybacks greater than three years, they did not plan on investing on such a "long-term."

The usual source of the capital for retrofit was profit, not loans. In the case of non-profit institutions such as schools, funds came from general funds, operations and maintenance funds, or State Emergency Funds, but not from floating new bonds.

2.3 COST OF SAVED ENERGY

It has often been contended that in a "least cost" national energy policy, it is appropriate to compare the costs of producing new energy sources to the costs of saving an equal amount of energy. Without regard to other policy considerations (national security, rate of implementation, equity, etc.), the least expensive energy strategy is the most beneficial. In this study, a comparison was performed between the actual cost-benefit of commercial building conservation and the average cost of supplying an equivalent amount of energy to the commercial sector.

To perform such a comparison, one must assign an investment cost to the retrofit. We collected the first cost and divided by the first year energy savings. We then have calculated the costs as if the money was obtained through a loan from a banking institution, and repaid over a number of years. Rosenfeld et al suggested using a loan repayment schedule or "capital recovery rate" (CRR) of 0.10 for the commercial building sector. The CRR is defined as the annual real cost, after inflation, of repayment of a loan; it is calculated as $CRR=I/(1-(1+I)^{-N})$ where I=real interest rate; i.e., above inflation, N=number of years of loan. The value of 0.10 is equivalent to I=10% and N=20 years. In this study, the source of retrofit capital was not loans. The useful life for most retrofits was substantially less than 20 years. For example, operations and maintenance tend to be ongoing expenses, lighting tubes need to be replaced every three years, boiler tune-ups are at least annual and caulking is usually replaced every ten years. Other retrofits such as conversion to variable on volume systems require inspection and possible replacement of damper leakage every few years. Since these shorter-term retrofits dominate the sample, we display on Figure 8A & 8B capital recovery rates of 0.16 and 0.25 based on N=10 and N=5 years respectively. Using the latter value, it can be seen that 62% of the sample had an actual cost of conserved energy below the mid-1981 commercial gas price, 82% are below the oil price and 89% are below the commercial electricity price. These prices are not the much higher "marginal or replacement" costs of producing and distributing new oil, gas, and electricity. If these production costs are used, even a higher percentage of the sample would fall into the "least cost" portion.

3.0 FAILED RETROFITS

Of the two hundred twenty-three buildings in which retrofits were installed, twenty (nine percent) failed to save energy, and in most instances, consumption actually increased.

In a series of sixteen New York State Owned Buildings (#45-#60 in Appendices A and B) five increased consumption after retrofit. However, ten other of these buildings achieved savings with a similar retrofit (tuning of combustion equipment) performed by the same personnel. Some variation in the magnitude of the savings was expected due to the different initial condition or efficiency of the combustion equipment. However, in no case should one expect a trend to increase consumption; two possible explanations are that the personnel who performed the tuning made a mistake (unlikely, given the savings in other buildings) or that on-site personnel failed to maintain the equipment at the peak efficiency following the tuning. No other changes in the building schedule or operation are known.

Similar discrepancies appear in eighteen Columbia, Maryland community centers (#207-#235). Many of these centers are of similar size, construction and use; retrofit measures though not identical, were similar and entirely specified by one consulting firm. The results range from a thirty-one percent (31%) increase in consumption to a savings of fifty-three percent (53%). It is likely that maintenance personnel (the only variable) undermined the potential of the retrofit. In addition, in all cases where reflective film was added to windows, the film failed to stay in place over time, requiring re-installation with a different adhesive (this had not been done prior to the completion of our study).

In eighty (80) Buffalo, New York schools (#120-#201) eleven failed to save energy without an apparent explanation. While we obtained an accurate description of the major retrofits in each school, the detail of actual operations and maintenance was vague. Based on the cases cited above, it is suspected that on-site personnel were the culprits.

Finally, in the "Saving Schoolhouse Energy" study of nine (9) schools (#98-#106) savings achieved were dramatically less than predicted. In every step of the retrofit process--selection, specification, installation and maintenance--errors could be detected "post mortem." In one school building, operator disinterest caused a blown steam trap to remain "in service" though installation of a new one would have paid back in weeks.

3.1 ESTIMATED VS. ACTUAL SAVINGS

Thousands of energy audits have taken place in the United States for the expressed purpose of providing estimates of costs and savings which would result from retrofitting a building. Yet, no systematic study has ever been done which compares these estimates with actual savings.

In this study, sources were available to allow partially, such a comparison: (1) The Maine Schools; (2) The Columbia, Maryland Community Centers; (3) The "Saving Schoolhouse Energy" Schools; (4) The Ohio State Secondary Schools and (5) one building monitored by Complete Building Services (CBS).

The twenty-one (21) Maine Schools and the CBS building planned a five-year (5) payback period when selecting retrofits. In both cases, the actual payback period was three years, thus the estimates under-valued the retrofits.[6]

On the Ohio State Campus, actual savings met or exceeded estimates of the engineers who performed the audit with "hand calculations".[7]

In the nine (9) "Saving Schoolhouse Energy" elementary schools, actual savings were far less than that predicted by detailed computer simulation. The reasons for this discrepancy have already been discussed.

For the eighteen (18) Columbia, Maryland Community Centers, estimated and actual post-retrofit energy use are shown in Table 3. No systematic difference could be found, again for reasons discussed in the previous section.

In total, of the sixty (60) buildings for which some quantitative judgment could be made, sixty percent (60%) saved more than estimated and forty percent (40%) less. No generalization can be made from this limited sample.

3.2 DURABILITY OF RETROFITS

It is possible to determine the durability of retrofit measures by comparing the energy consumption of the year immediately following retrofit to the consumption several years later. Figure 10 shows this relationship for fifteen (15) buildings. More than half of the buildings saved even more energy in the following years, and the remainder increased consumption slightly. There were no large changes due to eventual failures in the retrofit performance over time. Unfortunately this collection of data contains a very limited sample of buildings for which several years of consumption data are available after retrofit. Most of the data is only for a few years (2 or 3) following retrofit.

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(6) No estimates of energy use after retrofit were available.

(7) Estimates of post-retrofit energy use for three buildings are available in "A Methodology For The Prediction of Change in Energy Consumption As Result of HVAC System Operations Modifications" Purdue, April, 1976, Proceedings of the Conference on Improving Efficiency and Performance of HVAC Equipment and Systems for Commercial and Industrial Buildings.

4.0 CONCLUSIONS AND RECOMMENDATIONS

Given the variation between retrofit success and costs, few generalizations can be drawn from the study. The summary of key findings is shown in Table 4.

Building owners are not investing on the long-term. Three year paybacks--or at most five-year paybacks--are the limits of investment. Yet even with investment at this level taken from profits, the cost of saved energy is usually a fraction of costs to locate and process new energy sources.

There is some uncertainty regarding the likelihood of success when retrofitting. Failures occur most frequently when on-staff maintenance personnel are not competent to sustain the operability of the retrofitted equipment.

Few, if any, "innovative" retrofits were installed. The reason for reluctance by building owners is unknown, but likely to be for financial reasons or uncertainty regarding the probability of success. Instead, the typical recommended retrofits--operations and maintenance, lighting modifications, etc--are being installed most frequently.

The average savings of fossil fuel were 1.4 times the average savings of electricity, suggesting it is simpler and more beneficial financially to save fossil fuel than electricity in the commercial sector.

The paucity of retrofit examples in the multi-family sector suggests that this sector is lagging others in the commercial sector and should be a principal target of future study for possible Governmental action.

Continuation and expansion of a retrofit data base is needed to improve forecasting models as well as to allay fears of building owners regarding the viability of energy conservation. A larger data base would also be able to relate more directly to the overall building stock.

5.0 ACKNOWLEDGEMENTS

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John Flaherty, on sabbatical leave from Yuba Community College and working in the Building Energy Data (B.E.D.) Group at Lawrence Berkeley Laboratory inherited this study at the stage when the data were handwritten and hand processed. He generalized and adapted the B.E.D. computer data base to accommodate this commercial data, entered and critically processed the data and produced the final figures and tables. We are most indebted.

The Building Energy Data Group is coordinating further collection of data and analysis of both retrofitted and new commercial buildings. New collaborators are solicited and future expanded editions of this report are planned by Lawrence Berkeley Laboratory.

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REFERENCES

1. Corum, K., and Jackson, J. March 1980. ORNL commercial building energy use simulation, 1970 - 2000. Oak Ridge, Tenn., Oak Ridge National Laboratories, Technical Information Center.

2. Corum, K. 1981. Private communication.

3. DOE Technical Support Document No. 10. November 1979. Climate classification analysis. To the 1979 Notice of Proposed Rulemaking (NOPR) for Energy Performance Standards for New Buildings. DOE/CS/0112 (November 1979). The DOE Administrative Record Number of Document No. 10 is 9570.

4. Energy Information Administration (EIA). Non-residential buildings energy consumption survey: building characteristics. DOE/EIA-0246.

5. Federal Register. November 1979. Notice of proposed rulemaking: Energy performance standards for new buildings. Washington, D.C.

6. Hagler, Bailly and Company. 1980. Energy consumption in commercial buildings: a comparison with BEPS budgets. Springfield, Va.: Under contract to DOE, Division of BCS. Available from NTIS, U.S. Department of Commerce.

7. Hirst. E., Stelson, J., Carney, J., Goeltz, R. 1981. Analysis of energy audits at 48 hospitals. Oak Ridge, Tenn.: Oak Ridge National Laboratory ORNL/CON-77.

8. Maine Advancement Program. 1980. An analysis of fuel conservation in Maine Public Schools. Augusta, Me.

9. Misuriello, H., and Bily, R. April 1981. A study of actual metered energy savings for energy conservation retrofit measures reported for commercial buildings. Proceedings of the First International Energy Agency Conference On Advanced Energy Conservation. Technology and Their Commercialization.

10. National Electrical Contractors Association and National Electrical Manufacturers Association. 1976. Total energy management research report. Washington, D.C.

11. New Jersey Department of Energy. 1980. Energy conservation in state facilities: a progress report. Newark, N.J.

12. New York State Legislative Commission on Expenditure Review. 1980. Energy use in state facilities. Albany, N.Y.

13. Ohio State University, Department of Physical Facilities, Energy Conservation Division. 1980. "Annual status report of energy management programs through 1976-1977, 1977-1978, 1978-1979. Columbus, O.

14. RPA, Paris, France - RPA Management Consultants, Ltd. and United Kingdom for Buildings and Community Systems Division. 1980. Specific energy consumption in commercial buildings in France, Germany, Sweden, and the UK. Springfield, Va: Available from NTIS, U.S. Department of Commerce.

15. Rosenfeld, A., Goldstein, D., Gawell, K., and Claridge, D. August 1980. Solar/Conservation study, part 1 - buildings. Berkeley, Calif.: Lawrence Berkeley Laboratory Report-11300.

16. Ross, H.D. Conservation initiatives in United States Buildings. Office of Buildings and Community Systems, Buildings Division, Department of Energy. Available from NTIS, U.S. Department of Commerce.

17. Rudy, J., Sigworth, H.W. Jr., and Rosenfeld, A.H. 1979. Saving school house energy: final report. Berkeley, Calif.: Lawrence Berkeley Laboratory, University of California.

18. West Virginia Department of Finance and Administration. Energy report, 1979-1980, State of West Virginia. Charleston, W. Va.

Table 1: **Description of Retrofit Categories**

Operation + Maintenance (O)	All Actions Which Affect the Schedule of the Building Operation or the Manner in Which the HVAC Equipment Is Run; Does Not Refer to the Changing of the Design of the Primary or Secondary System Equipment
Lighting (L)	Replacement of Existing Lamps with More Energy Efficient Types, Delamping, Installing Task Lighting
HVAC (H)	Replacement of HVAC Equipment, Conversion of Equipment to a More Efficient Mode (e.g., Reheat to VAV) Rezoning of the Spaces
Windows (W)	Double or Triple Glazing of Windows, Addition of Reflecting Film Over Existing Windows, the Removal and Boarding of Windows
Weatherstripping & Caulking (C)	Self-Explanatory
Insulation (I)	Insulation of Walls, Roofs, Piping, and Ducts
Energy Management Control Systems (E)	Installation of New Central Computer Control Systems, Upgrading Present Systems
Architectural (A)	All Major Changes to the Actual Structure of the Building for the Purpose of Energy Conservation
Doors (D)	Replacement of Existing Doors with Tighter Fitting and Better Insulated Doors

Table 2. Stratifying the Sample By Building Type--Savings in those building categories where significant sample sizes were obtained did not show much variation.

	Site		Source	
Building Category	Ave % Savings	Sample Size	Ave % Savings	Sample Size
Elementary	24%	72	21%	72
Secondary	30%	38	28%	37
Large Office	23%	37	21%	24
Hospital	21%	13	17%	10
Community Center	56%	3	23%	18
Hotel	25%	4	24%	4
Corrections	7%	4	5%	4
Small Office	33%	1	30%	1
Shopping Center	11%	1	11%	1
Multi Family Apartment	44%	1	43%	1

Table 3: The Accuracy of Audits		
Bldg #	Estimated Savings	Actual Savings
207	2%(1)	53%(1)
208	7%	(2%↑)
209	22%	4%
210	17%	2%
212	42%	2%
213	34%	30%
214	42%	19%
215	27%	(32%↑)
216	35%	19%
217	9%	17%
218	24%	19%
219	16%	12%
220	19%	43%
221	18%	22%
222	19%	9%
223	33%	24%
226	23%	40%
230	22%	21%

(1)Retrofits not Specified by Auditor Were Installed Successfully

Table 4. Key Findings

	Excluding Failed Retrofits		Including Failed Retrofits	
1. Average Cost of Retrofit (1980$)	$0.62 ± 0.51/sq.ft.	N = 79	$0.89 ± 1.30/sq.ft.	N = 84
2. Average Savings (Source)				
Total Electricity and Fuel	23.0% ± 15.3%	N = 184	19.9% ± 17.4%	N = 204***
Electricity	18.9% ± 17.3%	N = 127**	8.3% ± 23.4%	N = 177
Fossil Fuel	26.4% ± 17.6%	N = 156**	23.7% ± 19.5%	N = 169
3. Average Cost of Saved Site Energy				
CRR = 0.25	$3.97 ± 4.67	N = 56*	$7.60 ± 13.85	N = 65
CRR = 0.16	$2.54 ± 2.99	N = 56*	$4.86 ± 8.87	N = 65
CRR = 1.0	$15.89 ± 18.70	N = 56*	$30.40 ± 55.41	N = 65
4. Portion of Sample which had failed retrofits	9% (20 of 223)			
5. Portion of Sample with less than 3 year simple payback	89% (58 of 65)			

* Excludes: (1) 5 European Buildings (#61, #63, #64, #65 and #67); (2) 3 "Failed" Retrofits (#99, #102 and #105); (3) 2 Buildings where cost of saved energy was over $100 per million Btu (#100 and #104), more than twice the highest cost of the rest of the sample

