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THE GE-BOMA ENERGY USE IN OFFICE BUILDINGS PROJECT: A SECOND LOOK AT THE DATA

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Abstract

In 1980, the US Department of Energy (DOE) funded the General Electric Company and the Building Owners and Managers Association (BOMA) to conduct a mail survey of more than 1,000 office buildings in 20 US locations in order to better understand energy use in this large sub-sector of commercial energy. Funding uncertainties precluded detailed analysis of the data. In this paper, the Lawrence Berkeley Laboratory, in a co-operative effort between DOE and BOMA, has taken a second look at the project to see what lessons we can learn about the data collection process and to carry the unfinished analysis a step further. We have reviewed the general circumstances under which the data were collected and conclude that, while participation by local BOMA chapters ensured a large numbers of responses, lack of established procedures for data verification affected the quality and usability of responses. We noted extreme ranges in the values for selected responses and speculate that these are the result of bad data rather than true characteristics of the surveyed offices. In general, large standard deviations for many of the responses make it impossible to draw meaningful, statistically sound conclusions from the data. For example, illustrative comparisons to the results from DOE's Non-residential Building Energy Consumption Survey were made, but cannot be considered conclusive. Similarly, separate multiple regression analyses of selected building characteristics on total energy use intensity and on electric energy use intensity, although statistically significant, explain no more than 24% of the observed variations in energy use intensities.

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I. INTRODUCTION

Energy costs continue to be important to office building owners and managers [Penz 1984]. In 1982, data gathered by the Building Owners and Managers Association, International (BOMA), a large trade organization of office building owners and managers, indicated that the costs of utilities accounted for nearly 40% of total operating costs (utilities includes energy, water, and other costs) [BOMA 1983]. From a building owner's or manager's perspective, the questions prompted by this percentage are: what are the sources of these costs? and to what extent can they be controlled? This report will not answer either of these important questions. It will, however, attempt to lay the groundwork for such answers by identifying issues related to the information required to provide these answers and how best to obtain this information. The basis for this analysis is a data base on energy use in office buildings that was created in 1980.

In 1979, BOMA, along with the Energy Analysis Program of the General Electric Company (GE), participated in a Department of Energy (DOE) study of energy use in office buildings. The study collected data from more than 1,000 large office buildings in 20 US cities. In 1985, Lawrence Berkeley Laboratory (LBL), in a cooperative effort sponsored by DOE and BOMA, agreed to re-examine this project in order to make recommendations for future efforts to collect and present meaningful energy use information for building owners and managers.

This report is divided into six major sections, following this introduction. The next section presents background information on DOE's and BOMA's previous efforts in developing a data base on energy use in office buildings. We argue that this background information, which may no longer be relevant for future studies, played a significant role in defining the GE-BOMA study of 1980. The third section describes the data collected by BOMA in 1980, as well as the initial analysis performed by GE. We review the mechanical aspects of the survey (the design and data collection process) and make recommendations to increase the type and quality of data that might be collected in a future survey. The fourth section describes preanalysis procedures that LBL first applied to the data. These procedures were an important prerequisite to our reanalysis of GE-BOMA data and have general applicability to analysis of building energy survey data. The fifth section summarizes the building and energy use characteristics of the survey data and provides an illustration of the effects of the pre-analysis procedures described in section four. The sixth section compares these data to others collected by the Energy Information Agency (EIA) on office buildings in the 1979 Non-Residential Buildings Energy Consumption Survey (NBECS). The seventh section contains our findings from bi-variate and multi-variate regression analyses of selected building characteristics on energy use. These analyses are intended to provide a simplified method that directly accounts for differences in energy use by offices.

II. BACKGROUND

The work by General Electric and the Building Owners and Managers Association (GE-BOMA) was one of the earliest sponsored by DOE to improve its understanding of energy use patterns of office buildings. This section identifies several trends that locate the GE-BOMA efforts in the larger picture of DOE's activities.

During the mid to late 1970's, DOE and its institutional predecessor, the Energy Research and Development Agency (ERDA), responding to an absence of data on building characteristics and performance, initiated several pioneering research projects. There was very little data on the ill-defined commercial sector, in particular, and the readily identifiable office building component of this sector was perceived to be a major consumer in this sector. Early DOE efforts focused on methods for providing energy conservation information tailored specifically to office buildings.

DOE's motivation could also be traced to policymaker's attempts to determine the feasibility of energy performance standards for buildings. That is, while design standards (e.g., ASHRAE Standard 90-1980 [ASHRAE 1980]) could be used to reduce energy use in new buildings, the large stock of existing buildings remained largely untouched by such measures. Many practitioners, familiar with the diversity of commercial buildings, cautioned against feasibility of any standards [Spielvogel 1978].

The direct precursor to GE-BOMA study was an ERDA study that had examined energy use in the office buildings of New York City [S&H 1977, S&H 1978a, S&H 1978b, S&H 1979, TRC 1980] This early study had five components. First, a general survey was administered and data collected for more than 1,000 buildings. Second, a subsample of 44 buildings was examined in greater detail. Third, five representative buildings were carefully analyzed with computer simulations of existing and potential (i.e., retrofitted) performance. Fourth, presentations on energy conservation were made to groups of building owners and managers. A fifth component, development and marketing of several promising energy conserving technologies, never went beyond the identification of potential products.

In reviewing this study, we identified four general issues that would be addressed with varying degrees of success by the GE-BOMA study in 1980:

1. *Generalizability of results*. By confining the work to an examination of office buildings in one city, albeit the city with the largest population of office buildings in the country, the ERDA study could not claim to represent nationwide trends.

2. *Significant difficulties in data collection*. Most building owners or their representatives did not have ready access to or knowledge of the information required for an evaluation of their buildings. For example, the ERDA study collected data on energy consumption directly from the utility, rather than from the building owner or manager.

3. *Search for reliable predictors*. The ERDA study asserted that energy use could be related to selected, quantifiable building characteristics. There was, however, no clear statistical basis for this conclusion.

4. *Institutional barriers to conservation in office buildings*. Building owners had little appreciation or understanding of energy use patterns in their buildings, were hesitant about "new" conservation practices or techniques, and were not, in general,

interested in large capital outlays.

The GE-BOMA study attempted to address the first three issues directly as a means for overcoming the fourth. That is, an underlying theme of the GE-BOMA study was that, if reliable data on a representative sample of office buildings could be collected and analyzed in a fashion that allowed relevant differences between buildings to be accounted for, then meaningful comparisons could be made and serve as the basis for informed energy conserving investments. Indeed, achievement of this goal continues to remain an important justification for federal efforts to stimulate energy conservation in the economy.

GE had earlier worked on several DOE-sponsored reports to characterize the stock of commercial buildings and identify sources of data on commercial buildings [GE 1980a]. One very promising source of data on office buildings was the Experience Exchange Report (EER) published annually by BOMA. The EER summarizes operating cost data submitted voluntarily by building owners and managers in a standardized format. GE subsequently performed several analyses of these data, but the results were limited by the questions asked on the EER reporting forms, and by the sampling biases in the buildings responding to the EER questionnaires [GE 1980b, GE 1981].

Based on the working relationship established between GE and BOMA through these analyses, DOE in 1979 funded BOMA to carry out an independent survey that would be drawn from the entire population of office buildings and would emphasize the buildings' energy-related features. GE, subject to strict procedures designed to maintain the confidentiality of individual responses, was asked to analyze the data. The details of this study are the subject of the next section.

