THE NONRESIDENTIAL BUILDINGS ENERGY CONSUMPTION SURVEY AS AN R&D PLANNING TOOL

Gerald D. Pine and James R. Brodrick - Gas Research Institute

The Gas Research Institute (GRI) is a non-profit organization that plans and manages research on behalf of its member natural gas utilities and their customers. GRI is currently developing concepts and prototypes for advanced gas technologies to be used in the commercial buildings sector. Proper targeting of this R&D depends on accurate knowledge of the energy use patterns and energy using equipment requirements of that sector. Information needed includes such basic data as the number and size distributions of particular building types, building age distributions, and types and magnitudes of energy service requirements. This type of information has not been readily available in the past or has been available in the form of scattered small data sets not in a form most useful to researchers. The Nonresidential Buildings Energy Consumption Survey (NBECS) of 1979[1] is an important first step in the direction of meeting the data needs of the energy research community.

1. Use of the NBECS Data by GRI

The Gas Research Institute first became involved with analysis of the 1979 NBECS data through a contract with Applied Management Sciences, Inc. That contract resulted in an overview report of the U.S. commercial sector and its energy use patterns. The overview has been published as a GRI report[2] that is readily available to interested parties, so we will not dwell on the subject here. However, a brief summary of the major uses of the NBECS and other similar data bases within GRI is useful in providing a context for our observations.

The primary reason for undertaking the description of non-residential building stock was to provide a data base for technology assessments at GRI. These technology assessments are useful to GRI in two common situations. First, the assessments are used to identify new R&D opportunities. Assessments provide detailed information about the cost and performance of existing energy technologies and the characteristics of markets in which the technologies must compete. This information can then be used to determine cost and performance goals that must be met for new concepts to result in new gas technologies that will offer consumer benefits necessary for any large-scale market penetration.

Second, once some research has been performed on a technology concept the cost and performance characteristics that are likely to be achieved can be predicted by the research contractors and the project managers. These characteristics may be quite different from the original research goals, or market conditions and may have changed drastically since research goals were established. In either case, it is useful for GRI to reevaluate the ability of its new technologies to compete and to estimate the size of the expected consumer benefits. Potential manufacturers of the new technologies and our member gas utilities frequently find such assessments essential. The manufacturers, especially small ones with limited analytical staffs, require information about the markets in order to evaluate the risk involved in participating as partners in large scale tests of the technologies and as agents for commercialization. Thus, the assessments are a critical element in ensuring successful transfer of the technologies to the private sector. Member utilities are interested in the applicability of new technologies in their service territories and in the effects on the operation of their systems. Note that the usefulness of the assessments to both these audiences becomes greater as more regional detail is provided. This fact will influence our conclusions about the usefulness and adequacy of the NBECS data base.

GRI must also satisfy its member utilities and the Federal Energy Regulatory Commission that it is spending its research funds wisely. One measure of performance is the near term benefits that are expected from technologies developed by GRI that have been successfully commercialized. As new technologies are added to the list of successfully commercialized technologies, estimates of the consumer benefits are developed and published. These analyses are generally performed at the national level, unlike the technology assessments discussed in the previous paragraph. The tools used for the benefits analyses are generally large energy models such as the Industrial Sector Technology Use Model (ISTUM)[3] and the Generalized Equilibrium Modeling System (GEMS)[4] because a substantial portion of the economic benefits result from changes in reduced gas prices, especially for technologies that reduce the projected price for natural gas. Even for national level benefits analyses, however, market information is crucial, but regional market data are somewhat less important. For these models, data such as the NBECS data are used to develop a model data base.

2. Limitations of the Data Base from GRI's Perspective

With the above remarks to put the GRI view of the NBECS data base into perspective, we proceed to discuss the subject at hand--the suitability of the NBECS data base as a planning tool for GRI. As with any statistical sample of a real population, especially the first sample of its kind, there are limitations. Some limitations arise from the relatively small sample size and are not easily remedied in the absence of substantial increases in funding. A second limitation to the usefulness of the data, though not its accuracy, results from limitations in the scope of the survey. Some types of additional information can only be obtained at a significant additional cost to the government; other types of additional information may be obtained at little or no additional cost by supplementing the questionnaires. Other limitations result from errors in the sample design or inexperience on the part of field workers collecting the data. Many of the latter

types of limitations can be avoided in future samples, and we share them with this audience in the hopes that it can provide useful suggestions to the Energy Information Administration as ways to avoid these and similar problems in the future through better design of questionnaires and better training of field workers.