** Some buildings all-electric, or only fossil fuel data available

*** Less than 223 (entire sample) because only site figures available--see Appendix A

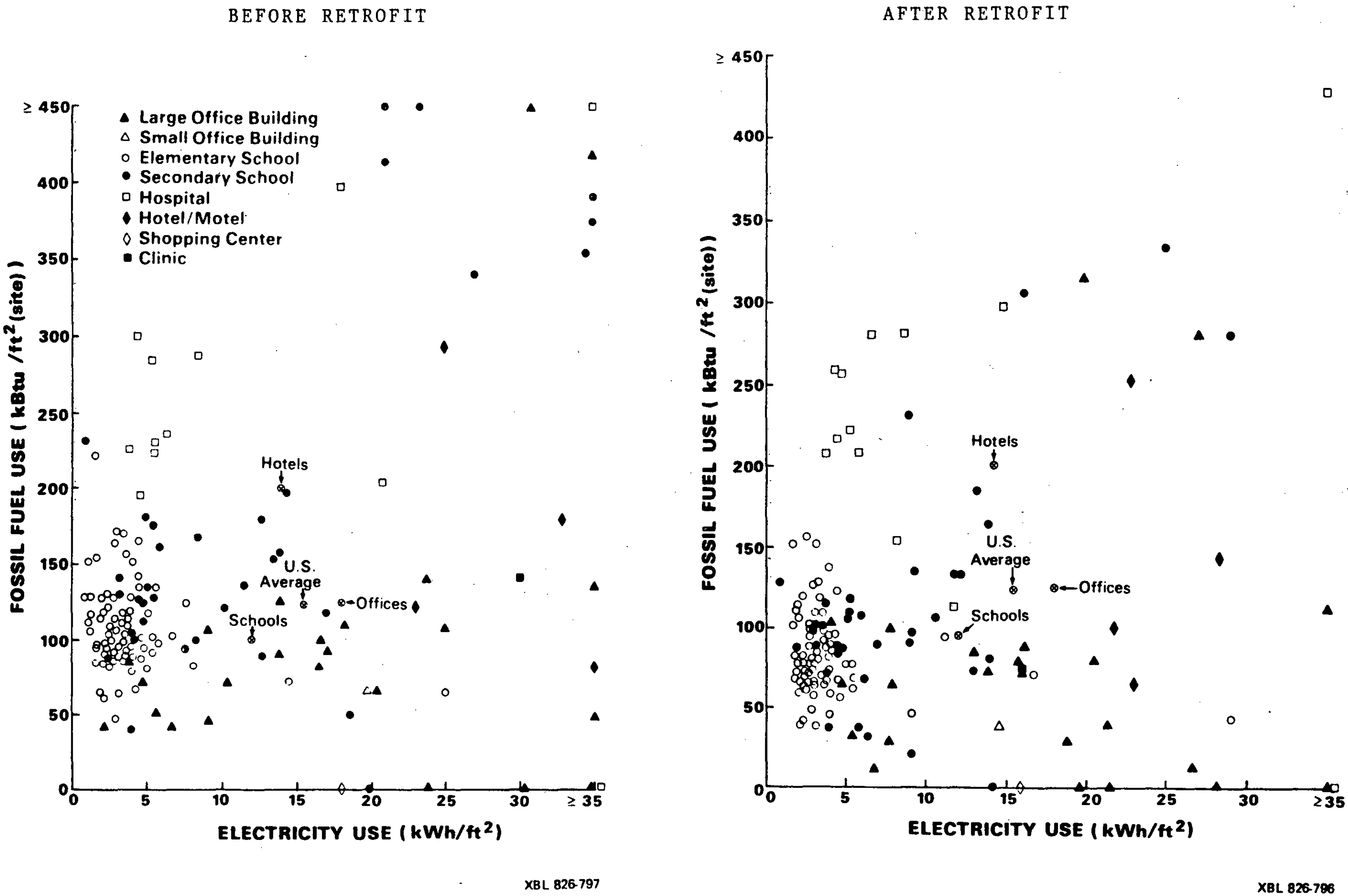


Fig. 1A, B. Energy Use Before and After Retrofit--Note that the largest energy users (located in the upper right of each figure) tend to have the greatest reduction in energy use. Also, the figures show the national average energy use for various building types (denoted as ⊗). Our sample shows that electrical energy use of schools is much below the published school national average (ORNL, 1980); the overall source energy difference is about 50%.

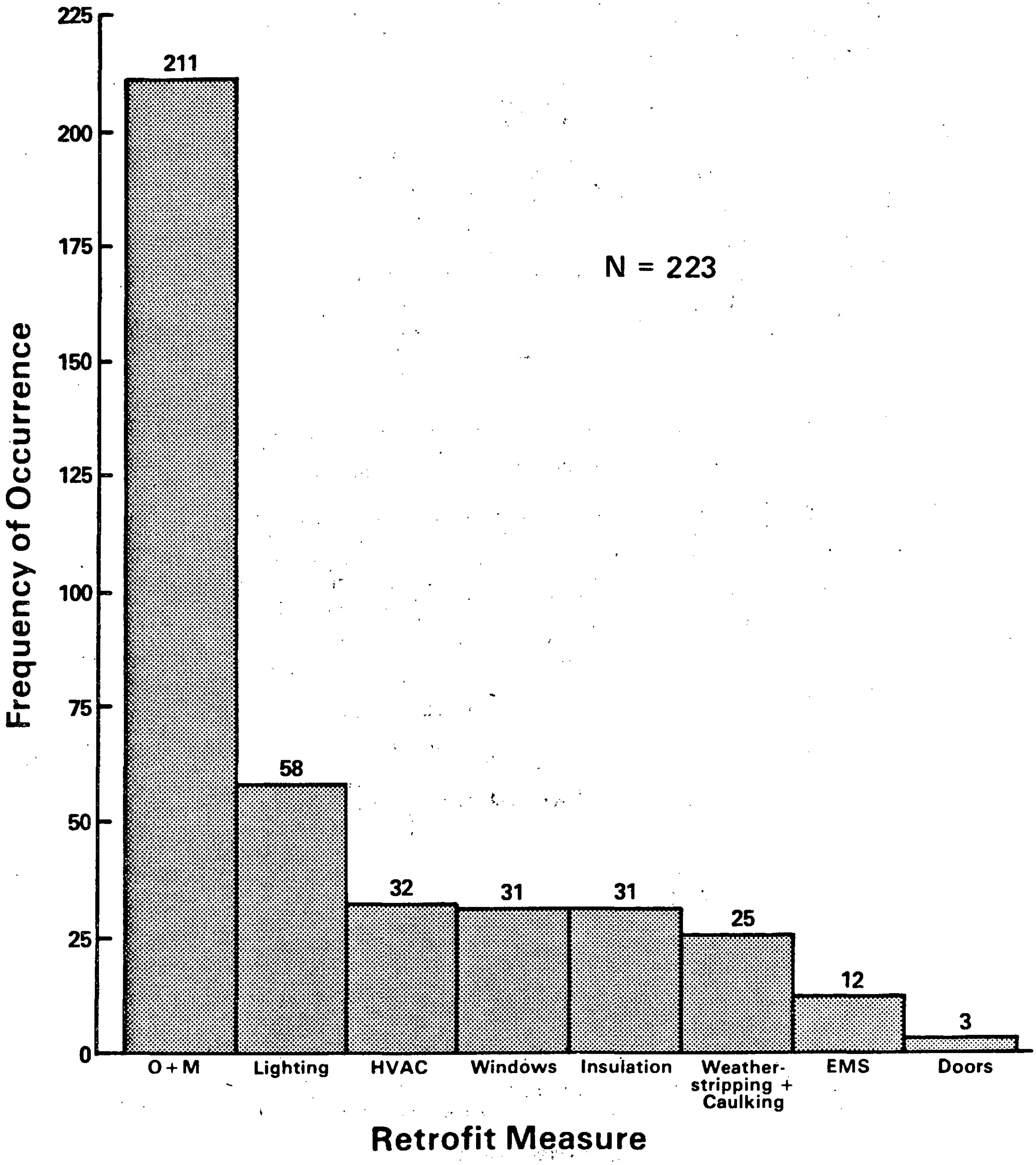


Fig. 2. Histogram of Installed Retrofits.

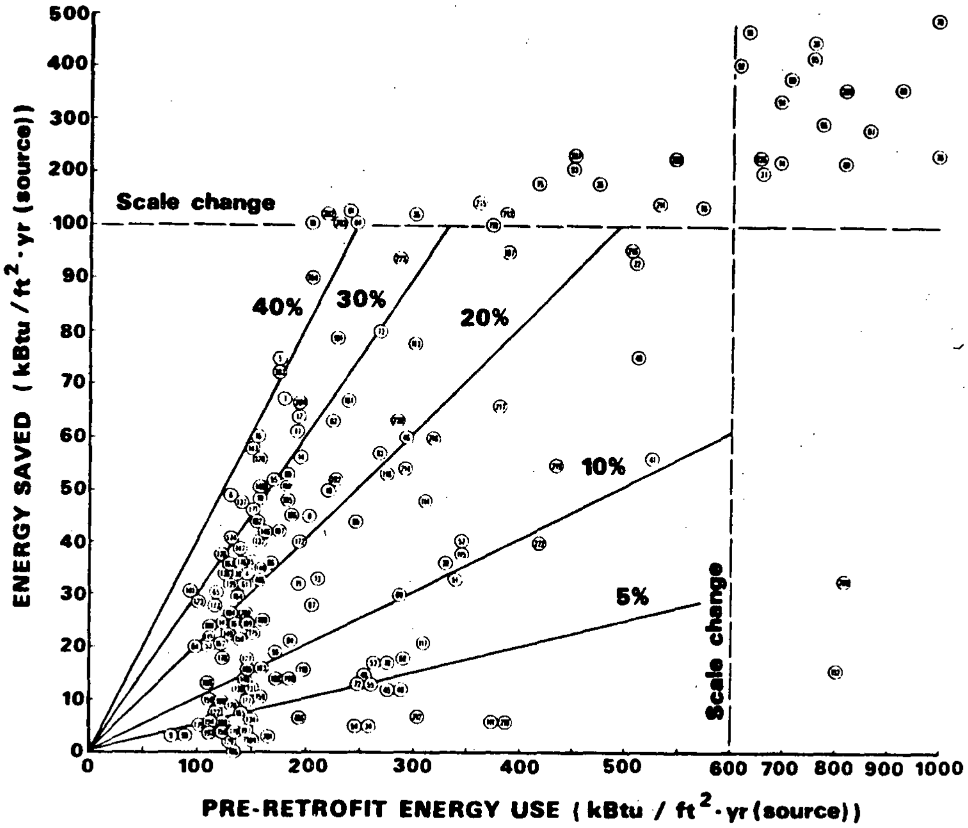


Fig. 3. Energy Savings Versus Energy Use--Beware the scale change on the figure. While there exists a general trend toward increased savings as pre-retrofit energy use increases, simple correlations do not exist; however, to guide the eye, we have plotted lines corresponding to 5% through 40% savings. To convert to SI energy use, multiply kBtu/sq. ft./yr by 0.9 to achieve $GJ/m^2/yr$.

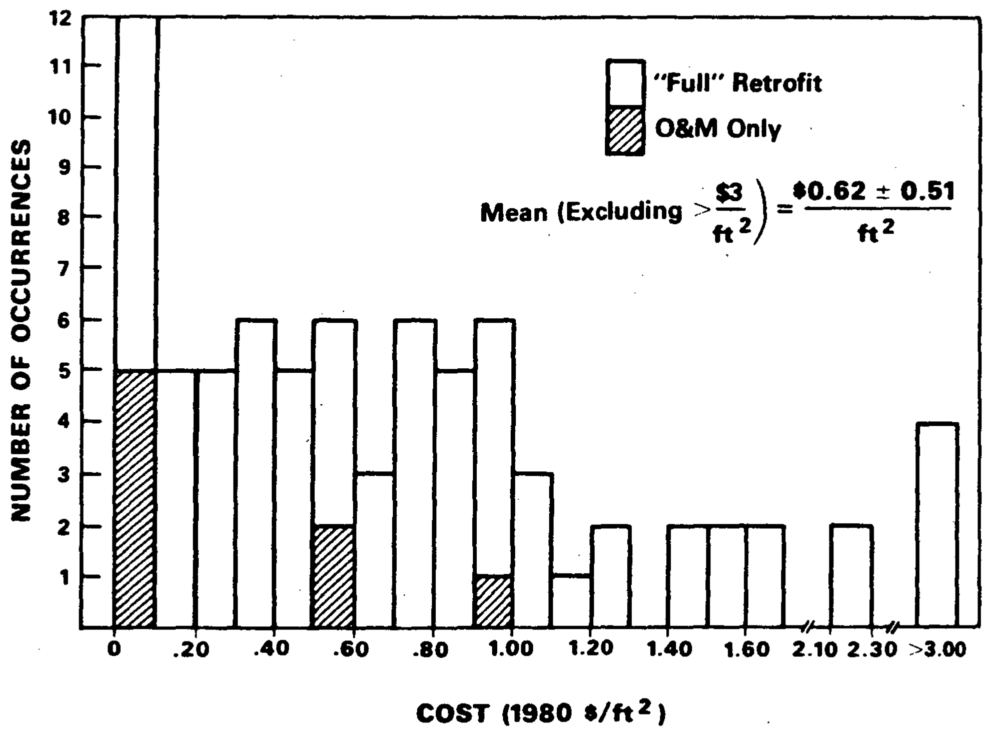
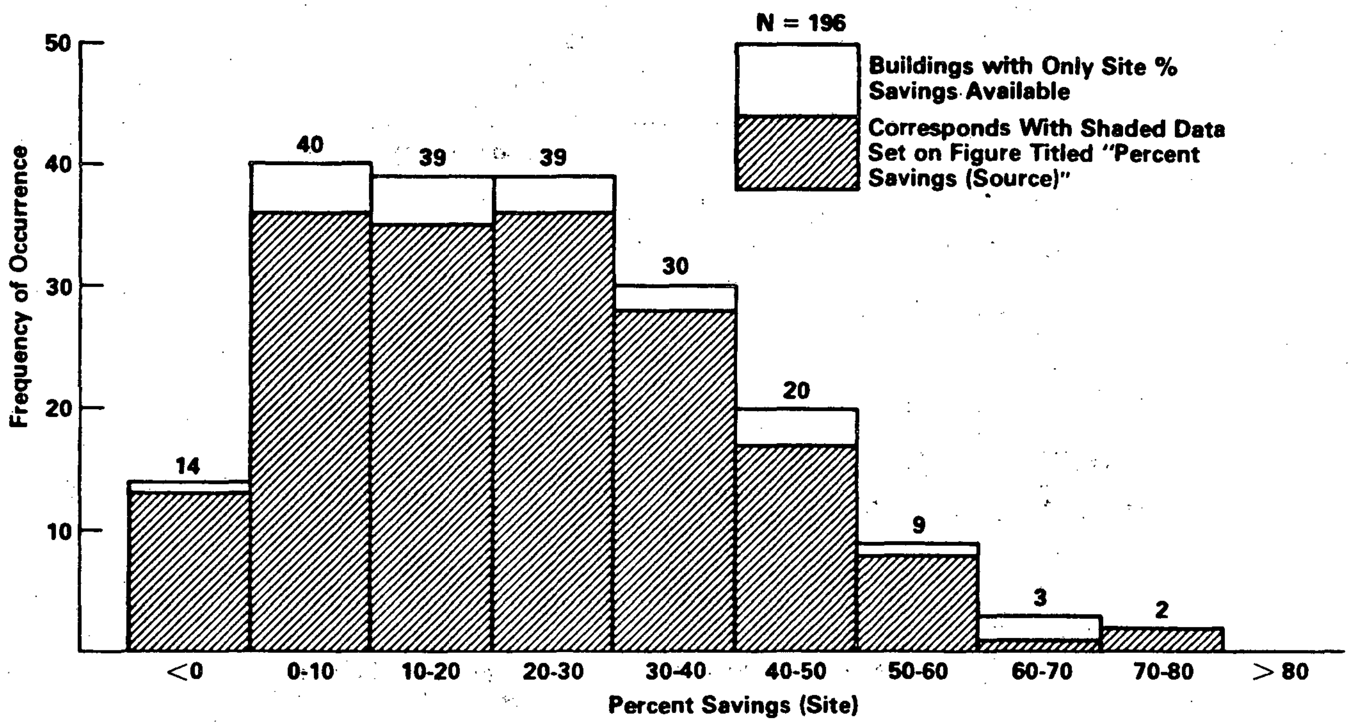


Fig. 4. Retrofit Cost--Those buildings over $3/sq. ft. are European.