III. THE GE-BOMA DATA BASE

BOMA is no stranger to large data collection activities. The EER is a major profit center for the organization and, in 1979, more than 3,000 buildings were represented in the EER. The data reported in the EER are collected annually in standardized forms. The report is designed to be a yardstick against which owners and managers can compare operating costs. For this reason, the metric is predominantly dollars (more precisely, dollars per square foot of rentable space). These prerequisites ensured that BOMA would be well-qualified to collect the large amounts of the data sought by DOE, yet, as we will discuss, they did not ensure that the quality of the data would be equal to its quantity in value.

The GE-BOMA study plan called for six tasks:

1. Data collection in 20 US cities;
2. Analysis of survey responses;
3. Tabular presentation of energy use as a function of building characteristics;
4. Comparison with the 1977 BOMA EER survey responses;
5. Analysis of 1979 energy use data; and
6. Formulation and estimation of an econometric model of building energy use, as a function of building characteristics and operating practices.

Only the first four tasks were completed because DOE decided not to continue the project [GE 1981]. In this section, we review the circumstances under which the data were collected, the collected data, GE's initial analyses, and data omitted by the survey.

The Data Collection Process

At the completion of the data collection process, approximately 1100 mail-in questionnaires were processed for the 20 cities in which the survey was administered. In this subsection, we focus on three features of the data collection process that were unique, with respect to BOMA's established EER data collection process, and that had profound effects on the amount and quality of data that were collected. A complete description of the data collection process is contained in a separate report [GE 1980a].

First, the questionnaire, developed by BOMA with input from GE, was administered only once. It did not benefit from repeated use and consequent refinement (as does the EER). One problem that resulted from use of a new questionnaire was that many questions required expertise not necessarily available to those responding. More importantly, there were no pre-existing procedures for data checking and verification. Such procedures are especially important for a mail survey where the respondents can misinterpret a question and have no one to verify their interpretation. We will describe important sources of ambiguity in the questionnaire in the following subsection and in our discussion of LBL's pre-analysis procedures in Section IV.

Second, the survey required substantial participation from local chapters. Local chapters determined the relevant population of offices (i.e., those over 40,000 square feet) and then administered the survey to a sample drawn (in an unspecified manner) from that population. Procedures for data collection evolved chapter by chapter. The EER questionnaires, by contrast, require some local administration, but are designed to ensure a high percentage of returns; less emphasis is placed on detailed procedures to verify the accuracy of the returns. We will illustrate how the apparent lack of standardized data checks and verifications affected the quality of responses in Section V.

A third important feature of the survey was that the sample of buildings was intended to be random to ensure that the results be generalizable. As with the EER, however, response was voluntary. Faced with no responses from some of the original sample, the local chapters had to resample to fill quotas for each city. As such, some degree of self-selection was inevitable. In addition, the non-response rate for some questions was large. We will not comment on the issue of randomness of the responses in subsequent discussions, since future surveys by BOMA will probably not be saddled with this requirement.

The Data Collected

The GE-BOMA questionnaire is divided into two general categories, "building statistics" and "building energy use." (The questionnaire is reproduced in Appendix A.) In the former category, information is reported on building location, gross physical specifications, age, type of occupancy, occupancy level, and rental rates. The latter category asks for information on energy use in 1977 and 1979, energy costs for electricity, tenant metering policies, sales of energy from the building premises to premises outside the building, operating hours and conditions, and major energy-using systems integral to the structure of the building (lighting and space conditioning systems).

The survey designers clearly intended the survey to be simple to fill out so it would have a high response rate. The three pages of questions are of the fill-in type and each of the 33 questions is worded simply, with little or no explanation. The price of this simplicity was some loss in accuracy in interpreting the results, because of ambiguity within and across questions.

As an example, one question asked for the total gross square footage of the building without defining gross square footage. The EER questionnaire, by contrast, makes a significant effort in explaining different definitions of square footage as well as the preferred BOMA method, which is accompanied by clarifying illustrations. Thus, when the survey requests information on, for example, the percentage of the building that is occupied by government agencies, the percentage reported is presumably the percentage of the total rentable area. Yet, no definition of this "building space" has been established. Very different estimates of energy use per square foot will arise, if the denominator is either the total gross square footage, the rentable square footage, the rentable office square footage, or even the rentable square footage that is currently occupied. The BOMA survey is not unique in obscuring this important distinction in reporting building area [Piette 1986].

GE's Analysis of the Data

The proposed analysis of the GE-BOMA data was never completed. What had been completed was summarized in a report to DOE [GE 1981]. This report contained two analyses. The first was a series of tabular presentations designed to indicate the extent to which the data collected were representative of the total population of office buildings from which the sample was chosen. The second analysis in GE's report was a comparison of findings from the GE-BOMA data base to the ongoing EER data base. In this subsection we briefly review these findings.

GE performed statistical tests to determine to what extent the buildings reported in the GE-BOMA data base were representative of the relevant population of office buildings (greater than 40,000 square feet). Data on the age, height, and floor area of the population were known from the lists of buildings greater than 40,000 square feet in each city (the samples were drawn from this list).

On a national basis, Chi-square tests were interpreted to show that the buildings in the GE-BOMA data base were "reasonably" (never defined) representative of the population with respect to age and height, but that the buildings in the data base were generally larger in floor area than the population. On a city-by-city basis, the differences were even greater for all three variables.

Following this comparison, the study reported on selected characteristics related to energy use, city-by-city. In all, 13 characteristics were tabulated:

- Type of heating fuel
- Rental rates
- Operating hours on weekdays
- Operating hours on weekends and holidays
- Winter operating temperatures, working hours
- Winter operating temperatures, non-working hours
- Summer operating temperatures, working hours
- Summer operating temperatures, non-working hours
- Office lighting levels
- Glazing as a percentage of wall area
- Economizer usage
- Heat pump vs. electric resistance heating

Few statistical conclusions were drawn from these tabulations. The written summaries of the tables focused on general trends and simple numerical counts.

The final component of the GE analysis compared data in the GE-BOMA data base to data in the BOMA 1977 EER data base. To ensure that the data were to some extent comparable, only data from the EER data base corresponding to the 20 cities sampled in the GE-BOMA data base were used in the analysis. In general, the buildings in the EER data base were more energy intensive than those in the GE-BOMA data base. The buildings in the EER data base also tended to be more reliant on steam and natural gas for heating.

The report explained that EER buildings were more energy intensive than the general population because EER buildings contained higher quality office space than those in the GE-BOMA data base. The implicit assumption, that better buildings used more energy because they had more to offer, was largely unsupported except by anecdote. The only evidence presented referred to the higher rental rates, newer condition, and ownership (never defined) of the EER buildings. No quantitative evidence was presented in the report.

Data Omitted from the GE-BOMA Survey

As with any survey, criticisms can always be made of the short-sightedness of the absence or neglect of important questions (in the next section, we will also discuss the issue of asking a given question unambiguously). In partial defense of the original survey, it is important to acknowledge the trade-off between asking more questions and getting uncertain or no results. Some information is not readily available and one, therefore, faces the risk of greater non-response, or worse, "guesstimation."

We will briefly describe, in descending order of importance, major categories where additional information would have been particularly useful.

1. *Precise definition of floor area.* We have described the importance of establishing a clear linkage between the energy used in a building and the floor area of the building for developing meaningful comparisons between buildings. In our opinion, information needed to determine this relationship is the single most important piece of data missing from the survey.

2. *Cost data for energy use other than electricity.* The relationship between the costs of different fuels, the total cost of operation, and the rental rate cannot be determined. It is ironic that this most significant omission would probably have been the easiest to correct and the easiest for a building owner to answer. The results may also be the easiest for building owners to understand since they are expressed in dollars.

