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MASTER

"If we fail to act soon, we will face an economic, social, and political crisis that will threaten our free institutions."

President Carter in his
energy address to Congress
April 18, 1977

DISCLAIMER

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ENERGY CONSERVATION IN EXISTING OFFICE BUILDINGS

PHASE I*

EXECUTIVE SUMMARY

This Phase I report summarizes the completed tasks which encompass: (1) a description of office buildings in New York City in terms of physical and operating characteristics and energy consumption, (2) an analysis of some of the inter-relationships between these characteristics and energy consumption, (3) the development of a statistical methodology for representative sample selection, and (4) an analysis of energy consumption patterns prior to and after the 1973 oil embargo, based upon a weather and occupancy/utilization normalization procedure developed for this purpose.

It is believed that this is the first time that a representative sample has been used to study energy consumption in existing buildings, when that energy consumption data has been normalized for occupancy/utilization factors and weather conditions, for comparative analysis.

A preliminary review of the data and information pertaining to New York City's office buildings, which represents the largest concentration of office buildings in the world, shows that there already has been about a 12% savings in normalized energy consumption when comparing 1971/1972, the two years before the 1973 embargo, with 1974/1975 - - largely due to simple adjustments in building operating temperatures and lighting practices. (The savings based upon raw data is 19%.)

This achievement has occurred despite the fact that owners and managers have little quantitative perception and knowledge of any precision relating to energy consumption patterns in their buildings. In general, they do not know how much they saved, how they compare with others, or what the potential benefits of further energy consumption measures can be. Without the widespread practice of continuous and accurate tracking of consumption, it will be difficult to achieve the next level of energy savings and easy for them to retrogress, as is demonstrated in individual cases in the report. And it will be very difficult to establish and maintain current 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.

The review shows that there is a substantial spread in physical characteristics, operating practices, and energy consumption patterns in office buildings, suggesting that a variety of retrofit measures and strategies may be necessary for different levels of conservation potential and economic benefits. This aspect will be explored in detail in Phase II. Examples that illustrate this spread are as follows:

	RANGE	MEAN	MEDIAN
1975 Consumption, normalized (MBTU/Sq Ft)	65-223	112	108
1975 Consumption, actual (MBTU/Sq Ft)	67-225	115	110
Age (years)	8-82	44	48
Total Building Area (SF)**	17,000-1,850,000	401,000	318,000
Total No. of Floors	4-51	24	22
Computer Area (SF)**	100-14,000	2,700	3,400
Total Wall Area (SF)**	7,400-503,000	130,000	106,000
Percent 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 U. S. Energy Research & Development Administration Contract No. EY-76-C-02-2799.000

** Numbers rounded off for easier reading

The strongest correlation between energy consumption and energy related attributes appears to be age, hours of lighting, hours of perimeter heating and cooling, and types of perimeter system. However, some buildings which evidence some of these high consumption attributes do not show high overall energy consumption. For this reason, Phase II is directed to assessing the value, impact, and feasibility of proposed conservation measures in the total context.

An examination of frequency distribution data shows that older buildings, as a class, use less energy per square foot and contain a substantially smaller amount of floor space than newer buildings. This suggests according less priority to energy conservation efforts in older buildings. In the next phase, the frequency distribution data will help determine where the most advantage (leverage) can be obtained for ascertained energy conservation measures.

The application of a computer simulation design program to a typical building and a hypothetical "average" building produced reasonable correlation with actual energy consumption.

A high degree of non-uniformity in quality and quantity of owner known information was found, necessitating more field inspection than anticipated. Also, much information gathered appears to have less energy related relevance than presupposed.

Even at this early stage, all the preceeding suggests:

- the need for a uniform building energy information form (questionnaire) to be adopted by the private and public sectors. Upon completion of the remaining phases, a proposed form, based upon the results of the complete study, will be prepared.
- the need for a nationally accepted system of normalization of energy consumption for occupancy/utilization and weather conditions.
- the need for a national representative sample (a "Neilsen Rating" sample, to borrow a phrase from TV terminology) which can be used to gauge energy consumption patterns and practices, year in and year out. It is believed that this may be implemented with a relatively small percentage of buildings in a limited number of geographical regions. A national sample size will be suggested upon completion of the study.
- the need for a major effort to educate building owners on the importance of tracking consumption, comparing patterns with others, and evaluating potential and installed conservation methods.
- the need for a large scale effort to correlate computer simulation design programs with actual operating results.

I. INTRODUCTION

In 1973, the oil embargo forced the United States to take a new look at energy consumption in all phases of national life. This study is concerned with the potential for energy conservation in office buildings.

So far, the major emphasis in energy conservation efforts for office buildings (and other types) has been the development of approaches for saving energy in new buildings. For example, the development by the engineering community of prescriptive standards such as ASHRAE 90-75 and the recently passed federal legislation, Public Law 94-385, Title III, directing the establishment of energy conservation performance standards both of which are limited to new construction. Also, the design and construction professions have become so sensitized to producing buildings that use energy prudently, that most buildings designed and built since 1973 use significantly less energy than those of a mere few years ago...witness all the energy conservation awards and publicity.

However, as a nation, we are not facing up to the real problem of energy conservation in existing space. In some cities, there is now little or no office building construction taking place, or being planned, because of economic conditions. In other cities, growth is slower than in the past. At current or anticipated growth rates and given the current renovation and rehabilitation trend which extends the longevity of buildings, it may be 50 years before there is an appreciable impact resulting from energy measures in new buildings.

Lack of information on precisely where the opportunities lie, problems relating to retrofitting, and other factors that bear upon making the decisions for conservation in existing buildings have been a deterrent to confronting the real challenges for achieving significant benefits.

For example, in 1973, a brief survey[1] on energy conservation in modern office buildings was prepared, based on data made available by the Interagency Committee on Public Utilities of New York City. This survey, although not fully representative of New York City buildings, indicated that there was a wide spread in energy consumption levels in existing buildings and suggested significant opportunity for substantial savings. It did not delineate where the potential was with respect to specific characteristics, nor how to go about taking advantage of it.

The goal of the study reported herein is to bring together sufficient information, in the office part of the commercial building sector, to permit the proposal of a strategy for energy conservation. This approach includes dealing with such matters as adopting standards, providing incentives, and assisting local and state governments and their constituencies in reaching decisions regarding appropriate and equitable implementation of conservation programs.

Most owners, engineers, architects, developers, investors, regulatory officials, manufacturers, contractors, and users lack direction and motivation to go beyond their present voluntary efforts. For example, the business community in New York City, through voluntary efforts, has saved between 5 and 10% in energy consumption in the 18 months following the 1973 crisis, according to Consolidated Edison's boxscores. The business community does not know how much of this is in the office building segment (or other segments) and how much more energy can be saved, or how to achieve such savings.

Manufacturers have limited information to determine whether or not (or how much) to invest in new retrofitting systems. Regulatory officials do not have a solid base for considering establishment of retroactive standards or for providing incentives. Investors and consumers are seeking more precise information about the impact of any changes. Efforts to legislate energy conservation programs have not met with success, partially due to lack of the meaningful data necessary to make rational judgments.

One of the problems experienced is that the real decision makers (the owners) have not widely implemented energy conservation programs requiring significant expenditures in existing office buildings, notwithstanding their apparent support of such endeavors or the support of the professionals and others who are retained by them. It is important to have firsthand insight into the real reasons for this.

This study is intended to overcome the aforementioned shortcomings. It is directed towards establishing the potential value of various retrofitting or procedural conservation measures in existing office buildings, beyond those achieved voluntarily in 1974 and 1975, and recommending strategies for translation in practical and workable industry-wide applications and standards.

The research is based upon an examination of more than 1000 office buildings containing about 250 million square feet of gross space in New York City. This city has more office space than any other city in the U. S. and a wide diversity of building types and ages. It is estimated that New York has about 4% of the nation's total office building inventory. Office buildings are substantial users of energy. Also, in New York City, this class of building represents over half of Consolidated Edison's electrical energy output.

The procedures in this study are predicated upon a three-step cascading evaluation based upon statistical sampling. In each succeeding step, the size of the sample decreases, but the amount of information increases.

There are eight specific objectives:

- Determine the physical and operational energy related characteristics of office buildings, and energy consumption patterns.
- Establish the potential value of various retrofitting or procedural conservation measures beyond those already achieved voluntarily since the energy crisis for various levels of conservation.
- Determine the economic, technical, and practical feasibility for achieving these additional savings.
- Determine the penalties, constraints, and other adverse consequences of possible conservation measures.
- Recommend how to overcome barriers to achieve feasible energy conservation measures.
- Develop realistic energy consumption budgets based upon the above, if this is the proper approach and, if not, propose an alternative approach.
- Develop energy conservation strategies and recommendations.
- Evaluate available data, concepts, reccommendations, and methodology for application to other building types and geographical sectors, and as factual input to otherwise theoretical design criteria for new buildings.

Achievement of the first of these objectives is the goal of Phase I of this study and the results are reported herein.

The steps in this first phase consist of:

1. Classification and description of the major office building inventory in New York City in terms of building characteristics which appear to bear upon energy consumption.

2. Selection of an appropriate sample through a statistical analysis of the building inventory.

3. Obtaining pertinent data on levels of energy use for buildings in the sample and information on physical characteristics of the buildings and their uses.

4. Analyzing the data and information obtained, categorizing and explaining differences.

5. Comparing energy consumption before and after the crisis brought on by the 1973 oil embargo.

REFERENCE

1. William H. Correale, "Energy Conservation in Modern Office Buildings", Journal of Environmental Systems, Baywood Publishing Company, (Winter 1973) Volume 3, Number 4.

II. CLASSIFICATION OF BUILDINGS STUDIED AND SAMPLE SELECTION

A. INVENTORY OF OFFICE BUILDINGS IN NEW YORK CITY

The general office building population of New York City has been under study[1] since the early 1970s in connection with the development of new legislation directed to the improvement of fire safety in this type of structure.

