DOE/ENERGY

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ENERGY CONSERVATION IN EXISTING OFFICE BUILDINGS

Final Report

November 1978

Work Performed Under Contract No. EY-76-C-02-2799

Syska and Hennessy
New York, New York

and

Tishman Research Corporation
New York, New York

U. S. DEPARTMENT OF ENERGY

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Phase I, Phase II, and Phase III reports, in combination with the Summary and Recommendations, constitute the Final Report of the study of "Energy Conservation in Existing Office Buildings," based upon more than 1,000 office buildings in New York City.

This Table of Contents covers the subject matter of all phases.

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ENERGY CONSERVATION IN EXISTING OFFICE BUILDINGS

FINAL REPORT

I. SUMMARY

A. GOALS

Recognizing the greater potential for energy conservation in existing office buildings rather than in new construction, this study was designed to provide information to owners and public policy makers to help them implement strategies for achieving energy conservation in such buildings.

The study's goals were to:

- determine physical and operational (energy related) characteristics of office buildings and their energy consumption patterns;
- analyze interrelationships between some of these characteristics and energy consumption;
- establish additional energy savings potential, since the two years following the 1973 oil embargo, and feasible practical conservation measures to achieve them;
- determine the impediments standing in the way of achieving the energy savings potential and recommend how to overcome these barriers;
- propose an energy consumption budget or goal approach;
- evaluate applicability of recommendations, findings, and developed methodologies to other building types and geographical regions of the United States.

B. METHODOLOGY

The study was based upon New York City office buildings, which represents the largest concentration of office buildings anywhere in the world. A three-part cascading sampling methodology was developed. It encompassed an examination of 1037 buildings containing more than one quarter billion square feet of gross space. From this population, a 44 building representative sample was selected for in-depth analysis to provide a 95% statistical confidence, after finding that random sampling was deficient in representation. It is believed that this is the first time that a representative sampling has been used to study energy consumption in existing buildings. An additional representative sample (five from the 44 buildings) was selected for further analysis.

Energy consumption data was normalized for occupancy/utilization factors and weather conditions, to the extent they affect consumption, permitting rational comparative analysis not otherwise possible. Again, it is believed that this is the first time this was done. DOE should foster widespread use of representative sampling and normalization procedures for energy conservation studies and analyses.

C. ENERGY SAVINGS SINCE THE OIL EMBARGO

The study shows that there was about a 12% savings in normalized energy consumption when comparing 1971/1972, the two years before the 1973 oil embargo, with 1974/1975—largely due to simple adjustments in building operating temperatures and lighting practices. The savings based upon raw data were an apparent 19%—about 50% greater than the normalized amount.

D. OWNER KNOWN INFORMATION

The 12% savings occurred despite the fact that owners and managers were found to have little quantitative perception relating to energy consumption patterns in their buildings.

Only 10% of the building owners monitored and compared their building's energy consumption to that of others. In general, except in terms of dollars, owners do not know how much they saved, or what the potential benefits of further energy consumption measures could be, absolutely or relatively. Without widespread practice of continuous and accurate tracking of consumption, it will be difficult for them to achieve the next level of energy savings and easy to retrogress, as has been observed in individual cases. And it will be very difficult to establish and maintain rational energy conservation policies and to guide decision makers in both the public and private sectors. It is essential that government concentrate its early efforts on overcoming this fundamental information deficiency and be sensitive to the fact that numbers, indicators, and other quantitative yardsticks hold enormous fascination for owners, consumers, and policy makers. They motivate people to examine likenesses and differences which inspire beneficial results in a competitive society such as ours.

Also, a high degree of non-uniformity in quality and quantity of owner known information relating to building characteristics and operation was found. This deficiency compounds the problem springing from lack of owner knowledge of energy consumption patterns as all these facets are interrelated. DOE should encourage use of uniform information forms and qualified persons to obtain required information.

E. CHARACTERISTICS OF OFFICE BUILDINGS

There is a substantial spread in physical characteristics, operating practices, and energy consumption patterns in existing office buildings, indicating that a variety of retrofit measures and strategies are necessary to achieve different levels of conservation and economic benefit.