3. *Relate fuel usage unambiguously to end uses.* It was particularly difficult to ascertain the heating fuel or fuels used or, more importantly, their relative magnitudes. For the survey to help building owners target conservation measures for their buildings, it must show the relative importance of the end use and fuel affected. The cooling fuels were better identified in this respect.

4. *No mention was made of special loads.* Three special loads deserve separate treatment: computer rooms with dedicated HVAC equipment, outside lighting, and parking garage energy use. These loads can skew energy use results greatly and must be accounted for so meaningful comparisons can be made between buildings. In making this recommendation, we assume that other special loads, food service and retail stores, are already treated separately, although the questionnaire is vague on this issue as well.

The list of omitted items can, of course, be endless. We have highlighted several important categories where significant benefits have been realized with low to moderate additional costs.

At a minimum, the questions must be stated unambiguously. Extensive explanations, however, may keep the respondent from making any response at all. One good alternative is used by the Energy Information Agency's (EIA) Nonresidential Building Energy Consumption Survey (NBECS) questionnaire, which is administered by telephone interviews, so respondents can clarify their questions.

IV. LBL PRE-ANALYSIS

In 1986, LBL received a fixed-format, magnetic tape containing the 1979 survey data GE had analyzed and returned to BOMA at the end of the project. Unfortunately, the documentation for the structure and format of the records on the tape was no longer available. Prior to any analysis, we used our primary analysis tool, the SPSS-X statistical software package, diagnostically to determine this information [SPSS 1983]. To further enhance our confidence in the subsequent analyses, we developed a series of pre-analysis procedures. The lessons learned from this process may be valuable for future surveys; an example of our procedures is illustrated in Section V.

The approach we adopted was to use as much data as possible. Thus, we attempted to rehabilitate bad data, where appropriate, or minimize its impact, rather than eliminate it entirely. We excluded data only as a last resort. The original data tape contained 1,105 records and, after eliminating 37, we performed our analyses on the remaining 1,068. Table IV-1 summarizes the distribution of these final records by city.

The methods we developed, however, imply a specific bias. While simple inspection was often all that was required to identify obviously bad data, we had no way of identifying data that were false, but appeared reasonable.

We used five methods for modifying the data:

1. *Format errors.* The data on the tape were written in fixed formats. After determining the structure of the data (visually, since no documentation was available), it was quite easy to spot instances where data straddled the boundaries of a field and in which direction the data had been shifted. Errors of this type were identified during the initial processing of data according to the data reading procedures of SPSS-X. Entire entries were eliminated because we could see no way to correct the formatting errors (4 total).

   In addition, we developed simple procedures for recoding data that were formatted ambiguously. A good example is lighting intensity. We interpreted an entry of "3" to mean "3.00 watts per square foot", we interpreted an entry of "35" to mean "3.50 watts per square foot", and we interpreted an entry of "358" to mean "3.58 watts per square foot."

2. *Multiple entries.* The original data consisted of 1,105 separate records, each presumed to represent a separate building. Closer inspection revealed that 24 were duplicates, which we eliminated. It is interesting to note that GE's original analysis appears to have included these duplicates in its summary tables.

3. *Inconsistent responses.* The primary statistic developed for our analyses was energy use per square foot. We checked the consistency of the reported square footage figures by comparing reported gross square footage with an imputed square footage that was based on the reported dimensions of the building. Reported height was divided by reported average floor-to-ceiling height to estimate number of floors. The estimated number of floors was multiplied by the reported length and width of the building to determine an imputed square footage (the implicit assumption is that all office buildings are box-like in shape). If the imputed square footage was greater than a factor of 10 over, or a factor of 10 less than the reported square footage, the entry was deleted. Nine entries were removed by this process. We

TABLE IV-1. Summary of GE-BOMA Data Base

City	Number of Buildings
Boston MA	50
Chicago IL	102
Philidelphia PA	53
Pittsburg PA	59
Atlanta GA	70
St. Louis MO	42
Dallas TX	49
Phoenix AZ	26
Seattle WA	27
Minneapolis MN	39
Omaha NB	17
San Francisco CA	60
Fort Worth TX	30
Miami FL	22
Milwaukee WI	25
Detroit MI	54
Washington DC	134
New York NY	66
Cleveland OH	45
Los Angeles CA	45
Denver CO	53

believe that many of these errors are due to improper keypunching (e.g., entering "10,000" square feet instead of "100,000").

4. *Commensurability filters*. Meaningful energy intensities (in the form of energy use per area) require that the energy reported in the numerator of the equation be unambiguously related to the square footage reported in the denominator. Responses for questions on individual tenant-metering and sales of energy outside the building were analyzed to determine such mismatches.

   We subtracted the square footage of tenants whose energy use was directly metered and billed by the utility from building totals. For the 16 buildings with such metering, the mean square footage subtracted was 43% with a standard deviation of 38% of the building total (the median was 25%). This procedure biases energy use upward for the remaining building by the amount of energy that cannot be metered individually, but still enters the (now) excluded space. A relevant example is HVAC energy from a central system.

   If energy was sold to parties outside the building (reported by 41 buildings), the entry was eliminated for the purpose of calculating energy intensities. Although a subsequent question in the survey asks what fraction of total energy was sold, no provision was made to specify which type of energy was sold or how to calculate the fraction sold (i.e., what conversion rate should be used to value each fuel type to determine the total energy use in common units).

   An unaddressed source of ambiguity is the energy use by activities that did not take place within the reported gross square footages, but were reported in energy use. Examples include exterior lighting and parking garages. No attempt was made to account for these effects.

   We could not, of course, calculate energy intensities for data entries that did not include energy use or square footage. Records lacking one or both of these pieces of information were omitted from the calculation of energy intensities.

5. *Impossible values*. Values that were not physically reasonable were generally eliminated. Unrealistic values for several attributes, for example, hours of operation (e.g. greater than 24 hours per day), lighting energy intensities (less than 1.0 or greater than 9.9 watts per square foot), year building opened (after 1980 or before 1800), and glazing area (less than 0 or greater than 100 percent) were simply ignored and the values for these variables were treated as missing.

Finally, because of known problems with the data, we used a general methodology for presenting our results that downplayed the significance of outliers. For all energy intensities, we relied on only the central 90 percent of cases; the lowest five and the highest five percent of the cases were ignored. To employ this procedure, we assumed that extreme outliers were spurious and should be ignored for the purposes of calculating the resulting "trimmed" means.

The effect of this procedure is illustrated in Table IV-2. This Table compares results for 1977 total energy use intensity with and without trimming. Not surprisingly, a dramatic reduction in standard deviation can be noted after the removal of outliers. If our previous assumption is correct, this illustration serves to reinforce the overwhelming importance for future surveys to pretest survey questions extensively, establish exhaustive data checking and verification procedures, and document resulting data collected.

TABLE IV-2. Effects of Trimmed Distributions on 1977 Energy Intensity

	Response (%)	Mean	Std. Dev.	Median	Minimum	Maximum
No Trim	67	160.0	307.1	105.1	0.1	5904.3
Trim min/max 5%	61	119.3	62.5	105.0	29.5	371.1

V. BASELINE ANALYSIS

In this section, we summarize our initial review of the GE-BOMA data base. This review consists of introducing four summary tables of the responses to individual items on the questionnaire and a limited analysis of energy intensities. We will emphasize primarily data quality issues arising from the discussion in Section IV of this report. The questionnaire is reproduced in Appendix A.