During the course of these earlier studies, an inventory of the so called E Classification of Buildings[2] (which also contain certain occupancies unrelated to office use) was generated. This inventory included data regarding a number of physical characteristics (e.g., building size, age, height, stairs, air conditioning, elevators) which are of interest to this energy study, and which were compiled from information provided by the Building and Fire Departments of the City of New York. Approximately 1037 buildings, used primarily for office activies, were described in this earlier work.

These data, while incomplete and in some instances not fully verified, nevertheless were useful in establishing the general physical nature of the building population to be addressed in this study.

The Class E building inventory list was compared with building records maintained by the Real Estate Board of New York for verification and for development of a final list of office buildings to be included herein.

The deletion of redundancies, buildings which had been demolished since the earlier list was prepared (1972), buildings found to no longer represent the subject building occupancy type, and the addition of buildings to the office building stock of the City, brought the total inventory to 1030 buildings.

B. QUESTIONNAIRE NO. 1

A brief, prelminary questionnaire (Questionnaire No. 1), shown in Appendix A-1, was developed and distributed in order to acquire information from as many buildings as possible.

Of the 1030 buildings in the inventory, 17 owners could not be reached. Therefore, Questionnaire No. 1 was mailed to the owners and/or managers of 1013 buildings.

505 usable returns were received (after as many as six follow-ups in some instances) and of these, further field investigations revealed that 69 buildings were not representative of the subject population, were deficient with respect to the availability of energy consumption records, had owners who were unwilling to cooperate in the study, or were deficient in some other respect. Thus, the subpopulation of buildings established for the study was 436...a 45% response to Questionnaire No. 1. These returns were validated by the Real Estate Board of New York for ownership accuracy.

Information requested in this preliminary questionnaire was organized under eight major categories, each having a number of parts. In addition to location and ownership information, the major areas of inquiry related to: age, gross area, rentable area, number of floors, window area, heating and air conditioning, lighting, and percent of space actually occupied.

Each building was assigned a unique code number (taken from the original inventory mentioned above) which has been carried through all subsequent computer analyses and outputs given in this report. In cases where buildings were deleted from the original inventory because they were demolished, or were found to have been converted to other uses, or because they did not conform to the office building occupancy type to be studied, the associated building identification code numbers were also deleted. As a consequence, subsequent code listings of buildings for which responses were received from Questionnaire No. 1, and the buildings within the selected sample are not always in continuous sequence.

The code numbers also are used to maintain the confidentiality of the information provided.

C. ANALYSIS OF 436 BUILDING SUBPOPULATION

Responses from the 436 building subpopulation (Questionnaire No. 1) were processed and the analyses are shown in Appendix A-2. Although the data available for the 1030 sample were incomplete, comparisons with the results for the 436 building sample are shown on the following pages for age, area, and height only.

A number of statistics of interest derived from Appendix A-2 are shown below with reference to:

1. Age *

6.5%	(28)	of the buildings were over 77 years old - 1900
23.1%	(100)	of the buildings were over 58 years old - 1919
58.2%	(252)	of the buildings were over 37 years old - 1940
85.8%	(367)	of the buildings were over 15 years old - 1962
100.0%	(433)	of the buildings were over 7 years old - 1970

Information unavailable for three buildings.

Because of the requirements that there be at least five years of energy consumption data available for each building in the study, no buildings occupied after 1970 were included in the subpopulation group used to select the study sample.** Some information and comment concerning representative buildings from the age group from 1970-1977 will be included in the final report.

The 436 building sample tends to be somewhat younger than the 1030 building group, but yet representative of the group.

2. Total Building Area

(Net rentable office area, commercial, and other spaces). The building sizes range between 2,398,000 square feet and 3930 square feet. The median size is 180,000 square feet; the average size is 300,987 square feet. The 436 building sample tends to be larger than the original 1030 building group.

3. Height in Stories

Heights range from 70 stories to 2 stories; with a median of approximately 16 stories and an average of 19 stories. The 436 building sample tends to be shorter than the original 1030 building group.

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* The significance of the date groupings is discussed on page III-19.

** The latest consumption data available at the start of the study were for 1975.

4. Windows

It was found that approximately 89% of the buildings in the subpopulation have operable windows and the distribution of ratio (%) of window to wall area is as follows:

Ratio of Window Area to Wall Area	% of Buildings
Less than 20%	9
20 - 40	44
41 - 60	28
over 60	17
No information available	2

5. Air Conditioned, Rentable Office Area

It was found that the percentage of rentable office space which is air conditioned is as follows:

% of Office Space Air Conditioned	% of Buildings Reporting
less than 25	6
26 - 75	11
76 - 100	82
No information available	1

6. Lighting Levels

The number of watts/sq ft ranged from a maximum of 6 down to 1, with 332 buildings reporting. The median was approximately 2.5 watts/sq ft and the average was 2.8 watts/sq ft.

7. Hours of Occupancy

Approximately 64% of the buildings were occupied only during normal hours (8 a.m. to 6 p.m.: five days a week). 30% were occupied up to 50% more than normal hours, and 5% reported occupancy times greater than 50% above normal hours. Information was not available for only 1% of the buildings.

Other analyses of data from the 436 building subpopulation were made on an area basis, to establish pattern of physical attributes categorized in accordance with the energy-related characteristics contained in the questionnaire (date of occupancy, height, window area/wall area, percent rentable space (air contioned), lighting, hours of occupancy, and central air conditioning type). Appendices A-3 through A-9 display the aggregated building area for each common response (to each attribute) contained in the questionnaire. For example, in Appendix A-7 the responding buildings indicating lighting levels of less than 1.99 watts/sq ft contained 11,363,034 square feet of floor space or 8.7% of the total square footage in all buildings. Table II-1 shows the breakdown in each of the original categories for the final 44 building sample as well as for a hypothetical sample based uopn the 436 building distribution.

In addition to their significance in the sample selection process, these square footage analyses are also important for later evaulation of energy conservation measures in connection with quantification of potential savings which might be derived.

D. SELECTION OF REPRESENTATIVE SAMPLE AND SAMPLE SIZE

The general procedure for sample selection from the subpopulation, followed a rational approach together with a random selection process in order to insure that those building characteristics, based upon recent energy consumption studies and the experience of the research team, considered to be most relevant were represented as far as possible in proportion to their occurrence in the total population. Figure II-1 shows the flow diagram of the sample selection process in its entirety.

It was desired that each building, in the sample to be selected for more detailed study, should contain as many "match" points as possible with respect to similar characteristics in the 436 building subpopulation. Accordingly, a computer search system was developed to generate lists of all buildings which could be contained within specified compartments. Each compartment would include all buildings displaying common responses to selected elements of the questionnaire.

The compartments chosen are shown in Table II-1 This table represents the subpopulation (436 buildings) in terms of commonality of physical characteristics for key information points contained in Questionnaire No. 1.

The class limits for each characteristic, not previously designated in the questionnaire, were selected in order to establish compartments or divisions for sample matching which would approximately reflect those building attributes considered to be most

SELECTION OF SAMPLE

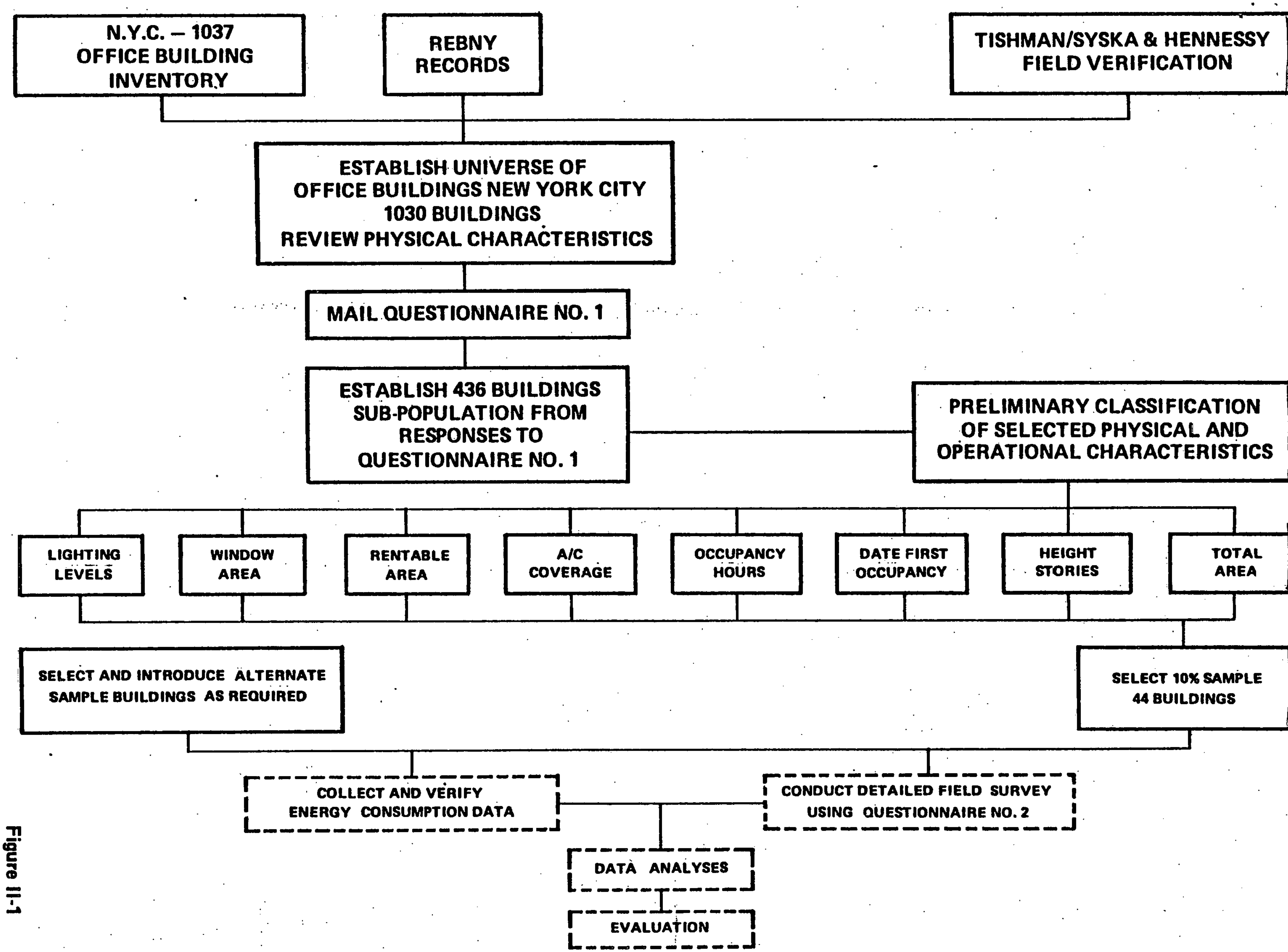

Figure II-1

relevant to the purposes of this study. For example, the age class limits or categories derived from (date of first occupancy) responses were selected to correlate influences of various building codes in force over the 109 year history of the building population under study. Similar divisions for story heights and gross floor areas were developed to follow known distributions in office buildings in New York City with respect to those particular characteristics.

