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Energy Conservation In Modern Office Buildings

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ABSTRACT

Emerging critical problems relating to the shortages of energy have fostered new inquiries into ways and means of reducing energy consumption in urban centers. The modern, high-rise office building in aggregate may consume as much as 20% of the total energy used in a large city and consequently is deserving of more careful analysis than has heretofore been given. A recent inquiry has verified the need for further study in depth of the apparent significant waste of energy in large office buildings.

For some time, much has been said and written concerning energy conservation in buildings, in many instances with specific reference to the failure of architects and engineers to give adequate, if any, consideration to energy conservation in the design of buildings.

An opportunity to verify the general criticism in its application specifically to the modern office building in New York City was offered to the Polytechnic Institute of New York through its Center for Urban Environmental Studies (CUES). The offer came from the Inter-departmental Committee on Public Utilities (ICPU) created initially as an advisory group to the Mayor of the City of New York regarding public utility expansion problems but which subsequently broadened its interests to include problems in communication services, fuel supplies, and electric power, and eventually, the determination of waste of certain forms of energy in building systems design and construction. The adoption of this latter area of activity was sparked primarily by the increasing inability of the electric utilities to fully meet the summer peaks of electric demand in buildings. The city adopted an energy conservation policy, the "save-a-watt" campaign was born, and the ICPU joined in the effort to implement the city policy. All of this was initiated in the Fall of 1970.

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It was already well known that one basic reason for the energy problem now facing not only New York City but the entire country, is the fact that the available supply of energy in its several forms, has not maintained its relationship with the demand for that energy. Since the most logical step to be taken to meet this worsening condition was reduction in demand, the ICPU chose to make a study of energy use, and possible waste, in office buildings, as one step in a larger program which will not be detailed here. It is in this study that the CUES participated.

In 1972 the ICPU selected 180 New York City office buildings for inclusion in its study. Its objectives were to obtain a broad picture of the manner in which all forms of energy were utilized, the volume of use of total energy, and a comparison of such total use among the buildings selected. Findings would provide a basis for further detailed study later and the possible development of criteria applicable to both new and existing buildings for the design of building systems which would reduce energy requirements. Such criteria would form the basis for the development of a course of action as a preliminary to a program of either voluntary or mandatory allocation of energy in these buildings in order to forestall any critical energy shortage.

The 180 buildings which were selected were recommended by the Real Estate Board of New York and all but a few of them were occupied within the past 15 years. The selection was made to include buildings with modern, extensive, air conditioning systems. The characteristics of the buildings selected for the purpose of this study were:

> year opened; number of stories; sq. ft. of rentable space; type of air conditioning system; electricity used (Kw hrs.); natural gas used (MCF); fuel oil used (gals.); and steam purchased (pounds); all covering a one year period (1971).

This data was requested in a questionnaire sent to each of the building owners. An analysis[1] of the responses received from 76 of the recipients is of considerable interest.

All of the energy available from the total of the several fuels utilized, including purchased steam, was reduced to the number of BTU per sq. ft. of rentable space for the year 1971. It was found that these varied from a high of 575 BTU $\times$ 10^3 per sq. ft. to a low of 62 BTU $\times$ 10^3 per sq. ft. and a median of about 161 BTU $\times$ 10^3 per sq. ft. All of the BTU per sq. ft. per year values were plotted in an effort to discern trends. When reduced to groups of buildings as shown in Table 1, some trends do develop but the broad bases of this study did not permit accounting for them.

[1] This original study was directed and the original findings were evaluated under the direction of Dr. Charles W. Lawrence, P.E., Public Utility Specialist with the I.C.P.U. of New York City.

Table 1. Business Buildings—Energy Consumption 1971—N.Y.C.

Year opened	*No. of bldgs.*	*Average annual BTU/sq. ft.*	*Av. no. of stories/bldg.*	*Av. area per story—sq. ft.*
1950-54	8	126×10^3	23.3	17,400
1955-59	26	162	26.7	20,100
1960-64	18	194	33.7	21,400
1965-69	17	266	33.5	21,400
1970	7	201	37.6	23,700

The trends shown in the table as well as other specific apparent trends are shown graphically in Figures 1 to 4.