The definitions used in each table are as follows. The response rate is defined as the number of usable responses divided by the total (1,068). For questions with subcategories, the response rate is still calculated on the basis of the total (i.e., the percent of responses in the subcategory is not based on the number of original usable responses for that question). Where applicable, the mean, standard deviation, median, minimum, and maximum values are reported. For the energy intensities reported in Table V-6, we report trimmed means, as described in the previous section. Table V-7 reports these intensities for data that have not benefited from the pre-analysis procedures.

Table V-1 summarizes building and structural characteristics from the data base. In general, the response rates for these questions exceed 90%. The response rates for the questions about the physical dimensions of the building were slightly lower. The maximum and minimum values for floor to ceiling height, number of parking levels, and number of basement levels, however, are unusually high and probably indicate spurious responses. Such responses reinforce the need for an extensive data checking and verification process in future survey work.

Table V-2 summarizes occupancy characteristics from the data base. Response rates were generally greater than 80%. In reviewing these data, the reader is cautioned that several translations of the raw data were employed. As an example, reported areas for different activity types have been expressed as percentages of total area. More importantly, many of the responses were adjusted to be reasonable or eliminated, as described in Section IV; hours of operation had to be at least 0 and no greater than 24, temperatures had to be greater than 40°F, and lighting intensities had to be at least 1.0 watt/sq.ft. and no greater than 9.0 watt/sq.ft.

Table V-3 summarizes features of the heating, ventilating and air-conditioning (HVAC) equipment. For air-conditioning type, multiple responses for the type of equipment used were permitted on the questionnaire. We combined these responses with information on primary air-conditioning equipment to determine a major air-conditioning system for each building. Heating fuels were not reported directly. In the next section, we will discuss our method for determining heating fuel types.

Table V-4 summarizes energy metering policies. The questions and their responses are both ambiguous. Tenant metering appears to refer to a situation in which the building owner or manager submeters usage by the tenant. It is unclear from the question, however, which energy source is being metered, although in most cases electricity is the logical choice. Nevertheless, it is clear from the responses to sales to outside parties that other forms of energy are sold. Tenant metering appears to be distinct from utility metering in which tenants are metered but billed directly by the utility. Responses to the question on sales to outside parties are also puzzling. While less than 7% report that a specific type of energy is sold, 15% report some energy being sold.

TABLE V-1. GE-BOMA Data - Building Characteristics

Item	Response (%)[1]		Mean	Std. Dev.	Median	Minimum	Maximum
First Year of Occupancy[2]	97		1954.9	23.8	1965	1840	1980
Total Gross Square Footage (1000 sqft)[3]	99		305.0	400.2	153.5	9.6	4000.0
Dimension - Height (ft)[4]	80		193.5	163.0	141.0	12.0	1136.0
Dimension - Length (ft)[4]	79		195.7	110.4	172.0	0+	1038.0
Dimension - Width (ft)[4]	78		122.3	68.9	103.0	13.0	600.0
Above-Ground Stories[4]	98		14.2	12.3	11	1	107
Floor-to-Ceiling Height (ft)[4]	92		11.8	3.2	12.0	4.0	79.0
Glazing as Percent of Exterior (%)[5]	94		44.4	23.6	40	0	100
Touch Adjacent Wall - North (%)[5]	87		3.7	14.3	0.0	0.0	100.0
Touch Adjacent Wall - South (%)[5]	87		4.6	17.0	0.0	0.0	100.0
Touch Adjacent Wall - East (%)[5]	87		5.3	18.4	0.0	0.0	100.0
Touch Adjacent Wall - West (%)[5]	86		5.6	19.2	0.0	0.0	100.0
Parking Levels[4]	95						
Above Ground[6]		29	2.1	3.0	1	0	21
Below Ground		34	1.8	1.9	1	0	29
None		46					
Basement Levels[4]	94						
Number		68	1.5	3.3	1	0	90
None		27					
Wall Composition[7]	97						
Concrete/Masonary		17					
Aluminum Curtain Wall		79					
Other		1					

Notes to Table V-1:

1. The response rate in first column for a question with multiple permissable responses is the total percent of usable responses, while the response rate in the second column is the response rate for the specific response as a percent of the total, 1,168 Unless more than one answer is allowed, the response rates in the second column should sum to equal the overall response rate in the first column (save for small rounding errors).
2. First year of occupancy was constrained to be at least 1800 and no greater than 1980 (the year of the survey).
3. Total gross square footage was constrained to be at least 5000 square feet. GE reports indicate that only buildings of more than 40,000 square feet were included in the sample.
4. No constraints were placed on allowable responses. Consequently, minimum and maximum values may appear unreasonable.
5. Percentages were constrained to be at least 0% and at most 100%.
6. May sum to greater than 100%, since it is possible to have both below and above ground parking in the same building.
7. Many responses for wall composition in the category ''other'' were determined to be either ''concrete/masonary'' or ''Aluminum Curtain Wall'' and were recoded accordingly.

TABLE V-2. GE-BOMA Data - Occupancy Characteristics

Item	Response (%)	Mean	Std. Dev.	Median	Minimum	Maximum
Retail Square Footage (%)[1]	42	9.7	18.7	3.2	0+	100.0
Bank Square Footage (%)[1]	38	15.8	24.0	4.3	0+	100.0
Restaurant Square Footage (%)[1]	40	3.0	4.7	1.9	0.1	61.0
Medical/Dental Square Footage (%)[1]	20	14.8	26.8	1.9	0+	100.0
Public Room/Aud. Square Footage (%)[1]	12	3.6	11.2	1.0	0+	100.0
Occupied by Government (%)[2]	90	8.7	25.6	0.0	0.0	100.0
Office Occupancy - 1977 (%)[2]	86	86.6	22.4	96.0	0.0	100.0
Retail Occupancy - 1977 (%)[2]	47	70.9	43.0	100.0	0.0	100.0
Office Occupancy - 1979 (%)[2]	94	93.7	14.3	100.0	0.0	100.0
Retail Occupancy - 1979 (%)[2]	50	73.4	41.9	100.0	0.0	100.0
Office Rent ($/sqft)[3]	80	11.5	4.2	11.0	2.0	40.0
Retail Rent ($/sqft)[3]	40	17.2	10.6	15.0	3.0	85.0
Normal Working Hours (hrs/day)[4]	96	11.9	4.0	11.0	1.0	24.0
Weekend/Holiday Hours (hrs/day)[4]	83	6.5	6.0	5.0	0.0	24.0
Summer Weekday Working Temp (°F)[5]	82	72.9	3.1	73.0	50.0	78.0
Summer Weekday Non-Working Temp (°F)[5]	39	76.0	5.7	76.0	55.0	90.0
Summer Weekend Working Temp (°F)[5]	62	73.4	3.2	73.0	60.0	88.0
Summer Weekend Non-Working Temp (°F)[5]	36	76.2	6.4	78.0	48.0	90.0
Winter Weekday Working Temp (°F)[5]	83	71.9	2.9	72.0	50.0	80.0
Winter Weekday Non-Working Temp (°F)[5]	54	65.0	7.1	65.0	40.0	97.0
Winter Weekend Working Temp (°F)[5]	67	70.6	5.0	72.0	40.0	80.0
Winter Weekend Non-Working Temp (°F)[5]	50	64.5	7.3	65.0	40.0	85.0
Lighting Intensity (watts/sqft)[6]	73	3.5	1.9	3.0	1.0	9.0
Percent Air Conditioned[2]	97	95.8	17.4	100.0	0.0	100.0

Notes to Table V-2:

1. Expressed as a percent of total gross square footage and constrained to be greater than 0% and less than 100%. Therefore, response rates refer to only those responses with a positive non-zero entry less than or equal to total gross square footage.
2. Constrained to be at least 0% and at most 100%.
3. Constrained to be at least 0 and at most 24.
4. Constrained to be at least 40°F and at most 90°F. We suspect that the absence of formating rules for the raw data may explain some anamolous minimum and maximum values.
5. Recoded to be at least 1.00 watts per square foot and no greater than 10.00 watts per square foot (see text for a description of recoding procedure).

