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Assessment of Energy Use in Multibuilding Facilities

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Contacts

This publication was prepared under the general direction of W. Calvin Kilgore, Director of the Office of Energy Markets and End Use (202/586-1617) and Lynda T. Carlson, Director of the Energy End Use and Integrated Statistics Division (EEUISD) (202/586-1112). Specific information regarding the contents or preparation of this publication can be obtained from Dwight K. French, Chief of the Transportation and Industrial Branch (202/586-1126). Questions regarding the Commercial Buildings Energy Consumption Survey may be referred to Martha M. Johnson, Survey Manager (202/586-1135). The FAX number for all EEUISD personnel is 202/586-0018.

Detailed technical questions on the topics in this current publication may be referred to the following members of the EEUISD:

Eugene M. Burns	Principal Author, Data Quality, Estimation	202/586-1125
Christy Hall	Table Preparation	202/586-1068
Vicki Moorhead	Figure Preparation and Report Production	202/586-1133
Jay K. Olsen	Data Imputation	202/586-1137
Hattie Ramseur	Report Production	202/586-1124

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Executive Summary

The purpose of this report is to address a known problem in the Energy Information Administration's (EIA) data systems regarding energy consumption in buildings. The problem is in measuring the consumption of energy in a particular building that is located within a multibuilding facility that utilizes district heating and/or cooling. When such a building is surveyed by EIA, total energy use for that particular building is normally not measured and can only be estimated from related information that is provided for the multibuilding facility as a whole. Since a facility usually includes a wide variety of building types with differing heating and/or cooling requirements, the estimation procedures are subject to error. This then adversely affects the quality of the energy consumption estimates that are made for the surveyed building.

The 1989 Facility Survey, an adjunct to the 1989 Commercial Buildings Energy Consumption Survey (CBECS), was targeted at multibuilding facilities with central physical plants. The Facility Survey was intended to determine the best way to collect information on district heating and cooling for commercial buildings. The total energy delivered in the form of district heat to commercial buildings is of the same magnitude as the total energy delivered from fuel oil. Roughly three-quarters of the commercial floorspace with district heating or cooling receives that district heating or cooling, not from a utility, but from a central physical plant located on the same facility.

The two main objectives of the Facility Survey were:

- to improve CBECS estimates of district heat consumption for commercial buildings that lacked individual metering, and

- to estimate primary fuel consumption by central physical plants that provide energy to commercial buildings.

In terms of these main objectives, the 1989 Facility Survey was largely unsuccessful. Cases lacking building-level data tended also to lack facility-level output data. Accurate estimates of primary fuel consumption by central plants could not be produced due to the widespread inability of respondents to provide good data, the small sample size (361 eligible facilities, of which 124 did not respond), and the considerable amount of inherent variation of the population.

However, the Facility Survey was successful at discovering the characteristics of these multibuilding facilities.

Key Findings

- In 1989, one-third of all commercial buildings (1.5 million buildings) and 41 percent of all commercial floorspace (26 billion square feet) were located on multibuilding facilities (with or without central physical plants) (Table ES1).

- Although only 4 percent of all commercial buildings were located on multibuilding facilities with central physical plants, these buildings accounted for 13 percent of all commercial floorspace and 28 percent of all commercial buildings energy consumption in 1989.

These findings demonstrate the importance of multibuilding facilities for the analysis of energy consumption in commercial buildings. In particular, commercial buildings located on multibuilding facilities with central physical plants tend to be considerably larger than commercial buildings in general, and tend to be either engaged in energy-intensive activities such as health care, or associated with industrial activities. By CBECS definition, commercial buildings can have up to 49 percent of their floorspace devoted to noncommercial use, so that predominantly

commercial buildings on industrial facilities may include significant amounts of manufacturing energy use. District heat energy may also be overstated if consumption reported to CBECS includes energy transmission losses between the central physical plant and the sampled buildings.

Table ES1. Commercial Buildings on Multibuilding Facilities, 1989

Commercial Buildings	Number of Buildings (thousand)	Floorspace (million square feet)	Energy Consumption (trillion Btu)[a]
All Buildings	4,528	63,184	5,788
Buildings on Multibuilding Facilities	1,497	25,947	2,901
Buildings on Multibuilding Facilities with Central Physical Plants	203	8,346	1,593

[a]Electricity, Natural Gas, Fuel Oil, and District Heat (Steam and Hot Water).

Source: Energy Information Administration, Office of Energy Markets and End Use, Forms EIA-871A through EIA-871F of the 1989 Commercial Buildings Energy Consumption Survey.

Characteristics of Facilities

What are the multibuilding facilities?

- The types of multibuilding facilities with the most commercial floorspace were colleges, universities and other schools, office complexes, shopping centers and malls, hospitals, industrial facilities, and warehouses. Each of these types of facilities contained over 2 billion square feet of commercial floorspace in 1989.

- A total of 2.5 billion square feet of commercial floorspace, including 1.0 billion square feet of warehouses and 741 million square feet of offices, was located on industrial facilities.

- Government (local, State, and Federal) owned 35 percent of the floorspace on multibuilding facilities (9.0 billion square feet). Government buildings consisted primarily of colleges and universities (2.2 billion square feet), other schools (2.8 billion square feet), and offices (1.2 billion square feet).

What types of multibuilding facilities are more likely to have central physical plants?

- Eighty-three percent of the college and university floorspace was located on facilities with central plants. In contrast, only 21 percent of the "other schools" floorspace (mainly elementary and secondary schools) was located on such facilities.

- Among hospitals, 79 percent of the commercial floorspace was located on facilities with central plants.

- Slightly more than half (52 percent) of the commercial floorspace on industrial facilities was located on facilities with central plants.

- Warehouse facilities, shopping centers and malls, religious facilities, entertainment complexes, and hotels and motels were unlikely to have central physical plants.

What are the characteristics of multibuilding facilities with central physical plants?

- In 1989, there were about 30,000 multibuilding facilities with central physical plants and at least one commercial building. These facilities contained 12 billion square feet of floorspace.

- Overall, 61 percent of the floorspace on facilities consisted of commercial buildings. By sector, 92 percent of the floorspace on commercial facilities, and 21 percent of the floorspace on industrial facilities, was contained in commercial buildings.

- The mean floorspace per facility was 395,000 square feet. Among commercial facilities the largest were colleges and universities (1,393,000 square feet); the smallest were other schools (114,000 square feet). Industrial facilities averaged 298,000 square feet.

Energy Outputs and Inputs[1]

What are energy outputs produced by the central physical plants?

- Of the facilities with central plants, 75 percent produced steam, while 25 percent produced hot water, 18 percent produced chilled water, and 24 percent reported electricity generation. (However, the incidence of electricity generation was probably overstated.)

- Sixty-seven percent of the central plants on commercial facilities produced steam, 32 percent produced hot water, and 33 percent produced chilled water.

- The commercial sector accounted for 75 percent of all chilled water plants, but only 20 percent of all plants reporting electricity generation.

- Central physical plants produced 3.8 quadrillion Btu of output in 1989, which consisted primarily of steam (79 percent of the total).

- Although commercial sector central plants produced less than 20 percent of the overall total, they produced 68 percent of the hot water and 78 percent of the chilled water.

What types of energy are used as inputs by the central physical plants?

- Natural gas, used at 64 percent of the central plants, was the most common energy input. Fuel oil and electricity were each used at about half of the central plants

- Thirty-one percent of all facilities used both fuel oil and natural gas. This overlap in fuel use may reflect either separate equipment or equipment with dual fuel capability.

- Some regional differences were evident. Seventy percent of the commercial plants in the Northeast used fuel oil, while 99 percent of the plants in the Midwest used natural gas.

- Total inputs to central plants were estimated at 5.8 quadrillion Btu, 32 percent of which was natural gas. The commercial sector physical plants accounted for 1.2 quadrillion Btu, 50 percent in the form of natural gas.

- The overall ratio of energy output (3.8 quadrillion Btu) to energy input (5.8 quadrillion Btu) was 0.66.

- Based on 0.66 as the ratio of outputs to inputs, it can be estimated that 0.8 quadrillion Btu of primary energy would have been required to produce the 0.5 quadrillion Btu of district heat consumed by commercial buildings on multibuilding facilities in 1989.

[1]The estimates of central physical plant energy inputs and outputs are subject to a substantial amount of reporting error, particularly with regard to the quantities of energy involved. Despite their weakness, these estimates are being presented due to the lack of any comparable national data on this important aspect of commercial energy consumption.

Apart from particular findings, the 1989 Facility Survey also raised awareness of the importance of multibuilding facilities in general. To the extent that the facility, rather than the individual building, coincides with the economic decision-making unit, facilities represent a fruitful area for future work on conservation and energy management.