A few examples illustrating this wide spread are as follows:

	RANGE	MEAN	MEDIAN
1975 consumption, normalized (MBTU/sq. ft.)	65-223	112	108
Age (years)	8-82	44	48
Total Building Area	17,000-1,850,000	401,000	318,000
Total Wall Area (SF)	7,400-503,000	130,000	106,000
Per Cent Glass on Wall	13-67	29	26
Temperature, winter day-F	68-75	71	71
Watts/sq. ft.—lighting	1.5-5.3	2.8	2.5

The study contains more than 750 bits of information and operating characteristics for each of the 44 sample buildings, monthly data on energy consumption for a five year period, and frequency distribution analyses for a variety of characteristics.

Some of the information gathered was deemed to be extraneous or showed less energy related relevance than presupposed. A revised building information form based upon the experience of the completed study was prepared and included in the Phase III report.

F. RETROFIT POTENTIAL AND STRATEGIES

Five representative buildings (one from each pentile of the energy consumption frequency distribution for the 44 buildings surveyed) were analyzed to determine the retrofit measures and strategies which might be employed to effect feasible energy reductions.

Post-World War II buildings show a potential savings of 20 to 35% with an average of 22%, based upon the 44 building sample, and 13 to 28% with an average of 21% based upon the 5 building sample for a 3 year payback.

Pre-World War II buildings show a potential savings of 8 to 25% with an average of 18% based upon the 44 building sample, and 8 to 11% with an average of 10% based upon the 5 building sample for a 3 year payback. Additional measures requiring a longer payback are not practical or cost effective.

An additional savings of only 2% is achievable by utilizing measures with a payback in excess of three years. A three year or less payback is considered reasonable by most owners. The indicated savings are those possible beyond the 12% already saved in 1974/1975.

Since the size of the post-World War II buildings is substantially larger than the pre-World War II buildings, the potential savings achievable by concentrating on this newer vintage class is significantly greater. Therefore, less priority should be accorded to energy conservation efforts in older buildings.

The strongest correlation noted between energy consumption and energy related attributes are: age, hours of lighting, hours of perimeter heating and cooling, and type of perimeter system (central or local).

The study shows that, in general, post-World War II buildings tend to have more ventilation than necessary; have excess heating, cooling, and lighting capacities; and have centralized control systems that hamper selective cuts in energy used in vacant or underutilized space. The savings that could be effected by reducing this excess capacity and controlling waste energy in underutilized or unoccupied space is significant.

Investments in appropriate devices or systems which: reduce the quantity of out-side air; better control heating, cooling, and ventilating; dim or provide energy-efficient lighting are specific retrofit strategies that can be feasibily implemented to provide a reduction in energy usage.

Twenty-six retrofit and operational strategies were analyzed. The projected energy savings achievable by these measures based on the gross areas of the 44 buildings are shown below.

POTENTIAL ENERGY SAVINGS BEYOND THAT ALREADY ACHIEVED BY 1975, BTU/YR./GROSS SQ. FT.

ENERGY SAVINGS AT BUILDING BOUNDARY	PAYBACK PERIOD					
	UP TO 3 YRS.	% SAVINGS	UP TO 5 YRS.	% SAVINGS	UP TO 10 YRS.	% SAVINGS
Total savings	24,708	21	25,778	22	27,591	24
Total savings — $/yr./sq. ft.	0.42		0.43		0.45	

G. ACTUAL CONSUMPTION VS. DESIGN PROJECTIONS

Application of a computer energy simulation program to a typical building produced reasonable correlation with actual energy consumption, but the information is inadequate to establish a reliable correlation and to determine long term validity.

H. OVERCOMING BARRIERS

Building owners, in large part, dictate the pace of energy conservation in existing office buildings through their attitudes, perceptions, and ultimate actions.