TABLE V-3. GE-BOMA Data - HVAC Characteristics

Item	Response (%)[1]	
Air Conditioning Type	96	
Electric Window		16
Electric Central		80
Gas		2
Steam Turbine		4
Steam Absorption		9
None		2
Economizer	93	
Yes		35
No		58
Humidification	5	
Yes		2
No		3
Electric Heating Type	26	
Heat Pump		6
Resistance		20

Note to Table V-3:

1. The response rate in first column for a question with multiple permissable responses is the total percent of usable responses, while the response rate in the second column is the response rate for the specific response as a percent of the total, 1,168 Unless more than one answer is allowed, the response rates in the second column should sum to equal the overall response rate in the first column (save for small rounding errors).

TABLE V-4. GE-BOMA Data - Energy Metering Policies

Item	Response (%)[1]	
Tenants Metered	94	
Yes		35
No		59
Utility Meters Tenant	65	
Yes		16
No		50
Utility Metered Tenant Floor Space[2]	21	
Building Sells Energy	96	
Yes		4
No		92
Sell Electric	2	
Sell Natural Gas	0+	
Sell Fuel Oil	0+	
Sell Steam	3	
Sell Chilled Water	1	
Sales as Percentage of Total Energy	15	

Notes to Table V-4:

1. The response rate in first column for a question with multiple permissable responses is the total percent of usable responses, while the response rate in the second column is the response rate for the specific response as a percent of the total, 1,168 Unless more than one answer is allowed, the response rates in the second column should sum to equal the overall response rate in the first column (save for small rounding errors).
2. Utility metered floor space was subtracted from total area in computing energy intensities. Table VI-2 summarizes the distribution of responses to this question.
3. Since the conversion factors were never stated for this question, its interpretation is dubious. Consequently, we do not report the distribution of responses and eliminated these entries from subsequent analyses.

Table V-5 reports on the energy cost data requested by the survey. (Unfortunately, only electricity costs were requested.) "Electricity cost" refers to reported electricity costs divided by floor area. The 1981 EER shows total energy costs for BOMA buildings to be $1.344 per square foot in 1979. The results in Table V-5 suggest that the bulk of these costs are represented by electricity.

For most commercial buildings, electricity costs are a function of both energy and demand charges. Consequently, the average effective rate can vary across utilities and within them. "Electricity rate" illustrates this range. The calculation is performed by dividing total electricity costs by the number of kilowatthours of consumption reported. For those entries which reported both demand and energy charges, we have calculated the reported demand charge costs as a percent of total electricity costs. That demand charges appear to represent a substantial fraction of electricity costs (on the order of 30%) has important implications for the relative importance of conservation measures that reduce primarily peak demands.

As described in Section IV, the responses to the energy metering questions were used to modify the data used to calculate the energy intensities presented in Table V-6. To repeat briefly, we subtracted the floor space metered by the utility from our floor space totals, eliminated all responses that indicated sales of energy to outside parties, and developed the summary statistics after removing the highest and lowest 5% of the responses.

The definitions used in Table V-6 are as follows. "Total" refers to the sum of all reported energy use converted to Btu's and divided by reported floor area (see Table V-6 for the conversion factors used). "All Electric" refers to normalized energy use for those buildings which indicated an electric heating system type (heat pump or resistance) and which reported only electricity consumption. The remaining energy categories refer to consumption normalized for each reported fuel type.

Table V-6 also reports percentage changes in energy use between 1977 and 1979 for the subset of data that reported consumption in both years and which were included in the trimmed distributions. The data indicate that no statistically significant change in energy occurred between 1977 and 1979.

In summary, the data exhibit tremendous variations. For the calculated energy intensities, the use of trimmed means still results in large standard deviations relative to mean values. These large standard deviations complicate meaningful comparisons, such as whether all-electric buildings use less energy than multi-fuel buildings.

The analyses are also biased by non-responses (e.g., consumed natural gas and electricity, but only reported electricity), as well as inaccurate reporting (incorrect units, data entry errors). We believe such inaccurate reporting to be the source of anomalously low minimum energy intensities, despite the use of trimmed distributions. Without having had more control over the data collection process, however, we cannot identify the exact sources of variability.

TABLE V-5. GE-BOMA Data - Electricity Costs

Item	Response (%)	Mean[1]	Std. Dev.	Median	Minimum	Maximum
Electricity Cost - 1977 ($/sqft)[2]	37	0.82	0.64	0.69	0.04	5.69
Electricity Cost - 1979 ($/sqft)[2]	44	1.17	1.49	0.83	0.02	13.76
Electricity Rates - 1977 ($/MWh)[3]	37	45	47	34	2	49.3
Electricity Rates - 1979 ($/MWh)[3]	45	72	47	40	2	1003
Demand Charge - 1977 (%)[4]	30	30.5	18.9	31.5	0+	97.2
Demand Charge - 1979 (%)[4]	38	29.0	19.9	28.9	0+	99.8

Notes to Table V-5:

1. Reported means are of the trimmed distributions in which the highest and lowest 5% of values are eliminated.
2. Calculated by dividing the sum of reported electricity charges (energy and demand) by the total gross square footage less any floor area metered directly by the utility.
3. Calculated by dividing the sum of reported electricity charges by the reported electricity use.
4. Calculated by dividing only non-zero demand charge entries by the sum of reported electricity charges.

TABLE V-6. GE-BOMA Data - Energy Use Intensities (kBtu/sqft)

Item	Response (%)	Mean[1]	Std. Dev.	Median	Minimum	Maximum
1977						
Total[2]	61	119.3	62.5	105.0	29.5	371.1
All Electric[3]	15	91.4	37.7	88.8	14.2	222.2
Electricity[4]	59	77.9	33.2	71.4	20.7	201.8
Natural Gas[5]	24	43.7	55.3	25.2	0.1	288.5
Fuel Oil[6]	9	43.0	31.0	38.2	1.5	168.4
Steam[7]	20	43.5	30.6	41.1	0.1	135.8
Coal[8]	3	81.0	57.2	65.1	3.1	290.2
1979						
Total[2]	71	114.8	60.1	99.8	26.6	356.6
All Electric[3]	18	85.3	34.7	84.2	6.2	192.5
Electricity[4]	69	76.0	33.3	70.4	16.7	192.5
Natural Gas[5]	28	43.8	60.6	21.3	0.1	429.3
Fuel Oil[6]	10	39.8	31.7	33.2	1.1	162.9
Steam[7]	21	39.7	27.6	36.3	0.1	130.8
Coal[8]	4	78.5	64.0	63.8	3.4	313.7
(1977-1979)/1977[9]						
Total (%)	59	-2.6	37.2	2.2	-576.1	70.4
Electricity (%)	57	-0.8	21.2	1.1	-160.4	85.5

Notes to Table V-6:

1. Reported means are of the trimmed distributions in which the highest and lowest 5% of values are eliminated.
2. Calculated by dividing the sum of all reported energy use (converted to site Btu, as defined in notes 3-7) by net floor area (total gross square footage minus utility metered tenant floor area).
3. Calculated by dividing the reported electricity of those buildings that both indicated an electric heating system type and did not report consumption of any other fuels by net floor area (as defined in note 1).
4. Electricity converted to site Btus using a conversion factor of 3,413 Btu/kWh.
5. Natural gas converted to site Btus using a conversion factor of 1,109 Btu/cubic foot.
6. Fuel oil converted to site Btus using a conversion factor of 128,300 Btu/gallon.
7. Steam converted to site Btus using a conversion factor of 1,000,000 Btu/1,000 pounds.
8. Coal converted to site Btus using a conversion factor of 25,130,000 Btu/short ton.
9. Calculated from the non-zero data contained in the trimmed distributions.