1. Introduction

This report presents findings from a methodological study to explore ways of improving energy data collection in the commercial energy sector, specifically relating to multibuilding facilities. Multibuilding facilities involve groups of buildings that are located at a single site, such as a college campus or a hospital complex. These facilities are owned and/or managed as a single unit, and frequently include a central physical plant which provides energy in the form of district heat to the individual buildings located on the facility. As such, they have presented significant data collection difficulties for the Commercial Buildings Energy Consumption Survey (CBECS), which is used by the Energy Information Administration (EIA) to collect energy consumption data from a sample of individual buildings in the commercial sector.

This study originally had two primary objectives: (1) to improve EIA's estimates of district heat consumption for commercial buildings in the CBECS sample that lacked individual metering and (2) to provide a basis for estimating primary fuel consumption by central plants serving commercial buildings. These objectives were later expanded to include additional questions relating to these central plants, including the extent to which they engage in cogeneration (which is more likely to be found at central plants than in ordinary commercial buildings), the amounts and forms of energy they consume (inputs), and the amount of energy they supply (outputs).

As an adjunct to the 1989 CBECS, EIA conducted a pilot Facility Survey using a sample selected from multibuilding facilities identified by CBECS respondents. The Facility Survey targeted district heating and cooling systems that presented the greatest problems for CBECS data collection--i.e., multibuilding facilities with central physical plants. The Facility Survey excluded multibuilding facilities with no central physical plant as well as facilities that did not include any buildings whose activities were primarily commercial in nature. Some industrial combined heat and power systems were included, but only in cases where the industrial site included at least one commercial building. The size of the multibuilding facilities ranges from large college campuses with central physical plants to small two-building systems in which an annex is heated with steam from a central plant located in the main building.

This chapter provides background information on the CBECS and on district heating and cooling, which is the most important type of energy-related service provided by multibuilding facilities with central physical plants. Chapters 2 and 3 present data results on multibuilding facilities from the 1989 CBECS and the pilot Facility Survey. Chapter 2 presents the characteristics of multibuilding facilities and the individual buildings located on these facilities. Chapter 3 provides estimates of energy inputs and outputs of multibuilding facilities with central physical plants. Chapter 4 assesses the quality of the pilot Facility Survey and includes recommendations for future work in this area. The appendices provide more detailed information on the Facility Survey itself, in particular the limitations on the use of these results.

Of particular importance is Appendix B, "Data Quality", which provides detailed information relating to the limitations of the data and the conclusions presented in this report. As a pilot study, the 1989 Facility Survey has some serious flaws and limitations which are recognized in this report. The methodology is nevertheless worth reviewing for its applicability to future work in this area. Given the absence of other comprehensive data, the survey results also provide useful insights (subject to appropriate caveats).

The Commercial Buildings Energy Consumption Survey

EIA is responsible for publishing national-level statistics on energy consumption by end users. Currently, the EIA publishes statistics for the residential, residential transportation (personal vehicles), commercial, and manufacturing sectors. For the commercial sector, consumption data are collected via a nationwide survey of commercial buildings, the CBECS.

The CBECS uses several different data collection strategies and instruments. The basic CBECS collects data only at the level of individual commercial buildings. In the Building Characteristics Survey, building characteristics, including physical and operating characteristics, are collected for each sampled building on the Building Questionnaire (Form EIA-871A). This form is administered by an in-person interview with a knowledgeable respondent.

The Building Questionnaire asks respondents to provide the names and addresses of the companies that supply energy to their buildings in the form of electricity, natural gas, fuel oil, or district heating and cooling and to sign a form authorizing EIA to collect billing information directly from these energy supply companies. A separate mail survey, the Energy Suppliers Survey, asks these energy suppliers to provide data on the amounts and costs of energy delivered to the building during the survey year. A specialized data collection form is used for each fuel type.

The survey design for the CBECS focuses on individual buildings in the sampling process, in the wording of the Building Questionnaire, and in the types of consumption data requested from energy suppliers. Ordinarily, this approach works well for surveys in the commercial sector, where energy consumption is largely building-related (i.e., energy is consumed to provide heating, cooling, lighting, and other services in the buildings where commercial activities take place).

The individual building approach does not work well, however, for buildings that are part of a multibuilding facility, as the relationships among all the buildings in such a facility make it difficult to collect data for individual buildings. In some cases, energy supplier data for individual buildings is nonexistent because energy sources are purchased for the group of buildings as a whole. A further complication arises at multibuilding facilities that include a central physical plant that transforms one source of energy into another form of energy. For example, natural gas may be transformed into steam or electricity that is supplied to the individual buildings.

CBECS data show that multibuilding facilities are a significant part of the commercial buildings sector, particularly with respect to district heating.

- In 1989, one-third of all commercial buildings (1.5 million) and 41 percent of all commercial floorspace (26 billion square feet) were located on a multibuilding facility.[1]

- Only 4 percent of all commercial buildings (203,000) were located on multibuilding facilities with central plants; however, these buildings accounted for 13 percent of all commercial floorspace and 28 percent of all commercial buildings energy consumption in 1989.

- District heating and cooling is found almost exclusively at multibuilding facilities. In 1989, commercial buildings located on multibuilding facilities accounted for 90 percent of all district steam or hot water consumed at commercial buildings (527 trillion Btu). Those located on multibuilding facilities with central physical plants accounted for 81 percent of all district steam or hot water consumed at commercial buildings (427 trillion Btu).

Data on district heating and cooling has been troublesome to track in the CBECS because respondents to the Energy Suppliers Survey typically cannot provide consumption data for individual buildings. The Facility Survey undertaken as an adjunct to the basic CBECS for 1989 was designed to learn more about energy use in multibuilding facilities, particularly with respect to district heating and cooling. The survey addresses both the consumption of district heating and cooling at individual buildings and the consumption of primary fuel at central physical plants.

[1]Energy Information Administration, Office of Energy Markets and End Use, *Commercial Buildings Characteristics 1989*, DOE/EIA-0246(89) (Washington, DC, June 1991), Table 52.

District Heating and Cooling in Commercial Buildings

District heating has been in use in the United States for over 100 years. There are three basic types of district heating systems in operation.

- **Systems associated with electric utility generating plants.** These systems, which circulate byproduct steam from electricity generation, were prevalent earlier in this century but lost ground to fuel oil and natural gas beginning in the 1930's and 1940's. As generating stations became larger, these systems were located further away from potential district heating customers, who took advantage of the increasing availability of alternative energy sources (fuel oil or natural gas) for their space-heating needs.

- **Systems operated by individual establishments, such as universities and hospitals.** This type of system, which may also provide chilled water for cooling, is the most common type today.

- **Systems operated by municipalities.** Currently the least common type of district heating, these systems are frequently part of urban redevelopment projects. In some cases, older district heating networks that were originally built and operated by utilities have been rehabilitated and are now operated by local authorities.

The lack of comprehensive and accurate national data makes it difficult to assess the extent of district heating and cooling.[2] The 1989 CBECS indicates that 13 percent of heated commercial floorspace was in buildings served by district steam or hot water, and 6 percent of air-conditioned commercial floorspace was cooled by district chilled water. Energy in the form of district heat accounted for 10 percent of the energy supplied to commercial buildings (585 trillion Btu) in 1989.[3]

The estimates for energy consumed as district heat have been increasing with each CBECS since 1979. Most of the increase, however, is recorded in older (pre-1980) buildings (Table 1) rather than in buildings constructed during the 1980's, and may reflect more accurate identification of district heating rather than actual increases in its use. The relative standard error associated with district heating estimates, however, is high. In the 1989 survey, for example, the relative standard error associated with the estimate for district heat consumption in buildings constructed between 1980 and 1989 exceeded 50 percent, rendering the estimate unpublishable.

CBECS surveys have evolved over the 1979-1989 period to reflect a growing understanding of the nature of district heating and cooling.

- Even though the 1979 and 1983 CBECS asked Building Characteristics Survey respondents whether purchased steam was brought into the sampled building, some respondents to the Energy Suppliers Survey portion of the survey provided no information on expenditures for "purchased" steam by these buildings. This disparity may relate to the unfamiliarity of CBECS respondents with financial details related to energy systems.

[2]International Energy Agency, *District Heating and Combined Heat and Power Systems: A Technology Review*, (Paris, Organization for Economic Co-Operation and Development, 1983), p. 258.

[3]Energy Information Administration, Office of Energy Markets and End Use, *Commercial Buildings Characteristics 1989*, DOE/EIA-0246(89) (Washington, DC, June 1991), Tables 79 and 80; Energy Information Administration, Office of Energy Markets and End Use, *Commercial Buildings Energy Consumption and Expenditures 1989*, DOE/EIA-0318(89) (Washington, DC, April 1992), Table 11.