It was found that most owners:

- were not surprised that data in the first phase of this study showed that only 10% of the building owners monitored and compared their energy consumption to that of others;

- indicated they were considering or had just started tracking consumption because they were beginning to appreciate its value. One owner, on becoming familiar with the results of the study, sent his designer back to the drawing board because he now understood enough to become dissatisfied with the anticipated energy consumption of a new office structure he was building. This is an example of instant payback and illustrates how much an owner can influence the decision if he understands energy consumption patterns and their significance;

- have little faith in advertising claims for energy cutting devices or systems. Believing the claims are exaggerated or inapplicable to their needs, they are evaluating information on potential benefits with skepticism, resulting in prolonged assessment before satisfying themselves as to their merits;

- are waiting for feedback from those who have already implemented retrofit measures and are seeking advice from many quarters before reaching decisions.

Partially compensating for these conservative approaches, (which in aggregate may be termed the "learning curve" or "learning constraint") that slow the pace of introduction of energy conservation measures in buildings is a new owner attitude that is emerging.

Many office building owners have come to realize that it is in their self interest to cut energy use to protect their investment in the future. This longer-term view helps accelerate the learning process and gives rise to a more positive attitude. The fact that electrical energy costs continue to rise and are approaching the $0.10/KWH mark in New York City has had a significant effect on owner attitude and has begun to make more energy conservation measures attractive.

Nevertheless, the basic barrier identified in this study, viz., the relatively lengthy time for an owner to move up on the learning curve to the point where he feels confident enough to be decisive, may be ameliorated further by continuing DOE educational and demonstration efforts and by DOE tracking consumption patterns using a representative sampling to permit owners to make comparisons.

More owners must be persuaded to track their energy patterns continuously, month-by-month. The methodology for tracking energy consumption should be standardized as quickly as possible because it is relatively simple and not likely to be as controversial as that for assessment of potential savings.

While it may make sense to eventually standardize an assessment approach to help owners in understanding potential benefits for their building(s), it appears more important now to motivate owners to make a proper assessment of potential savings by any reasonable methodology rather than waiting to obtain adequate data on correlation between computer programs and actual consumption and other refinements.

It has become apparent that government incentives, while being useful in accelerating owner's timing in making commitments, are not needed to motivate owners whose cost for energy is approaching the $0.10/KWH average level. They may be more appropriate in those parts of the country where energy costs are low and are expected to remain low.

Most owners are not planning to borrow money for energy conservation retrofitting but instead are budgeting for future energy conservation improvements using existing income.

I. CONSUMPTION BUDGETS

Unlike a new building where there is considerable flexibility during the design process, each existing office building has many fixed physical and operating characteristic limitations which makes the potential for reducing energy consumption in each case unique.

An energy budget or goal unique to each building, set by the owner, is recommended. It should be based on the potential annual savings peculiar to the specific building using practical measures with a maximum three year payback period (unless the owner will accept a longer payback period).

Once a goal is set, an owner need not limit himself to use of energy conserving measures upon which the goal was predicated. New and improved energy conservation measures are being brought to market every month and the owner should be encouraged to use the best possible devices and procedures in any appropriate combination. After instituting conservation measures, owners should be urged to reassess their goals regularly, with a maximum interval of three years, because more conservation may be achievable as technological advances are commercialized. Comparative information on consumption will be invaluable, as well, to those who set public policy.

To help foster voluntary energy conservation budget setting by owners for existing office buildings, it is recommended that DOE obtain and publish annually, for at least a five year period, the budgets set by owners during the prior year for a representative cross section of existing office buildings, results achieved, and other pertinent information. This recommendation is consistent with and supplements the recommendation regarding DOE tracking consumption patterns to help owners move up more quickly on the learning curve.

J. APPLICABILITY OF RECOMMENDATIONS AND METHODOLOGIES

One cannot interpolate or extrapolate the New York City office building data with regard to potential energy savings to obtain insights for other cities and regions, because of different climates, likely different building mixes, and different regional operating practices. However, it is believed that broad-based correlations or relationships similar to those observed for New York City are likely to be found in other geographical areas with respect to most of the variables. In particular, it is believed older buildings are likely to use less energy no matter where located because older buildings are likely to have local heating and cooling systems, local switching, lower lighting levels, and lower electrical and mechanical capacities.