For each information point in Table II-1, the number of buildings in the selected 44 building sample is shown, and the figure in parenthesis is the hypothetical number dictated by the 436 building subpopulation distribution.

In order to confirm the appropriateness of the above procedure, a number of samples chosen only by random sampling methods were also examined. It was found that these random samples tended to be deficient in the representation of one or more specific characteristics considered to be necessary if subsequent studies of the sample were to properly deal with all of the significant energy consumption factors of interest in the building population study.

The statistical analysis validating the selection of the 44 building sample size is shown in Appendix A-10.

E. ALTERNATE SAMPLE BUILDINGS

Since the sample array was to be chosen by computer procedures, it was anticipated that certain buildings so selected might not conform to practical requirements of the study. For example: owners might not be willing to cooperate in the in-depth follow-up building survey; buildings might change ownership or be scheduled for major renovation or demolition during the course of the study; or on inspection, the building might prove to be atypical in particulars of relevance to the investigation. Also, it is desirable to have a balance in type of ownership, e.g., public, investment, institutional, and no domination by an individual owner.

To provide for the replacement of such computer selected buildings, a computer-generated, ranked list of all buldings which most nearly conformed to each of the buildings in the originally selected list was prepared. Examples of these pools of "replacement" buildings are shown in Appendix A-11. For example, in the case of Building No. 55, it can be seen that there is a wide array of replacement buildings available which match the eight characteristics (shown by code in the identifying number) in eight out of eight, seven out of eight, or six out of eight cases.

19 of the original 44 computer-selected sample buildings were replaced through the above matching process.

A comparison of physical characteristics between the selected sample and the 436 building subpopulation is shown in Table II-1. The last column shows the actual number of buildings in each category compared with the theoretical number necessary to match the original 436 building distribution.

TABLE II-1
COMPARISON OF SELECTED CHARACTERISTICS
436 BUILDING SUBPOPULATION & 44 BUILDING SAMPLE

Characteristic	% of 436 Building Subpopulation with this response	% of 44 Building Sample with this response	Actual (Theoretical) No. of Buildings in each
Lighting Watts/S.F.			
Not avail.	23.6	29.5	13(10)
0 - 1.99	8.0	9.1	4(4)
2 - 2.99	37.2	43.2	19(16)
3 - 3.99	19.7	6.8	3(9)
4 - +	11.5	11.4	5(5)
Window Area/Wall Area			
Not avail.	2.1	2.3	1(1)
0 - 20%	8.9	6.8	3(4)
21 - 40%	44.0	36.4	16(19)
41 - 60%	28.0	34.1	15(12)
Greater than 60%	17.0	20.4	9(8)
Rentable Space Air Cond.			
0 - 25%	5.7	4.5	2(2)
26 - 50%	4.4	6.8	3(2)
51 - 75%	6.2	4.5	2(3)
Greater than 75%	82.1	81.8	36(36)
Not avail.	1.6	2.3	1(1)
Central Air Cond.-Type			
Not avail	2.1	4.5	2(1)
Not central	39.7	43.2	19(17)
Electric Driven	24.3	27.3	12(11)
Steam Driven	20.6	20.5	9(9)
Steam Absorption	13.3	4.5	2(6)

(continued on following page)

Characteristic	% of 436 Building Subpopulation with this response	% of 44 Building Sample with this response	Actual (Theoretical) No. of Buildings in each
Hours of Occupancy			
Not avail.	1.1	0.0	0(1)
Normal Hours	63.8	75.0	33(28)
20% over normal	22.9	11.4	5(10)
21 - 50% over normal	7.1	9.1	4(3)
More than 50% over normal	5.0	4.5	2(2)
Age of Buildings			
Not avail.	.7	0.0	0(0)
Prior to 1900	6.4	6.8	3(3)
1901 - 1919	16.5	18.2	8(7)
1920 - 1940	34.9	40.9	18(15)
1941 - 1962	26.4	27.3	12(12)
1963 - 1970	15.1	6.8	3(7)
After 1970	0.0	0.0	0(0)
Height of Buildings			
0 - 9 Stories	17.7	13.6	6(8)
10 - 14	26.4	22.7	10(11)
15 - 19	15.4	13.6	6(7)
20 - 29	21.6	25.0	11(9)
30 - 39	10.6	13.6	6(5)
More than 39	8.5	11.4	5(4)
Area of Buildings			
0 - 25,999 S.F.	5.0	2.2	1(2)
26,000 - 69,999 S.F.	19.0	18.2	8(8)
70,000 - 383,694 S.F.	50.9	52.3	23(23)
383,695 - 999,999 S.F.	20.0	20.5	9(9)
- 1,000,000 S.F.	5.0	6.8	3(2)

REFERENCES

1. Local Law No. 5 of 1973.

2. New York City Building Code, 1968.

III. SURVEY OF SAMPLE BUILDINGS

A. QUESTIONNAIRE NO. 2

The principal survey instrument for the study consisted of a detailed questionnaire (see Appendix B-1) designed to be executed in the field for each sample building under the direction of a professional team familiar with construction and operation of office buildings. The nine sections of the questionnaire included an "Interview Record", and eight response divisions as follows:

I - Owner- Management Occupancy Information

II - Energy Consumption and Metering

III - Heating, Ventilation and Air Conditioning

IV - Exterior Walls

V - Lighting

VI - Temperature Control

VII - Elevators

VIII - Conservation

At a meeting in Washington, D.C. on May 5, 1976, at the invitation of ERDA, the objectives of the project were discussed and the invitees shared their experiences and offered their comments regarding surveys, audits, and studies they had made. See Appendix B-2 for list of attendees.

An early draft of the nine part questionnaire, used for the interviews, was sent to representatives of the Federal Energy Administration, General Electric Company, National Bureau of Standards, Honeywell, Building Owners and Managers Association, Westinghouse Corporaton, ERDA, and Consolidated Edison Company of New York for review and comments.

The questionnaire was put through six drafts, including editing after two trial runs on a real building. The final draft reflects all constructive comments.

The questionnaire, frequently referred to as the second cut questionnaire, is designed to be used solely for a face-to-face interview, and for ready transcription to the computer. It was constructed to provide most of the information that was believed necessary to make the desired analyses.

A third cut sample will be used for an analysis which will complete the total array of information desired. The experience gained from using the second cut questionnaire and the third cut sample will provide adequate information to recommend the framework for creating a universal questionnaire. Standardization of information gathering will be helpful to the federal government, as well as to the private sector, to help achieve their respective objectives. Some of the information obtained may not be useful for broader based evaluations and will be deleted. Any information not obtained that is found to have value will be added.

1. <u>Data Acquisition Procedures</u>

a. Personnel

Interviewers were selected from the staffs of Syska & Hennessy, Tishman Research Corporation, and AMRA. All personnel were engineers or researchers familiar with building systems, construction, and operation. A total of thirteen interviewers participated in the interviewing sessions for the 44 buildings. Some of the interviewers worked in teams when conducting interviews for their first building assignment.

As experience was gained, interviews were conducted on an individual basis.

b. Instructions to Interviewers

Upon completion of the format of the questionnaire in its semi-final form, a briefing session was held with all interviewers for the purpose of instructing them in its content and in the intent of each of the questions. The questionnaire was reviewed on a line-by-line basis. Questions and comments were offered by the prospective interviewers and, where found practical, were incorporated in the final version of the questionnaire.

The questionnaire was not finalized until experience had been gained from interviews with the building manager (and his assistants) of Building No. 52 and Building No. 650, the first two builidngs studied.

A "Guide for Interviewers" (Appendix B-3) was prepared and distributed to the interviewers and another briefing session was held, after the questionnaires of the first few buildings were completed. Problems, difficulties, and pitfalls experienced by the interviewers were related and procedures for coping with them were instituted.

As the interviews proceeded, it was found necessary to issue additional instructions to the interviewers to assure uniformity in the responses obtained. These additional instructions were issued in the form of written addenda to the original questionnaire.

c. Soliciting of Owners' Cooperation

Owners of each of the buildings selected for the study were solicited (by mail and by telephone follow-up) by the Real Estate Board of New York for permission to conduct the interviews. The owners generally designated the building managers and/or engineers whom the interviewers should see.

d. The Interview

Considerable delays were experienced in arranging conferences with the building manager due to the pressures of their normal day-to-day duties. In some cases, emergencies arose which required the immediate attention of the manager and the conference would have to be adjourned and another date arranged.

The questionnaire was reviewed on a line-by-line basis with the building manager and the intent of the questions clearly explained. Where the information was not immediately available, another interview was arranged to permit the manager to obtain the necessary data. The building operating engineer and other asistants to the manager were consulted on questions of a technical nature.

Since no building manager had area data broken down in the format which we required, it was necessary to refer to building plans to develop these figures. In the buildings with more sophisticated management, these figures were calculated for us by the staff.

In most cases, however, we were permitted to borrow the plans and calculate the area at our convenience.

Where plans were not available and the building not too large or complex, the interviewer made field measurements. In buildings where it was judged that this field measurement effort would be much too time consuming, the survey of the building was terminated and arrangment made to conduct interviews for a "substitute" building.