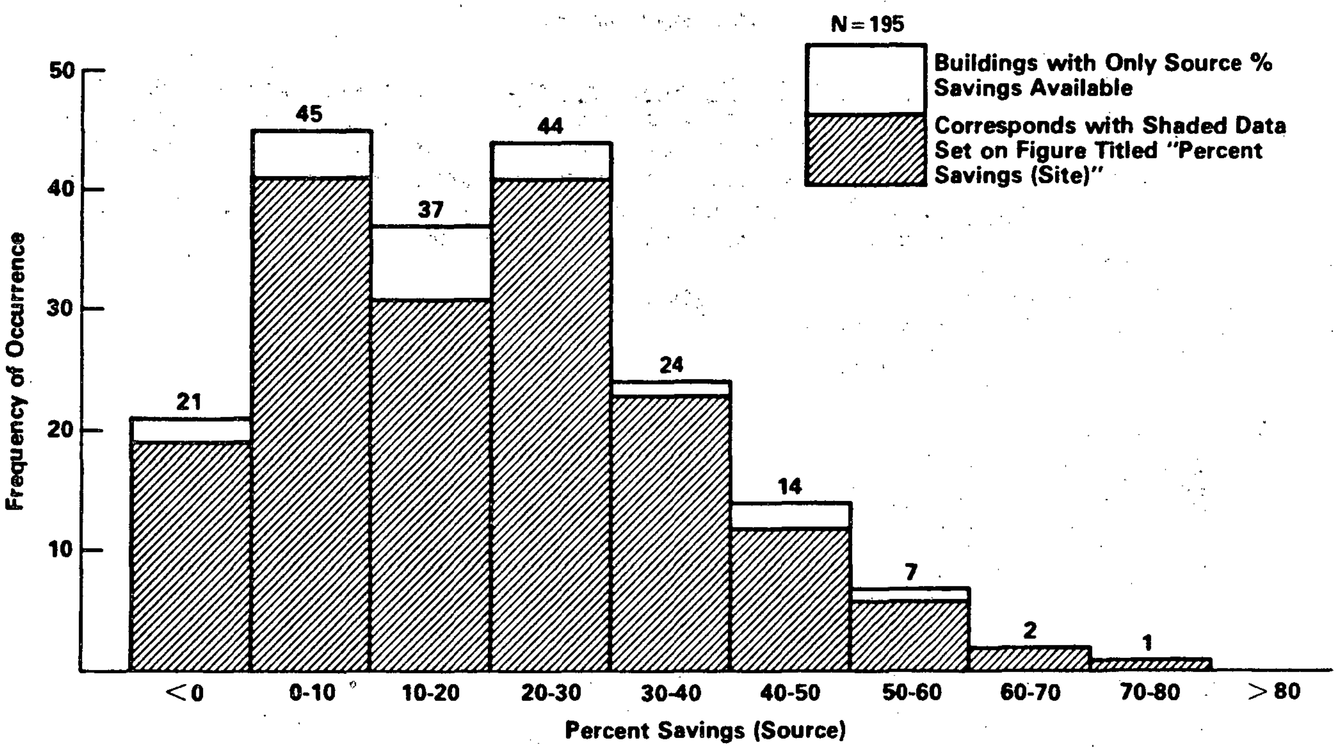


Fig. 5A, B. Site and Source Energy Savings--There is some controversy regarding the accounting of energy savings, whether to express savings in terms of site or source energy. As shown here, little difference in both the average savings or the distribution of savings occurred in the sample for either accounting.

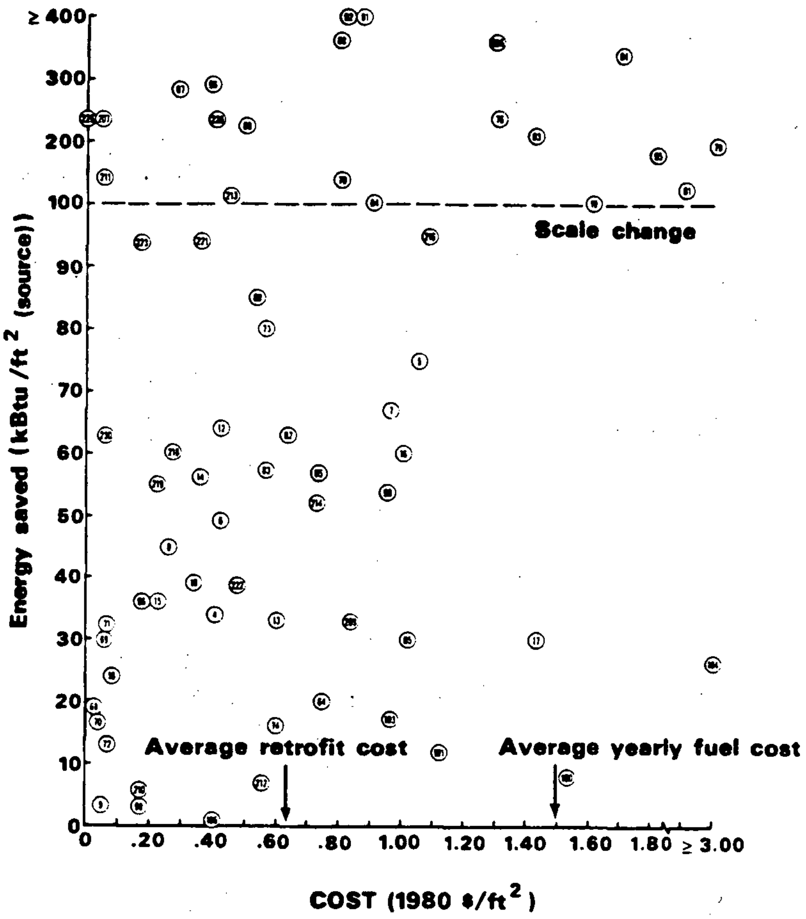
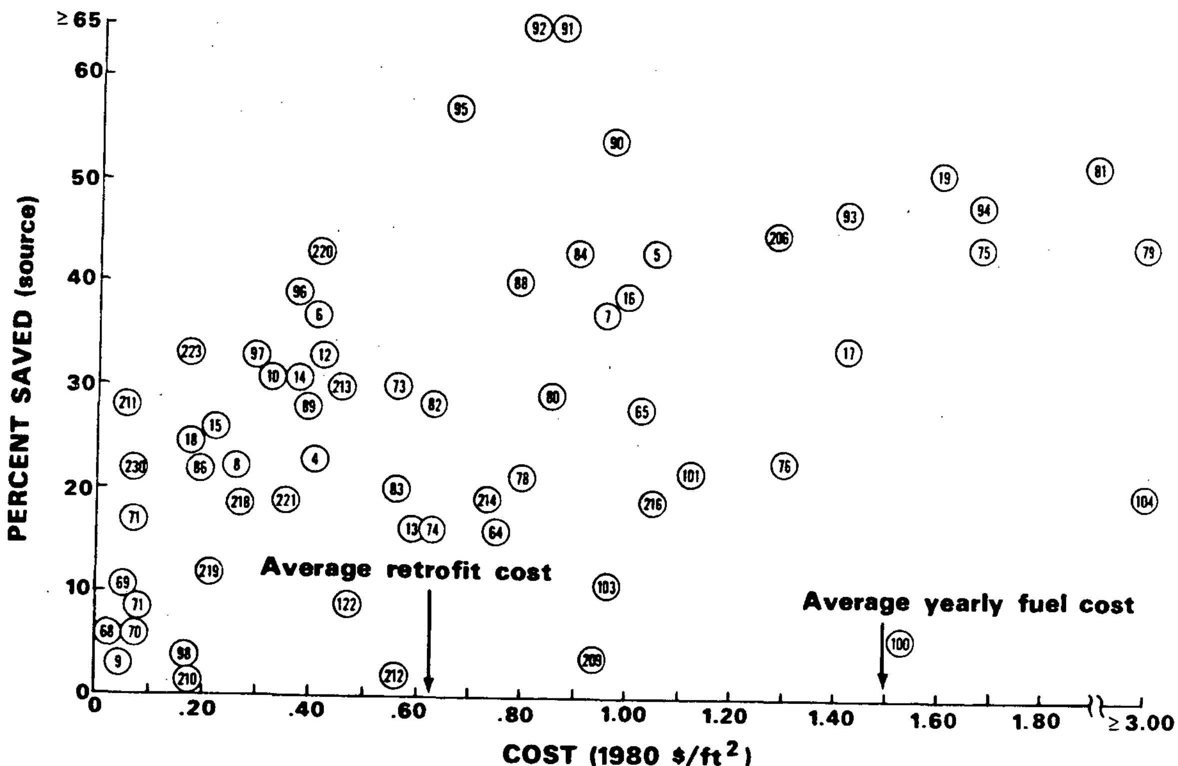


Fig. 6A, B. Energy Savings Versus Cost--Note the scale change on the upper figure. There is tremendous scatter in the data; however in nearly all cases, the savings were very cost-effective. Below, the scatter is reduced when percentage energy savings is plotted versus cost (except at low costs). Note the arrows (↓) denote the average retrofit cost and the average fuel cost/year before retrofit.



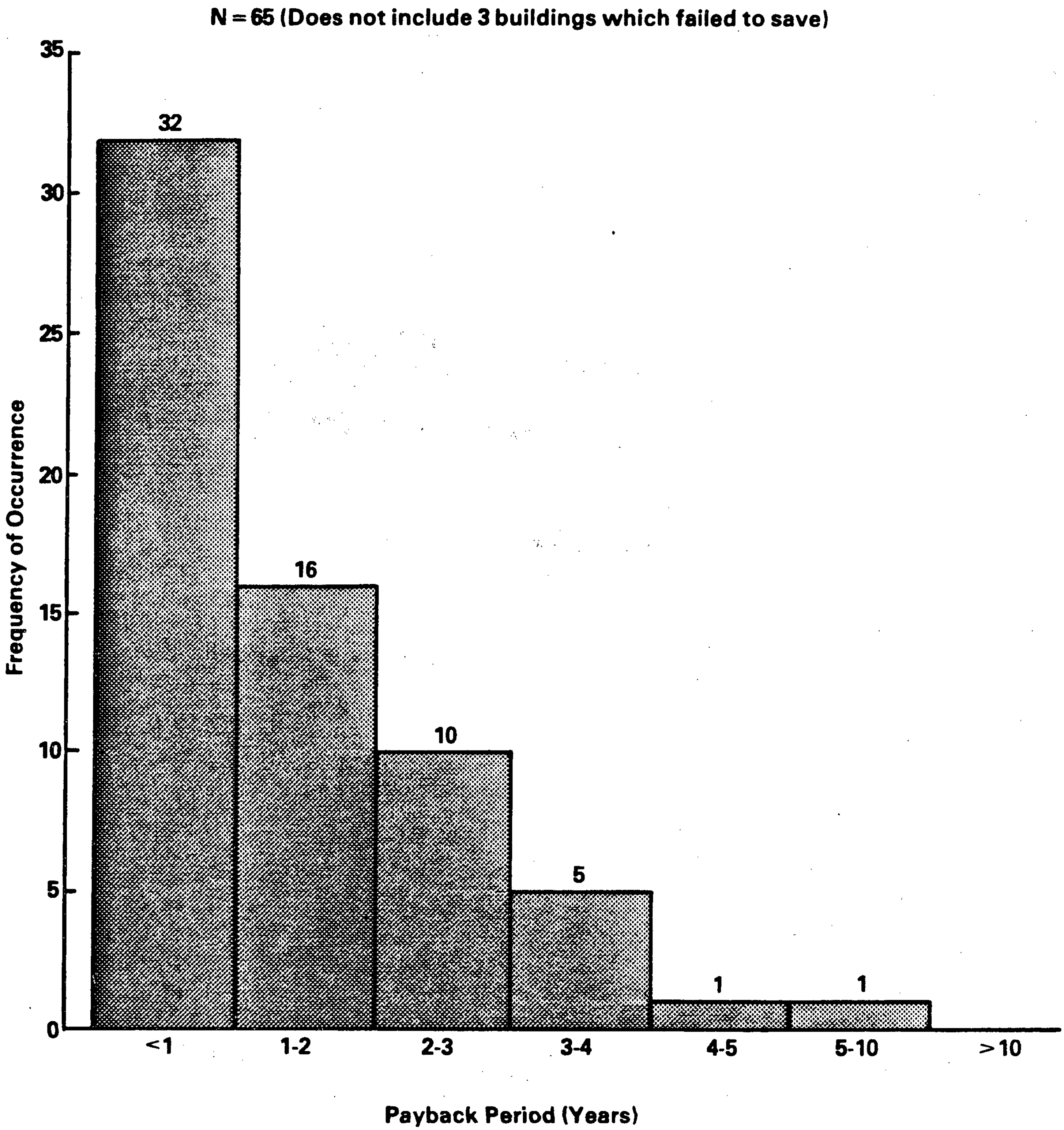
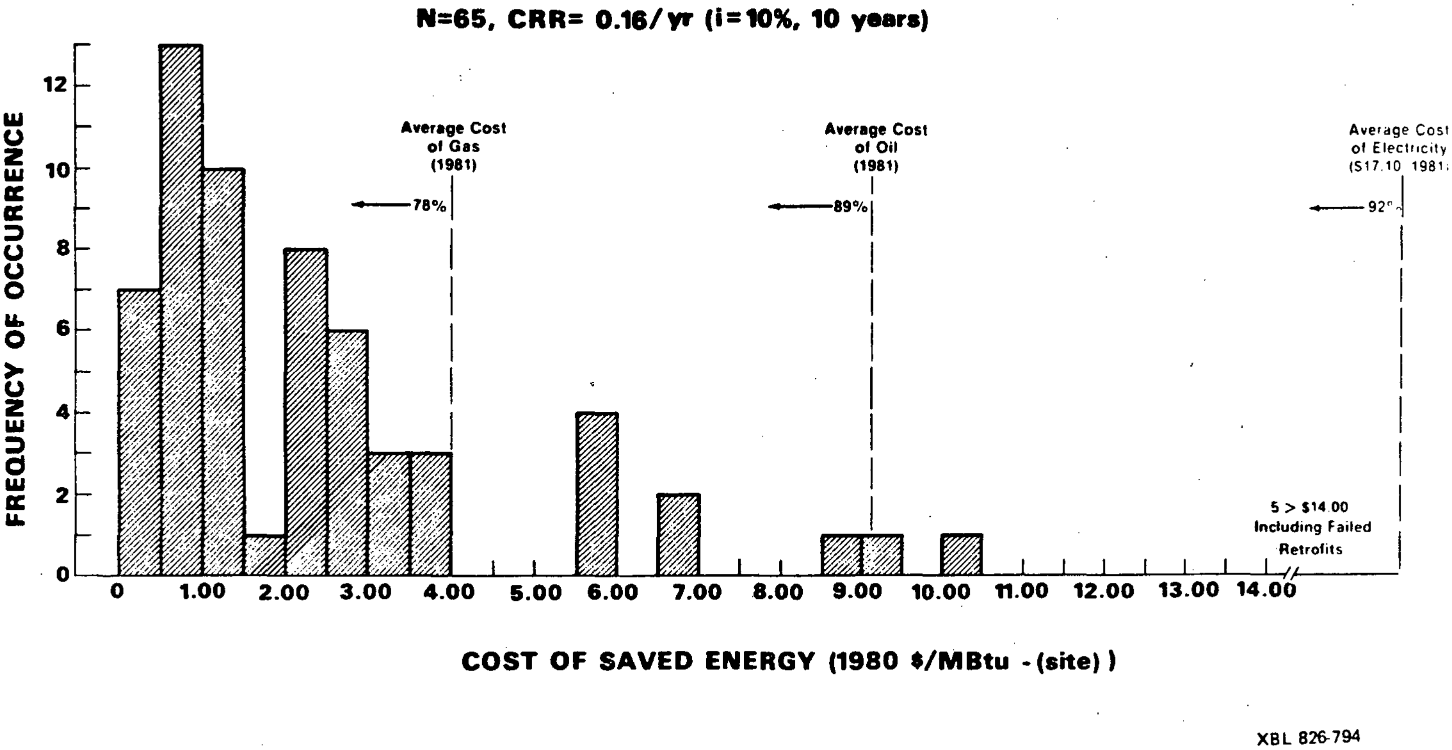


Fig. 7. Simple Payback Period--Note that 89% of the sample achieved a payback within three years. Payback was calculated based on local utility costs or reported "cost avoidance."