Table 1. Estimates of District Heat Consumption by CBECS Survey Year, for Buildings Constructed Before 1980

CBECS Survey Year	Floorspace Served by District Heat (million square feet)	District Heat Consumption (trillion Btu)	Consumption (thousand Btu per square foot)
1979	3,593	192	53
1983	3,883	253	65
1986	4,367	390	89
1989	5,722	548	96

Notes: •The 1979 and 1983 CBECS asked for purchased steam; the 1986 CBECS asked for purchased and nonpurchased steam and hot water; the 1989 CBECS asked for district steam or district hot water piped into the building. •See the "Glossary" for definitions of terms used in this report. •Totals may not equal sum of components because of independent rounding.

Source: Energy Information Administration, Office of Energy Markets and End Use, 1979, 1983, 1986 and 1989 Commercial Buildings Energy Consumption Surveys.

- The 1983 CBECS included questions about the temperature and pressure of the delivered steam. Responses to these questions indicated that respondents were including both hot water and steam in their reported district "steam" consumption.

- The 1986 CBECS addressed the above sources of confusion by defining district heating and cooling and explicitly asking about both purchased and nonpurchased sources. The definition included district steam, district hot water, and district chilled water piped into a building from a central source that is located outside the building and serves more than one building.

- The procedures developed for the 1989 CBECS to identify district heating situations are now standard for CBECS. When estimates from the 1992 CBECS become available, the estimates are expected to remain in the range of the 1989 CBECS estimate.

The 1989 CBECS made a special, one-time effort to collect more accurate consumption data about district heating and cooling in commercial buildings by undertaking an adjunct survey of multibuilding facilities with central plants, the Facility Survey. The facility survey collected data, by mail, at the entire facility level, using the Facility Form EIA-871B (Appendix F), to supplement the usual CBECS building-level data. (See Appendix A, "The Facility Survey," for more information on how this survey was conducted.)

In designing the Facility Survey, it was necessary to establish clear, workable definitions of district heating and cooling. Some types of district heating and cooling were easy to identify (e.g., electric utilities that sell steam and municipal systems that resemble utilities). District heating or cooling purchased from a utility or similar vendor is usually metered and billed in much the same way as electricity or natural gas. Thus, consumption information is relatively easy to obtain for district heating and cooling purchased from utilities or municipal systems.

Roughly three-quarters of the commercial floorspace with district heating or cooling, however, is served by a central physical plant within the multibuilding facility itself.[4] Such systems typically do not meter steam, hot water, or chilled water use by individual buildings. Instead, they may maintain metering records for an entire district, for a system that serves several buildings, or for the total output of the central plant only. Some systems may not even maintain records of the overall output, in which case the only available data may be the total volume of fuel input to the facility.

[4]Energy Information Administration, Office of Energy Markets and End Use, *Commercial Buildings Characteristics 1989*, DOE/EIA-0246(89) (Washington, DC, June 1991), Tables 52 and 55.

Partly as a result of improved identification, the 1989 survey estimate for pre-1980 floorspace served by district heat was 31 percent higher than the 1986 CBECS estimate (Table 1). The improved identification of district heating also affects estimates of natural gas, fuel oil, and other fuels commonly used as central plant inputs. For example, estimates of commercial consumption of these fuels may be lower than they otherwise would be under procedures used in the earlier CBECS, since the 1989 CBECS more accurately identifies this consumption as inputs to central physical plant buildings rather than as consumption by individual commercial buildings.

2. Buildings and Facilities

This chapter presents information on the characteristics of multibuilding facilities and of the buildings located on such facilities. Typical examples of multibuilding facilities are: university campuses, hospital complexes, industrial establishments, and hotels or motels consisting of more than one building at the same site. The Energy Information Administration (EIA) defines a building's principal activity on the basis of how that particular building is used, rather than on the main economic activity of the building's owner or occupant. A commercial building, as defined by the EIA's Commercial Buildings Energy Consumption Survey (CBECS), is one in which more than 50 percent of the floorspace is used for commercial activities. The principal activity of a facility on which a commercial building is located may or may not also be commercial. For example, an office building could be located on a college campus or an industrial site, as well as in an office park.

The first section of this chapter focuses on the buildings in the 1989 CBECS that were located on multibuilding facilities. Because the facilities were selected from a sample of commercial buildings, the results represent only those facilities that included at least one commercial building as defined by the CBECS. This section presents estimates for aggregates of all such buildings, regardless of whether the facility had a central physical plant. These estimates (presented in Tables 2 through 5) were developed using the weights and methodology described in both 1989 CBECS reports.[5]

The second section of this chapter focuses on only those multibuilding facilities identified via the CBECS that also have a central physical plant. Estimates for aggregates of such facilities (presented in Tables 6 through 8) were developed using a network estimator described in Appendix C, "Estimation." Details on the sample design for the Facility Survey are provided in Appendix A of this report.

Buildings on Multibuilding Facilities

An estimated 1.5 million buildings in the 1989 CBECS were located on multibuilding facilities (Table 2). The total floorspace of these buildings was about 25.9 billion square feet. This section presents information on the principal activities of these buildings and the facilities on which they were located, the extent to which the facilities had their own central physical plants, and the amount of energy consumed on multibuilding facilities.

Principal Activities of Facilities

The principal activities of multibuilding facilities were obtained from two sources. Information came directly from the Facility Survey (Form EIA-871B) for the 261 facilities that responded to the survey. For the 132 facilities that did not respond, as well as for the multibuilding facilities without central physical plants, information on the principal activity of the facility came from the sampling and interview forms for the individual CBECS buildings that were located on multibuilding facilities. For estimation purposes, the principal activity was treated as a building characteristic (like ownership). Therefore, it was not necessary to derive special facility weights (via the network estimator) in developing these estimates.

Colleges, universities, and other schools were the most prevalent types of multibuilding facilities, together accounting for over 300,000 commercial buildings and over 7 billion square feet of commercial floorspace (Table 2). Multibuilding office facilities included 191,000 buildings and almost 4 billion square feet. Other important types of multibuilding facilities were shopping centers and malls, hospitals, industrial facilities, and warehouses. Each

[5]Energy Information Administration, Office of Energy Markets and End Use, *Commercial Buildings Characteristics 1989*, DOE/EIA-0246(89) (Washington, DC, June 1991), Appendix B; Energy Information Administration, Office of Energy Markets and End Use, *Commercial Buildings Energy Consumption and Expenditures 1989*, DOE/EIA-0318(89) (Washington, DC, April 1992), Appendix B.

Table 2. Principal Activity of Multibuilding Facility and Principal Activity of Commercial Buildings, Number of Buildings and Floorspace

Commercial Building Characteristics	All Buildings on Facilities	Principal Facility Activity				
		College and University	Other School	Office	Shopping Center and Mall	Hospital
	Buildings (thousand)					
All Buildings on Facilities	1,497	77	226	191	161	34
Principal Building Activity						
Assembly	231	14	35	Q	Q	Q
Education	194	26	156	Q	NC	Q
Food Sales and Service	45	Q	Q	NC	Q	NC
Health Care	20	Q	NC	Q	NC	9
Lodging	81	15	Q	Q	Q	Q
Mercantile and Service	250	Q	Q	Q	122	Q
Office	219	10	Q	118	Q	7
Parking Garage	27	Q	Q	7	Q	Q
Warehouse	300	Q	Q	Q	Q	Q
Other	48	Q	Q	Q	NC	Q
Vacant	83	Q	Q	22	Q	Q
Ownership and Occupancy						
Nongovernment Owned						
Owner Occupied	794	26	43	78	83	14
Nonowner Occupied	308	Q	Q	79	78	Q
Government Owned	395	45	180	33	Q	19
	Floorspace (million square feet)					
All Buildings on Facilities	25,947	3,549	3,558	3,944	2,699	2,129
Principal Building Activity						
Assembly	3,013	793	385	Q	Q	Q
Education	4,578	1,404	2,917	Q	NC	Q
Food Sales and Service	304	Q	Q	NC	Q	NC
Health Care	1,409	Q	NC	Q	NC	1,288
Lodging	1,683	584	Q	Q	Q	Q
Mercantile and Service	3,254	Q	Q	Q	2,316	Q
Office	4,527	250	Q	2,866	Q	158
Parking Garage	641	Q	Q	187	Q	Q
Warehouse	4,026	Q	Q	Q	Q	Q
Other	1,061	Q	Q	Q	NC	Q
Vacant	1,451	Q	Q	270	Q	Q
Ownership and Occupancy						
Nongovernment Owned						
Owner Occupied	12,438	1,240	670	1,505	1,444	1,315
Nonowner Occupied	4,530	Q	Q	1,212	1,255	Q
Government Owned	8,979	2,238	2,849	1,227	Q	746

See footnotes at end of table.