Figure 1 relates the consumption of energy in business buildings to their height. The points plotted represented groups of buildings of the same height and an average within each group of the average annual consumption in BTU per sq. ft. $\times 10^3$.

Figure 2 relates the consumption of energy in business buildings to the year in which they were opened. Consumption again is the average annual per year in BTU per sq. ft. $\times 10^3$. This figure also shows the same relationship for average use in groups of buildings opened within the same five year period. In both instances "apparent" trends in energy consumption is indicated.

Figure 3 relates the same five year groups of buildings to the average height of each group, a relationship of some interest as affecting total energy consumption

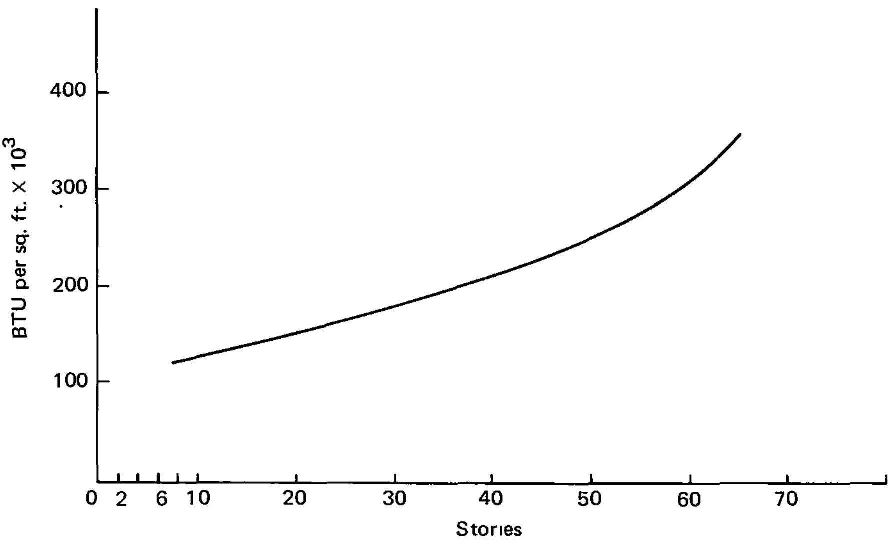

Figure 1. Approximate annual energy consumption in buildings grouped by height.

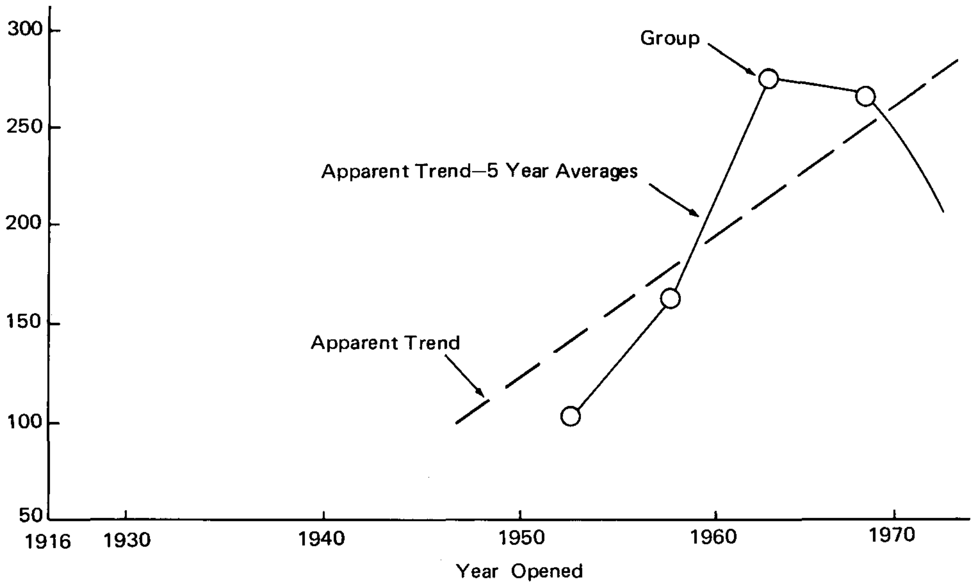

Figure 2. Approximate annual energy consumption—BTU per sq. ft. X 10^3 vs. year building (groups) opened.