2.1 Limitations From Sample Size

In view of our comments about the desirability for detailed regional data to increase the usefulness of analyses to GRI member utilities and potential equipment manufacturers, it should come as no surprise that one of the most important limitations of the NBECS data base from GRI's point of view is the limited sample size. There are about 6000 buildings in the 1979 NBECS data base. GRI performs analyses of residential/commercial applications for 16 geographical regions of the U.S. This large number of regions is necessary to account for differences in climate, fuel prices, building construction practices, variation in the availability of major fuels, and other regionally varying parameters. We are concerned with specific types of commercial buildings because the energy requirements and types of energy conversion technologies used to supply energy services may be quite different for the different types of buildings. The characteristics of energy technologies are typically very different depending on the size of the building in which the equipment is used. In addition, the characteristics of the competitive environment for new gas technologies will be different for the different fuels (oil, gas, and electricity) that are used to supply the services. When the NBECS data base is subdivided among the building categories, the size categories, and the fuel types, the sample for a given category on the average may be no more than 10-20 buildings. In many cases, the sample will be even smaller. Clearly, we have a problem with statistical significance when such a small sample is used. Therefore, we would prefer that the sample size be increased in order to increase our confidence in any differences that are apparent when the sample size is subdivided. For our purposes, a sample size five to ten times as large as the present one would be highly desirable.

2.2 Limitations From Sample Scope

The NBECS data set could be made considerably more useful to GRI and to other organizations interested in energy analysis if some additional detail were obtained in future surveys. It is recognized that such additional data would, of course, require substantial increases in funding levels. Some of the most important additions (in our view) are summarized below.

At GRI we are using the NBECS data, supplemented by additional data sources, to define standard or prototype buildings, which will be simulated using DOE 2.1[5] or other similar computer codes. The construction materials comprising the building envelope can be important in determining the building energy use, especially for smaller buildings. The present NBECS data set includes no information about the envelope construction. We recommend that such information be included in future surveys.

Another important determinant of energy use in commercial buildings is the stock and use of energy using equipment. Lighting, for example, is typically an important energy user in large office buildings. Similarly, computers or other energy-intensive equipment can strongly influence a building's energy use. For such buildings as restaurants, hospitals, and some schools, water heating may be a significant contributor to energy use. Finally, occupancy, thermostat setbacks, and other measures of the intensiveness of the use of a building and its energy systems are important characteristics in defining the energy use profiles and in sizing equipment. We recommend that information on building and energy system use and operation characteristics be collected in future surveys, at least on a selective basis. Submetering of a subsample of the buildings to identify the contributions of major uses such as lights, water heating, space heating, and cooling would be a most useful complement to the existing data base.

Variations in equipment efficiencies, capacities, age, and other characteristics can be as important as the building envelope or climate variations in determining building energy use patterns. We discuss the need for improved questions about energy using equipment in the following section, but even when the questions have been improved to remove ambiguities and to better identify the generic equipment types (heat pumps, absorption chillers, etc.), the data sets can be made much more useful by collecting and reporting specific information about the equipment types. For example, significant differences in the efficiency of heat pumps will occur depending on the age of the equipment and the specific models installed in the building. Ideally, information about the equipment age, capacity, and specific models would be included on the data tapes.

Lacking such detailed information as suggested in the above paragraphs, the relative importance of climate-dependent loads and loads related to internal building loads can be inferred from time series data on the fuel consumption. For example, monthly fuel consumption data for major fuels used by the building together with identification of the services supplied by the fuels could be used to estimate heating, cooling, and base-load components of the buildings fuel requirements.

3. Ambiguities and Misleading Presentation of Data

From GRI's point of view, data on the building energy systems are ambiguous and incomplete. This is the most important area that needs improvement in future surveys. The questionnaire and subsequent follow up interviews did not identify the prevalence of heat pump systems, for example. The categories on the questionnaire were often so ambiguous and the terminology used resulted in system data that are not meaningful to engineers and equipment designers. The assistance of engineers knowledgable about building systems should be sought in designing future questionnaires. We would prefer that major

types of energy using equipment be better defined.

Another set of problems exists for users of published reports, but is not a problem for users who make use of the data tapes. The standard ranges presented for building size categories and building vintage, for example, make interpretation of the data somewhat tricky. The problem is illustrated by Figure 1. The building size categories in the published reports may be misinterpreted easily. The standard categories are less than 1000, 1000-5000, 5000-10,000, 10,000-25,000, 25,000-50,000, 50,000-100,000, 100,000-200,000, 200,000-500,000, 500,000-1,000,000 and over 1,000,000 square feet. Additional categories that contain equal increments of square feet (0-5000, 5000-10,000, 10,000-15,000, etc.) would be valuable in understanding the relative importances of the various categories. In addition, since the over 50,000 square feet category contains about 45% of all the stock with respect to floor area, this category should be further broken down to show whether there is a smooth monotonic decline with increasing size or whether there are peaks in the relative importance of specific sizes.