Table 2. Principal Activity of Multibuilding Facility and Principal Activity of Commercial Buildings, Number of Buildings and Floorspace (Continued)

Commercial Building Characteristics	Principal Facility Activity					
	Industrial	Hotel and Motel	Entertainment Complex	Warehouse	Religious	Other
	Buildings (thousand)					
All Buildings on Facilities	162	55	123	213	118	137
Principal Building Activity						
Assembly	Q	Q	62	Q	96	Q
Education	Q	NC	NC	Q	Q	NC
Food Sales and Service	Q	Q	Q	Q	Q	Q
Health Care	NC	NC	NC	NC	NC	Q
Lodging	NC	48	Q	NC	Q	Q
Mercantile and Service	17	Q	Q	23	NC	50
Office	44	Q	Q	Q	Q	Q
Parking Garage	Q	NC	Q	Q	Q	Q
Warehouse	62	Q	Q	164	NC	29
Other	13	NC	Q	Q	NC	22
Vacant	16	Q	Q	Q	Q	Q
Ownership and Occupancy						
Nongovernment Owned						
Owner Occupied	125	48	78	113	113	73
Nonowner Occupied	18	Q	Q	80	Q	25
Government Owned	Q	NC	39	Q	NC	39
	Floorspace (million square feet)					
All Buildings on Facilities	2,532	653	936	3,132	944	1,872
Principal Building Activity						
Assembly	Q	Q	614	Q	804	Q
Education	Q	NC	NC	Q	Q	NC
Food Sales and Service	Q	Q	Q	Q	Q	Q
Health Care	NC	NC	NC	NC	NC	Q
Lodging	NC	562	Q	NC	Q	Q
Mercantile and Service	134	Q	Q	201	NC	330
Office	741	Q	Q	Q	Q	Q
Parking Garage	Q	NC	Q	Q	Q	Q
Warehouse	1,045	Q	Q	2,243	NC	344
Other	241	NC	Q	Q	NC	335
Vacant	323	Q	Q	Q	Q	Q
Ownership and Occupancy						
Nongovernment Owned						
Owner Occupied	1,937	593	605	1,465	916	747
Nonowner Occupied	396	Q	Q	1,079	Q	308
Government Owned	Q	NC	315	589	NC	816

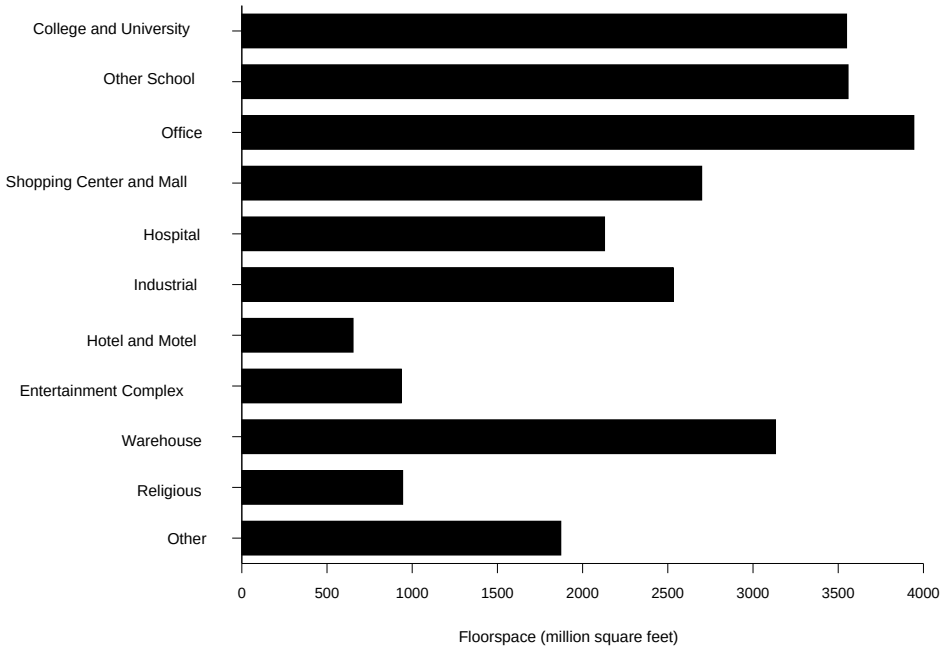
NC = No cases in sample.

Q = Data withheld because the Relative Standard Error (RSE) was greater than 50 percent, or fewer than 20 buildings were sampled.

Notes: •See the "Glossary" for definitions of terms used in this report. •Totals may not equal sum of components because of independent rounding.

Source: Energy Information Administration, Office of Energy Markets and End Use, Forms EIA-871A, "Building Questionnaire," and EIA-871B, "Facility Form" of the 1989 Commercial Buildings Energy Consumption Survey.

Figure 1. Floorspace of Commercial Buildings on Multibuilding Facilities, by Principal Facility Activity



Source: Energy Information Administration, Office of Energy Markets and End Use, Form EIA-871A, "Building Questionnaire," and EIA-871B, "Facility Form" of the 1989 Commercial Buildings Energy Consumption Survey.

of these latter types of facilities contained over 2 billion square feet of commercial floorspace (Figure 1).

Additional insights about the commercial building sector from the information on Table 2 include:

- A total of 2.5 billion square feet of commercial floorspace, including 1.0 billion square feet of warehouses and 741 million square feet of offices, was located on industrial facilities. Predominantly vacant buildings accounted for 13 percent of the commercial floorspace on industrial facilities (323 million square feet).

- Of the 1.7 billion square feet of lodging buildings on multibuilding facilities, 584 million square feet were located on colleges and universities, while only 562 million square feet were part of hotel and motel complexes.

- Only 40 percent of the 3.5 billion square feet of commercial floorspace on colleges and universities consisted of education buildings (i.e., classroom buildings).

- Government (local, State, federal) owned 35 percent of the floorspace on multibuilding facilities (9.0 billion square feet). These buildings consisted primarily of colleges and universities (2.2 billion square feet), other schools (2.8 billion square feet), and offices (1.2 billion square feet).

The regional distribution of buildings on multibuilding facilities roughly matched the Census Region distribution of all commercial buildings. The South contained 44 percent of the commercial buildings, and 37 percent of the commercial floorspace, on multibuilding facilities (Table 3).

Table 3. Commercial Buildings on Multibuilding Facilities by Census Region, Number of Buildings and Floorspace

Commercial Building Characteristics	All Buildings on Facilities	Census Region			
		Northeast	Midwest	South	West
	Buildings (thousand)				
All Buildings on Facilities	1,497	247	232	652	367
Principal Facility Activity					
College and University	77	18	9	20	29
Other School	226	11	21	106	88
Office	191	18	17	99	57
Shopping Center and Mall	161	38	31	57	35
Hospital	34	6	10	12	7
Industrial	162	16	42	82	22
Hotel and Motel	55	Q	Q	20	25
Entertainment Complex	123	43	24	39	Q
Warehouse	213	46	39	84	44
Religious	118	20	Q	66	Q
Other	137	27	19	67	23
	Floorspace (million square feet)				
All Buildings on Facilities	25,947	4,766	5,483	9,635	6,062
Principal Facility Activity					
College and University	3,549	779	576	1,145	1,048
Other School	3,558	360	772	1,664	763
Office	3,944	480	357	1,807	1,299
Shopping Center and Mall	2,699	Q	827	685	705
Hospital	2,129	447	1,026	432	224
Industrial	2,532	369	708	1,068	387
Hotel and Motel	653	Q	Q	185	371
Entertainment Complex	936	216	161	324	Q
Warehouse	3,132	815	551	1,067	698
Religious	944	209	Q	500	Q
Other	1,872	557	350	756	208

Q = Data withheld because the Relative Standard Error (RSE) was greater than 50 percent, or fewer than 20 buildings were sampled.

Notes: •See the "Glossary" for definitions of terms used in this report. •Totals may not equal sum of components because of independent rounding.

Source: Energy Information Administration, Office of Energy Markets and End Use, Forms EIA-871A, "Building Questionnaire," and EIA-871B, "Facility Form" of the 1989 Commercial Buildings Energy Consumption Survey.

Central Physical Plants

The key characteristic used for determining which multibuilding facilities to include in the Facility Survey was the presence of a central physical plant. In the 1989 CBECS, 14 percent of the commercial buildings on multibuilding facilities were located on facilities that included a central physical plant (Table 4). Buildings on facilities with central physical plants accounted for 32 percent of the floorspace on multibuilding facilities.