VI. COMPARISONS WITH NBECS RESULTS FOR 1979

In this section, we compare our data base to the office building components of the DOE Energy Information Agency's (EIA) 1979 Nonresidential Building Energy Consumption Survey (NBECS) data base. The comparison indicates the degree to which the buildings in the GE-BOMA data base are representative of the nation's stock of office buildings.

In Section II, we pointed out that the need for generalizable results was an important motivation for studies of energy use in buildings. This need has been largely filled by EIA's NBECS. Starting in 1979 and continuing in roughly four year cycles, EIA conducts the only public or private collection of data for a large statistical sample of non-residential buildings in the US. The survey's explicit goal is to ensure high quality responses with statistical integrity. Data are collected through personal interviews with persons responsible for individual buildings and through mail questionnaires to the utilities that supplied energy to these buildings.

The results of the first survey in 1979 were published in three volumes and the processed data are available on magnetic tape. The first volume summarizes findings on building characteristics [EIA 1981a]; the second reports on fuel characteristics and conservation practices [EIA 1981b]; the third and fourth contain summaries of consumption and expenditures [EIA 1983a, EIA 1983b]. To date, however, EIA has placed less emphasis on the analysis and interpretation of collected data; the focus has been on summary presentations.

We used the summary presentations in these volumes to make three tables comparing the EIA and GE-BOMA survey responses. We could not, however, make out a question-by-question comparison between the two surveys. With regard to the type of fuels used, in particular, we were required to re-interpret responses to several questions in the GE-BOMA questionnaire, which taken as a whole, approximate those in the EIA survey.

Table VI-1 compares building characteristics in the two surveys. The most dramatic difference lies in the size of the buildings. The GE-BOMA sample is dominated by buildings that are, on average, much larger (in total square footage and number of floors) than the nation's stock of offices, as represented by the EIA sample. The GE-BOMA offices also tend to have more glazing as a percentage of exterior surface area and are often newer than the nation's stock of offices. The geographic distribution of buildings in the two surveys, as measured by census region, are closer, generally within 4%. Nevertheless, this distribution, as measured by degree-days, indicates that the GE-BOMA sample contains more buildings in areas of milder climatic conditions.

Table VI-2 compares the building's fuel use and operational characteristics. The figures presented for fuel use are not, however, directly comparable. For the GE-BOMA data, we included only the fraction of total responses that reported consumption. Thus, although it is almost certain that all of the GE-BOMA offices used electricity, only 82% of the sample reported electricity use. We cannot determine or correct for the impact of these nonresponses. In addition, many energy sources reported on in the NBECS survey were not represented in the GE-BOMA questionnaire.

TABLE VI-1. NBECS Comparison - Building Characteristics

	NBECS - Office[1]	GE-BOMA[2]
Census Region		
Northeast	17	21
North Central	32	30
South	33	29
West	17	20
1979 Heating and Cooling Degree-Days		
< 2000 CDD & > 7000 HDD	10	6
< 2000 CDD & 5500 to 7000 HDD	33	31
< 2000 CDD & 4000 to 5499 HDD	23	16
< 2000 CDD & < 4000 HDD	16	38
> 2000 CDD & < 4000 HDD	19	9
Year of Occupancy		
< 1900	8	2
1901 to 1920	9	11
1921 to 1945	20	14
1946 to 1960	20	12
1961 to 1970	20	27
1971 to 1973	7	14
> 1974	17	20
Total Square Footage		
< 1000	15	0
1001 to 5000	43	0
5001 to 10000	19	0+
10001 to 25000	14	2
25001 to 50000	4	8
50001 to 100000	2	23
> 100000	1	67
Number of Floors		
1 Floor	50	1
2 Floors	25	5
3 Floors	15	6
> 3 Floors	10	88
Glass as Percentage of Exterior Surface		
> 75%	2	14
> 50% & < 75%	7	29
> 25% & < 50%	28	37
< 25%	63	19

Notes to Table VI-1:

1. Population weighted distributions from 1979 NBECS office building cross-tabulations published in DOE/EIA-0246, March, 1981.
2. Unweighted distributions of responses from GE-BOMA survey.

TABLE VI-2. NBECS Comparison - Fuel Characteristics

	NBECS - Office[1]	GE-BOMA[2]
Energy Sources[3]		
Electricity	100	82
Natural Gas	59	34
Fuel Oil/Kerosene	16	12
Liquid Pet. Gas	4	-
Wood	1	-
Coal	1	4
Steam	2	25
Other	1	-
Heating Fuel Used[4]		
Natural Gas	52	34
Electricity	35	26
Fuel Oil	14	12
LPG	4	-
Wood	1	-
Coal	0	5
Steam	2	25
Other	1	-
None	2	1
Air Conditioning Fuel Used[6]		
Electricity	85	81
Natural Gas	6	1
Other	1	16
None	10	2
Hours of Operation for a Typical Week		
< 39	8	1
40 to 48	46	6
49 to 60	29	37
61 to 84	10	38
> 84	6	18
Percent of Building Cooled		
None	10	1
1% to 25%	6	2
26% to 50%	16	1
51% to 75%	11	1
76% to 99%	9	7
100%	48	86

Notes to Table VI-2:

1. Population weighted distributions from 1979 NBECS office building cross-tabulations published in DOE/EIA-0278, June, 1981.
2. Unweighted distributions of responses from GE-BOMA survey. A dash ("-") indicates that the GE-BOMA survey did not ask about the use of this energy source.
3. GE-BOMA data represent response rates for the reporting of fuel use. Thus, although it is certain that all GE-BOMA offices used electricity, only 82% reported consumption on the survey.
4. The NBECS column refers the use of a given energy source for the end use (heating or cooling) and may sum to more than 100%. The GE-BOMA column refers to response rates for the use a given energy source and may sum to more than 100%.

The major difference in reported fuel use between the two surveys is that a much larger fraction of GE-BOMA offices use steam as a fuel. Within air-conditioning fuels, the majority of GE-BOMA responses listed under the category labeled "other" are, in fact, steam. With respect to operational characteristics, the GE-BOMA buildings tend to operate longer hours and air condition a greater fraction of their floorspace.

Table VI-3 compares energy intensities between the two surveys. The GE-BOMA means and standard deviations represent trimmed values in which the highest and lowest 5% of values are not included. The NBECS RSE refers to an EIA measure of variability that is analogous to a standard deviation normalized to the sample mean. We have expressed the standard deviations from the GE-BOMA sample on a comparable basis.

The mean and median values for the GE-BOMA offices are lower than those for the NBECS offices. Nevertheless, the large standard deviations associated with the GE-BOMA data preclude a statistically based comparison that would determine, which sample, for example, was more energy intensive.