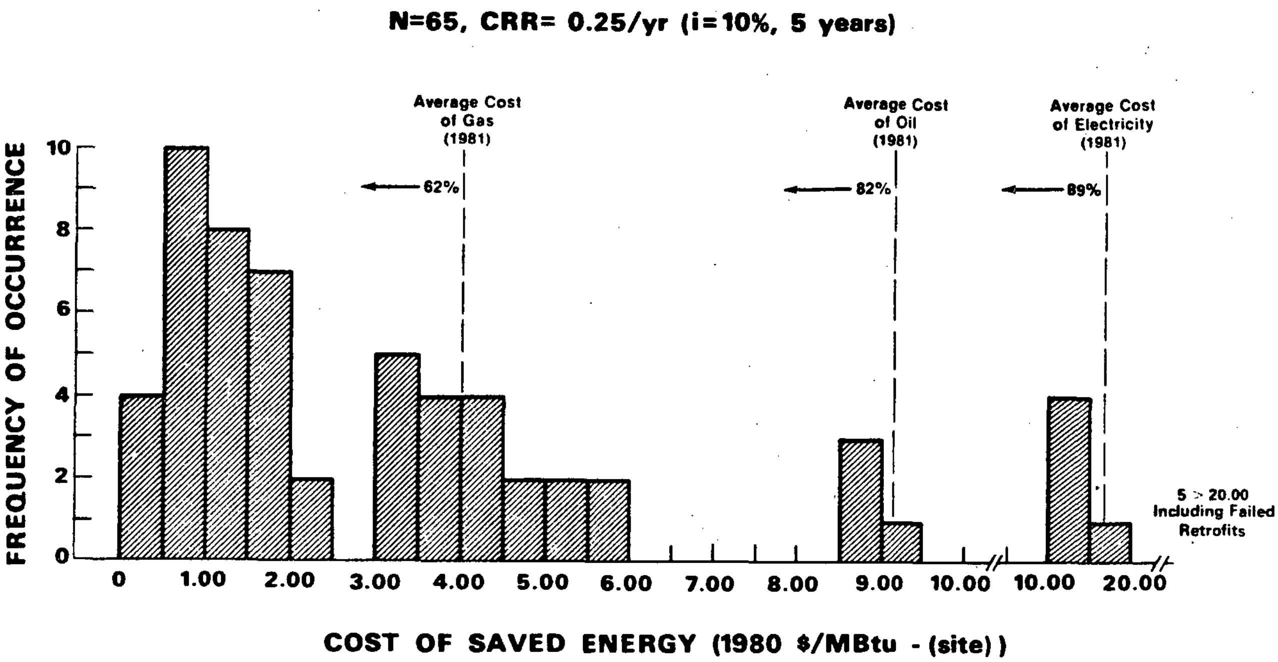


Fig. 8A, B. Cost of Saved Energy--While the cost of saved energy shows a wide distribution, it is usually less than the cost of supplying an equivalent amount of energy. At a CRR= 0.25, 9% of the sample saved energy at a cost less than the mid-1981 commercial building electricity cost as estimated by the U.S. Energy Information Administration. Note that the cost of saved energy (CSE) is related to the payback period (PP) by the following equation: CSE = CRR*PP* Current Fuel Price per million Btu.

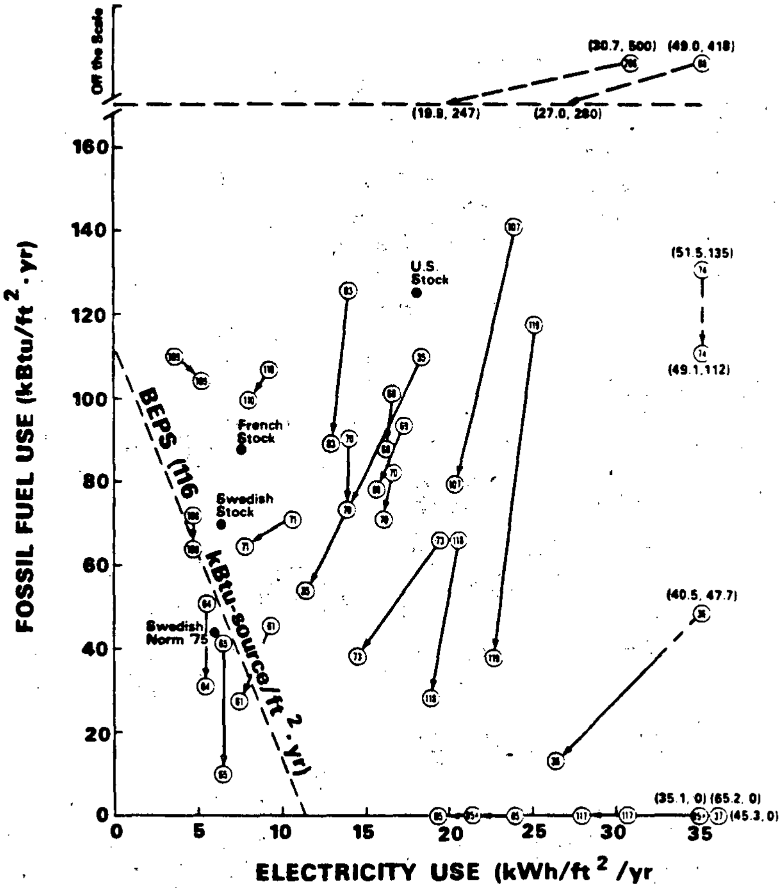


Fig. 9. Energy Use in Office Buildings--The energy use of office buildings is shown before and after retrofit, connected by arrows. Dotted arrows are for buildings which are off scale. As in other building types, the fossil fuel energy savings exceed the electrical energy savings. The "BEPS" line is in terms of resource energy.

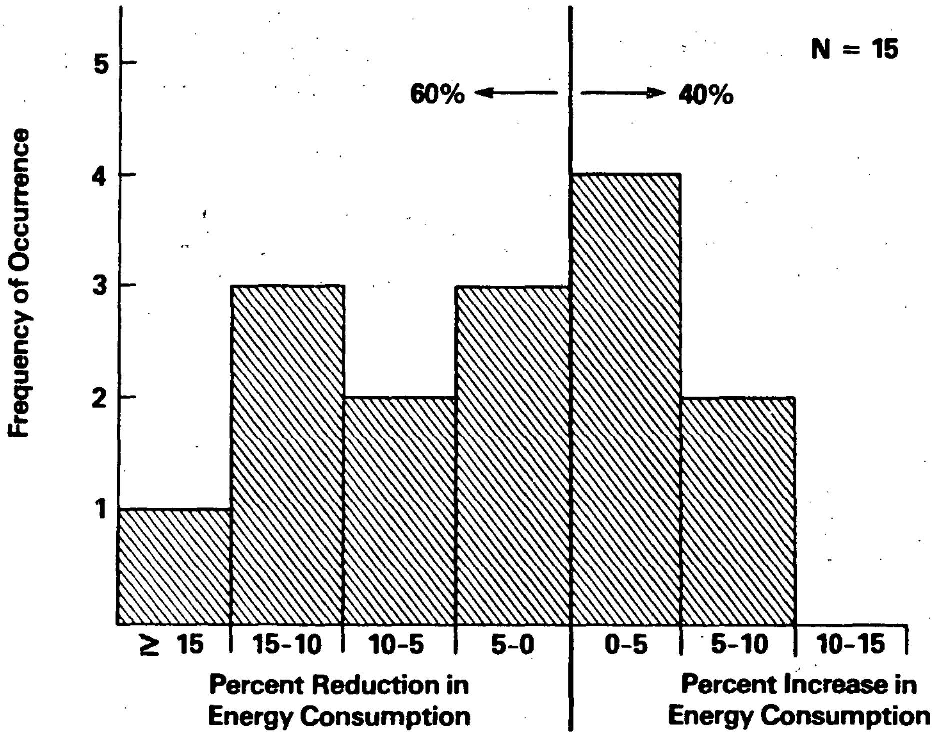


Fig. 10. Retrofit Durability--Energy savings over time tended to be sustainable, with no building increasing its energy use more than 10% after the first year following successful retrofit. Most buildings actually showed a steady decline in energy use in subsequent years.

APPENDIX A: Data Sources

The following is a listing of the reports, companies, and associations which provided data, with a description of their efforts in retrofitting. Also described are some of the difficulties in collecting this data due to the collection effort taking place remotely and "after the fact." The numbers presented parenthetically correspond to the building number of Appendix B which provides more detailed information about each building.

(1-21) Maine Advancement Program (MAP)

The MAP consisted of twenty-one (21) Maine public elementary schools which were retrofitted with state financial assistance via a 90% subsidy to the local school (the remaining 10% was paid for by the school). The state subsidy required schools to be oil-heated and retrofits to have a payback of five years or less. Retrofits concentrated on reducing space heating needs by boarding over windows and re-insulating walls.

(22-33) Total Energy Management Research Report

Research was conducted by the National Electric Contractors Association (NECA) and the National Electrical Manufacturers Association (NEMA) to evaluate the effectiveness of their manual entitled Total Energy Management: A Practical Handbook on Energy Conservation and Management. The manual is intended to provide guidance to building owners and operators on opportunities to save energy in the building. The study involved fourteen (14) office buildings located in Philadelphia, Pennsylvania. NECA-NEMA selected three sample groups for study: (1) Building Managers were provided solely with the Total Energy Management (TEM) manual, #22-#25; (2) Managers were provided with the TEM manual and the assistance of a professional consulting engineer, #26-#28; (3) Managers were given no assistance or consulation, #29-#33. The last group was intended as a control group. Two of its buildings did not retrofit and showed an increased consumption during the study period; however, the remaining three (3) buildings in this group were retrofitted "spontaneously" with an average savings of 24%. The first two sample groups saved 29% and 16% respectively. The small sample size and intervening factors such as changing occupancy prevented NEMA-NECA from drawing conclusions from the intended experiment.

(34-44) Hagler, Bailly and Company

In a study to find commercial buildings whose energy consumption was less than the levels once proposed in the Federal Building Energy Performance Standards (NOPR, 1979), eleven buildings were found which provided information for this study. Although no cost information was gathered by the original investigators, follow-up conversations allowed some cost data to be included in this report.

(45-60) New York State Owned

The Bureau of Energy Conservation (BEC) of New York State began auditing state buildings in 1975. As part of the audit, in 1976 combustion specialists from BEC examined the combustion equipment controls and made modifications where necessary. An independent follow-up study was performed by the Legislative Commission on Expenditure Review (LCER) who studied the utility records of twenty (20) state facilities visited by the BEC staff.

The LCER report contains fossil fuel consumption from 73/74 through 78/79 and electricity usage for the two years of 73/74 and 78/79. Electricity consumption was interpolated linearly for the missing years.

In addition to the LCER report, consumption data for these buildings was also available from the New York State Energy Office for the years 77/78 and 78/79. Discrepancies in the two data sources are shown in Appendix C.

(61-67) RPA

RPA-Paris examined energy use in a few "model" commercial buildings located in Europe. These buildings included new and retrofit examples. The retrofit examples included in this report represent second or third generation attempts to save energy (they are very low energy users); we could not obtain data for the first two efforts.

(68-74) Flack and Kurtz

The engineering consulting firm of Flack and Kurtz submitted data for seven office buildings located in New York City. Before and after energy consumption by fuel type, retrofit measures, cost of retrofit and cost avoidance are available for all buildings.

(75-84) EBASCO

EBASCO Services, Incorporated of New York, NY., retrofits commercial buildings, guaranteeing the savings with a cash payment of any utility bills which exceed the estimated amount after the completion of work. The buildings are either presently being retrofitted or work has been completed recently. Therefore post-retrofit consumption is not the metered value. The data is considered valid, if not conservative, however, due to EBASCO's cash guarantee. Included are four hospitals, three universities, one office building and one multi-family apartment.

(85-84A) Complete Building Services (CBS)

Complete Building Services is a mechanical contracting firm located in Washington, D.C. CBS provides building energy management from their remotely located central office through a central computer control system. Included in this study are an office and shopping mall which are connected to this system. Retrofit costs are for both installation and the monthly service fees.

(85A) Claude, Terry and Associates

Claude, Terry & Associates of Atlanta, Georgia submitted data for one large office building located in Tucker, Georgia.

(86) Robert Fuller and Associates

Data for this school located in Worthington, Ohio was provided by Robert Fuller and Associates, a consulting firm in the area of commercial building retrofit. Energy consumption by fuel type and type and cost of retrofit are available.

Energy conservation began in this school as a matter of necessity. This area of Ohio experienced a natural gas shortage in 1976-1977. As a result, the school conserved energy by sacrificing comfort and by closing on certain days. The following year the gas supply increased as did the consumption (by 6%); however, many retrofit programs which were started during the shortage were continued and/or completed in that year. In the following (78/79) year consumption reduced again. The result is an overall energy reduction of 24% with the school once again comfortable.

(87) Tampa Board of Education

As a test, the Tampa Board of Education installed a computerized energy management control system in one school. It is possible that the system will be expanded to other schools due to the success (28% savings) with its use at this school. Before and after energy consumption, retrofit description and investment are available.

(88-97) Ohio State University

These buildings, one (1) office, seven (7) classrooms, one community center, and one clinic are located on the campus of Ohio State University.

The average percentage savings is 49%, the highest in the sample. Prior to retrofit, these buildings had dual duct or reheat systems and were operated twenty-four (24) hours a day. Energy consumption was well above the average for universities. Due to the initial conditions at the school, high energy savings were easy to obtain at an average cost of $\$.84/ft^2$ (1980 \$).

(98-106) Saving School House Energy

Ten elementary schools were retrofitted by the American Association of Schools Administration with co-funding from industry and the Federal Government. Reductions in energy consumption were substantially less than anticipated. In some cases the consumption actually increased.

(107-116) New Jersey State Owned

Several state facilities are examined. Data includes energy use by fuel type for 72/73 and 78/79. Specific measures implemented in each facility are not included. The report stated that energy consumption declined as a result of operation and maintenance procedures only. An attempt was made to gather more information concerning individual projects and cost; however, this information could not be obtained.

(117-119) West Virginia State Owned

The West Virginia Department of Finance and Administration wrote "State of West Virginia - Energy Report, 1979-80". Included are before and after energy consumption for the years 1975 and 1979 and retrofit measures for the capitol complex buildings. Seven office buildings are included; however, a separate gas and electric meter does not exist for each building. Therefore, two buildings are reported individually and five buildings are grouped together in this study.

(120-201) Buffalo, New York Board of Education

The Buffalo Board of Education submitted energy consumption data by fuel type for the eighty (80) elementary and secondary schools in this area. Energy data from 72/73 to 79/80 is available. All schools were reported to have completed O&M measures; however, it was not possible to determine exactly which procedures were carried out at each school. Major retrofits, such as replacing HVAC equipment or installing double glazing are known for each school.

(204-205) Conservation Initiatives in United States Buildings

The paper gave an overview of the present energy use and the potential for reductions. Included is a compilation of some retrofit case studies for which before and after total site energy, retrofit measures and investments are available.

(206) Hammer Consulting Engineers

The data for this building was provided by Hammer Consulting Engineers who performed the work on the building. The large office is an all electric and energy data is available for 1976-1979.