Table 4. Commercial Buildings on Multibuilding Facilities by Presence of a Central Physical Plant, Number of Buildings and Floorspace

Commercial Building Characteristics	All Buildings on Facilities	with Central Plant on Facility	Without Central Plant on Facility
		Buildings (thousand)	
All Buildings on Facilities	1,497	203	1,294
Principal Facility Activity			
College and University	77	54	23
Other School	226	44	182
Office	191	10	181
Shopping Center and Mall	161	Q	158
Hospital	34	19	15
Industrial	162	53	109
Hotel and Motel	55	Q	49
Entertainment Complex	123	Q	121
Warehouse	213	NC	213
Religious	118	Q	115
Other	137	11	126
		Floorspace (million square feet)	
All Buildings on Facilities	25,947	8,346	17,601
Principal Facility Activity			
College and University	3,549	2,929	620
Other School	3,558	731	2,828
Office	3,944	845	3,099
Shopping Center and Mall	2,699	Q	2,641
Hospital	2,129	1,691	438
Industrial	2,532	1,304	1,228
Hotel and Motel	653	Q	539
Entertainment Complex	936	Q	861
Warehouse	3,132	NC	3,132
Religious	944	Q	927
Other	1,872	583	1,289

NC = No cases in sample.

Q = Data withheld because the Relative Standard Error (RSE) was greater than 50 percent, or fewer than 20 buildings were sampled.

Notes: •See the "Glossary" for definitions of terms used in this report. •Totals may not equal sum of components because of independent rounding.

Source: Energy Information Administration, Office of Energy Markets and End Use, Forms EIA-871A, "Building Questionnaire," and EIA-871B, "Facility Form" of the 1989 Commercial Buildings Energy Consumption Survey.

Some types of facilities were more likely than others to have central physical plants (Figure 2).

- Warehouse facilities, shopping centers, religious facilities, entertainment complexes, and hotels and motels were unlikely to have central physical plants.

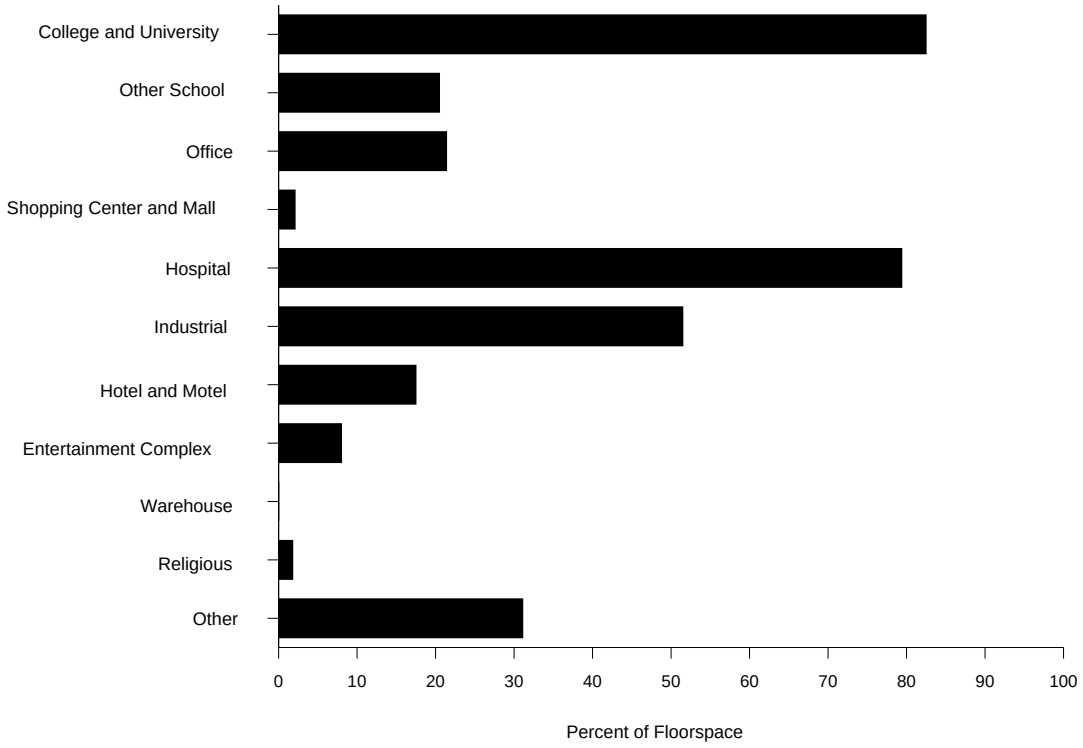
- Only 21 percent of the "other schools" floorspace (mainly elementary and secondary schools) was located on facilities with central physical plants, but 83 percent of the college and university floorspace was located on such facilities.

- Among hospitals, 79 percent of the commercial floorspace was located on facilities with central physical plants.

- Slightly more than half (52 percent) of the commercial floorspace on industrial facilities was located on facilities with central physical plants.

- Only 21 percent of the commercial floorspace on office facilities was located on facilities with central physical plants.

Figure 2. Percent of Commercial Floorspace on Multibuilding Facilities with Central Physical Plants by Principal Facility Activity



Source: Energy Information Administration, Office of Energy Markets and End Use, Form EIA-871A, "Building Questionnaire," and EIA-871B, "Facility Form" of the 1989 Commercial Buildings Energy Consumption Survey.

Energy Consumption

Buildings on multibuilding facilities accounted for 50 percent (2.9 quadrillion Btu) of the energy consumed in all commercial buildings in 1989. This amount included 49 percent of the electricity, 44 percent of the natural gas, 34 percent of the fuel oil, and (not surprisingly) 90 percent of the district heat (Table 5).[6]

In 1989, commercial buildings on facilities with central physical plants consumed 1.6 quadrillion Btu of energy, accounting for 28 percent of the total consumed by all commercial buildings and 55 percent of the energy consumed on all multibuilding facilities. District heat comprised 30 percent of the energy consumed by commercial buildings on facilities with central physical plants.

Commercial buildings in multibuilding facilities with central physical plants consumed 191,000 Btu per square foot in 1989, considerably more than the 92,000 Btu per square foot consumed by commercial buildings overall.[7] However, this difference does not mean that buildings served by central physical plants are less

Table 5. Energy Consumed at Commercial Buildings on Multibuilding Facilities
(Trillion Btu)

Commercial Building Characteristics	Major Fuels	Electricity	Natural Gas	Fuel Oil	District Heat
All Buildings on Facilities	2,901	1,345	905	123	527
Principal Facility Activity					
College and University	541	215	Q	Q	197
Other School	253	88	133	20	Q
Office	412	278	69	Q	63
Shopping Center and Mall	225	142	80	3	*
Hospital	478	140	173	Q	147
Industrial	439	228	106	Q	82
Hotel and Motel	69	29	35	Q	Q
Entertainment Complex	70	32	35	4	*
Warehouse	143	72	65	6	NC
Religious	45	12	21	11	1
Other	225	110	73	Q	Q
Central Physical Plant					
Present on Facility	1,593	635	423	60	476
Not Present on Facility	1,308	711	482	63	51

* Value rounds to zero in the units displayed.
NC = No cases in sample.
Q = Data withheld because the Relative Standard Error (RSE) was greater than 50 percent, or fewer than 20 buildings were sampled.
Notes: •"District Heat" includes district steam and district hot water. •See the "Glossary" for definitions of terms used in this report. •Totals may not equal sum of components because of independent rounding.
Source: Energy Information Administration, Office of Energy Markets and End Use, Forms EIA-871A through EIA-871F of the 1989 Commercial Buildings Energy Consumption Survey.

[6]Energy Information Administration, Office of Energy Markets and End Use, *Commercial Buildings Energy Consumption and Expenditures 1989*, DOE/EIA-0318(89) (Washington DC, April 1992), Table 11.

[7]Energy Information Administration, Office of Energy Markets and End Use, *Commercial Buildings Energy Consumption and Expenditures 1989*, DOE/EIA-0318(89) (Washington, DC, April 1992), Table 13.

energy-efficient than other commercial buildings. As Table 4 shows, some of the types of facilities most likely to have central physical plants (hospitals and industrial) are likely to be dominated by energy-intensive building types.

Characteristics of Facilities

The results presented in this section are based on the Facility Survey, and only pertain to multibuilding facilities with central physical plants. The estimation methodology is described in Appendix C, "Estimation."

Separate estimates of facility characteristics are made for the industrial and commercial sectors[8] for two reasons: (1) to examine overlap between EIA's commercial and manufacturing surveys and (2) in expectation that commercial and industrial facilities would have different characteristics, especially regarding energy use. Energy is used in the commercial sector largely for space conditioning (heating and cooling) and lighting, both of which are related to building floorspace. Industrial energy consumption is driven largely by processing requirements. The industrial and commercial sectors overlap where industrial establishments combine both industrial and commercial buildings on the same multibuilding site.