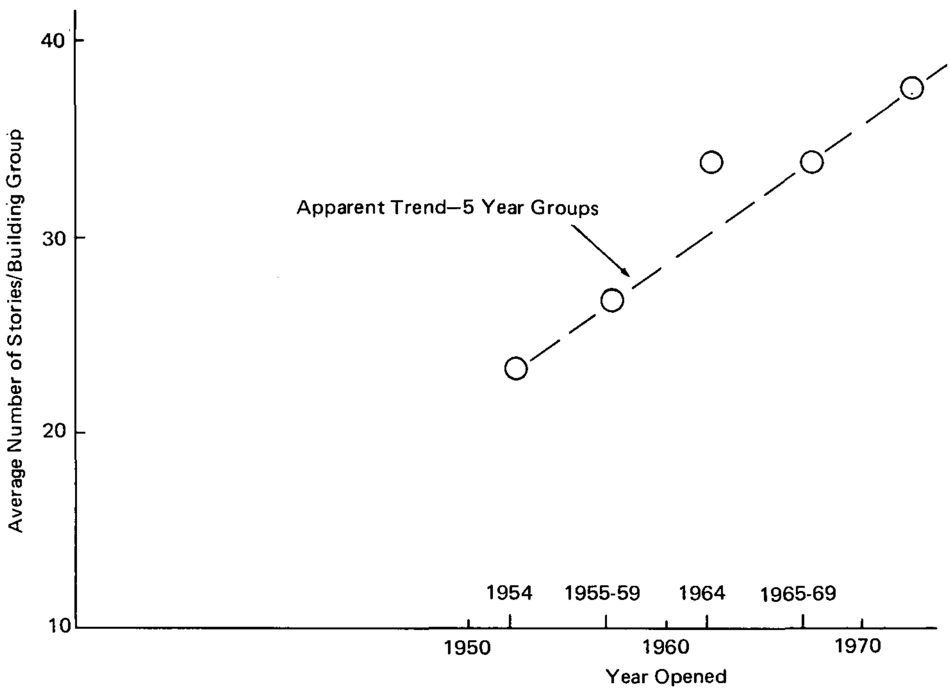

Figure 3. Average height of buildings vs. year building (groups) opened.

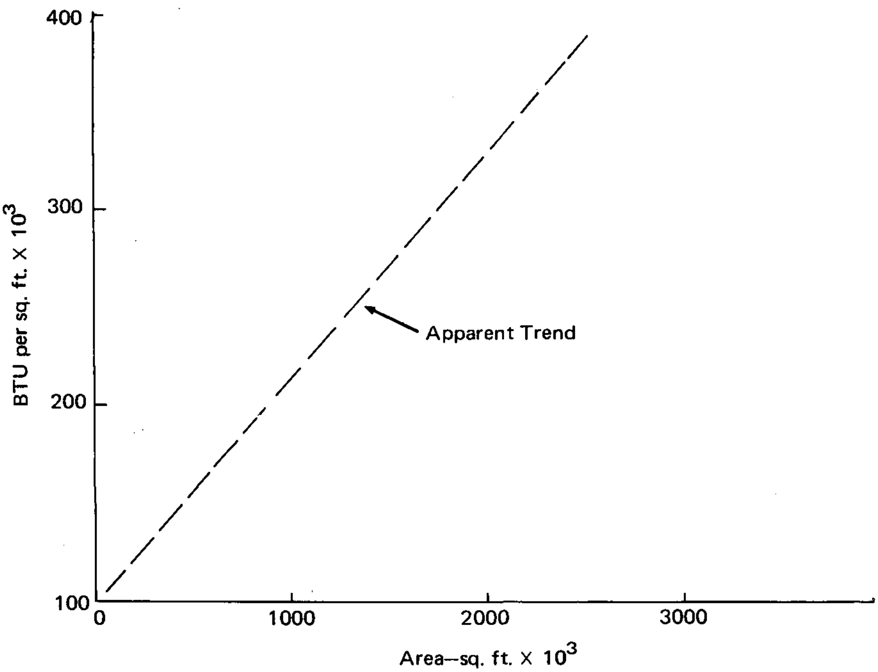

Figure 4. Average annual energy consumption vs. total rentable space.

on a unit basis. The apparent trend in this instance is much more readily identified and shown.