(206-230) Columbia Association

The Columbia Association of Columbia, Maryland submitted data concerning the retrofitting of the communities buildings. Hittman Associates recommended certain energy conservation measures and the Association implemented all measures with less than a three year payback. Data includes total source energy consumption before and after retrofit (1976 and 1978), retrofit measures and investment. Unfortunately the records of the raw energy data containing site consumption by fuel type have been lost. It should be noted that retrofits involving reflective film over windows will not show energy savings in the data due to a glue failure.

A.2 Additional Data Sources

A number of other data sources exist which could offer additional information concerning the success or failure of energy conservation measures. The following data have not been included in this report for reasons discussed below.

"Cost Containment in Hospitals Through Energy Conservation" discusses the conservation efforts of twenty-one (21) hospitals. Included in each case study is a brief building description, retrofit measure and cost savings. This booklet was written by FRS Dressler Corporation, under contract to the Department of Health, Education and Welfare, and is available from the Government Printing Office, Washington, D.C.

"Campus Energy Management Projects" addresses energy conservation measures, investments and cost savings of more than sixty (60) colleges in the United States and Canada. A copy of this report can be obtained from the Association of Physical Plant Administrators, Washington, D.C. Neither of the above reports generally include the actual energy consumption before and after retrofit for the building or institution.

The Maryland State Department of Education has been keeping records for fifteen hundred (1500) schools (elementary and secondary) since 1977. Energy use by fuel type and cost of energy, on an annual and monthly basis is available. In order to determine the cost and type of retrofit implemented in each school, the individual schools or counties must be contacted.

The United States Postal Service maintains energy records for all the Post Offices in the country. One hundred of the largest buildings (20% of the total floor area) have been retrofitted within the last year. Late in 1981 a final report will be available stating energy and cost savings, type and cost of retrofit. The remaining Post Offices (24,000) have made operational and maintenance revisions.

Energard Corporation located in Bellevue, Washington is an energy management consulting firm which conducts audits, aids in the design phase, and monitors energy use for commercial buildings. This firm has a total data base of 300 buildings (150 of which are currently being worked on). To obtain information concerning specific buildings, a cost of \$30 - \$50 per building should be expected to be paid to Energard according to company sources.

APPENDIX B: Data Tables

The following table represents all the data collected and calculated for this study. The explanation of the table headings is as follows:

A. BUILDING NUMBER:
B. LOCATION: City and state where building is located.
C. AREA: Gross floor area in square feet.
D. USE CATEGORY: predominant use of building's occupied space. ELEM: elementary school; SEC: secondary school or university building; LO: Large office building; HOTEL: hotel or motel; HOS: hospital; CORR: correctional facility; RETAIL: retail or mercantile building; MF-APT: multifamily apartment; CLINIC: outpatient health facility; MALL: collection of retail establishments; COMM CEN: community center, auditorium, etc.; PC: psychiatric center (classified as a hospital in the figures); DC: developmental center (classified as a hospital in the figures).
D1. RETROFIT MEASURE: The retrofits installed; O: operations and maintenance; L: Lighting; W: Windows; C: caulking and weatherstripping; I: insulation; H: heating, ventilation or air conditioning systems; A: architectural changes (actually only doors); E: automated energy management control systems.
E. BEFORE ELECTRICITY: electrical energy use before retrofit in kWh/ft^2.
E1. BEFORE ELECTRICITY SITE: obtained by multiplying column E (kWh/ft^2) by 3.413 to express in units of $kBtu/ft^2$.
E2. BEFORE ELECTRICITY SOURC: obtained by multiplying column E1 ($kBtu/ft^2$) by 3.
E(F). BEFORE FUEL SOURC: oil, gas or steam use at source before retrofit. These values are the same as the site values for oil and gas, while for steam the site value was multiplied by 1.2 to obtain a corresponding source value. Units are in $kBtu/ft^2$.
E(T). BEFORE TOTAL SOURC: the sum of electricity and fuel use before retrofit in $kBtu/ft^2$, obtained by adding columns E2 and E(F).
F. AFTER ELECTRICITY: electrical energy use after retrofit in kWh/ft^2.
F1. AFTER ELECTRICITY SITE: obtained by multiplying column F (kWh/ft^2) by 3.413 to express in units of $kBtu/ft^2$.
F2. AFTER ELECTRICITY SOURC: obtained by multiplying column F1 ($kBtu/ft^2$) by 3.
F(F). AFTER FUEL SOURC: oil, gas or steam use after retrofit. (See comments above for E(F))
F(T). AFTER TOTAL SOURC: the sum of electricity and fuel use after retrofit in $kBtu/ft^2$ obtained by adding columns F2 and F(F).
G1. SAVED SITE: the amount of site energy saved due to retrofit in $kBtu/ft^2$. This was obtained by taking the sum of site electricity and fuel before retrofit and subtracting the sum of site electricity and fuel after retrofit.
G2. SAVED SOURC: the amount of source energy saved due to retrofit in $kBtu/ft^2$ obtained by taking column E(T) and subtracting column F(F).
H1. SAVED PERCENT SITE: the percent G1 (SAVED SITE) is of the sum of the site electricity and fuel before retrofit.
H2. SAVED PERCENT SOURC: the percent column G2 (SAVED SOURC) is of column E(T) (BEFORE TOTAL SOURC).
K. SIMP PAYB YRS: the simple payback period in years. This is based on

either local utility costs, or cost avoidance values provided by building operators or owners. When a monthly service fee was part of the cost of the retrofit as was the case in automated energy management control systems, these costs were included in calculating payback.

J. COST OF RETROFIT: the cost of the retrofit in 1980 dollars per gross floor area in square feet. Costs were normalized to 1980 dollars, based on the Gross National Product Price Deflators.

L1. COST PER ANNUAL SAVINGS SITE: obtained by taking column J and dividing it by column G1. In units of 1980 dollars per million Btu per year (1980 $/MBtu/yr).

L2. COST PER ANNUAL SAVINGS SOURC: obtained by taking column J and dividing it by column G2. In units of 1980 dollars per million Btu per year (1980$/MBtu/yr).

L3. COST OF CONSERVED SITE ENERGY, CRR=.16: This is the conventional "Cost of Conserved Energy" for a real interest rate of 10% and a retrofit life of 10 years. It is obtained by multiplying column L2 by 0.16.

L4. COST OF CONSERVED SITE ENERGY, CRR=.25: This is the conventional "Cost of Conserved Energy" for a real interest rate of 10% and a retrofit life of 5 years. It is obtained by multiplying column L2 by 0.25.

M. COOLG DEGR DAYS: the typical number of cooling degree days for the city in which the building is located, assuming a base temperature of 50 degrees Fahrenheit.

N. HEATG DEGR DAYS: the typical number of heating degree days for the city in which the building is located, assuming a base temperature of 60 degrees Fahrenheit.

A	B		C	D	D1	E	E1	E2	E(F)	E(T)	F	F1	F2	F(F)	F(T)
						<-- ANNUAL ENERGY USE PER SQ. FT. -->									
						<------- BEFORE ------>					<-------- AFTER -------->				
						<--ELECTRICITY-->			FUEL	TOTAL	<--ELECTRICITY-->			FUEL	TOTAL
BLDG NO	LOCATION		AREA (KSQFT)	USE CAT.	RETROFIT MEASURE	(KWH)	(KBTU) SITE	(KBTU) SOURC	(KBTU) SOURC	(KBTU) SOURC	(KWH)	(KBTU) SITE	(KBTU) SOURC	(KBTU) SOURC	(KBTU) SOURC
-----	--------------------		*******	-----	--------	*****	-----	-----	*****	-----	*****	-----	-----	*****	-----
1	AUBURN	ME	33.6	ELEM	W				112	112.0				74	74.0
2	AUBURN	ME	55.6	ELEM	W I				88	88.0				45	45.0
3	AUBURN	ME	133.5	SEC	O C				115	115.0				84	84.0
4	BREWER	ME	111.7	SEC	OLWC	4.33	14.8	44.4	100	144.4	3.85	13.1	39.4	72	111.4
5	BREWER	ME	16.7	ELEM	O WC	2.14	7.3	21.9	152	173.9	2.04	7.0	20.9	78	98.9
6	BREWER	ME	10.4	ELEM	O WC	2.46	8.4	25.2	106	131.2	2.46	8.4	25.2	61	86.2
7	BREWER	ME	15.6	ELEM	OLWC	4.51	15.4	46.2	134	180.2	3.05	10.4	31.2	82	113.2
8	CHINA	ME	28.8	ELEM	O I	3.54	12.1	36.3	170	206.3	3.32	11.3	34.0	127	161.0
9	LIMESTONE	ME	147.6	SEC	O	4.03	13.8	41.3	39	80.3	3.87	13.2	39.6	37	76.6
10	LITCHFIELD	ME	26.0	ELEM	O WC	2.30	7.9	23.6	133	156.6	2.40	8.2	24.6	83	107.6
11	MILLINOCKET	ME	17.6	ELEM	WCI				123	123.0				71	71.0
12	PORTLAND	ME	55.6	ELEM	O CI	5.70	19.5	58.4	135	193.4	5.00	17.1	51.2	78	129.2
13	PORTLAND	ME	21.5	ELEM	O CI A	4.50	15.4	46.1	165	211.1	3.90	13.3	40.0	138	178.0
14	PORTLAND	ME	99.0	ELEM	O CI	4.10	14.0	42.0	152	194.0	3.60	12.3	36.9	99	135.9
15	PORTLAND	ME	153.7	EL+SEC	O CI	3.60	12.3	36.9	112	148.9	3.30	11.3	33.8	78	111.8
16	DEXTER	ME	8.8	ELEM	O W H	2.40	8.2	24.6	130	154.6	3.00	10.2	30.7	64	94.7
17	DEXTER	ME	54.8	ELEM	O W I	3.40	11.6	34.8	156	190.8	4.10	14.0	42.0	90	132.0
18	DEXTER	ME	66.5	SEC	O C	5.00	17.1	51.2	171	222.2	4.50	15.4	46.1	124	170.1
19	DEXTER	ME	5.8	ELEM	O W H	3.00	10.2	30.7	173	203.7	2.90	9.9	29.7	73	102.7
20	ELLSWORTH	ME	90.5	SEC	O W I A				146	146.0				72	72.0
21	LAMOINE	ME	14.4	ELEM	O W I A				96	96.0				48	48.0
22	PHILADELPHIA	PA	496.0	LO	OL										
23	PHILADELPHIA	PA	207.8	LO	OL										
24	PHILADELPHIA	PA	435.0	LO	OL										
25	PHILADELPHIA	PA	385.0	LO	OL										
26	PHILADELPHIA	PA	255.2	LO	OL										
27	PHILADELPHIA	PA	149.4	LO	OL										
28	PHILADELPHIA	PA	422.3	LO	OL										
29	PHILADELPHIA	PA	113.8	LO	OL										
30	PHILADELPHIA	PA	218.1	LO	OL										
31	PHILADELPHIA	PA	245.9	LO	O										
32	PHILADELPHIA	PA	234.8	LO	O										
33	PHILADELPHIA	PA	545.1	LO	OL										
34	HOUSTON	TX	486.9	SEC	OL	11.50	39.3	117.8	137	254.8	11.90	40.6	121.9	128	249.9
35	ST PAUL	MN	840.0	LO	OL	18.30	62.5	187.5	110	297.5	11.50	39.3	117.8	55	172.8
36	ATLANTA	GA	320.0	LO	OL	40.50	138.3	414.9	57	472.1	26.60	90.8	272.5	15	287.5
37	HOUSTON	TX	578.2	LO	OL	65.20	222.7	668.0		668.0	45.30	154.7	464.1		464.1
38	ATLANTA	GA	566.8	HOTEL	E	23.10	78.9	236.7	123	359.7	21.80	74.4	223.3	100	323.3
39	ATLANTA	GA	197.0	HOTEL	H	66.00	225.4	676.2	81	757.2	23.00	78.5	235.6	65	300.6
40	CHICAGO	IL	331.5	HOTEL	O H	32.30	110.3	330.9	179	509.9	28.40	97.0	291.0	144	435.0
41	PHILADELPHIA	PA	430.5	HOTEL	H	25.00	85.4	256.1	294	550.1	22.80	77.9	233.6	254	487.6
42	CLEVELAND	OH		HOS	O										
43	LONG BEACH	CA		HOS	L E										
44	NEW BRUNSWICK	NJ		HOS	OL										
45	NEWARK	NJ	938.8	DC1	O	5.50	18.8	56.3	223	279.3	5.70	19.5	58.4	209	267.4
46	BINGHAMTON	NY	3308.5	SEC	O	13.40	45.8	137.3	154	291.3	9.30	31.8	95.3	135	230.3
47	SYRACUSE	NY	1322.2	PC	O	4.60	15.7	47.1	196	243.1	4.50	15.4	46.1	218	264.1
48	ROME	NY	1385.0	PC	O	5.50	18.8	56.3	230	286.3	5.20	17.8	53.3	221	274.3
49	MORRISTOWN	NY	1124.5	SEC	O	8.30	28.3	85.0	168	253.0	8.20	28.0	84.0	154	238.0
50	ALBANY	NY	553.3	CORR	O				289	289.0				302	302.0
51	STATEN ISLAND	NY	2639.2	DC	O	5.30	18.1	54.3	285	339.3	4.70	16.1	48.2	258	306.2
52	ISLIP	NY	2681.8	PC	O	4.40	15.0	45.1	300	345.1	4.40	15.0	45.1	260	305.1
53	LONG ISLAND	NY	4361.4	PC	O	3.80	13.0	38.9	226	264.9	3.80	13.0	38.9	209	247.9
54	NAPPONOCK	NY	755.0	CORR	O	5.60	19.1	57.4	193	250.4	6.20	21.2	63.5	182	245.5
55	ROCHESTER	NY	1201.3	CORR	O	5.10	17.4	52.2	205	257.2	5.40	18.4	55.3	189	244.3
56	CLINTON	NY	1317.4	CORR	O	9.20	31.4	94.3	382	476.3	10.30	35.2	105.5	392	497.5
57	AUBURN	NY	1074.0	CORR	O				192	192.0				189	189.0
58	ELMIRA	NY	1315.5	CORR	O	3.60	12.3	36.9	180	216.9	3.80	13.0	38.9	187	225.9
59	ALBANY	NY	553.0	CORR	O	3.20	10.9	32.8	140	172.8	3.50	12.0	35.9	118	153.9
60	NEW YORK	NY	2018.6	PS	O	6.30	21.5	64.5	236	300.5	6.60	22.5	67.6	281	348.6
61	PARIS	FR	988.2	LO	O	9.10	31.1	93.2	46	139.2	7.60	26.0	77.9	29	106.9
62	ROCHEFORT	FR	6.4		O H										
63	STOCKHOLM	SW	96.9	LO	O W I	2.10	7.2	21.5	43	64.5					
64	STOCKHOLM	SW	452.1	LO	O W E	5.60	19.1	57.4	50	107.4	5.40	18.4	55.3	32	87.3
65	STOCKHOLM	SW	183.0	LO	O W	6.60	22.5	67.6	41	108.6	6.60	22.5	67.6	11	78.6