- In 1989, there were 30,729 multibuilding facilities with central physical plants and at least one commercial building (Table 6). These facilities contained 12 billion square feet of floorspace. Forty-two percent of the facilities were commercial, and these included 55 percent of the floorspace contained in multibuilding facilities with central physical plants.

- Overall, 61 percent of the floorspace on facilities consisted of commercial buildings. By sector, 92 percent of the floorspace on commercial facilities, and 21 percent of the floorspace on industrial facilities, was contained in commercial buildings.

- The mean floorspace per facility was 395,000 square feet. Commercial facilities were larger than industrial facilities, 517,000 square feet versus 298,000 square feet. Among commercial facilities the largest were colleges and universities (1,393,000 square feet); the smallest were other schools (114,000 square feet) (Figure 3).

Sixty percent of all facilities contained 200,000 square feet or less of floorspace (Table 7). On the other hand, 2,596 facilities were larger than 1 million square feet, with 314 of these larger than 5 million square feet. As would be expected, larger facilities tended to have more buildings. Overall, 32 percent of all facilities, and 52 percent of commercial facilities, had 4 or fewer buildings. The largest facilities in the sample contained over 1,000 buildings.

The Facility Survey estimate of 1989 commercial floorspace on multibuilding facilities with central physical plants, 7.4 billion square feet (Table 6), is lower than the corresponding 1989 CBECS Building Characteristics Survey estimate, 8.3 billion square feet (Table 4). The Building Characteristics Survey estimate is likely to be more accurate for three reasons:

- The Building Characteristics Survey used a more efficient sample design. Estimates from the Building Characteristics Survey were based on a national probability sample of buildings, while facilities were sampled indirectly through the buildings sample. The network estimator's use of information (including imputed data) from the Facility Survey introduced an additional source of variability and possible bias in the facilities estimate. (The network estimator is described in Appendix C, "Estimation.")

[8]In addition to commercial and industrial facilities, estimates for "All Sectors" include a few (4) facilities which were reported to be residential. These were facilities such as apartment complexes, from which a commercial building (e.g., management office) had been selected for the 1989 CBECS Building Survey.

Table 6. Number and Floorspace of Multibuilding Facilities with Central Physical Plants

Facility Characteristics	Number of Facilities	Facility Floorspace (million square feet)		Floorspace per Facility (thousand square feet)	Percent Commercial Floorspace
		Total	Commercial		
	All Sectors				
All Facilities	30,729	12,114	7,403	395	61
Census Region					
Northeast	4,739	2,111	1,563	446	74
Midwest	5,472	2,631	1,689	482	64
South	16,637	5,172	2,300	311	45
West	3,881	2,199	1,851	584	84
Total Floorspace (square feet)					
200,000 or Less	18,500	1,537	743	83	49
200,001 to 500,000	8,034	2,506	1,292	312	51
500,001 to 1,000,000	1,599	1,032	863	646	84
1,000,001 to 5,000,000	2,282	4,262	3,116	1,868	73
Over 5,000,000	314	2,777	1,390	8,826	52
	Commercial Sector				
All Facilities	12,790	6,607	6,075	517	92
Census Region					
Northeast	1,691	1,323	1,231	806	93
Midwest	2,379	1,565	1,505	662	96
South	6,048	1,807	1,720	299	95
West	2,672	1,912	1,619	719	85
Principal Facility Activity					
College and University	2,267	3,093	2,781	1,393	90
Other School	6,244	712	655	114	92
Office	947	749	745	805	99
Hospital	2,146	1,614	1,481	754	92
Other	1,185	438	413	374	94
Total Floorspace (square feet)					
200,000 or Less	7,281	509	494	70	97
200,001 to 500,000	2,470	817	775	330	95
500,001 to 1,000,000	1,377	872	796	633	91
1,000,001 to 5,000,000	1,455	2,768	2,692	1,903	97
Over 5,000,000	207	1,641	1,319	7,942	80

See footnotes at end of table.

Table 6. Number and Floorspace of Multibuilding Facilities with Central Physical Plants (Continued)

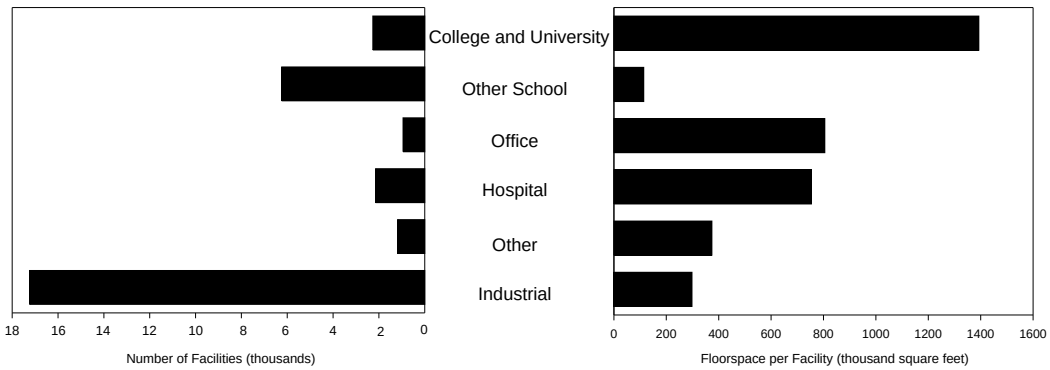
Facility Characteristics	Number of Facilities	Facility Floorspace (million square feet)		Floorspace per Facility (thousand square feet)	Percent Commercial Floorspace
		Total	Commercial		
	Industrial Sector				
All Facilities	17,241	5,121	1,073	298	21
Census Region					
Northeast	Q	Q	Q	Q	Q
Midwest	Q	932	155	Q	17
South	10,521	3,346	562	319	17
West	Q	Q	Q	Q	Q
Total Floorspace (square feet)					
200,000 or Less	11,219	1,028	249	92	24
200,001 to 500,000	5,050	1,557	403	308	26
500,001 to 1,000,000	Q	Q	Q	Q	Q
1,000,001 to 5,000,000	650	Q	289	1,920	Q
Over 5,000,000	Q	Q	Q	Q	Q

Q = Data withheld because the Relative Standard Error (RSE) was greater than 50 percent, or fewer than 20 buildings were sampled.

Notes: •"All Sectors" estimates include multibuilding residential facilities. •See the "Glossary" for definitions of terms used in this report. •Totals may not equal sum of components because of independent rounding.

Source: Energy Information Administration, Office of Energy Markets and End Use, Form EIA-871B, "Facility Form" of the 1989 Commercial Buildings Energy Consumption Survey.

Figure 3. Number of Multibuilding Facilities and Average Floorspace per Facility by Principal Facility Activity



Source: Energy Information Administration, Office of Energy Markets and End Use, Form EIA-871B, "Facility Form" of the 1989 Commercial Buildings Energy Consumption Survey.

Table 7. Number of Buildings on Multibuilding Facilities with Central Plants, Number of Facilities

Facility Characteristics	All Facilities	Number of Buildings on Facility				
		4 or Less	5 to 10	11 to 25	26 to 100	Over 100
	All Sectors					
All Facilities	30,729	9,701	11,032	4,347	4,672	978
Total Floorspace (square feet)						
200,000 or Less	18,500	7,612	9,235	Q	Q	NC
200,001 to 500,000	8,034	1,504	892	Q	Q	Q
500,001 to 1,000,000	1,599	334	Q	Q	Q	Q
1,000,001 to 5,000,000	2,282	Q	Q	346	823	Q
Over 5,000,000	314	Q	Q	Q	Q	215
	Commercial Sector					
All Facilities	12,790	6,678	2,980	1,453	1,092	587
Principal Facility Activity						
College and University	2,267	Q	Q	Q	511	Q
Other School	6,244	Q	1,441	Q	Q	Q
Office	947	Q	Q	Q	Q	Q
Hospital	2,146	Q	Q	428	227	Q
Other	1,185	Q	Q	Q	Q	Q
Total Floorspace (square feet)						
200,000 or Less	7,281	5,373	1,519	Q	Q	NC
200,001 to 500,000	2,470	Q	Q	694	Q	NC
500,001 to 1,000,000	1,377	329	Q	Q	375	Q
1,000,001 to 5,000,000	1,455	Q	Q	217	509	Q
Over 5,000,000	207	Q	Q	Q	Q	Q
	Industrial Sector					
All Facilities	17,241	Q	Q	Q	Q	Q
Total Floorspace (square feet)						
200,000 or Less	11,219	Q	Q	Q	Q	NC
200,001 to 500,000	5,050	Q	Q	Q	Q	Q
500,001 to 1,000,000	Q	Q	Q	Q	Q	Q
1,000,001 to 5,000,000	650	Q	Q	Q	Q	Q
Over 5,000,000	Q	NC	Q	Q	Q	Q

NC = No cases in sample.