It is believed that all geographical areas will evidence widespread building characteristics, operating practices, and consumption patterns—the older community having the greatest spread.

Because there has been a history of design and technical cross-fertilization between office building designers and engineers from New York City and other cities, it is believed that New York City office buildings, from an energy relevant standpoint, are not too dissimilar from buildings in the rest of the country with a similar climate. Adoption of new technology, practices, and designs do not usually have regional boundaries.

Therefore, while information using representative sampling should be obtained for the entire country, it is not necessary to wait to utilize the broad-based findings and recommendations in this study on a national scale.

II. RECOMMENDATIONS

The following recommendations may be implemented by DOE or by appropriate non-governmental organizations, with DOE encouragement or assistance. Although these recommendations pertain to existing office buildings (the scope of this study), generally, they are applicable to most other building types.

- Develop a uniform and nationally acceptable system for tracking and making comparative analyses of energy consumption patterns and trends: to enable owners to compare rationally energy consumption in their buildings month by month, year by year—and with that of other similar buildings in the same or other regions of the country; and to enable government to assess intelligently energy conservation achievements nationally or locally, resulting from their policies and programs.

  This will require:

  — adoption and promulgation of a nationally recognized standard for normalization of energy consumption for occupancy/utilization and weather conditions;

  — development of a nationally representative sample to gauge energy consumption and widespread dissemination of the information on a regular and timely basis;

  — fostering the use of a uniform building energy information form(s) for reporting information.

- Increase efforts to educate bulding owners on the importance of, and methodology for, properly tracking energy consumption in their buildings; comparing consumption patterns and trends with those of others (when such information is available as recommended above); and assessing the results of conservation measures after they have been taken.

- Correlate computer simulated design programs with actual operating results and develop a nationally acceptable methodology(ies) for the assessment of potential energy savings resulting from proposed alternative conservation measures. Until an assessment approach is standardized, owners should be encouraged to make appropriate assessment of potential savings for each of their buildings, by any reasonable methodology, utilizing qualified professional personnel for their analyses.

- Encourage owners to develop separate and individual energy budgets or goals for each of their existing buildings, based on potential annual savings unique to the specific building, using practical conservation measures with a maximum three year payback period (unless the owner will accept a longer payback period) . . . . and to monitor the results springing from the implementation of such measures.

To help foster energy conservation budget setting and implementation of appropriate conservation measures obtain and publish annually, for a representative cross section of existing office buildings, for at least a five year period, the budgets set by owners during the prior year, results achieved, and other pertinent information. This is consistent with and supplements the recommendation regarding tracking of consumption patterns, countrywide, to help owners move up more quickly on the learning curve.

- Concentrate on, and give priority to, energy conservation efforts in post-World War II buildings which, as a class, have more square footage and greater potential for energy savings.

- Concentrate on, and give priority to, energy conservation measures that minimize consumption of energy in partially or totally unoccupied and unutilized space—utilizing the most efficient and effective devices, systems, and procedures available to achieve this by:

  - providing heating, cooling, lighting, and ventilating only when and to the extent necessary;

  - controlling, localizing, replacing, or modifying the use of energy consuming equipment whose capacity is greater than necessary.

  Examples of potentially beneficial retrofit and operational strategies for consideration for immediate use are indicated in this report, but consideration should be given to advances in retrofit technology as they are commercialized. For example, it is anticipated that devices that will control ventilation air more effectively than at present and devices that will shut off lights or a local air conditioning unit automatically when no one is present will be commercially available in the early 1980s.

- Do not provide additional government incentives to motivate owners to make commitments to conserve more energy except where energy costs are low and are expected to remain low. They are not needed as cost of energy approaches the 10¢/KWH average level, and owners move up on the learning curve to feel confident enough to be decisive in committing funds for energy conservation measures.

- While information using representative sampling should be obtained for the entire country, do not wait to utilize, on a national scale, the broad-based findings and recommendations springing from this New York City office building study.

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