The problem with the vintage of buildings is similar to the size range problem. Figure 2 shows the distribution of buildings by year of construction. The ranges of years of construction contain different numbers of years. Presentation of distributions for ranges containing equal numbers of years would be more useful. For example, a first glance at Figure 2 would suggest that there was a lull in construction for the years 1971-73 compared to the previous period (1961-70) and to the following period (1974-79). However, if the 1971-73 and 1974-79 categories are combined, construction for the 1971-79 time period is greater than the construction for the 1961-70 time period. Use of the raw data on the computer tapes completely eliminates the problem by letting users develop their own categories, but this is an expensive proposition and should not be necessary.

We would recommend that users of the NBECS data be polled for preferred presentation formats for future publications. It is likely that other users will have problems similar to those of GRI in using the data.

4. Comparison to Alternative Data Sources

Because the NBECS data base does not meet the complete needs of GRI (nor does any other source for that matter), we have found it useful to analyze additional data sources to increase our knowledge of commercial buildings. In particular, we have made use of the McGraw-Hill/F.W. Dodge data base[6] to add to our knowledge of building geometry and construction trends. One significant problem has resulted when we attempted to use the NBECS and F.W. Dodge data bases together. Namely, the NBECS data base and the Dodge data base use different definitions of the specific commercial subsectors (offices, warehouses, etc.). As the Dodge data base is much larger than the NBECS data base, we recommend that attention be given to mapping between the two data bases. A mapping of the NBECS categories by Standard Industrial Classification codes[7] would also be useful.

We have used data from the Bureau of the Census' Annual Housing Surveys[8], the Residential Energy Consumption Survey[9], and from the National Association of Home Builders[10] to characterize the residential sector. We have concluded that the collection and publication of residential sector data as part of the NBECS data base has little value. We recognize that the collection of residential sector data was not the intent of the NBECS effort, and that presentation of this data is done more as a matter of completeness than in order to provide useful information on that sector. However, it is our judgement that its inclusion in the published tables may result in misinterpretations by the occasional user. For this reason, we recommend that data on residential buildings be excluded from published tables or included only in a summary table.

5. Summary and Conclusions

Although the focus of this paper is the need for improvements in the NBECS data base, it is important to note that the data base has provided a valuable new source of data about the inventory of commercial sector building stock in the United States. The data base has proven to be an important tool for GRI in planning its research programs in the buildings sector area. There are no other data sources that are as comprehensive in coverage or as consistent in presentation of data as NBECS. However, we conclude that significant improvements can and should be made to enhance its usefulness. Our major recommendations are as follows:

1. The size of the buildings sample should be increased by a factor of five to ten to allow better resolution with respect to region, building type, and fuel use.
2. Additional data should be collected in future surveys, including data about the construction materials used for the envelope and more detailed energy systems characteristics.
3. More information should be collected to identify the relative fuel demands required to meet major energy services such as lighting and water heating. Submetering of a subsample of buildings would be ideal from GRI's perspective.
4. Time series data on fuel consumption should be collected and reported.
5. Future surveys should be modified extensively to better identify and distinguish among the various different types of heating and cooling systems used in the buildings. In particular, attention should be paid to the vintages and efficiencies of the equipment in order to separate the effects of the building construction, local climates, and system efficiencies on fuel consumption.
6. In future published reports, the categories selected for such properties as building floor area and year of construction should be presented in approximately equal increments to

better display trends in building characteristics.

7. Information should be presented in such a way as to allow easier comparison to other sources of buildings data, such as the F. W. Dodge buildings data, and to correlate buildings subsectors with their uses according to SIC codes.