In each building, a "walk-thru" inspection of the building was made to get a "feel" of the building; check on the general reliability of some of the responses; and in many cases to obtain information of which the manager or his assistants were not aware.

Some of the information required in the questionnaire could not be obtained, and although many managers responded to some of these questions it was felt by the interviewers their responses were based on representative figures they might have been exposed to rather than on actual fact or measurement. Questions relating to lighting watts per square foot and figures relating to air circulated fell into this category.

e. Substitution of Selected Buildings

In a number of instances, as the interviews and investigations progressed, it developed that the building selected was not suitable for our purposes. These buildings were dropped from the list and replaced by the procedure previously described. Some of the reasons for judging the building unsuitable for the study were as follows:

1) Owner would not release some pertinent data.

2) A large turnover in tenancy during the period under study - making it impossible to obtain adequate data as to hours of occupancy, energy consumption, or modes of operation.

3) Building provided unmetered steam and/or chilled water to another building where a reasonable proportioning of

energy use could not be estimated. Where the energy could be proportioned on a logical basis, an estimate was made and the building retained. The estimated energy figures have been noted as such in the computer printouts.

4) Significant physical alterations made during the period under study, where adequate information could not be provided.

f. The Checking Process

All questionnaires, when completed, were reviewed by the principal investigators for the following:

1) Completeness.

2) Credibility of responses.

3) Conformity with established instructions.

4) Spot checking of arithmetic.

When discrepencies or omissions were discovered, the interviewers were required to follow-up and obtain the required data by telephone or by additional visits as necessary.

Some arithmetic errors were discovered later on during the computer runs, since the program had build-in arithmetic checks. These too were followed up and the corrections made.

With the exception of the Interview Record and the section containing Owner-Management Occupancy Information, (withheld to preserve the anonymity of owners and buildings) the full response for each of the 44 sample buildings springing from the field interviews is given in Appendix B-4. These data are presented in computer output form and include additional unstructured comments made by the interviewer during the course of the survey of each building. There are over 750 information points on the response record. The data was edited and cross checked wherever possible. The verification process resulted in corrections from time-to-time. It is believed that the degree of accuracy is high since the total time consumed in the process was as much as 50 manhours. Further insight into this will be obtained upon completing the next Phase.

B. ENERGY CONSUMPTION DATA COLLECTION

For each of the 44 buildings, electrical and other fuel consumption data were collected for the 5-year study period. The other fuel data included utility provided district steam, No. 2 oil, No. 4 oil, No. 6 oil and natural gas. The electrical, steam and gas data were obtained from the Consolidated Edison Company of New York (after acquiring written permission from the owners) based on their records of the periodic reading of appropriate building meters. Where tenant metering was involved it was impractical to obtain releases so Consolidated Edison furnished the data as an aggregate of all meters in the building. Apparent discrepancies were verified with the owners' records. The oil data were obtained from the delivery records of the owners, managers, or the oil companies. All the data obtained from the sources other than the owner/manager of the buildings were compared with their records for accuracy where available.

Several buildings have multiple electrical and steam meters representing various sections or tenants of the building. Consumption data (electrical, steam or gas) were obtained for all the meters in all the buildings for all the meter reading periods ranging from January 1971 through January 1976. These meter reading periods did not always coincide with the beginning or the end of calendar months, nor were all meter periods identical for various meters in the same building.

For the purpose of comparison between buildings, energy consumption data were converted from meter reading periods to calendar month basis for each of the 60 months in the study period as follows.

The number of days was computed from each unique meter reading period. Since the last meter reading period in the study period for most buildings occurred somewhere in the month of December 1975, consumption data for the last few days of 1975 would have been lost. To remedy this, data for one additional meter reading period, namely in January 1976, were obtained where possible. Energy consumption data (KWH, pounds of steam and cubic feet of gas) for each meter were uniformly distributed over the corresponding meter reading period on a daily basis. This in effect generated an energy consumption profile for each meter in all buildings for every day of the 5-year study period.

From this daily profile, all meters in each building were added up on a calendar month basis to produce a monthly consumption profile for electricity and the other fuels as applicable. Certain assumptions had to be made for some buildings where information was missing, where a part of the energy was given to or received from another building, or for buildings using oil since oil deliveries were on other than a monthly basis. These assumptions, together with consumption data, are listed in detail in Appendix B-5.133 In general, if data were unavailable for a month, average values were substituted.

From this monthly electrical and other fuel consumption profile, for each of the buildings, a monthly energy consumption was generated by converting electricity and other fuel to British thermal units (BTU). The following average conversion factors were used:

3413 BTU per KWH
1060 BTU per pound of steam
1024 BTU per cubic foot of gas
139,000 BTU per gallon of No. 2 oil
149,000 BTU per gallon of No. 4 oil
153,000 BTU per gallon of No. 6 oil

For each building the consumption data were presented in the following format: (See Appendix B-5.)

1. Electrical and the other fuel consumption by months and years.

2. Energy consumption in BTU per square foot along with arithmetic mean, standard deviation and variance on monthly and annual basis.

C. WEATHER DATA PROCESSING

Hourly observations of dry bulb temperature, relative humidity and cloud cover were obtained from the National Oceanic and Atmospheric Administration (NOAA) for LaGuardia Airport for the five year study period from 1971 through 1975. This data base, 131,472 points in all (8670 hours per year - 8784 hours for the leap year - times 3 observations per hour times 5 years) was screened and edited for inconsistencies and missing data.

Monthly and annual heating and cooling degree days were generated for the 5-year study period based on 65 deg. F. ambient temperature. The degree days were used for normalizing the 5-year energy consumption data for weather.

A summary of the heating and cooling degree days for 1971 through 1975 is presented in Appendix B-6 with arithmetic means and standard deviations.

D. NORMALIZATION OF DATA FOR EFFECTS OF WEATHER AND OCCUPANCY/UTILIZATION

Previous studies reported office building energy consumption statistics on the basis of raw data - usually in the form of BTU per gross square foot per year. No effort was made to analyze the effects on these consumption data of the weather, the percentage of the space that was occupied, or the number of hours that the buildings were used. Since energy consumption has been tracked over a 5-year period in order to get some understanding of the effects of conservation efforts, it seemed important to attempt to modify or normalize the raw data for these variables which have an obvious impact on consumption.

There was concern that some of the energy conservation achievements claimed actually may have been due to improper or ignored factors. It is likely that some of the building space unoccupied during periods of economic recession was the real reason for an indication of energy savings. Unoccupied space may be unlit, unconditioned, and without office machines that use energy.

Some buildings are used more intensively than others, e.g., two shifts instead of one, 12 hours instead of 10 hours, or 6 days instead of 5 days per week. Obviously, not taking these differences into account can distort comparative information on energy consumption.

It is not clear whether weather corrections used previously have taken into account that weather only influences a portion of the energy consumption.

It must be emphasized that while the results of the normalization are expressed in terms of numbers, they must be viewed as approximate, since the computations are based on assumptions and rough estimates in many instances. However, regardless of the above, it is believed that the normalization shown here provides more reliability, for comparison purposes, than use of the raw data.

1. Derivation of Weather Index

In order to be able to compare the building annual energy consumptions for 1971 through 1975 on a common base weather year, a weather index was derived. This index represents the effect of severity or mildness of a given year's weather and, when divided into that year's energy consumption, removes the effect of deviation of that year's weather from the common base year. For the purpose of this study, 1975 - the last year for the study period - was selected as the common base year, and assigned an index of 1.0.

In deriving this weather index it must be remembered that the weather is only one factor causing energy consumption and therefore the degree day variation can not be applied directly to energy consumption. Obviously, it is impossible to determine exactly what percentage of the total energy consumption is weather related and therefore experience and judgment must be used and the results must be regarded as approximate in nature.

It has been observed, and confirmed through simulation as well as actual measurement, that approximately 35% of a building's annual energy consumption can be attributed to heating while only 15% is attributable to cooling. (This applies to the New York region).

Based on this, a weight of 0.35 was assigned to a year's heating degree days deviation from 1975 heating degree days and a weight of 0.15 was assigned to cooling degree days deviation from 1975 cooling degree days. The weather indices for different years were then derived as follows:

Weather Index = Iw =

$$1.00 + \frac{\text{(Htg. Degree Days Deviation from 1975)}}{\text{Htg. Degree Days for 1975}} \times 0.35$$

$$+ \frac{\text{(Cooling Degree Days Deviation from 1975)}}{\text{Cooling Degree Days for 1975}} \times 0.15$$

Year	Htg DegDays A	Δfrom 1975 B	0.35X B/4715 C	Cooling DegDays D	Δfrom 1975 E	0.15X E/868 F	Iw = 1.+C+F
1971	4976	261	0.0194	1059	191	0.0330	1.0524 = 1.05
1972	5503	788	0.0585	700	-168	-0.0290	1.0295 = 1.03
1973	4628	-87	-0.0064	1126	258	0.0446	1.0382 = 1.04
1974	4902	187	0.0139	954	86	0.0149	1.0288 = 1.03
1975	4715	0	0	868	0	0	1.00

Example Building No. 11

	1971	1972	1973	1974	1975	Mean
Actual MBTU/sq ft/yr	148	142	126	83	98	119
Weather Index	1.05	1.03	1.04	1.03	1.00	
Normalized MBTU/sq ft/yr	141	138	121	81	98	116

The indices for the individual years were applied to all 44 buildings and the resulting consumption figures are shown in Appendix B-8.3. Comparison of the mean energy consumption for the 5-year period shows a weather normalized reduction of 20 MBTU/sq ft/yr compared to 27 MBTU/sq ft/yr from the original raw data (Appendix B-8.1), or a reduction of 15% compared to 19%.

2. Derivation of Occupancy/Utilization Index

The Occupancy/Utilization Index is made up of two varying components - the percentage of the usable space occupied during normal hours of occupancy (assumed as 8 a.m. to 6 p.m., Monday through Friday) and the space occupied at hours other than normal. Data, of varying degrees of reliability, were collected on each building.