A	C1	C2	H1	H2	K	J	L1	L2	L3	L4	M	N	
BLDG NO	<---- S A V E D ----> (KBTU/SQFT) SITE	SOURC	(PERCENT) SITE	SOURC	SIMP PAYB YRS	COST OF RETRO-FIT (1980$ /SQFT)	COST PER ANNUAL SAVINGS (1980 $/ MBTU/YR) SITE	SOURC	COST OF CONSEVED SITE ENERGY ($/MBTU) CRR= .16	CRR= .25	COOLG DEGR DAYS	HEATG DEGR DAYS	COMMENTS
					****	******					*****	*****	
1	38.0	38.0	34	34	3-4	.89	23.4	23.4	3.7	5.9	1890	6035	
2	43.0	43.0	49	49	2-3	.19	4.4	4.4	.7	1.1	1890	6035	
3	31.0	31.0	27	27	<1	.01	.3	.3	.1	.1	1890	6035	
4	29.6	32.9	26	23	1-2	.41	13.8	12.5	2.2	3.5	1896	6496	
5	74.3	75.0	47	43	1-2	1.05	14.1	14.0	2.3	3.5	1896	6496	
6	45.0	45.0	39	34	1-2	.42	9.3	9.3	1.5	2.3	1896	6496	
7	57.0	67.0	38	37	1-2	.96	16.8	14.3	2.7	4.2	1896	6496	
8	43.8	45.3	24	22	<1	.26	5.9	5.7	1.0	1.5	1896	6496	
9	2.5	3.6	5	5	3-4	.05	19.6	13.7	3.1	4.9	128	9632	
10	49.7	49.0	35	31	<1	.34	6.8	6.9	1.1	1.7	1890	6035	
11	52.0	52.0	42	42	3-4	2.30	44.2	44.2	7.1	11.1	1379	8044	
12	59.4	64.2	38	33	<1	.42	7.1	6.5	1.1	1.8	1890	6035	
13	29.0	33.1	16	16	2-3	.60	20.7	18.1	3.3	5.2	1890	6035	
14	54.7	58.1	33	30	<1	.36	6.6	6.2	1.1	1.6	1890	6035	
15	35.0	37.1	28	25	<1	.22	6.3	5.9	1.0	1.6	1890	6035	
16	64.0	59.9	46	39	1-2	1.00	15.6	16.7	2.5	3.9	1896	6496	
17	63.6	58.8	38	31	2-3	1.42	22.3	24.1	3.6	5.6	1896	6496	
18	48.7	52.1	26	23	<1	.18	3.7	3.5	.6	.9	1896	6496	
19	100.3	101.0	55	50	2-3	1.60	15.9	15.8	2.6	4.0	1896	6496	
20	74.0	74.0	51	51							1896	6496	
21	48.0	48.0	50	50							1896	6496	
22	17.0		15								3679	3753	
23	17.0		18								3679	3753	
24	43.0		36								3679	3753	
25	60.0		27								3679	3753	
26	53.0		4								3679	3753	
27	43.0		36								3679	3753	
28	9.0		8								3679	3753	
29	9.0		8								3679	3753	
30	2.0		2								3679	3753	
31	-32.0		-23								3679	3753	
32	50.0		27								3679	3753	
33	39.0		20								3679	3753	
34	7.6	4.9	4	2							7150	864	
35	78.2	124.7	45	42							2575	6842	
36	89.7	184.6	46	39							4880	2189	STEAM FED, FUEL INCREASED 20 PERCENT
37	68.0	203.9	31	31							7150	684	
38	27.4	36.3	14	10							4880	2189	
39	162.8	456.5	53	60							4880	2189	
40	48.3	75.0	17	15							3372	4952	
41	47.5	62.5	13	11							3679	3753	
42	61.0		18								2807	4901	
43	174.0		62								4928	772	
44	53.0		12								3482	3818	
45	13.3	12.0	6	4							3533	3911	
46	33.0	61.0	17	21							2231	5908	
47	-21.7	-21.0	-9	-8							2621	5379	
48	10.0	12.1	4	4							2621	5379	
49	14.3	15.0	7	6							2621	5379	
50	-13.0	-13.0	-3	-3							2619	5596	
51	29.0	33.1	10	10							3533	3911	
52	40.0	40.0	13	12							3278	4023	
53	17.0	17.0	7	6							3278	4023	
54	9.0	4.9	4	2							2619	5596	
55	15.0	12.9	7	5							2580	5417	
56	-13.8	-21.3	-2	-3							2180	6488	
57	3.0	3.0	2	2							2621	5779	
58	-7.7	-9.0	-3	-3							2231	5908	
59	21.0	18.9	14	11							5596	2619	
60	-46.0	-48.1	-17	-15							3653	3739	
61	22.1	32.4	29	23							193	4986	
62	242.0		61		3-4	8.80	36.4		5.8	9.1			
63	22.0		43			3.08	140.0		22.4	35.0	159	7832	
64	18.7	20.0	27	19		.75	40.1	37.4	6.4	10.0	159	7832	
65	30.0	30.0	47	28		1.02	34.0	34.0	5.4	8.5	159	7832	

A	B		C	D	D1	E	E1	E2	E(F)	E(T)	F	F1	F2	F(F)	F(T)
						<-- ANNUAL ENERGY USE PER SQ. FT. -->									
						<------- BEFORE ------>					<-------- AFTER -------->				
						<--ELECTRICITY-->			FUEL	TOTAL	<--ELECTRICITY-->			FUEL	TOTAL
BLDG NO	LOCATION		AREA (KSQFT) *******	USE CAT.	RETROFIT MEASURE	(KWH) *****	(KBTU) SITE	(KBTU) SOURC	(KBTU) SOURC *****	(KBTU) SOURC	(KWH) *****	(KBTU) SITE	(KBTU) SOURC	(KBTU) SOURC *****	(KBTU) SOURC
66															
67	CAMBRIDGE	UK	133.5	SEC	O H E										
68	NEW YORK	NY	1500.0	LO	O	16.60	56.7	170.1	120	290.1	16.10	55.0	164.9	107	271.9
69	NEW YORK	NY	589.0	LO	O	17.10	58.4	175.2	112	287.2	15.80	54.0	161.9	95	256.9
70	NEW YORK	NY	449.0	LO	O	16.50	56.3	169.0	98	267.0	16.00	54.6	163.9	86	249.9
71	NEW YORK	NY	448.0	LO	O H	10.40	35.5	106.5	85	191.5	7.90	27.0	80.9	78	158.9
72	NEW YORK	NY	412.0	LO	O H	13.90	47.5	142.4	108	250.4	13.80	47.1	141.4	86	227.4
73	HARTSDALE	NY	48.0	SO	O	19.70	67.3	201.8	66	267.8	14.60	49.9	149.6	39	188.6
74	NEW YORK	NY	141.0	LO	O H	51.50	175.9	527.6	162	689.6	49.10	167.7	503.0	134	637.0
75	MACON	GA	600.0	HOSP	O W H	20.70	70.7	212.1	203	415.1	11.80	40.3	120.9	113	233.9
76	LOS ANGELES	CA	208.0	HOSP	O H	45.70	156.1	468.2	563	1031.2	35.40	120.9	362.7	428	790.7
77															
78	NEW YORK	NY	1507.0	HOSP	OL CIH E	16.90	57.7	173.1	396	569.1	14.60	49.9	149.6	299	448.6
79	ENGLEWOOD	CA	148.0	HOSP	OL H	126.00	430.3	1290.9		1290.9	70.00	239.1	717.2		717.2
80	MADISON	NJ	354.0	SEC	OL CIH	5.50	18.8	56.3	128	184.3	4.60	15.7	47.1	84	131.1
81	LOS ANGELES	CA	124.0	SEC	OLW H E	18.50	63.2	189.5	50	239.5	9.20	31.4	94.3	20	114.3
82	MADISON	NJ	686.0	SEC	OLW IH	10.20	34.8	104.5	121	225.5	7.00	23.9	71.7	90	161.7
83	NEW YORK	NY	1482.0	LO	OLW IH	13.90	47.5	142.4	125	267.4	13.00	44.4	133.2	85	218.2
84	NEW YORK	NY	76.0	MF	WCIH	.90	3.1	9.2	233	242.2	.90	3.1	9.2	129	138.2
84A	POTOMAC	MD	158.5	MALL	E	18.00	61.5	184.4		184.4	15.90	54.3	162.9		162.9
85	ROCK SPRINGS	MD	136.0	LO	E	23.90	81.6	244.9		244.9	19.60	66.9	200.8		200.8
85A	TUCKER	GA	251.3	LO	OLW H	35.10	119.9	359.6		359.6	21.50	73.4	220.3		220.3
86	WORTHINGTON	OH	62.1	SEC	OL	7.50	25.6	76.8	90	167.2	6.30	21.5	64.5	66	131.0
87	TAMPA	FL	216.0	SEC	E	19.90	68.0	203.9		203.9	14.30	48.8	146.5		146.5
88	COLUMBUS	OH	221.8	LO	OL H	49.00	167.3	502.0	418	920.0	27.00	92.2	276.6	280	556.6
89	COLUMBUS	OH	114.9	SEC	OL H	43.00	146.8	440.5	375	815.5	25.00	85.4	256.1	334	590.1
90	COLUMBUS	OH	66.3	SEC	OL H	21.00	71.7	215.1	491	706.1	9.00	30.7	92.2	232	324.2
91	COLUMBUS	OH	79.5	SEC	OL H	21.00	71.7	215.1	414	629.1	9.00	30.7	92.2	91	183.2
92	COLUMBUS	OH	102.7	SEC	OL H	27.00	92.2	276.6	340	616.6	13.00	44.4	133.2	73	206.2
93	COLUMBUS	OH	108.9	CLINIC	OL H	30.00	102.5	307.4	142	449.4	16.00	54.6	163.9	75	238.9
94	COLUMBUS	OH	94.5	COMMCE	OL H	26.00	88.8	266.4	431	697.4	17.00	58.1	174.2	181	355.2
95	COLUMBUS	OH	84.0	SEC	OL H	35.70	121.9	365.7	392	757.7	13.20	45.1	135.2	185	320.2
96	COLUMBUS	OH	104.7	SEC	OL H	23.40	79.9	239.7	530	769.7	16.20	55.3	166.0	306	472.0
97	COLUMBUS	OH	181.6	SEC	OL	34.60	118.2	354.5	510	864.5	28.90	98.7	296.1	280	576.1
98	LUBBOCK	TX	36.8	ELEM	O	2.10	7.2	21.5	62	83.5	2.10	7.2	21.5	60	81.5
99	LANGHORNE	PA	49.3	ELEM	O	3.20	10.9	32.8	64	96.8	4.70	16.1	48.2	57	105.2
100	GLENROCK	NJ	45.4	ELEM	O I	3.40	11.6	34.8	86	120.8	4.40	15.0	45.1	68	113.1
101	WARWICK	RI	27.6	ELEM	O I	4.00	13.7	41.0	70	111.0	4.00	13.7	41.0	45	86.0
102	SIOUX FALLS	SD	33.7	ELEM	O	25.00	85.4	256.1	65	321.1	29.00	99.0	297.1	44	341.1
103	COLUMBUS	OH	43.8	ELEM	O	3.70	12.6	37.9	120	157.9	4.40	15.0	45.1	96	141.1
104	KENNIWICK	WA	40.1	ELEM	OL I	5.00	17.1	51.2	81	132.2	3.50	12.0	35.9	70	105.9
105	STEVENS PT	WI	44.0	ELEM	OL	8.20	28.0	84.0	51	135.0	9.20	31.4	94.3	46	140.3
106	LINCOLN	NB	32.0	ELEM	OL	2.90	9.9	29.7	48	77.7	2.90	9.9	29.7	48	77.7
107	NEWARK	NJ	1527.0	LO	O	23.70	80.9	242.8	140	382.8	20.30	69.3	208.0	80	288.0
108	NEWARK	NJ	2077.0	LO	O	4.70	16.1	48.2	71	119.2	4.80	16.4	49.2	65	114.2
109	NEWARK	NJ	650.0	LO	O	3.80	13.0	38.9	110	148.9	4.10	14.0	42.0	105	147.0
110	NEWARK	NJ	1268.0	LO	O	9.10	31.1	93.2	107	200.2	8.30	28.3	85.0	100	185.0
111	NEWARK	NJ	9485.0		O	8.50	29.0	87.1	287	374.1	8.60	29.4	88.1	281	369.1
112	NEWARK	NJ	1624.0	CORR	O	18.80	64.2	192.6	607	799.6	18.60	63.5	190.6	594	784.6
113	NEWARK	NJ	837.0	SEC	O	13.80	47.1	141.4	159	300.4	11.10	37.9	113.7	108	221.7
114	NEWARK	NJ	10311.0	SEC	O	12.60	43.0	129.1	180	309.1	12.10	41.3	124.0	137	261.0
115	NEWARK	NJ	7592.0	SEC	O	14.40	49.2	147.5	197	344.5	13.90	47.5	142.4	164	306.4
116	NEWARK	NJ	400.0	LO	O										
117	CHARLESTON	WV	226.8	LO	OL	30.20	103.1	309.4		309.4	28.10	96.0	287.9		287.9
118	CHARLESTON	WV	88.3	LO	OL	20.30	69.3	208.0	66	274.0	18.80	64.2	192.6	29	221.6
119	CHARLESTON	WV	1079.2	LO	OLW E	25.00	85.4	256.1	117	373.1	22.60	77.2	231.5	39	270.5
120	BUFFULO	NY	64.0	ELEM	O	2.20	7.5	22.5	105	127.5	3.00	10.2	30.7	88	118.7
121	BUFFALO	NY	87.0	ELEM	O	3.10	10.6	31.8	95	126.8	3.10	10.6	31.8	110	141.8
122	BUFFALO	NY	139.0	ELEM	O	1.80	6.1	18.4	98	116.4	2.70	9.2	27.7	95	122.7
123	BUFFALO	NY	109.0	ELEM	O	2.90	9.9	29.7	70	99.7	2.00	6.8	20.5	51	71.5
124	BUFFALO	NY	81.8	ELEM	O	2.10	7.2	21.5	113	134.5	2.40	8.2	24.6	120	144.6
125	BUFFALO	NY	67.8	ELEM	OL	2.00	6.8	20.5	85	105.5	1.80	6.1	18.4	82	100.4