TABLE VI-3. NBECS Comparison - Energy Intensity

	NBECS - Office[1]		GE-BOMA				
	Mean (kBTU/sqft)	RSE[2] (%)	Mean[3] (kBTU/sqft)	Std.Dev./Mean (%)	Median (kBTU/sqft)	Minimum (kBTU/sqft)	Maximum (kBTU/sqft)
Total	124	7.0	116	52.9	100	28	361
Northeast	144	22.3	109	42.8	103	38	295
North Central	147	5.2	141	46.2	126	45	364
South	112	9.0	103	48.0	90	20	281
West	83	8.9	93	45.5	86	13	240

Notes to Table VI-3:

1. From 1979 NBECS office building energy intensities published in DOE/EIA-0318(79)/2, December, 1983.
2. Relative standard error, similar to a standard deviation, defined in DOE/EIA-0318(79)/2.
3. Calculated from a trimmed distribution in which the highest and lowest 5% of values are eliminated.

VII. ANALYSIS OF SELECTED PERFORMANCE INDICATORS

Energy use intensities, in which differences in building area are normalized, are only the first step in making meaningful comparisons between buildings and identifying opportunities for conservation measures. In addition, quantification of such influences as climate, operation, and other building characteristics is essential. In this section, we summarize results from the application of bi-variate and multi-variate regression techniques to estimate the effect of the presence or absence of selected building characteristics on energy intensity. Successfully identifying these impacts also helps identify the most statistically significant items that we may want to include to simplify future questionnaires.

We developed separate multiple regression equations to explain total energy intensity and electricity intensity. We used two methods, in parallel, as a preliminary filter to isolate the variables used in our final equations. The first method used one-way analysis of variance (ANOVA) tests to select a preliminary set of variables for examination. We will refer to this set of variables selected from this as those arising from method 1. Our criteria for selection was that the analysis yield an F-ratio that is significant at the level of 5%. While one-way F-ratios are an important means for identifying potential explanatory variables, they can also be misleading. That is, they may identify individual variables as significant when taken one at a time but not so when taken in conjunction with other variables. By the same token, they may also fail to identify important variables, which would reveal themselves when analyzed along with other variables.

For this reason, we used a second method to identify variables for inclusion in our final regression equations. The second method involved multiple regressions of logical groupings of subsets of variables on energy intensity. From these regressions, we selected the most significant variables (using the same statistical criteria as in the one-way analyses) from each grouping for inclusion in a second preliminary set of explanatory variables. We will refer to this set of variables as those arising from method 2.

Tables VII-1 and VII-2 summarize the results of these two selection processes. An asterisk indicates variables selected by method 1. An ampersand indicates the variables selected by method 2 (the logical groupings used in method 2 are separated by an extra space in the table).

In the next phase of analysis, we regressed the collection of data selected by each method separately as a final filter to identify the most promising set of explanatory variables from each method. Variables were selected if, when regressed together with the other variables in the collection, they were significant at the 5% level. In many cases, both regressions identified the same variables for inclusion in the final equations.

The reduced sets of significant variables from each method were then combined into a single collection. These variables were then regressed using a step-wise procedure to yield a final set of statistically significant variables for the final regression equations.

The results of our final regression equations are summarized in Tables VII-3 and VII-4. These tables identify the variables, their regression coefficients, and their overall significance for each energy use intensity. In general, we find that the explanatory power of our final equations is low. The adjusted R-squareds are generally less than 25%; that is, the final equation explains only 25% of the variation in energy use. Nevertheless, the

TABLE VII-1. One-Way Analysis for 1979 Total Energy Intensity

Factor	Degrees of Freedom	F-ratio	Probability
City	20/740	5.0676	0.0000 *&
Cooling Degree-Days	19/741	5.3313	0.0000 *&
Heating Degree-Days	19/741	5.3313	0.0000 *&
Location	2/756	0.5068	0.6026
Year of Occupancy	79/666	1.2098	0.1144
Gross Area	12/748	1.3625	0.1787
Net Area	11/692	0.9603	0.5338
Number of Floors	56/692	1.3072	0.0708
Height	276/353	1.2627	0.0196 *
Floor to Ceiling Height	13/677	1.5402	0.0980
Volume/Area	53/702	1.3490	0.0540
Wall Construction	2/741	1.1819	0.3073
Glazing Area	68/658	1.0571	0.3597
Building Touch North	20/656	0.4230	0.9878
Building Touch East	25/653	0.9055	0.5984
Building Touch South	23/647	1.3823	0.1102
Building Touch West	28/637	0.7933	0.7683
Banking Area	1/759	0.6649	0.4141
Banking Percentage Area	57/253	1.4067	0.0405 *
Retail Area	1/759	0.0021	0.9634
Retail Percentage Area	43/295	1.3226	0.0954
Restaurant Area	1/759	0.7742	0.3792
Restaurant Percentage Area	17/293	1.0415	0.4128
Medical Area	1/759	0.7336	0.3920
Medical Percentage Area	39/112	0.5016	0.9922
Public Area	1/759	1.2276	0.2682
Public Percentage Area	15/81	0.6152	0.8544
Weekly Operating Hours	78/561	1.3091	0.0473 *&
Office Occupancy	45/682	1.7418	0.0023 *
Retail Occupancy	37/356	0.9675	0.5271
Lighting Intensity	8/585	1.4536	0.1713
Summer Operating Temp	17/631	1.6104	0.0564
Winter Operating Temp	14/644	1.3966	0.1488
Winter Set-Back	29/384	1.7221	0.0128 *&
Summer Set-Back	19/263	1.3034	0.1805
Annual Average Temp	13/632	1.5049	0.1103

* selected by method 1
& selected by method 2

TABLE VII-1. One-Way Analysis for 1979 Total Energy Intensity cont

Factor	Degrees of Freedom	F-ratio	Probability
Electricity Use	1/759	2.9257	0.0076 *
Natural Gas Use	1/759	12.4572	0.0004 *&
Fuel Oil Use	1/759	5.7136	0.0171 *&
Steam Use	1/759	1.6692	0.1968
Coal Use	1/759	59.4785	0.0000 *&
Resistance vs. Heat Pump	1/200	3.0099	0.0843
A/C Type	5/722	1.9624	0.0021 *
Percent Air Conditioned	25/720	0.7368	0.8214 &
Economizer	1/710	3.9752	0.0000 *
Electricity Cost	9/419	6.5644	0.0000 *
Demand Charge Fraction	67/259	0.9332	0.6237
Utility Meters Tenant	1/494	12.5272	0.0004 *
Tenants Metered	1/712	2.3172	0.1284
Office Rent	29/580	0.7585	0.8165
Retail Rent	29/241	0.7969	0.7634

* selected by method 1
& selected by method 2

TABLE VII-2. One-Way Analysis for 1979 Electricity Intensity

Factor	Degrees of Freedom	F-ratio	Probability
City	20/719	3.8413	0.0000 *&
Cooling Degree-Days	19/720	3.9622	0.0000 *&
Heating Degree-Days	19/720	3.9622	0.0000 *&
Location	2/735	3.6206	0.0272 *
Year of Occupancy	78/646	2.5232	0.0000 *&
Gross Area	12/727	0.4891	0.9218
Net Area	11/672	0.6229	0.8101
Number of Floors	56/671	1.5485	0.0078 *
Height	277/342	1.0089	0.4675
Floor to Ceiling Height	13/656	2.6316	0.0014 *&
Volume/Area	53/682	1.4414	0.0247 *
Wall Construction	2/720	0.2326	0.7925
Glazing Area	68/639	0.9319	0.6324
Building Touch North	21/634	1.1604	0.2803
Building Touch East	24/638	0.9653	0.5122
Building Touch South	23/632	1.3037	0.1559
Building Touch West	28/620	1.2015	0.2198
Banking Area	1/738	3.6226	0.0574 &
Banking Percentage Area	58/245	1.3357	0.0691
Retail Area	1/738	7.3168	0.0070 *&
Retail Percentage Area	42/288	1.4440	0.0445 *
Restaurant Area	1/738	1.1910	0.2755
Restaurant Percentage Area	17/286	0.5516	0.9245
Medical Area	1/738	1.4722	0.2254
Medical Percentage Area	39/110	0.6833	0.9119
Public Area	1/738	1.2531	0.2633
Public Percentage Area	13/83	0.7750	0.6837
Weekly Operating Hours	75/548	1.7107	0.0004 *&
Office Occupancy	44/663	2.0688	0.0001 *
Retail Occupancy	34/347	1.2493	0.1659
Lighting Intensity	8/571	0.9256	0.4946
Summer Operating Temp	17/618	1.6526	0.0473 *
Winter Operating Temp	14/635	1.4016	0.1465
Winter Set-Back	30/378	2.2080	0.0004 *&
Summer Set-Back	19/258	1.3945	0.1291
Average Temp	13/620	1.3541	0.1770