Gross square feet and square feet of currently occupied space were precise; average percentage of occupancy for each of the 5 years represented the owner's best estimate; and off-hours usage represented the owner's best estimate for 1975. We then assumed that these latter applied to all 5 years.

Just as assumptions had to be made for the effect of weather on energy consumption, assumptions must be made for the effects of percentage of occupancy and hours of utilization on energy consumption. In order to arrive at some conclusions, we broke down the building utilization into parts. The basic utilization or operation is at <u>no</u> occupancy for the entire week - 168 hours. The second part is occupancy for normal operating hours - 8 a.m. to 6 p.m. Monday through Friday - 50 hours. If a building operated only during this period at 100% occupancy we assigned it an index number of 1.00. The third part is utilization at some percentage of occupancy at hours above the normal. In simple block form this appears as follows:

C	? hours at ?% occupancy
B	50 hours at ?% occupancy (for 100%, index = 1.00)
A	168 hours at 0% occupancy

For normal occupancy (index = 1.00) assumption is made as to the relationship of A & B in order to be able to deal with the effect of varying occupancy and utilization. Taking into consideration the large number of variables, it is estimated that A represents 1/3 of the total energy consumed in the normal week. Thus variations in occupancy and utilization can have an effect on only 2/3 of the total energy consumed in the normal operation.

Therefore, the total occupancy hours (the summation of % occupancy X hours of the occupancy) have been computed; divided by 50 to get an Occupancy/Utilization Factor; subtracted 1.00 to get the increment; multiplied by 2/3 to get the energy increment and added 1.0 to get the Occupant/Utilization Index. The building's energy consumption for the year is then divided by the Occupancy/Utilization Index to get its normalized energy consumption (50 hour, 100% occupancy base).

In equation form this is expressed as follows:

$$\text{Occupancy/Utilization Factor} = F_o = \frac{\Sigma \text{Hr.util.} \times \% \text{ occ.}}{50}$$

$$\text{Occupancy/Utilization Index} = I_o = 1.00 + 2/3\,(F_o - 1)$$

$$\text{Occupancy/Utilization Normalized Energy Consumption} = E_o = \frac{E_{act}}{I_o}$$

Example - Building No. 11

Total Occupancy/Utilization Hours (data from B174, B175 series of columns).

Hours	X	Days	X	% Occ.	=	Occ./Utiliz.Hrs.
10		5		100		50
4		5		3		0.60
4		5		3		0.60
6		5		3		0.90
10		2		3		0.60
4		2		3		0.24
4		2		3		0.24
6		2		3		0.36

Σ Hr. util. X % Occ. = 53.54

$$F_o = \frac{53.54}{50} = 1.07$$

Occupancy/Utilization Index = Io = 1.00 + 2/3 (1.07-1.00)

= 1.05

	1971	1972	1973	1974	1975	Mean
Actual MBTU/sq ft/yr	148	142	126	83	98	119
Occ./Utiliz. Index	1.05	1.05	1.05	1.05	1.05	
Normalized MBTU/sq ft/yr	141	135	120	79	94	114

The Occupancy/Utilization Indices were computed for each of the 44 buildings for each of the 5 years as shown in Appendix B-7. The indices were then divided into the original raw data figures (Appendix B-8.1) to get the new consumption data shown in Appendix B-8.2. This new consumption data can be compared with the original raw energy consumption data for the effects of Occupancy/Utilization on an individual building basis.

Comparison of the mean energy consumption for the 5 year period shows an Occupancy/Utilization normalized reduction of 21 MBTU/sq ft/yr compared to 27 MBTU/sq ft/yr from the original raw data, or a reduction of 16% compared to 19%.

3. Application of Both Indices

If we now take the previously derived weather indices for the 5 years and divide them into the appropriate energy consumption figures shown in Appendix B-8.2 (Occupancy/Utilization Normalized Energy Consumption data), the resulting Appendix B-8.4 shows the energy consumption figure by year for each building, normalized for weather and Occupancy/Utilization. Thus each figure theoretically represents the energy that building would have consumed as it was operated in that particular year assuming 1975 weather and 100% occupancy for only 50 hours per week.

Again, these results can be compared with those of Appendices B-8.1, .2, and .3. In particular, a comparison of the mean energy consumption for the 5-year period shows a normalized reduction of 14 MBTU/sq ft/yr compared to 27 MBTU/sq ft/yr from the original raw data, or a reduction of 11% compared to 19%.

Example - Building No. 11

MBTU/sq ft/yr	1971	1972	1973	1974	1975	Mean	% Red. '71-'75
Actual	148	142	126	83	98	119	34
Weather Normalized	141	138	121	81	98	116	31
Occupancy Normalized	141	135	120	79	94	114	33
Weather/Occ. Normalized	134	131	115	77	94	110	30

E. ANALYSIS OF DATA FROM QUESTIONNAIRE NO. 2

Highlights of the physical characteristics data are shown in Table III-1. The analyses shown in the Appendix are as follows:

APPENDIX

B-9.1 - Total gross area
B-9.2 - Total office area
B-9.3 - Total non-office area
B-9.4 - Above grade area
B-9.5 - Below grade area
B-9.6 - Total vacant area
B-9.7 - Total occupied space
B-9.8 - Core area
B-9.9 - Mechanical area
B-9.10 - Commercial area
B-9.11 - Computer area
B-9.12 - High consumption area
B-9.13 - Age (years)
B-9.14 - Total number of floors
B-9.15 - Percent of glass
B-9.16 - Total surface area
B-9.17 - Volume (cu. ft.)
B-9.18 - Average floor area
B-9.19 - Total wall area
B-9.20 - Wall/above grade area (%)
B-9.21 - Glass/above grade area (%)
B-9.22 - Total Wattage
B-9.23 - Total A/C tonnage
B-9.24 - Day temperature - winter
B-9.25 - Day temperature - summer
B-9.26 - Energy consumption (MBTU's/sq ft)

B-10.1	-	Total gross area in terms of age
B-10.2	-	Total gross area in terms of total wall area
B-10.3	-	Total gross area in terms of wall/above grade (%)
B-10.4	-	Total gross area in terms of glass/ above grade area (%)
B-10.5	-	Total gross area in terms of total wattage
B-10.6	-	Total gross area in terms of total surface area
B-10.7	-	Total gross area in terms of number of floors
B-10.8	-	Total gross area in terms of average floor area
B-10.9	-	Total gross area in terms of building volume
B-10.10	-	Total gross area in terms of total A/C tonnage
B-10.11	-	Total gross area in terms of day temperature - winter
B-10.12	-	Total gross area in terms of energy consumption
B-10.13	-	Energy consumption in terms of total gross area
B-10.14	-	Energy consumption in terms of age (yrs)
B-10.15	-	Energy consumption in terms of total building wattage
B-10.16	-	Energy consumption in terms of glass/ above grade area
B-10.17	-	Energy consumption in terms of average floor area
B-10.18	-	Energy consumption in terms of total number of floors
B-10.19	-	Energy consumption in terms of volume (cu. ft.)
B-10.20	-	Energy consumption in terms of total A/C tonnage
B-10.21	-	Energy consumption in terms of day temperature - winter
B-10.22	-	Energy consumption in terms of total wall area
B-10.23	-	Energy consumption in terms of wall/ above grade area

NOTE: Appendix B-11 series of data have the same titles as Appendix B-10, the difference being that the characteristics in Appendix B-11 are sorted according to descending order of the base variable, rather than ascending.

B-12	-	Selected area characteristic percentage of total gross area for each building
B-13	-	Ratio of total gross area to total exposed area
B-14	-	Listing of all indices for all characteristics

TABLE III

HIGHLIGHTS OF DATA FOR SPECIFIED CHARACTERISTICS

(Questionnaire No. 2)

Characteristic	Range	No. of Data Points	Mean	Median	Standard Deviation
Consumption (MBTU/Sq Ft)	223 - 64	44	112	108	35
Age (Years)	82 - 8	44	44	48	20
Total Vacant Area (Sq Ft)	164895-0	44	15728	1673	29841
Total Occ. Area (Sq Ft)	1801891-16790	44	385900	311492	401189
Total Build Area (Sq Ft)	1842494-16790	44	401628	317709	417094
Core Area (Sq Ft)	475002-0	44	65592	44146	88159
Mechanical Area (Sq Ft)	118750-280	44	21211	14982	26099
Garage Area (Sq Ft)	47059-3150	9	3837	12332	9998
Commerical Area (Sq Ft)	129607-0	44	17394	9500	24375
Other Non-Off Area (Sq Ft)	84554-0	44	11893	4877	18033
Total Non-Off Area (Sq Ft)	635571-6771	44	119927	90604	131896
Computer Area (Sq Ft)	14076-100	21	2690	3371	4231
High Cons. Area (Sq Ft)	285015-1537	10	7972	4000	43002
Other Office Area (Sq Ft)	1317776-10019	44	271037	118479	285803
Total Office Area (Sq Ft)	1332776-10019	44	281702	218103	296329
Grand Tot Office Area (Sq Ft)	1842494-16790	44	401628	317709	417094
Above Grade Non-Off (Sq Ft)	598911-5007	44	88910	49600	110111
Above Grade Office (Sq Ft)	1259465-10019	44	275791	218102	286786
Below Grade Non-Off (Sq Ft)	124800-0	44	28879	1500	30237
Below Grade Office (Sq Ft)	129289-88	13	8046	6340	25863
Below Grade Total (Sq Ft)	241135-0	44	36927	19159	45312
Owner Occupied Area (Sq Ft)	755523-0	44	65474	2000	146742
Largest Tenant Area (Sq Ft)	735545-0	42	70372	19872	157898
Total Tenant Area (Sq Ft)	1282559-0	44	200202	79860	279396
Vacant Available Area (Sq Ft)	164895-1000	11	11638	15108	32503
Vacant Unavailable Area (Sq Ft)	73266-2613	6	3710	14000	13008
Vacant Area Total (Sq Ft)	1332776-10019	44	281701	217503	296329
Total No. Tenants	100-0	42	36	20	46
No. of Persons in Bldg.	6000-65	36	1271	1000	1562
No. of Fls. Above Grade	49-4	44	22	20	11
No. of Fls. Below Grade	3-0	44	2	2	1
Total No. of Fls.	51-4	44	24	22	11
Local Cooling Syst Tonn.	1700-0	44	317	165	391
Total Wall Area (Sq Ft)	502864-7398	44	130503	106591	110984
Total Roof Area (Sq Ft)	80077-1486	44	20854	15070	18730
Total Exposure Area (Sq Ft)	539765-8884	44	151357	130498	123546
Non Exposed Area (Sq Ft)	103238-0	44	18703	13002	20845
Total Envelope Area (Sq Ft)	548007-17433	44	170060	148000	125031
Percent-Wall Area/Tot Fl Area	98-12	44	44	41	18
Percent Glass on Wall Exp.	67-13	44	29	26	13
Glass Area on Walls (Sq Ft)	211329-1691	44	38136	25221	40820
Average Fl Area (Sq Ft)	45594-1526	44	15527	12487	11492
Building Volume (Cu Ft)	23338256-183290	44	4814809	3737204	5175989