A	C1	C2	H1	H2	K	J	L1	L2	L3	L4	M	N	
	<—— S A V E D ——>					COST OF RETRO- FIT	COST PER ANNUAL SAVINCS (1980 $/ MBTU/YR)		COST OF CONSEVED SITE ENERGY ($/MBTU)				
BLDG NO	(KBTU/SQFT) SITE	SOURC	(PERCENT) SITE	SOURC	SIMP PAYB YRS ****	(1980$ /SQFT) ******	SITE	SOURC	CRR= .16	CRR= .25	COOLG DEGR DAYS *****	HEATG DEGR DAYS *****	COMMENTS
66													
67	47.0		44		1-2	.62	13.2		2.1	3.3			
68	14.7	18.1	8	6	<1	.02	1.3	1.0	.2	.3	3653	3739	STEAM FED, FUEL INCREASED 20 PERCENT
69	21.4	30.3	13	11	<1	.06	2.6	1.8	.4	.6	3653	3739	STEAM FED, FUEL INCREASED 20 PERCENT
70	13.7	17.1	9	6	<1	.05	3.9	3.2	.6	1.0	3653	3739	STEAM FED, FUEL INCREASED 20 PERCENT
71	15.5	32.6	13	17	<1	.06	4.1	2.0	.7	1.0	3653	3739	STEAM FED, FUEL INCREASED 20 PERCENT
72	22.3	23.0	14	9	<1	.06	2.9	2.8	.5	.7	3653	3739	STEAM FED, FUEL INCREASED 20 PERCENT
73	44.4	79.2	33	30	<1	.56	12.6	7.1	2.0	3.2	3653	3739	
74	36.2	52.6	11	8	<1	.60	16.7	11.5	2.7	4.2	3653	3739	STEAM FED, FUEL INCREASED 20 PERCENT
75	120.4	181.2	44	44	2-3	1.68	14.0	9.3	2.2	3.5	6068	1492	
76	170.2	240.5	24	23	1-2	1.30	7.6	5.4	1.2	1.9	5442	522	
77													
78	104.9	120.6	23	21	1-2	.80	7.6	6.6	1.2	1.9	3653	3739	
79	191.2	573.7	44	44	5-10	3.06	16.0	5.3	2.6	4.0	1414	2925	
80	47.1	53.2	32	29	4-5	.85	18.1	16.0	2.9	4.5	3533	3911	
81	61.8	125.3	55	52	3-4	2.16	35.0	17.2	5.6	8.7	5442	522	
82	41.9	63.8	27	28	2-3	.63	15.0	9.9	2.4	3.8	3533	3911	
83	43.1	49.2	25	18	1-2	.56	13.0	11.4	2.1	3.3	3653	3739	
84	104.0	104.0	44	43	2-3	.90	8.7	8.7	1.4	2.2	3653	3739	
84A	7.2	21.5	12	12	2-3	.39	54.4	18.1	8.7	13.6	4237	3182	
85	14.7	44.1	18	18	1-2	.38	25.9	8.6	4.1	6.5	4237	3182	ALL ELECTRIC
85A	46.4	139.3	39	39							4880	2189	
86	28.0	36.2	24	22	<1	.19	6.8	5.2	1.1	1.7	3183	4513	
87	19.1	57.4	28	28	<1	.11	5.8	1.9	.9	1.4	8172	364	ALL ELECTRIC
88	213.1	363.4	36	39	<1	.79	3.7	2.2	.6	.9	3183	4513	
89	102.5	225.4	20	28	<1	.49	4.8	2.2	.8	1.2	3183	4513	
90	300.0	381.9	53	54	1-2	.97	3.2	2.5	.5	.8	3183	4513	
91	364.0	445.9	75	71	<1	.86	2.4	1.9	.4	.6	3183	4513	
92	314.8	410.4	73	67	<1	.83	2.6	2.0	.4	.7	3183	4513	
93	114.8	210.4	47	47	2-3	1.42	12.4	6.7	2.0	3.1	3183	4513	
94	280.7	342.2	54	49	1-2	1.68	6.0	4.9	1.0	1.5	3183	4513	
95	283.8	437.5	55	58	<1	.67	2.4	1.5	.4	.6	3183	4513	
96	248.6	297.8	41	39	<1	.37	1.5	1.2	.2	.4	3183	4513	
97	249.5	288.4	40	33	<1	.29	1.2	1.0	.2	.3	3183	4513	
98	2.0	2.0	3	2		.17	85.0	85.0	13.6	21.3	4745	2603	
99	1.9	-8.4	3	-8		.51	271.6	-61.0	43.5	67.9	3482	3818	
100	14.6	7.8	15	6		1.53	104.9	197.3	16.8	26.2	3533	3911	
101	25.0	25.0	30	23		1.12	44.8	44.8	7.2	11.2	2625	4682	
102	7.3	-20.0	5	-5		.94	128.1	-47.0	20.5	32.0	2746	6543	
103	21.6	16.8	16	11		.96	44.4	57.0	7.1	11.1	3183	4513	
104	16.1	26.4	16	20		5.12	317.6	194.2	50.8	79.4	3260	3616	
105	1.6	-5.2	2	-3		.13	82.0	-24.8	13.1	20.5	2331	7033	
106	0.	0.	0	0		.40					3634	4875	
107	71.6	94.8	32	25							3533	3911	
108	5.7	5.0	7	4							3533	3911	
109	4.0	1.9	3	1							3533	3911	
110	9.7	15.2	7	8							3533	3911	
111	5.7	5.0	2	1							3533	3911	
112	13.7	15.0	2	2							3533	3911	
113	60.2	78.7	29	26							3533	3911	
114	44.7	48.1	20	16							3533	3911	
115	34.7	38.1	14	11							3533	3911	
116	23.0		43								3533	3911	DATA NORMALIZED TO 5000 HDD AT 65 D
117	7.2	21.5	7	7							3750	3500	
118	42.1	52.4	31	19							3750	3500	
119	86.2	102.6	43	27							3750	3500	
120	14.3	8.8	13	7							2388	5591	
121	-15.0	-15.0	-13	-11							2388	5591	
122	-.1	-6.2	0	-4							2388	5591	
123	22.1	28.2	28	28							2388	5591	
124	-8.0	-10.1	-6	-6							2388	5591	
125	3.7	5.0	4	5							2388	5591	

A	B		C	D	D1	E	E1	E2	E(F)	E(T)	F	F1	F2	F(F)	F(T)
						<-- A N N U A L E N E R G Y U S E P E R S Q. F T. -->									
						<------- B E F O R E ------>					<-------- A F T E R -------->				
						<--ELECTRICITY-->			FUEL	TOTAL	<--ELECTRICITY-->			FUEL	TOTAL
BLDG NO	LOCATION		AREA (KSQFT)	USE CAT.	RETROFIT MEASURE	(KWH)	(KBTU) SITE	(KBTU) SOURC	(KBTU) SOURC	(KBTU) SOURC	(KWH)	(KBTU) SITE	(KBTU) SOURC	(KBTU) SOURC	(KBTU) SOURC
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126	BUFFALO	NY	41.9	ELEM	O	3.90	13.3	40.0	86	126.0	3.00	10.2	30.7	58	88.7
127	BUFFALO	NY	78.8	ELEM	O	3.40	11.6	34.8	110	144.8	3.80	13.0	38.9	89	127.9
128	BUFFALO	NY	83.1	ELEM	OL	2.30	7.9	23.6	128	151.6	2.00	6.8	20.5	76	96.5
129	BUFFALO	NY	51.3	ELEM	O	3.10	10.6	31.8	95	126.8	3.90	13.3	40.0	83	123.0
130	BUFFALO	NY	36.7	ELEM	O	3.60	12.3	36.9	105	141.9	2.20	7.5	22.5	107	129.5
131	BUFFALO	NY	69.8	ELEM	OL	1.90	6.5	19.5	129	148.5	2.00	6.8	20.5	111	131.5
132	BUFFALO	NY	46.0	ELEM	O	5.50	18.8	56.3	102	158.3	5.50	18.8	56.3	62	118.3
133	BUFFALO	NY	58.5	ELEM	O	3.70	12.6	37.9	83	120.9	4.70	16.1	48.2	67	115.2
134	BUFFALO	NY	74.0	ELEM	O	2.30	7.9	23.6	119	142.6	2.10	7.2	21.5	114	135.5
135	BUFFALO	NY	73.7	ELEM	O	2.90	9.9	29.7	114	143.7	3.40	11.6	34.8	120	154.8
136	BUFFALO	NY	120.0	ELEM	O	2.60	8.9	26.6	100	126.6	2.40	8.2	24.6	68	92.6
137	BUFFALO	NY	62.3	ELEM	O	2.60	8.9	26.6	111	137.6	1.90	6.5	19.5	71	90.5
138	BUFFALO	NY	41.9	ELEM	O	3.90	13.3	40.0	96	136.0	4.20	14.3	43.0	59	102.0
139	BUFFALO	NY	128.6	ELEM	O	3.80	13.0	38.9	91	129.9	2.40	8.2	24.6	73	97.6
140	BUFFALO	NY	83.7	ELEM	O	4.20	14.3	43.0	100	143.0	3.60	12.3	36.9	92	128.9
141	BUFFALO	NY	125.3	ELEM	O	2.80	9.6	28.7	63	91.7	2.20	7.5	22.5	39	61.5
142	BUFFALO	NY	107.5	ELEM	O	3.10	10.6	31.8	96	127.8	2.20	7.5	22.5	66	88.5
143	BUFFALO	NY	61.2	ELEM	O	4.70	16.1	48.2	101	149.2	4.70	16.1	48.2	38	86.2
144	BUFFALO	NY	110.0	ELEM	O	2.20	7.5	22.5	90	112.5	2.70	9.2	27.7	89	116.7
145	BUFFALO	NY	101.1	ELEM	O	2.30	7.9	23.6	94	117.6	3.00	10.2	30.7	64	94.7
146	BUFFALO	NY	120.0	ELEM	O W	3.60	12.3	36.9	120	156.9	2.80	9.6	28.7	88	116.7
147	BUFFALO	NY	140.0	ELEM	O	3.90	13.3	40.0	87	127.0	3.60	12.3	36.9	65	101.9
148	BUFFALO	NY	65.0	ELEM	O	2.80	9.6	28.7	128	156.7	1.70	5.8	17.4	102	119.4
149	BUFFALO	NY	14.9	ELEM	O	2.50	8.5	25.6	103	128.6	2.50	8.5	25.6	80	105.6
150	BUFFALO	NY	73.5	ELEM	OL	2.30	7.9	23.6	86	109.6	2.80	9.6	28.7	72	100.7
151	BUFFALO	NY	99.0	ELEM	O	1.70	5.8	17.4	155	172.4	2.60	8.9	26.6	157	183.6
152	BUFFALO	NY	107.5	ELEM	O	4.20	14.3	43.0	67	110.0	5.50	18.8	56.3	68	124.3
153	BUFFALO	NY	65.2	ELEM	O	2.30	7.9	23.6	60	83.6	2.20	7.5	22.5	41	63.5
154	BUFFALO	NY	52.8	ELEM	O W	2.30	7.9	23.6	89	112.6	2.60	8.9	26.6	80	106.6
155	BUFFALO	NY	42.9	ELEM	O W	3.80	13.0	38.9	128	166.9	3.40	11.6	34.8	80	114.8
156	BUFFALO	NY	96.0	ELEM	O	2.40	8.2	24.6	99	123.6	2.50	8.5	25.6	94	119.6
157	BUFFALO	NY	68.5	ELEM	O W	3.30	11.3	33.8	95	128.8	2.80	9.6	28.7	129	157.7
158	BUFFALO	NY	82.0	ELEM	O	2.60	8.9	26.6	109	135.6	2.70	9.2	27.7	86	113.7
159	BUFFALO	NY	62.7	ELEM	O	2.90	9.9	29.7	123	152.7	2.80	9.6	28.7	113	141.7
160	BUFFALO	NY	60.2	ELEM	O	1.90	6.5	19.5	64	83.5	2.20	7.5	22.5	60	82.5
161	BUFFALO	NY	59.1	ELEM	O	1.50	5.1	15.4	223	238.4	1.80	6.1	18.4	153	171.4
162	BUFFALO	NY	73.8	ELEM	O	3.10	10.6	31.8	89	120.8	2.60	8.9	26.6	73	99.6
163	BUFFALO	NY	79.7	ELEM	OL	2.50	8.5	25.6	108	133.6	2.00	6.8	20.5	80	100.5
164	BUFFALO	NY	74.0	ELEM	O	4.60	15.7	47.1	87	134.1	3.60	12.3	36.9	67	103.9
165	BUFFALO	NY	72.2	ELEM	O	3.00	10.2	30.7	106	136.7	2.80	9.6	28.7	100	128.7
166	BUFFALO	NY	45.6	ELEM	O	2.90	9.9	29.7	163	192.7	3.20	10.9	32.8	153	185.8
167	BUFFALO	NY	70.2	ELEM	O	3.00	10.2	30.7	101	131.7	3.80	13.0	38.9	58	96.9
168															
169	BUFFALO	NY	73.7	ELEM	O	3.60	12.3	36.9	98	134.9	3.00	10.2	30.7	79	109.7
170	BUFFALO	NY	69.0	ELEM	O	2.80	9.6	28.7	93	121.7	2.50	8.5	25.6	78	103.6
171	BUFFALO	NY	80.6	ELEM	O	2.10	7.2	21.5	128	149.5	2.70	9.2	27.7	76	103.7
172	BUFFALO	NY	78.0	ELEM	O	4.50	15.4	46.1	141	187.1	3.60	12.3	36.9	110	146.9
173	BUFFALO	NY	78.5	ELEM	OL	1.60	5.5	16.4	97	113.4	1.70	5.8	17.4	68	85.4
174	BUFFALO	NY	79.5	ELEM	OL	2.30	7.9	23.6	109	132.6	1.90	6.5	19.5	74	93.5
175	BUFFALO	NY	80.2	ELEM	OL	2.40	8.2	24.6	122	146.6	3.30	11.3	33.8	90	123.8
176	BUFFALO	NY	83.6	ELEM	O	2.10	7.2	21.5	115	136.5	2.00	6.8	20.5	81	101.5
177	BUFFALO	NY	34.3	ELEM	O	4.80	16.4	49.2	95	144.2	3.80	13.0	38.9	95	133.9
178	BUFFALO	NY	13.0	ELEM	O	3.10	10.6	31.8	103	134.8	4.20	14.3	43.0	88	131.0
179															
180	BUFFALO	NY	54.8	ELEM	O	2.50	8.5	25.6	81	106.6	2.40	8.2	24.6	69	93.6
181	BUFFALO	NY	191.0	ELEM	O	14.50	49.5	148.6	72	220.6	16.60	56.7	170.1	72	242.1
182	BUFFALO	NY	280.0	ELEM	O H	3.50	12.0	35.9	118	153.9	2.70	9.2	27.7	82	109.7
183	BUFFALO	NY	104.5	ELEM	O	6.70	22.9	68.6	103	171.6	4.70	16.1	48.2	56	104.2
184	BUFFALO	NY	112.4	ELEM	O	7.60	26.0	77.9	125	202.9	4.00	13.7	41.0	72	113.0
185	BUFFALO	NY	201.5	ELEM	O H	5.40	18.4	55.3	91	146.3	5.20	17.8	53.3	78	131.3

A	G1	G2	H1	H2	K	J	L1	L2	L3	L4	M	N	
	<---- S A V E D ----->					COST OF RETRO-FIT	COST PER ANNUAL SAVINGS (1980 $/ MBTU/YR)		COST OF CONSEVED SITE ENERGY ($/MBTU)				
BLDG NO	(KBTU/SQFT) SITE	SOURC	(PERCENT) SITE	SOURC	SIMP PAYB YRS	(1980$ /SQFT)	SITE	SOURC	CRR= .16	CRR= .25	COOLG DEGR DAYS	HEATG DEGR DAYS	COMMENTS
-----	-----	-----	-----	-----	****	******	-----	-----	-----	-----	*****	*****	----------
126	31.1	37.2	31	30							2388	5591	
127	19.6	16.9	16	12							2388	5591	
128	53.0	55.1	39	36							2388	5591	
129	9.3	3.8	9	3							2388	5591	
130	2.8	12.3	2	9							2388	5591	
131	17.7	17.0	13	11							2388	5591	
132	40.0	40.0	33	25							2388	5591	
133	12.6	5.8	13	5							2388	5591	
134	5.7	7.0	4	5							2388	5591	
135	-7.7	-11.1	-5	-7							2388	5591	
136	32.7	34.0	30	27							2388	5591	
137	42.4	47.2	35	34							2388	5591	
138	36.0	33.9	33	25							2388	5591	
139	22.8	32.3	22	25							2388	5591	
140	10.0	14.1	9	10							2388	5591	
141	26.0	30.1	36	33							2388	5591	
142	33.1	39.2	31	31							2388	5591	
143	63.0	63.0	54	42							2388	5591	
144	-.7	-4.1	-0	-3							2388	5591	
145	27.6	22.8	27	19							2388	5591	
146	34.7	40.2	26	26							2388	5591	
147	23.0	25.1	23	20							2388	5591	
148	29.8	37.3	22	24							2388	5591	
149	23.0	23.0	21	18							2388	5591	
150	12.3	8.9	13	8							2388	5591	
151	-5.1	-11.2	-2	-6							2388	5591	
152	-5.4	-14.3	-6	-12							2388	5591	
153	19.3	20.0	29	24							2388	5591	
154	8.0	5.9	8	5							2388	5591	
155	49.4	52.1	35	31							2388	5591	
156	4.7	4.0	4	3							2388	5591	
157	-32.3	-28.9	-29	-21							2388	5591	
158	22.7	22.0	19	16							2388	5591	
159	10.3	11.0	8	7							2388	5591	
160	3.0	.9	4	1							2388	5591	
161	69.0	66.9	30	28							2388	5591	
162	17.7	21.1	18	17							2388	5591	
163	29.7	33.1	25	25							2388	5591	
164	23.4	30.2	23	23							2388	5591	
165	6.7	8.0	6	6							2388	5591	
166	9.0	6.9	5	4							2388	5591	
167	40.3	34.8	36	26							2388	5591	
168													
169	21.0	25.1	19	19							2388	5591	
170	16.0	18.1	16	15							2388	5591	
171	50.0	45.9	37	31							2388	5591	
172	34.1	40.2	22	21							2388	5591	
173	28.7	28.0	28	25							2388	5591	
174	36.4	39.1	31	29							2388	5591	
175	28.9	22.8	22	16							2388	5591	
176	34.3	35.0	28	26							2388	5591	
177	3.4	10.2	3	7							2388	5591	
178	11.2	3.7	10	3							2388	5591	
179													
180	12.3	13.0	14	12							2388	5591	
181	-7.2	-21.5	-5	-9							2388	5591	
182	38.7	44.2	30	29							2388	5591	
183	53.8	67.5	43	39							2388	5591	
184	65.3	89.9	43	44							2388	5591	
185	13.7	15.0	13	10							2388	5591	