* selected by method 1

& selected by method 2

TABLE VII-2. One-Way Analysis for 1979 Electricity Intensity cont

Factor	Degrees of Freedom	F-ratio	Probability
Natural Gas Use	1/738	1.6480	0.1996
Fuel Oil Use	1/738	8.4388	0.0038 *&
Steam Use	1/738	7.449	0.0065 *&
Coal Use	1/738	5.6386	0.0178 *&
Resistance vs. Heat Pump	1/193	0.2277	0.6337 &
A/C Type	5/701	7.1386	0.0000 *&
Percent Air Conditioned	25/698	2.0290	0.0023 *&
Economizer	1/690	10.4657	0.0013 *&
Electricity Cost	9/409	7.7029	0.0000 *
Demand Charge Fraction	67/253	1.1627	0.2051
Utility Meters Tenant	1/483	13.0264	0.0003 *
Tenants Metered	1/695	2.0985	0.1479
Office Rent	27/570	1.3497	0.1133
Retail Rent	29/237	1.1246	0.3085

* selected by method 1
& selected by method 2

explanatory power of the variables in the final equations are very good; they are typically significant at better than 5%.

For total energy use intensity (see Table VII-3), we found that coal fuel use, the number of heating degree-days, the amount of winter set-back, location, and weekly operating hours explained 17% of the variation in energy intensity and that the equation was significant at the 5% level.

For electric energy use intensity (see Table VII-4), we found that first year of occupancy, weekly operating hours, the presence of resistance or heat pump electric heating, the price of electricity, and location explained 24% of the variation in energy intensity and that the equation was significant at the 5% level. We are encouraged by the reasonableness of the variables included in the final equations. The sign of the coefficients follows intuition on the most important influences on building energy use. Nevertheless, we cannot help but speculate that the low explanatory power of our regressions were, in part, due to the poor quality of our data.

TABLE VII-3. Multiple Regression Results for Total Energy Use Intensity (kBtu/sq.ft.yr)

Adjusted R^2=	0.17	F=	4.09	Significance =	0.00

Variable	Type *	B	Beta
Coal Use	D	70.61	0.25
Degrees of Winter Set-Back	C	-1.29	0.14
Weekly Operating Hours	C	0.28	0.15
Location - Boston MA	D	-1.38	-0.01
Location - Chicago IL	D	31.63	0.17
Location - Philidelphia PA	D	-1.80	-0.01
Location - Pittsburg PA	D	-16.03	-0.07
Location - Atlanta GA	D	-26.43	-0.10
Location - St. Louis MO	D	-20.26	-0.09
Location - Dallas TX	D	-3.06	-0.01
Location - Phoenix AZ	D	-3.89	-0.01
Location - Seattle WA	D	-24.55	-0.06
Location - Minneapolis MN	D	2.86	0.01
Location - Omaha NB	D	13.30	0.03
Location - San Francisco CA	D	-24.54	-0.06
Location - Fort Worth TX	D	-3.85	-0.01
Location - Miami FL	D	-34.00	-0.06
Location - Milwaukee WI	D	12.90	0.04
Location - Detroit MI	D	6.77	0.02
Location - Washington DC	D	-20.00	-0.10
Location - New York NY	D	-17.53	-0.08
Location - Cleveland OH	D	-10.07	-0.03
Location - Los Angeles CA	D	-34.79	-0.06
Constant		112.37	

* D = Dummy Variable
C = Continuous

TABLE VII-4. Multiple Regression Results for Electricity Energy Use Intensity (kWh/sq.ft.yr)

Adjusted R^2=	0.24	F=	5.83	Significance =	0.00

Variable	Type *	B	Beta
Year of Occupancy	C	0.34	0.23
Weekly Operating Hours	C	0.24	0.23
Resistance vs. Heat Pump	D	0.01	0.14
Electricity Price	C	0.14	0.12
Location - Boston MA	D	14.11	0.09
Location - Chicago IL	D	22.09	0.21
Location - Philidelphia PA	D	29.66	0.18
Location - Pittsburg PA	D	5.31	0.04
Location - Atlanta GA	D	5.80	0.04
Location - St. Louis MO	D	0.68	0.01
Location - Dallas TX	D	35.56	0.20
Location - Phoenix AZ	D	26.15	0.07
Location - Seattle WA	D	18.71	0.09
Location - Minneapolis MN	D	5.60	0.03
Location - Omaha NB	D	39.75	0.09
Location - San Francisco CA	D	-0.35	-0.00
Location - Fort Worth TX	D	13.88	0.08
Location - Miami FL	D	3.68	0.01
Location - Milwaukee WI	D	13.33	0.06
Location - Detroit MI	D	24.80	0.13
Location - Washington DC	D	10.33	0.11
Location - New York NY	D	-8.35	-0.07
Location - Cleveland OH	D	9.40	0.04
Location - Los Angeles CA	D	3.85	0.02
Constant		-610.95	

* D = Dummy Variable
C = Continuous

VIII. SUMMARY

In 1980, the General Electric Company and the Building Owners and Managers Association conducted a mail survey of more than 1,000 office buildings in 21 U.S. locations. Because of funding uncertainties, GE's analysis of the data was never completed. In preparation for future energy use surveys carried out by BOMA or others, we have taken a second look at the project to determine what lessons can be learned about the process and to carry the unfinished analysis a step further.

We first examined the data and reviewed the general circumstances under which they were collected. We observed that while participation by local BOMA chapters ensured high numbers of responses, lack of established procedures for data verification affected the quality of responses. The lack of verification required us to interpret and modify the data for analysis.

In summarizing responses for each question on the mail survey, we observed high response rates for most questions. At the same time, we found extreme ranges in selected responses and speculated that these were the result of bad data rather than true characteristics of the surveyed offices. Large standard deviations for many of the responses made it impossible to draw meaningful, statistically sound conclusions from the data.

We compared the GE-BOMA data base to selected characteristics of the U.S. stock of office buildings as summarized in EIA's 1979 NBECS reports. We found that the offices in the GE-BOMA data base were much larger, had more glazing, used more steam as a fuel, and operated longer hours than the U.S. stock. In other areas, such as age, location, and climate, the two were more similar. Again, we could not make direct comparisons of energy use intensities because large standard deviations found in the intensities of the GE-BOMA buildings precluded meaningful comparisons.

We performed multiple regression analyses of selected building characteristics on total energy use intensity and on electric energy use intensity. Our final equations could explain no more than 24% of the observed variations in energy use intensities. Nevertheless, the statistical significance of the final equations was high.

IX. REFERENCES

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Appendix A. GE-BOMA Questionnaire