Q = Data withheld because the Relative Standard Error (RSE) was greater than 50 percent, or fewer than 20 buildings were sampled.

Notes: •"All Sectors" estimates include multibuilding residential facilities. •See the "Glossary" for definitions of terms used in this report. •Totals may not equal sum of components because of independent rounding.

Source: Energy Information Administration, Office of Energy Markets and End Use, Form EIA-871B, "Facility Form" of the 1989 Commercial Buildings Energy Consumption Survey.

- The floorspace data were collected more carefully in the Building Characteristics Survey because the Building Questionnaire was administered by interviewers who were trained in the definition of what constituted an in-scope commercial building. The Facility Form was mailed to respondents, who were required to read a two-page instruction form. The resulting floorspace data showed a variety of serious reporting errors (Appendix B, "Data Quality").

- Commercial floorspace had to be imputed for nearly half of the facilities eligible for the Facility Survey. In contrast, 99 percent of the Building Characteristics Survey respondents provided data on the building square footage category, and 82 percent provided the exact square footage.

Cogeneration

One of the goals of the Facility Survey was to provide information about the extent of cogeneration in the commercial sector. Cogeneration is the combined production of electric power and another form of useful energy (such as heat or steam) by a single process. The CBECS sample design, which is targeted at individual commercial buildings, deliberately screens out buildings in which over half the floorspace is noncommercial. This technique also effectively screens out many commercial buildings with central physical plants, which are required in order for cogeneration to take place. As a consequence, CBECS has never been able to survey more than a handful of buildings with cogeneration activities.

Several questions on the Facility Form focused specifically on cogeneration. One question asked whether the facility had been designated as a qualifying facility under the Public Utilities Regulatory Policies Act of 1978 (PURPA). In return for meeting certain criteria, designation as a qualifying facility guarantees that electric utilities will purchase any excess output from the facility. Another question asked whether the central plant had a cogeneration system. Those with cogeneration systems were asked to supply (1) the total nameplate capacity and (2) information on whether it was electrically interconnected with an electric utility.

Due to nonresponses and reporting errors, the Facility Survey was unable to identify much more cogeneration activity than previous CBECS had identified. As discussed in Appendix B, "Data Quality," the question on qualifying facilities had a very high nonresponse and the question on cogeneration elicited severe reporting errors. After much imputation, 9,570 facilities were estimated to be qualifying facilities (Table 8). Hospitals accounted for 10 percent of the qualifying facilities identified. Conversely, 45 percent of the hospitals were qualifying facilities.

Estimates for the number of facilities with cogeneration systems were unpublishable at the national level. However, over one-third (122) of the 314 largest facilities (containing more than 5,000,000 square feet of floorspace) reported cogeneration systems. Of these 122 facilities, 88 were connected to the grid. In the commercial sector, 28 percent of the largest facilities, but only 12 percent of the next largest (1 to 5 million square feet), reported cogeneration systems. These limited data suggest that the incidence of cogeneration systems declines sharply with decreasing facility size.

Table 8. Qualifying Facilities and Cogeneration, Number of Multibuilding Facilities

Facility Characteristics	Number of Facilities	Qualifying Facilities	Cogeneration System	
			Total	Connected to Grid
	All Sectors			
All Facilities	30,729	9,570	Q	Q
Total Floorspace (square feet)				
200,000 or Less	18,500	Q	Q	Q
200,001 to 500,000	8,034	Q	Q	Q
500,001 to 1,000,000	1,599	612	Q	Q
1,000,001 to 5,000,000	2,282	540	Q	Q
Over 5,000,000	314	Q	122	88
	Commercial Sector			
All Facilities	12,790	Q	Q	Q
Principal Facility Activity				
College and University	2,267	Q	Q	Q
Other School	6,244	Q	Q	Q
Office	947	Q	Q	Q
Hospital	2,146	962	Q	Q
Other	1,185	Q	Q	Q
Total Floorspace (square feet)				
200,000 or Less	7,281	Q	Q	Q
200,001 to 500,000	2,470	Q	Q	Q
500,001 to 1,000,000	1,377	563	Q	Q
1,000,001 to 5,000,000	1,455	328	176	164
Over 5,000,000	207	Q	57	Q
	Industrial Sector			
All Facilities	17,241	Q	Q	Q
Total Floorspace (square feet)				
200,000 or Less	11,219	Q	Q	Q
200,001 to 500,000	5,050	Q	Q	Q
500,001 to 1,000,000	Q	Q	Q	Q
1,000,001 to 5,000,000	650	Q	Q	Q
Over 5,000,000	Q	Q	Q	Q

Q = Data withheld because the Relative Standard Error (RSE) was greater than 50 percent, or fewer than 20 buildings were sampled.

Notes: •"All Sectors" estimates include multibuilding residential facilities. •See the "Glossary" for definitions of terms used in this report. •Totals may not equal sum of components because of independent rounding.

Source: Energy Information Administration, Office of Energy Markets and End Use, Form EIA-871B, "Facility Form" of the 1989 Commercial Buildings Energy Consumption Survey.

3. Central Physical Plant Outputs and Inputs

One purpose of this study was to obtain information about energy aspects of the central physical plants on multibuilding facilities. The Facility Survey tried to obtain estimates for the amounts and forms of energy these central physical plants consumed (inputs) and the amounts and forms of energy they sent out to the facility (outputs). Many data and reporting problems were encountered, as described in Appendix B, "Data Quality."

The best results obtained were those identifying the types of energy inputs and outputs at central physical plants. The only potentially significant problem with the data identifying forms of energy output from the central physical plant involved electricity. Electricity supplied by an off-site utility may have been incorrectly identified as a central plant output. The identification of central plant energy inputs was also fairly reliable, although some energy sources reported as central plant inputs may actually have been consumed at another part of the facility, bypassing the central physical plant.

The reported quantities of energy output and input from the central physical plant, however, should be treated as rough estimates. Many respondents were unable to provide information on energy output quantities, necessitating high imputation rates (Table B4). Electricity quantities shown in the tables are the inputs and outputs that were reported by the respondents rather than a calculated net electricity quantity (output minus input). These estimates may be overstated, since some of this electricity may not have been generated by the central plant.

Central Physical Plant Outputs

In all sectors, steam was by far the most common output of central physical plants (Table 9).

- Of the 30,729 facilities with central plants, 75 percent produced steam, while 25 percent produced hot water, 18 percent produced chilled water, and 24 percent produced electricity.

- Eighty-three percent of the 7,395 facilities that produced electricity also produced steam. This number can be considered an upper bound on the number of plants with cogeneration systems.

- Production of chilled water was generally associated with either steam (66 percent of chilled water plants) and/or hot water (39 percent of chilled water plants).

In commercial-sector facilities, steam was slightly less prevalent as a central plant output, while hot water and chilled water were more common.

- Sixty-seven percent of central plants on commercial facilities produced steam, 32 percent produced hot water, and 33 percent produced chilled water.

- The commercial sector accounted for 75 percent of all chilled water plants, but only 20 percent of all plants that reported electricity output (Figure 4).

- Chilled water was least common as a central plant output among schools other than colleges and universities (16 percent); 50 percent of the rest of the central plants in the commercial sector produced chilled water.

Table 9. Number of Multibuilding Facilities by Types of Central Physical Plant Energy Outputs

Facility Characteristics	Number of Facilities	Types of Energy Outputs			
		Steam	Hot Water	Chilled Water	Electricity
	All Sectors				
All Facilities	30,729	23,131	7,570	5,655	7,395
Census Region					
Northeast	4,739	Q	882	730	Q
Midwest	5,472	2,678	Q	699	Q
South	16,637	13,927	Q	2,381	Q
West	3,881	2,518	Q	Q	Q
Energy Outputs					
Steam	23,131	23,131	1,836	3,712	6,135
Hot Water	7,570	1,836	7,570	2,185	Q
Chilled Water	5,655	3,712	2,185	5,655	Q
Electricity	7,395	6,135	Q	Q	7,395
Energy Inputs					
Fuel Oil	14,332	12,941	1,344	Q	Q
Natural Gas	19,693	15,608	4,746	4,574	3,886
Coal	Q	Q	Q	Q	Q
Electricity	14,983	10,518	4,593	4,789	Q
	Commercial Sector				
All Facilities	12,790	8,567	4,127	4,259	1,481
Principal Facility Activity					
College and University	2,267	1,861	530	994	Q
Other School	6,244	Q	Q	1,005	Q
Office	947	291	Q	Q	Q
Hospital	2,146	1,756	Q	902	Q
Other	1,185	769	Q	687	Q
Census Region					
Northeast	1,691	1,304	Q	613	Q
Midwest	2,379	1,589	Q	568	Q
South	6,048	Q	Q	1,734	Q
West	2,672	1,728	842	1,345	Q
Energy Outputs					
Steam	8,567	8,567	1,180	2,443	Q
Hot Water	4,127	1,180	4,127	1,617	Q
Chilled Water	4,259	2,443	1,616	4,259	Q
Electricity	1,481	Q	Q	Q	1,481
Energy Inputs					
Fuel Oil	3,355	2,613	832	1,069	Q
Natural Gas	8,691	5,419	3,575	3,337	1,441
Coal	Q	Q	Q	Q	Q
Electricity	5,559	3,454	1,891	3,411	1,358

See footnotes at end of table.