Characteristic	Range	No. of Data Points	Mean	Median	Standard Deviation
Theor. Surf. Area (Sq Ft)	408329-16133	44	128411	120426	90664
Act. Surf. Area (Sq Ft)	548007-17433	44	170060	148000	125031
Temp-Winter Day (Deg-F)	75-68	41	71	71	1
Temp-Winter Night (Deg-F)	68-42	33	58	55	31
Temp-Summer-Day (Deg-F)	78-68	32	75	75	33
Hrs Maint. - Winter-Day	16-6	41	11	11	4
Hrs Maint. - Winter-Night	18-2	36	13	12	6
Hrs Maint. - Summer-Day	16-8	32	11	10	5
Tot. Build. Wattage (Watts)	5527482-25189	39	986899	780667	998780
Tot. Fix. Wattage-System I	225-90	37	177	178	89
Total Number of Elevators	38-1	44	10	7	9
Watts/Sq Ft	5.3-1.5	39	2.8	2.5	.8

The frequency distribution analyses were prepared in order to assess the role and contribution of each sample building in the several relevant aggregated statistics. Moving (cumulative) averages were also computed in order to evaluate aggregated characteristics of sample subjects.

For example, Appendix B-9.1 (total gross area) indicates that the ten largest buildings (23% of the buildings), contain 10,136,185 square feet of space, which represents 57.4 percent of all of the space in the 44 building sample. The average office floor area of these ten buildings is given as 1,013,619 square feet.

This same table reveals that the median office floor area statistic is approximately 315,000 square feet, and the average area for all buildings in the sample is 401,629 square feet. (See Appendix A-10.3)

Appendix B-9.2 through Appendix B-9.12 present similar analyses for other area statistics of interest.

Appendix B-9.13 through Appendix B-9.25 present frequency distribution analyses for building age, height, percent of glass in walls, total surface area, volume, average floor area, wall area, wall above grade, glass above grade, lighting wattage, A/C tonnage, and temperatures (winter-day, summer-day).

Appendix B-9.26 displays a frequency distribution analysis for the energy consumption for 1975. The basic consumption data as obtained from Consolidated Edison for each sample building have been normalized. This is discussed on page III-8. The table shows a range of annual consumption from 223-65 MBTU/sq ft, a median of 108 and an average of 112.

A number of frequency distribution analyses indicating the cross-correlations for pairs of selected characteristics were also performed and are shown in Appendix B-10.1 through B-10.23 and Appendix B-11.1 through B-11.23.

The first sequence of Tables (Appendix B-10.1 through B-10.23 has been structured with the second of the two characteristics (in the title) arranged in descending order, and the second sequence (B-11.1 through B-11.23), has been organized with the first characteristic arranged in descending order.

For example, in Appendix B-10.1, the distribution is constructed on a descending order of building age, from 82 years (Building No. 241) to 8 years (Building No. 650). This same table shows that approximately 50 percent of all sample buildings are 48 years old or older. The cross-correlation with respect to gross building area allows the observation that these 48 year old or older buildings, contain 5,684,354 square feet of floor space or 32.2 percent of all such space (17,671,675 square feet) in the entire 44 building sample.

The second part of the same table (Appendix B-10.1) which shows Cumulative Averages for Stated Characteristics, indicates that the average building area for this sample subset is 258,380 square feet.

In the sequence of tables starting with Appendix B-11.1 the sample buildings are ordered from the largest (1,842,494 square feet total area) to the smallest (16,790 square feet total area) and the age factor becomes the dependent element (the largest building is 8 years old, and the smallest is 62 years old).

Age is one of the most significant attributes bearing directly or indirectly on energy consumption.

The buildings in the sample were reported to have been first occupied over a period from 1895 to 1969. During this span of time there were four major building codes and two zoning resolutions in force for various segments of the 82 years covered. During certain periods, more than one code could be followed legally (and some difficulty in relating energy consumption characteristics and codes is therefore encountered). Consequently, we have advanced the break points slightly in our analysis. The significant dates of change were:

1916 - New Building Code adopted and First Zoning Resolution adopted

1938 - New Building Code adopted

1940 - Significant changes in Zoning Resolutions

1961 - New Zoning Resolution adopted

1968 - New Building Code adopted

While the chronological age of any building has its own special significance in terms of style, condition, and cycles of renovation which may have taken place, the influences of prevailing building codes, zoning ordinances and other regulations affect many characteristics relating to energy consumption and also deserve attention. An examination of the energy consumption of the buildings arranged by age and aggregated into periods roughly analogous to the above periods shows the following:

Dates	No. of Bldgs.	% of Bldgs.	% of Area	Energy Consumption Range	Average Consumption
Before 1900	3	6.8	1.1	83-115	95
1901 - 1919	8	18.2	12.8	76-135	105
1920 - 1940	18	40.9	28.3	68-223	109
1941 - 1962	12	27.3	36.2	66-198	126
1962 - 1970	3	6.8	21.6	78-163	115

When age is related to total gross areas (Appendix B-10.1) it is observed that the older buildings as represented by a median age of 48 years and a mean of 60 years, represent slightly less than 1/3 of the sample (32.9%) building gross area. Furthermore, the first quintile contains only 10 percent of the total space; suggesting that the age factor alone appears not to be of great significance to gross energy saving potential in older buildings.

By contrast, an examination of the age characteristic for the larger buildings shown in Appendix B-11.1 indicates that the 9 largest buildings constituting approximately the upper quintile with regard to size, contain approximately 55% of all space and have a mean age of less than 30 years. The mean size of the nine largest buildings is approximately 1,000,000 square feet which is greater than twice the average for the entire 44 building sample (401,627 square feet).
44 building sample (401,627 square feet).

Examining age-related attributes, e.g, materials and type of construction and mechanical equipment provide insights which explain why older buildings, generally, consume less energy. These analyses are discussed elsewhere.

All this suggests that energy saving potential efforts in older buildings, as a class, may not be as worthwhile as in newer buildings.

Appendix B-12, presents a summary of selected area characteristics expressed as percentages of the total (gross) area for each building in the sample. For example, the maximum vacant area reported for any building was 54 percent (Building No. 754).

The questionnaire column location where each piece of area data shown in the summary may be found, is given in the main body of the table alongside each specific area characteristic, (i.e. vacant area, is derived from column BI035 in the questionnaire response output in Appendix B-4). The total gross area for each building is also shown at the conclusion of this table for reference purposes.

Appendix B-13 shows the ratio of total floor area to total exposed area (walls and roof) for each of the 44 buildings in the sample. The average ratio is 2.45 and the range varies from 7.3 (Building No. 565) to 1.0 (Building No. 241).

A series of matrices were generated so that any characteristic for any selected building in the sample could be compared with that of any other building. To accomplish this, a set of indices was developed which was defined as the ratio of each building characteristic to the average value of that characteristic for the entire sample.

A tabulation of sixty such characteristics is shown in Appendix B-14 together with the index for each building, the average value for all 44 sample buildings, and the number of responses upon which each statistic is based. In this version of the table, the building numbers are shown as column headings in descending order of annual consumption (MBTU/sq ft) for 1975.

In Appendix B-14, it can be seen that Building No. 55 consumed 1.984 times the average annual energy rate (in 1975) which was 112 MBTU/sq ft. All 44 sample buildings responded and were included in the statistic. It can also be observed that Building No. 55, with an index of 1.984, consumed 1.984/1.762 or 1.13 times more than Building No. 645 whose index is 1.762. Since the average for all buildings is 112 MBTU/sq ft, Building No. 55 consumed 1.984 (112×10^3) = 223 MBTU/sq ft per year (1975).

These matrices can also be used to scan patterns of other characteristics and compare them with energy consumption. For example, the 1.762 index for energy consumption for Building No. 645 and the 0.569 index for energy consumption for Building No.472 may be related to other characteristics which may be indicative of high energy consumption, as follows:

Characteristic	Building No. 645 Index	Building No. 472 Index
Core area	1.516	0.434
High consumption areas	3.582	0
Largest tenant area	3.200	0.134
Total tenants	1.268	0.399
Number of floors above grade	1.350	1.035
Total number of floors	1.256	1.047
Local cooling system installed tonnage	5.353	0.771
Age of building	0.342	1.095
Total vacant area	0	0.191
Percent glass on wall exposure	2.058	0.720
Total build, wattage-lighting	2.270	0.643
Total number elevators	1.345	0.384
Total exposure area	0.994	0.380

Other similar Tables were developed in which all indices which do not exceed the average by more than 20%, 40%, 60%, 80% and 100% respectively, have been crossed out to assist in the analysis.

For example, in one such work table the matrix displays that Building No. 762 has nine characteristics which deviate by more than 80% from the aggregated sample averages for those characteristics. These characteristics are: total vacant area, garage area, other non-office area, commercial area, computer area, high consumption area, below grade (non-office) area, vacant area (total), local cooling system installed tonnage.

The deviation from the average of the installed air conditioning tonnage characteristic is 3.779 which represents the most outstanding variance from the sample mean for that characteristic.