A	B		C	D	D1	E	E1	E2	E(F)	E(T)	F	F1	F2	F(F)	F(T)
						<-- ANNUAL ENERGY USE PER SQ. FT. -->									
						<------ BEFORE ------>					<------- AFTER ------->				
						<--ELECTRICITY-->			FUEL	TOTAL	<--ELECTRICITY-->			FUEL	TOTAL
BLDG NO	LOCATION		AREA (KSQFT)	USE CAT.	RETROFIT MEASURE	(KWH)	(KBTU) SITE	(KBTU) SOURC	(KBTU) SOURC	(KBTU) SOURC	(KWH)	(KBTU) SITE	(KBTU) SOURC	(KBTU) SOURC	(KBTU) SOURC
186	BUFFALO	NY	191.6	ELEM	O	5.70	19.5	58.4	99	157.4	4.30	14.7	44.1	80	124.1
187	BUFFALO	NY	180.0	ELEM	O	5.20	17.8	53.3	119	172.3	4.60	15.7	47.1	83	130.1
188	BUFFALO	NY	236.0	SEC	O	4.50	15.4	46.1	127	173.1	5.20	17.8	53.3	106	159.3
189	BUFFALO	NY	42.0	SEC	O	4.70	16.1	48.2	112	160.2	3.30	11.3	33.8	101	134.8
190	BUFFALO	NY	185.2	SEC	O	4.80	16.4	49.2	125	174.2	3.30	11.3	33.8	89	122.8
191	BUFFALO	NY	175.0	SEC	O	5.50	18.8	56.3	177	233.3	3.80	13.0	38.9	115	153.9
192	BUFFALO	NY	155.0	SEC	O	5.90	20.1	60.4	161	221.4	5.30	18.1	54.3	117	171.3
193	BUFFALO	NY	168.4	SEC	O	2.40	8.2	24.6	88	112.6	2.00	6.8	20.5	89	109.5
194	BUFFALO	NY		SEC	O	3.70	12.6	37.9	101	138.9	3.60	12.3	36.9	103	139.9
195	BUFFALO	NY	197.0	SEC	O	3.30	11.3	33.8	142	175.8	3.00	10.2	30.7	97	127.7
196	BUFFALO	NY	185.0	SEC	O	5.10	17.4	52.2	134	186.2	4.50	15.4	46.1	89	135.1
197	BUFFALO	NY	160.0	SEC	O	3.80	13.0	38.9	102	140.9	4.80	16.4	49.2	88	137.2
198	BUFFALO	NY	255.0	SEC	O	8.20	28.0	84.0	100	184.0	9.20	31.4	94.3	98	192.3
199	BUFFALO	NY	175.0	SEC	O	5.50	18.8	56.3	127	183.3	6.00	20.5	61.5	108	169.5
200	BUFFALO	NY	167.0	SEC	O	4.00	13.7	41.0	96	137.0	3.80	13.0	38.9	72	110.9
201	BUFFALO	NY	211.0	SEC	O	3.40	11.6	34.8	130	164.8	5.10	17.4	52.2	110	162.2
202	ROCKVILLE	MD	195.2	SEC	E	12.60	43.0	129.1	89	218.1	6.40	21.9	65.6	32	97.6
203	ROCKVILLE	MD	218.5	SEC	E	10.50	35.9	107.6	119	226.6	5.80	19.8	59.4	47	106.4
204	CLAYTON	OH	287.2	SEC	O C E	17.00	58.1	174.2	117	291.2	14.00	47.8	143.4	83	226.4
205	CROTON-ON-HUDSON	NJ	7.7	COMCEN	OLW										
206	AUSTIN	TX	219.0	LO	OL H	30.70	104.8	314.5	500	814.5	19.90	68.0	203.9	247	450.9
207	COLUMBIA	MD	31.9	COMCEN	O I										
208	COLUMBIA	MD	14.4	COMCEN	O C										
209	COLUMBIA	MD	3.2	COMCEN	O CI										
210	COLUMBIA	MD	2.4	COMCEN	O C										
211	COLUMBIA	MD	28.9	COMCEN	OL										
212	COLUMBIA	MD	4.1	COMCEN	OLWCI										
213	COLUMBIA	MD	2.7	COMCEN	OLWCI										
214	COLUMBIA	MD	2.7	COMCEN	O W I										
215	COLUMBIA	MD	1.3	COMCEN	O WC										
216	COLUMBIA	MD	1.5	COMCEN	O CI										
217	COLUMBIA	MD	1.5	COMCEN	O CI										
218	COLUMBIA	MD	2.1	COMCEN	O										
219	COLUMBIA	MD	2.3	COMCEN	O C										
220	COLUMBIA	MD	1.6	COMCEN	O CI										
221	COLUMBIA	MD	1.8	COMCEN	O CI										
222	COLUMBIA	MD	1.3	COMCEN	OLWCI										
223	COLUMBIA	MD	6.4	COMCEN	OL C										
224	COLUMBIA	MD		COMCEN											
225	COLUMBIA	MD		COMCEN											
226	COLUMBIA	MD	12.6	COMCEN	OL										
227	COLUMBIA	MD		COMCEN											
228	COLUMBIA	MD		COMCEN											
229	COLUMBIA	MD		COMCEN											
230	COLUMBIA	MD	11.8	COMCEN	O										
231	COLUMBIA	MD		COMCEN											
232	COLUMBIA	MD		COMCEN											
233	COLUMBIA	MD		COMCEN											
234	COLUMBIA	MD		COMCEN											
235	COLUMBIA	MD		COMCEN											

A	C1	C2	H1	H2	K	J	L1	L2	L3	L4	M	N	
	<---- S A V E D ---->					COST OF RETRO-	COST PER ANNUAL SAVINGS (1980 $/ MBTU/YR)		COST OF CONSEVED SITE ENERGY ($/MBTU)				
BLDG NO	(KBTU/SQFT) SITE	SOURC	(PERCENT) SITE	SOURC	SIMP PAYB YRS ****	FIT (1980$ /SQFT) ******	SITE	SOURC	CRR= .16	CRR= .25	COOLG DEGR DAYS *****	HEATG DEGR DAYS *****	COMMENTS
186	23.8	33.3	20	21							2388	5591	
187	38.0	42.1	28	24							2388	5591	
188	18.6	13.8	13	8							2388	5591	
189	15.8	25.3	12	16							2388	5591	
190	41.1	51.4	29	29							2388	5591	
191	67.8	79.4	35	34							2388	5591	
192	46.0	50.1	25	23							2388	5591	
193	.4	3.1	0	3							2388	5591	
194	-1.7	-1.0	-0	-0							2388	5591	
195	46.0	48.1	30	27							2388	5591	
196	47.0	51.1	31	27							2388	5591	
197	10.6	3.8	9	3							2388	5591	
198	-1.4	-8.2	-0	-3							2388	5591	
199	17.3	13.9	12	8							2388	5591	
200	24.7	26.0	23	19							2388	5591	
201	14.2	2.6	10	2							2388	5591	
202	78.2	120.5	59	55							4237	3182	
203	88.1	120.2	57	53							4237	3182	
204	44.2	64.7	25	22		.08	1.8	1.2	.3	.5		5622	
205	100.0		52			5.83	58.3		9.3	14.6		3739	
206	289.9	363.6	48	45		1.28	4.4	3.5	.7	1.1		1737	
207		236.0		53	<1	.02		.1			4237	3182	ONLY HAVE SOURCE TOTALS
208		-8.0		-1		.02		-1.9			4237	3182	ONLY HAVE SOURCE TOTALS
209		33.0		4	1-2	.94		28.5			4237	3182	ONLY HAVE SOURCE TOTALS
210		6.0		2	<1	.17		28.3			4237	3182	ONLY HAVE SOURCE TOTALS
211		148.0		28		.05		.3			4237	3182	DROPPED FROM STUDY
212		7.0		2		.56		80.0			4237	3182	ONLY HAVE SOURCE TOTALS
213		117.0		30	<1	.45		3.8			4237	3182	ONLY HAVE SOURCE TOTALS
214		54.0		19	1-2	.73		13.5			4237	3182	ONLY HAVE SOURCE TOTALS
215		-176.0		-31		.78		-4.4			4237	3182	ONLY HAVE SOURCE TOTALS
216		95.0		19	2-3	1.09		11.5			4237	3182	ONLY HAVE SOURCE TOTALS
217		66.0		17							4237	3182	ONLY HAVE SOURCE TOTALS
218		60.0		19	1-2	.27		4.5			4237	3182	ONLY HAVE SOURCE TOTALS
219		55.0		12	<1	.21		3.8			4237	3182	ONLY HAVE SOURCE TOTALS
220		233.0		43	<1	.41		1.8			4237	3182	ONLY HAVE SOURCE TOTALS
221		94.0		19	<1	.36		3.8			4237	3182	ONLY HAVE SOURCE TOTALS
222		39.0		9	1-2	.47		12.1			4237	3182	ONLY HAVE SOURCE TOTALS
223		69.0		24	<1	.17		2.5			4237	3182	ONLY HAVE SOURCE TOTALS
224		94.0		33							4237	3182	
225											4237	3182	
226		230.0		40	<1	0.					4237	3182	ONLY HAVE SOURCE TOTALS
227											4237	3182	
228											4237	3182	
229											4237	3182	
230		63.0		22	<1	.06		1.0			4237	3182	ONLY HAVE SOURCE TOTALS
231											4237	3182	
232											4237	3182	
233											4237	3182	
234											4237	3182	
235											4237	3182	WINDOW DID NOT WORK BECAUSE OF GLUE

APPENDIX C: Weather Effects on Retrofits

In this study, pre- and post-retrofit energy consumption was not normalized by any climate parameters, such as heating degree days (HDD) and cooling degree days (CDD). While such normalization may be desirable in some cases, we do not consider it critical for the following reasons:

a. Much of the energy consumption in commercial buildings, especially those with large floor areas, tend to be independent of weather. These consumptions include lighting, miscellaneous electrical uses such as typewriters, computer terminals, coffee pots and miscellaneous steam or gas uses such as hot water, sterilization processes and laboratory equipment; these consumptions can represent the majority of the energy use of the building especially after retrofit. Normalization of total energy use would overestimate the effect of changing weather conditions, since these independent energy uses would be normalized inappropriately in the process. Ideally, normalization would be for heating and cooling which depend on weather to some degree.

b. In large commercial buildings, the heating and cooling consumption is usually dominated by the internal load (lights, people, miscellaneous equipment). Internal loads are again, weather-independent. As an example, computer simulations of a 100,000 square foot energy-efficient office building "moved" to five different cities were performed. Table C1 shows the heating and cooling consumption (H+C) and the relevant heating and cooling degree days for the cities. Despite the wide variation in the climatic values, heating and cooling consumption did not vary much at ventilation levels commonly used by designers. Only at very high ventilation rates, where in colder climates, preheat was required, did any significant difference in heating and cooling consumption appear. When added to the other energy consumptions in the building, the significance of this difference is greatly reduced.

c. A statistical analysis (See DOE Technical Support Document No. 10 of NOPR, 1979) has been performed on 168 buildings of 1975-76 vintage, attempting to relate heating and cooling consumption to various weather parameters. Although heating and cooling degree days correlated best of all weather parameters, the correlation was not strong. The best correlation occurred for base temperatures of 60 degrees for heating and 50 degrees for cooling, which we show in Appendix B.

Because of the above reasons, we felt that normalization was both difficult and unnecessary. Energy savings were not only in terms of heating and cooling, but lighting and other miscellaneous processes for which normalization would have been inappropriate.

Table C.1 Weather Dependence of the Energy of an Energy Efficient Office Building, Simulated in Five Cities. The entries under HDD_{60F} are Fahrenheit Heating Degree Days, Base 60°F, under CDD_{50F} are Cooling Degree Days, Base 50°F.

Ventilation: 5 cfm/person = 2.5 l/sec-person	HDD_{60F}	CDD_{50F}	Annual Site Energy Use (kBtu/ft^2) Heat + Cooling	Other	Total
Washington, D.C.	3182	4237	8	29.3	37.3
Atlanta	2189	4880	8	29.3	37.3
Chicago	4952	3272	9	29.3	38.3
Los Angeles	522	5442	6	29.3	35.3
Seattle	3657	1832	5	29.3	34.3
Average	2900	3932			36.5
Std. Dev.	±1660 (±57%)	±1425 (±36%)			±1.6 (±4.5%)
Ventilation: 20 cfm/person = 10 l/sec-person					
Washington, D.C.			14	29.3	43.3
Atlanta			13	29.3	42.3
Chicago			18	29.3	47.3
Los Angeles			6	29.3	35.3
Seattle			10	29.3	39.3
Average					41.5
Std. Dev.					±4.5 (±11%)
Ventilation: 35 cfm/person = 17.5 l/sec-person					
Washington, D.C.			22	29.3	51.3
Atlanta			19	29.3	48.3
Chicago			28	29.3	57.3
Los Angeles			8	29.3	37.3
Seattle			19	29.3	48.3
Average					48.5
Std. Dev.					±7.3 (±15%)

APPENDIX D: Office Buildings and a Comparison with Standards

The average energy use per unit of floor area of office buildings is very close to the United States average commercial building stock energy use per unit of floor area, according to the ORNL model. It has been proposed to use the office building sector as a surrogate for the United States commercial building stock in some forecasting analysis (Rosenfeld, 1980).

Figure 9 shows a plot of the twenty-one (21) office buildings for which we have fossil fuel and electrical consumption available; also plotted are the consumptions of the current United States office building stock, the French office stock, and the Swedish office stock.

Both of the European stock consumptions are about half as energy intensive as the United States building stock. Air conditioning is a frequent practice in the United States office buildings, while it is rare in Europe. This may account for the greatly reduced levels of electricity consumption in the European countries. In the retrofitted buildings, fossil fuel was saved in much greater proportion than electricity, suggesting also that savings in heating were simpler to accomplish than air conditioning.

It is also interesting to note that the once proposed new Building Energy Performance Standards (now terminated) are about as stringent as the 1975 Swedish Building Code. Three of the buildings using less energy than the BEPS levels are located in France and Sweden; these have been retrofitted several times, at a cost exceeding any United States buildings in the sample. The one United States building which meets the standards is a very large (over two million square feet) office building (#108) in New Jersey.(*)

* The report by Hagler, Bailly and Company (HBC, 1980) states that many United States buildings already meet the proposed BEPS levels, especially hospitals. In this study we were able to find many schools which also were less than the standards; in total 21% of the buildings in the sample met or exceeded the BEPS levels before retrofit, mostly schools and hospitals.

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TECHNICAL INFORMATION DEPARTMENT
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720