Figure 4 relates average annual consumption in BTU per sq. ft. X 10^3 to the total rentable space of the buildings. The apparent trend in the growth or decrease of such consumption with increased height is also indicated.

The completed survey gives few clues as to the basic reasons for the trends indicated. This analysis by CUES was a further step taken to develop, where possible, indications of the reasons for the very wide spread in basic total energy consumption in tall office buildings. The survey and this analysis do not meet that goal. Much more detailed study of these buildings to include the construction and use of their service systems, architecture, and operation and maintenance is obviously needed to find those basic reasons. However, the results of this study do make it seem likely that in the design of buildings up to now, insufficient attention has been given to the element of energy conservation.

It is recognized that there are extremely significant considerations which are not revealed by either the survey or this analysis. Some of them were included in the ICPU questionnaire but did not provide sufficient information for productive analysis. Some examples of these considerations include variations in type of occupancy within the "business" classification, the daily hours of normal occupancy, building exposure and type of air conditioning system, the impact of adjacent structures, tenant habits and the like. Appendix "A" which follows, suggests a more detailed questionnaire which could be used to elicit further information.

There is no question but that more detailed information is needed if conclusions leading to the control and improvement of the design of those elements of buildings that involve energy consumption are to be found. CUES did participate with the Administration and Management Research Association of New York City, Inc. (AMRA), the ICPU, and the firm of Syska and Hennessy, Inc., in the preparation of a proposal whose goals are to develop criteria for achieving conservation of energy in buildings. More specifically, its goals included the development of new design and construction criteria applicable to facilities related to heating and hot water, ventilation and air conditioning, lighting, service equipment, and building losses. Building categories would be developed and finally energy allocations would have been recommended.

The subject is of particular importance today largely because of the subsequent development of fuel shortages. The work of the ICPU in New York City with the assistance of CUES and others has led to some voluntary efforts to conserve energy in buildings. More specific guidelines are nevertheless needed and should be developed. The energy crunch will be with us for some time to come.

Appendix A

QUESTIONNAIRE

OFFICE BUILDINGS–ENERGY REQUIREMENTS

The ____
of the City of ___________ is making a study of buildings in the city with respect to their energy requirements. Information is needed as detailed in this questionnaire. It is hoped that you will give the City your cooperation by completing the answers requested and returning the questionnaire as directed below.

A. *GENERAL*

1. Full address of the building ______________________________
   ____
2. Give age in years ____

3. Number of stories, including basements ________________
4. Total sq. ft. of rentable or occupiable space ________________
5. Normal occupant load—*Persons* ________________
   a. Number of hours worked daily by such normal occupant loads ______
   b. Number of days of such normal occupancy per week ________
6. What is the nature of the major occupancy or use of the building and give related details ________________
7. Detail major tenant power-consuming equipment or appliances drawing power from the building services (computers, private elevators, kitchens) ________________
8. State power consumption (or submit copies of bills) for each month of recent full year covering the following utilities:
   a. Electric—Kw hrs. ________________
   b. Gas—cubic ft. ________________
   c. Fuel oil (give type)—Gals. ________________
   d. Purchased steam—Pounds ________________
9. Give name of owner or agent and address if different from that of building ________________
10. Name of resident manager ________________