F. CORRELATION OF ENERGY CONSUMPTION DATA (1975) WITH BUILDING CHARACTERISTICS

Several building characteristics were selected that were deemed to have an influence on the energy consumption and for which data were available. These characteristics, 51 in all, included (1) building construction details such as areas of floors walls, roofs and glass, number of stories, age in years, etc., (2) building management details such as metering, ownership, areas occupied by owner versus tenants, etc., (3) building operation details such as number of operating hours, number of persons working, ratio of visitors to workers, lighting watts per square foot, number of elevators, etc., and (4) building air conditioning system details such as type of system, central and local refrigeration tonnage, hours of heating and cooling equipment operation, temperatures maintained, amount of outside air intake, types of controls, etc. These selected characteristics are listed in Table III-2.

The energy consumption data for 1975 were used for correlation studies since the building characteristics reported were those of 1975 and additionally, this was the only year for which all the necessary data were available. It was observed from the building survey that all buildings were not always fully occupied nor were the hours of occupancy the same for all buildings. In order to be able to compare buildings on an equal basis, an Occupancy/Utilization index was derived that represented the influence of usage on total energy consumption. The procedure for calculating this index has already been described. The actual gross energy consumption per square foot for each building for 1975 was then divided by the Occupancy/Utilization index for the building to generate the normalized energy consumption data.

The energy consumption data, actual as well as normalized, are presented along with the significant building characteristics including totals and arithmetic means where applicable. (See Appendix C-1.)

Each of the 51 selected building characteristics was then plotted as a single independent variable against the actual and the normalized energy consumption for 1975. These plots were made for 44 points (representing all 44 buildings), 11 points (representing the

TABLE III-2

LIST OF BUILDING CHARACTERISTICS
SELECTED FOR PLOTTING AGAINST ENERGY CONSUMPTION OF 1975

1 - Building Age in Years
2 - Gross Area (in 1000 sq ft)
3 - % Net Area
4 - % Occupied Area
5 - % Office Area
6 - % Above Grade
7 - Wall Area (as % of Gross Floor)
8 - Glass Area (as % of Gross Floor)
9 - Glass Area (as % of Gross Wall)
10 - Exposed Envelope (as % of Gross Floor)
11 - Total Envelope (as % of Gross Floor)
12 - Computer Area (as % of Gross Floor)
13 - % Area Occupied by Owner
14 - % Area Occupied by Tenant
15 - Gross Volume
16 - No. of Floors Above Grade
17 - No. of Floors Below Grade
18 - Floor Height
19 - Building Height Above Grade
20 - Building Ownership
21 - Building Management
22 - Metering (1=Util. 2=Owner 3=Rent Inc.)
23 - Area per Person
24 - Annual Hours of Full Occupancy
25 - Persons/sq ft -- Full Occup. Hours
26 - Ratio of Visitors/Workers
27 - Lighting Watts/sq ft
28 - Annual Hours of Full Lighting
29 - Watts/sq ft -- Full Lighting Hours
30 - Perimeter System Type
31 - Heating Medium Type (Other/Steam)
32 - Hours of Perimeter Cooling
33 - Hours of Perimeter Heating
34 - Area/Ton (Local Ref.)
35 - Area/Ton (Central Ref.)
36 - Area/Ton (Total Ref.)
37 - Temp. Control (Mgmt. or Occupt.)
38 - Winter Day Temperature
39 - Winter Night Temperature
40 - Summer Day Temperature
41 - Mild Weather Cooling (O.A. or Mech.)
42 - Percent Minimum Outside Air
43 - O.A. Reduction (Comp/Part/None)
44 - O.A. Temp. When Heating Starts
45 - O.A. Temp. When Cooling Starts
46 - No. Days Heating is On
47 - No. Days Cooling is On
48 - Cleaning (Starting Time)
49 - Cleaning (Hours of Duration)
50 - Total No. of Elevators
51 - Elevators -- Floors Travelled

means of the groups of 4 buildings each) and 4 points (representing the means of the 4 quartiles). The 44 point plots, and to some extent the 11 point plots, showed a high degree of scatter and did not reveal correlation as dramatically as the 4 point quartile plots. For this reason and partially to keep the size of this report manageable, only the 4 point quartile plots are presented in Appendix C-2 (the actual 1975 energy consumption) and Appendix C-3 (the normalized 1975 energy consumption).

While regression lines have not been drawn on these plots, a visual examination shows apparent linear correlation between energy consumption and several building characteristics. Notable among these are the following:

- BUILDING AGE
- ANNUAL HOURS OF FULL LIGHTING
- TYPE OF PERIMETER SYSTEM
- HOURS OF PERIMETER HEATING
- HOURS OF PERIMETER COOLING

In Phase II of this study these characteristics will be examined more carefully.

G. COMPUTER PROGRAM SIMULATION

In order to get a more definitive understanding of the influence of various building parameters on the annual energy consumption, it was decided to simulate two buildings on the AXCESS program: one representing a real, typical building from the 44 building sample and the other representing a hypothetical building having the mean characteristics of the sample.

Building No. 930 was chosen as the typical building since its age, area, and height are in close proximity to the sample averages. A building model was generated using as much as feasible the actual survey data for Building No. 930. Assumptions were made based on engineering judgement for data such as air conditioning zoning and control parameters that were unavailable from the survey.

This model of the typical building, called 'base scheme', was run on the AXCESS Program for the year 1975. A number of variations in the building parameters such as lighting load, inside design temperatures, wall and roof thermal transmittance coefficients, etc., were also analyzed on the program.

A description of the 'base scheme', its variations and the results of the energy analysis are presented in Appendix D-1.

The approximate effect of changing selected building parameters on energy consumption is as follows:

CHANGE OF PARAMETER	ENERGY CONSUMPTION EFFECT
- Occupant density reduced from 100 sq ft/person to 200 sq ft/person - Increase outside air from 20% to 30%	less than 1%
- Increase indoor summer design from 75 deg F to 80 deg F	1-5%
- Reduce night temperature from 65 deg F to 55 deg F - Reduce night temperature from 65 deg F to 55 deg F and day temperature from 70 deg F to 65 deg F - Omit economizer cycle - Increase glass area from 35% to 50% - Reduce roof "U" factor from .25 to .10	5-10%
- Change lighting by one watt/ sq ft - Use double glazing	10-15%
- Change from constant volume to terminal reheat	50%

For the hypothetical building simulation, a model was generated using as far as possible the arithmetic averages of all the numeric data available from the survey. Such data included the areas, percent glass, lighting load, inside temperatures, lighting and occupancy utilization patterns, etc. Again, engineering assumptions were made for data that were not available from the survey, or where the arithmetic averages could not be ascertained. The hypothetical building model was also run on the AXCESS program for the year 1975.

A description of the hypothetical building and the results of the energy analysis are presented in Appendix D-2.

The following table compares the actual versus AXCESS program estimates of 1975 energy consumption (in MBTU/sq ft) for the typical and the hypothetical building.

	ACTUAL	NORMALIZED	ESTIMATED	% DEVIATION FROM ACTUAL	% DEVIATION FROM NORMALIZED
TYPICAL BUILDING	75	68	72	- 4	+ 6
HYPOTHETICAL BUILDING	115	112	124	+ 8	+ 11

IV. FINDINGS AND CONCLUSIONS

A. DEVELOPMENT OF A STATISTICAL METHODOLOGY FOR REPRESENTATIVE SAMPLE SELECTION

1. A methodology, outlined in Section II, was developed to permit evaluation of energy conservation in existing office buildings. A relatively small representative sample was used with reasonable statistical confidence that it reflects the energy consumption characteristics of the total office building population. It is believed that this is the first time this methodology has been used.

2. When compared with a random sampling method, it was found that random samples tend to be no more representative of the larger building population. Secondly, our experience has demonstrated that many of the randomly selected buildings would have been unavailable; thus creating a problem of providing a statistically acceptable substitute.

B. DESCRIPTION OF OFFICE BUILDINGS IN TERMS OF PHYSICAL AND OPERATING CHARACTERISTICS AND DEVELOPMENT OF PROCEDURE FOR OBTAINING RELEVANT INFORMATION

1. A detailed questionnaire (Questionaire No. 2, see Appendix B-1) was developed as the principal field survey instrument to obtain a description of the office buildings in terms of physical and operating characteristics. It is believed that this questionnaire is more comprehensive than other questionnaires in use, and covers some facets previously omitted. It may be necessary to refine or modify the questionnaire based upon the further detailed examination of selected buildings in the next phase of this study, and the determination of the relevance and significance of the answers in both this phase and the subsequent phases of this study. A need for uniformity in obtaining information in the future is apparent.

2. Most building owners or their representatives do not have ready access to or knowledge of the information required for an adequate evaluation of their buildings. Generally, they do not know how much their energy consumption changes from year to year, the quantitative benefits from changes they have used or will introduce, and how they compare with similar buildings.

For the most part, their decisions with respect to energy conservation appear to be intuitive or based on qualitative assessment. Only 10% of the building owners indicated that they monitor energy consumption and compare their energy usage with other similar buildings. The perception of even this small fraction of owners as to how they compare, generally proved erroneous when the energy consumption of their building was compared with the consumption of other buildings in the sample.

Without widespread practice of continuous, uniform, and accurate tracking of consumption, it will be difficult for owners to achieve the next level of energy savings and easy for them to retrogress (as is evident from our results). And it will be very difficult to establish and maintain rational energy conservation policies and to guide decision makers.

3. In many cases, the only reliable and practical way of obtaining valid information was for the interviewer to get it himself. This had not been anticipated. Reliance on answers, without on-site evaluation or validation by qualified personnel may result in erroneous information.

4. There is a substantial spread in physical characteristics, operating practices, and energy consumption patterns in office buildings. Some of the highlights follow. The report contains more than 750 bits of information for each sample building plus energy consumption data for 60 months during the 1971-1975 period, for each source of energy.