REFERENCES

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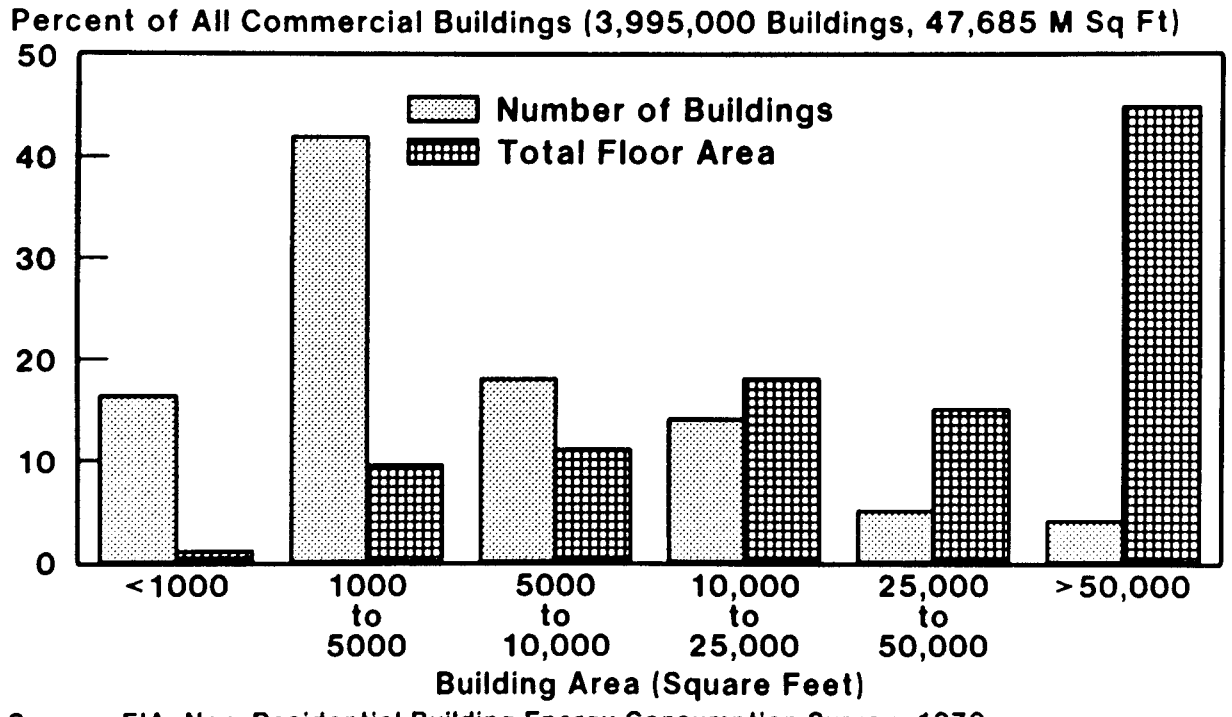
Figure 1. Size Distribution of Commercial Buildings by Number and Total Area



Source: EIA, Non-Residential Building Energy Consumption Survey, 1979

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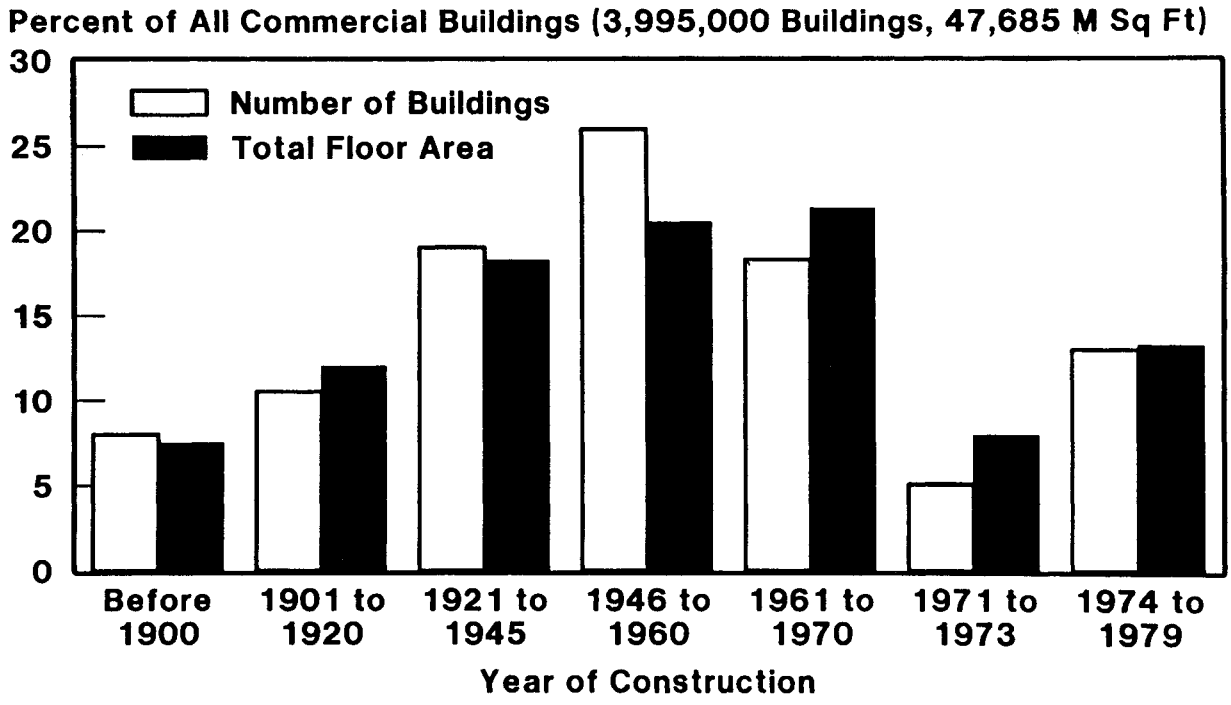
Figure 2. Age Distribution of Commercial Buildings by Number and Total Area



Source: EIA, Non-Residential Building Energy Consumption Survey, 1979

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