B. *ARCHITECTURAL*

1. Give the class of construction of the building ________________
2. What is the nature of the exterior wall construction, give type, size of windows, and kind of insulation, if any ________________
3. Of what materials is the structural frame? ________________
   a. Materials for floor construction ________________
4. Number of full height stairways including smokeproof tower ________
5. How many other shafts in the building including elevator shafts ________ Give types ________________
6. Give square footage and ceiling height of main lobby on the street floor ________________
   a. Number of street entrances to the lobby ________________
   b. Number of shop entrances into the lobby ________________
7. What is the average ceiling height on upper floors ________________

C. *HEATING AND HOT WATER SYSTEM*

1. Is the heating system one pipe steam, two pipe steam or hot water? ____
   a. At what temperature and pressure is steam or hot water distributed? ________________
   b. If steam system is steam generated in the building or purchased ______

c. If all or part of the heating is electric indicate locations and major characteristics of installations ______

2. At what temperature is domestic hot water supply furnished? ______
   a. Does the hot water supply system include a temperature regulator? ______

3. Types of boilers ______
   Give total capacity in horsepower ______
4. Type of fuel used for boilers ______
   a. Are the burners automatic or manually controlled? ______
5. Is steam or hot water recycled? ______
   a. Is any of the steam or hot water generated reused for other than heating purposes? ______
   If so, approximately what per cent ______
6. What temperature levels are maintained in the occupiable areas during heating cycles? ______
   a. For how many hours daily ______
7. Is heat furnished to any unoccupiable areas? ______
   a. If so, estimate total square feet of such areas ______
8. Is heating combined with cooling to maintain comfort levels? ______

D. *LIGHTING*

1. What type and size of lighting fixtures is in major use in the building? ______
   a. How many hours per average day is such lighting in use? ______
   b. Does this use include perimeter fixtures? ______
   c. How old are most fixtures (years)? ______
2. What foot-candle level of lighting is installed in the average office? ______
3. Is the heat given off by the light fixtures used or re-used in any way? If so, indicate in what way and to what extent ______
4. Are controls manual or automatic? ______
5. Are light fixtures utilized in the buildings' ventilation system? ______
   a. If so, indicate method used. ______

E. *AIR CONDITIONING SYSTEM(S)*

1. Is the building air conditioned? ______
   a. If so, is it by a central system, zoned system, by floor units or by window units? ______
2. What type of system is it? ______
   a. What fuel or fuels does it utilize? ______
   b. How is the system classified (central station, dual duct, heat pump, etc.)? ______

3. Is air cooling included? __________ If "yes," at what temperature level are most spaces maintained? __________
   a. If cooling is included, give total installed capacity of refrigerating equipment in tons __________
   b. Is outdoor air utilized to help conserve refrigeration? __________
   c. Are any other controls utilized to regulate heating, cooling and humidity? __________ If so, what are they __________
4. Is "waste" heat utilized in the system? If so, describe __________
5. What is the installed total capacity of the system in cubic feet per minute? __________
6. How many hours per day is it operated and for how many days in the year? __________
7. What is the installed total capacity of all fans in the system in horsepower? __________

F. *SERVICE EQUIPMENT*

1. How many elevators are in the building? __________
2. Are they electrically operated? __________
   a. If not, what other form of energy is employed? __________
3. Are all cars utilized full time each day? __________
   a. *If not, describe the programmed use of each car per day* __________
4. What is the installed total capacity (name plate) in horsepower of the elevator motors? __________
5. Are the elevators of the same age as the building? __________
   a. If not, give dates __________
6. Does the building have escalators? __________ How many? __________
   a. If so, give installed total capacity in horsepower __________
7. How many hours each working day do the escalators operate? __________
8. Are the escalators in separate shafts? __________
   a. If so, how many shafts and for what heights __________
9. Does the mechanical equipment for the building include miscellaneous fans and pumps (not part of the air conditioning system)? __________
   a. If so, how many and what is their total installed capacity in horsepower __________
   b. On the average, how many hours per day do they operate? __________
   c. For how many days per week do they operate? __________

G. *OPERATION AND MAINTENANCE*

1. Describe the details of management control affecting the maintenance and operation of the building with emphasis upon the control of the several energy consuming systems __________

2. What are the habits of the building occupants with respect to the waste (or conservation) of energy? ______________________________