	RANGE*	MEAN*	MEDIAN*
1975 Consumption, normalized (MBTU/Sq Ft)	65-223	112	108
1975 Consumption, actual (MBTU/Sq Ft)	67-225	115	110
Age (years)	8-82	44	48
Total building area (SF)	17,000-1,850,000	401,000	318,000
Total no. of floors	4-51	24	22
Computer area (SF)	100-14,000	2,700	3,400

(Continued on next page)

* Numbers rounded off for easier reading, in some instances.

	RANGE*	MEAN*	MEDIAN*
Total wall area (SF)	7,400-503,000	130,000	106,000
Percent glass on wall	13-67	29	26
Temperature, winter day-F	68-75	71	71
Temperature, winter night-F	42-68	58	55
Temperature, summer day-F	68-78	75	75
Watt/SF - lighting	1.5-5.3	2.8	2.5
Commercial area (non-office) SF	0-130,000	17,300	9,500
No. of persons in building	65-6000	1,300	1,000
Average floor area	1,500-46,000	15,000	12,500
Core Area (SF)	0-475,000	65,600	44,100

* Numbers rounded off for easier reading, in some instances.

Other examples portraying the variety of characteristics and practices are as follows:

- The tenants in 21% of the sample buildings are billed and metered directly by the utility for electricity; in 8% of the billings they are billed by an owner through submetering; in 71% of the buildings they are on rent inclusion.

- 16% of the buildings have induction units at their perimeter; 13% have fan coil units; 7% have incremental air cooled units; and 64% have radiation units.

- During the heating season, perimeter units that heat operate from as many as 24 hours to as few as 6 hours, on week days.

- During the cooling season, perimeter units that cool operate from as many as 16 hours to as few as 8 hours, on week days.

- 61% of the buildings have interior space heating coils.

- The estimated range of tonnages for local cooling systems are 15-1700; for central cooling systems, from 145-6000.

- 98% of the buildings have single glazing.

- 71% of the buildings have cavity wall.

- Only 7% of the buildings have insulated exterior walls and 20% have roof insulation.

- 30% of the buildings have 5 or more different lighting systems.

- 98% of the buildings have room by room local lighting switches and 43% control areas of less than or equal to 1500 sq ft..

- Based on a spot check of all buildings an average of 19% of the rooms had lights on with no one present. The range of averages was from 0 to 100%.

- In 45% of the buildings, temperature was under the control of the occupant; in 55% of the buldings, control was all or partially in the hands of the building management.

- Central heating systems serving the perimeter are started as early as September 30th and as late as November 15th.

- Central cooling systems serving the perimeter of the building are started as early as March 1st and as late as May 15th. One building has its central cooling system capable of being operated all year.

5. The office buildings studied have been built under regulatory influences of at least four major building codes and two zoning resolutions, the earliest of which dates back to the appearance of the first high rise office buildings in the nation. Some of the most significant aspects of modern building technology that have evolved during the same period of time include: the widespread use of elevators; the appearance of engineered heating, ventilating, air conditioning, and lighting systems; and the development of a wide range of new building matrials all of which greatly influenced building size, configuration, and operating characteristics.

   Also, there has been a dramatic evaluation of basic fuels and energy technology during the life span of these office buildings.

C. ENERGY CONSUMPTION PATTERNS BEFORE AND AFTER THE 1973 OIL EMBARGO AND DEVELOPMENT OF A NORMALIZATION PROCEDURE FOR EACH COMPARATIVE ANALYSIS

1. A procedure, outlined in Section III, was developed to normalize energy consumption data for building occupancy and utilization factors as well as for weather conditions, for comparative analysis. It is believed that this is the first time this had been done.

2. Without normalization, it is possible that building space that was unoccupied or not utilized was at least a partial reason for some of the prior indications of energy savings, since vacant space might be unlit or devoid of equipment that uses energy. In addition, buildings that were used more intensively than others, such as for two shifts, may have been unjustifiably considered imprudent in their use of energy.

3. There has been about a 12% savings in normalized energy consumption when comparing 1971-1972, (the two year period before the 1973 oil embargo) with 1974-1975, the subsequent two year period.

MEAN ENERGY CONSUMPTION - MBTU/SQ FT/YEAR

YEAR	ACTUAL		NORMALIZED FOR UTILIZATION/WEATHER	
1971	142)	143	126)	129
1972	144)		131)	
1973	132		123	
1974	116)	116 (18.9% saving)	115)	114 (11.6% saving)
1975	115)		112)	

4. A comparison of the mean energy consumption for the same periods shows a reduction of about 19% would have been indicated, if the raw data had been used without an adjustment.

5. Savings, since the embargo, have been due in large part to simple adjustments in lighting practices and building operating temperatures.

87% of the owners have reduced energy consumption primarily by reducing lighting levels, eliminating lamps, or by using lower voltage lamps and curtailing usage. The average lighting power density in 1975 was 2.8 watts/sq ft. Although there is no actual comparative data for prior years, it was not uncommon, during the late 1960s and early 1970s, to design buildings with significantly higher lighting power densities.

Thermostats on the average are maintained at 71 deg F during a typical winter day and at 75 deg F during a typical summer day without cooling at night. This is generally more conservative of energy than pre-embargo practice.

No other widespread conservation measures have been identified, although there appears to be an increasing sensitivity to curtailing the duration of time that electrical energy is used.

D. CORRELATION OF ENERGY CONSUMPTION DATA WITH BUILDING CHARACTERISTICS

1. There appears to be a correlation between energy consumption (MBTU/Sq Ft/Year) and the following building characteristics:

   - BUILDING AGE
   - ANNUAL HOURS OF FULL LIGHTING
   - TYPE OF PERIMETER SYSTEM
   - HOURS OF PERIMETER HEATING
   - HOURS OF PERIMETER COOLING

   In Phase II of this study, these characteristics will be examined further.

   The correlation between energy consumption and age appears to reflect the influences in paragraph B.5 above. Examination of age related attributes provide insights which explain why older buildings generally consume less energy. For example, older buildings generally have local air conditioners which can be shut down when space is not in use.

2. Some buildings which have some apparent high energy characteristics do not show high energy consumption. This suggests that existing buildings cannot be rated for energy consumption by isolating individual characteristics, since the effect of these may be diluted by the complex interaction of the numerous other characteristics of the building. For this reason, Phase II is directed at assessing the value, impact, and feasibility of proposed energy conservation measures in the total context of the building operation.

E. FREQUENCY DISTRIBUTION ANALYSES

1. These analyses permit the assessment of the role and contribution of each building or a combination of buildings in the relevant aggregated statistics. For example:

- 20% of the buildings have a mean age of less than 30 years and contain 55% of all such space;
- 50% of the buildings are 48 years or older and contain 32% of all such space.

Since the newer buildings contain a greater percentage of space and show higher energy consumption than the older buildings the energy saving potential efforts in older buildings, as a class, may not be as worthwhile as in newer buildings.

This kind of information will be valuable in assessing the cost savings potential of proposed programs in the latter phases and will help establish recommended priorities.

F. COMPUTER PROGRAM SIMULATION

1. The energy consumption predicted by computer simulation of a typical building and a hypothetical building, having the mean characteristics of all buildings, fell within an acceptable range variation from actual and normalized consumption figures (-4% to +11%).

2. Evaluation of changes in building parameters for the typical building showed variations from less than 1% to more than 50% in energy consumption.

V. INTERIM RECOMMENDATIONS

A. DEVELOPMENT OF A STATISTICAL METHODOLOGY FOR REPRESENTATIVE SAMPLE SELECTION:

1. Utilize representative sampling in all future energy conservation studies.

2. Develop a national representative sampling (a "Neilsen Rating" sample to borrow a TV phrase) to be used to gauge energy consumption patterns and usage year in and year out. It is believed that this may be implemented with a relatively small percentage of buildings in a limited number of geographical regions. A national sampling plan will be suggested upon completion of the study.

B. DESCRIPTION OF OFFICE BUILDINGS IN TERMS OF PHYSICAL AND OPERATING CHARACTERISTICS AND DEVELOPMENT OF PROCEDURE FOR OBTAINING RELEVANT INFORMATION

1. Promote the widespread use of a nationally recognized uniform building energy information form (questionnaire). Upon completion of the remaining phases of this study, proposed form based on results of the complete study will be recommended.

2. Overcome a fundamental information deficiency that is thwarting the achievement of more energy conservation, by instituting a major widespread effort to educate owners on how to: conduct continuous and accurate tracking of energy consumption in their buildings, normalize the data, evaluate results of their conservation efforts, and compare consumption patterns with those of others.

   Enlist the assistance of the public utilities, owner trade associations, lending institutions, and professional organizations in this educational effort.

3. Urge that information required for determining potential retrofit measures and their benefits and for other energy conservation purposes be obtained by precise on-site inspection by qualified and experienced persons, instead of by cursory reviews, mail questionnaire, or opinions.

4. The heterogeneity of building characteristics and patterns of consumption suggest that a variety of retrofit measures and strategies may be

necessary for different levels of conservation potential and economic benefits. This aspect will be explained in Phase II.

C. ENERGY CONSUMPTION PATTERNS BEFORE AND AFTER THE 1973 OIL EMBARGO AND DEVELOPMENT OF A NORMALIZATION PROCEDURE FOR SUCH COMPARATIVE ANALYSIS

1. Adopt normalization procedures for building occupancy and utilization factors as well as weather conditions for realistic comparative analyses of energy consumption.

2. In determining existing and potential energy conservation, utilize 1975 as a base year, changing the base year every three or four years to bring realism and equity to measurement of achievements and establishing of goals.

D. CORRELATION OF ENERGY CONSUMPTION DATA WITH BUILDING CHARACTERISTICS

1. Recommendations in this area will be made after completion of the next phase.

E. FREQUENCY DISTRIBUTION ANALYSES

1. Use the frequency distribution analyses to determine where the greatest advantage (leverage) may be obtained for ascertained energy conservation measures and to help establish recommended priorities. This will be done in the next phases.

F. COMPUTER PROGRAM SIMULATION

1. Start a research program to correlate energy consumption predicted by computer simulation design programs with actual consumption under operating conditions.