Table 9. Number of Multibuilding Facilities by Types of Central Physical Plant Energy Outputs (Continued)

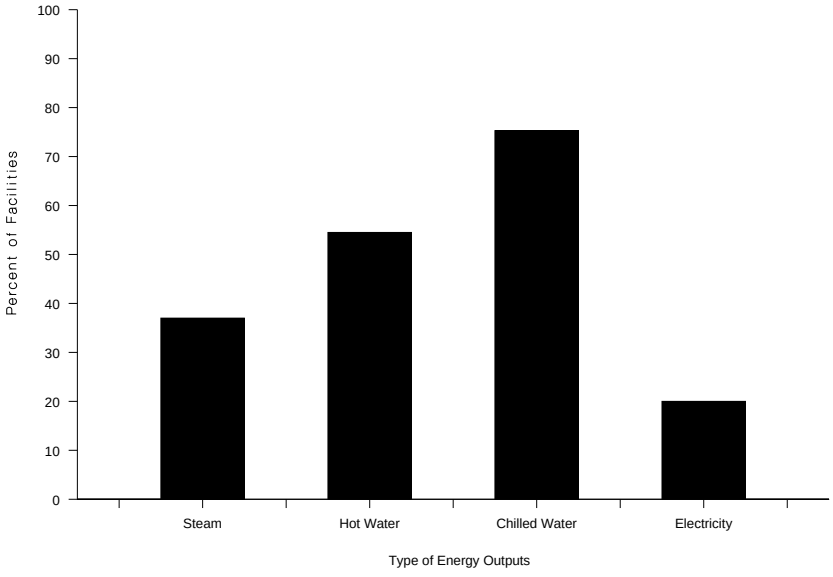
Facility Characteristics	Number of Facilities	Types of Energy Outputs			
		Steam	Hot Water	Chilled Water	Electricity
	Industrial Sector				
All Facilities	17,241	14,180	Q	Q	Q
Census Region					
Northeast	Q	Q	Q	Q	Q
Midwest	Q	Q	Q	Q	Q
South	10,521	9,913	Q	Q	Q
West	Q	Q	Q	Q	Q
Energy Outputs					
Steam	14,180	14,180	Q	Q	Q
Hot Water	Q	Q	Q	Q	Q
Chilled Water	Q	Q	Q	Q	Q
Electricity	Q	Q	Q	Q	Q
Energy Inputs					
Fuel Oil	10,491	10,151	Q	Q	Q
Natural Gas	10,318	9,819	Q	Q	Q
Coal	Q	Q	Q	Q	Q
Electricity	9,121	Q	Q	Q	Q

Q = Data withheld because the Relative Standard Error (RSE) was greater than 50 percent, or fewer than 20 buildings were sampled.

Notes: •"All Sectors" estimates include multibuilding residential facilities. •See the "Glossary" for definitions of terms used in this report. •Totals may not equal sum of components because of independent rounding.

Source: Energy Information Administration, Office of Energy Markets and End Use, Form EIA-871B, "Facility Form" of the 1989 Commercial Buildings Energy Consumption Survey.

Figure 4. Commercial Multibuilding Facilities As a Percent of All Multibuilding Facilities by Types of Energy Outputs



Source: Energy Information Administration, Office of Energy Markets and End Use, Form EIA-871B, "Facility Form" of the 1989 Commercial Buildings Energy Consumption Survey.

To estimate total central physical plant output, it was necessary to assign a Btu value to outputs of chilled water. Chilled water amounts (usually reported in ton-hours) were converted to Btu equivalents by assuming a coefficient of performance (COP). The COP is the ratio of the rate of heat removal (where 1 ton-hour equals 12,000 Btu of cooling) to the rate of energy input (Btu). There was little basis for choosing a COP, as the Facility Survey did not ask (1) whether the output quantities were measured as produced at the central physical plant or as received at the buildings served by the plant or (2) the type of equipment used at the central physical plant. A COP of 4.3 would be appropriate for an efficient chiller. Lower COPs, accounting for distribution energy and losses, would lead to higher chilled water Btu equivalents. The effective system-wide COP could actually be closer to 1.0. The estimates presented here assumed a COP of 2.0, a value chosen arbitrarily to represent distribution losses of about 50 percent.

Central physical plants produced 3.8 quadrillion Btu in 1989 (Table 10), consisting primarily of steam (79 percent of the total). Although commercial sector physical plants produced less than 20 percent of the total (735 trillion Btu), they produced 68 percent of the hot water and 78 percent of the chilled water.

The quantity of district heat produced at central physical plants on commercial facilities can be estimated by adding together commercial sector steam production (426 trillion Btu) and commercial sector hot water production (134 trillion Btu), for a total of 560 trillion Btu. This value is close to the 527 trillion Btu estimated as 1989 commercial buildings' district heat consumption (Table 5). Although this is a relatively small net difference, the gross difference may be much larger. This is because the commercial buildings total includes some buildings on industrial facilities, while some commercial facilities include buildings that are not commercial.

Electricity output estimates can be compared with independent estimates of electricity generation obtained from EIA's "Annual Nonutility Power Producer Report," which was completed by nonutility power producers with an installed capacity of 5 or more megawatts.[9] The 428 trillion Btu of electricity output by all central plants (Table 10) corresponds to 125 billion kilowatthours of delivered electricity, while the 74 trillion Btu output by commercial facility central plant corresponds to 23 billion kilowatthours. According to EIA's nonutility power estimates, nonutility power producers generated 215 billion kilowatthours in 1990, of which 61 billion kilowatthours was generated by producers in the transportation, public utilities, and mining industries. This leaves 154 billion kilowatthours in industry groups likely to have had at least some associated commercial buildings, which is roughly comparable to the 125 billion kilowatthours estimated here. However, EIA's total nonutility power production estimate of 7 billion kilowatthours for nonutility generators in the services and public administration industry groups was considerably lower than the Facility Survey total, a further indication that output electricity was misreported in the 1989 Facility Survey.

[9]Lawrence Prete, Janet Gordon, and Betty Williams, "Nonutility Power Producers," *Electric Power Monthly*, DOE/EIA-0226(92/04) (Washington, DC: Energy Information Administration, April 1992), Table FE8.

Table 10. Central Physical Plant Energy Output Quantities
(Trillion Btu)

Facility Characteristics	Total Outputs	Steam	Hot Water	Chilled Water	Electricity
	All Sectors				
All Facilities	3,776	2,982	196	129	428
Census Region					
Northeast	Q	Q	Q	Q	Q
Midwest	631	482	Q	Q	107
South	Q	Q	Q	Q	Q
West	241	96	Q	Q	27
Energy Inputs					
Fuel Oil	Q	Q	Q	Q	Q
Natural Gas	1,744	1,269	171	115	188
Coal	900	Q	Q	Q	Q
Electricity	1,386	928	156	111	190
Energy Outputs					
Steam	3,556	2,982	Q	98	Q
Hot Water	375	Q	196	Q	Q
Chilled Water	624	Q	Q	129	Q
Electricity	Q	Q	Q	Q	428
	Commercial Sector				
All Facilities	735	426	134	101	74
Principal Facility Activity					
College and University	375	200	Q	49	Q
Other School	38	23	Q	Q	Q
Office	54	22	Q	Q	Q
Hospital	208	147	Q	27	20
Other	60	Q	Q	Q	Q
Census Region					
Northeast	131	96	Q	Q	Q
Midwest	236	176	Q	Q	Q
South	183	79	Q	38	16
West	186	75	Q	Q	Q
Energy Inputs					
Fuel Oil	371	243	Q	32	31
Natural Gas	660	371	123	94	72
Coal	Q	Q	Q	Q	Q
Electricity	551	280	Q	89	69
Energy Outputs					
Steam	617	426	Q	78	60
Hot Water	221	47	134	Q	Q
Chilled Water	408	187	Q	101	53
Electricity	266	141	Q	41	74

See footnotes at end of table.

Table 10. Central Physical Plant Energy Output Quantities (Continued)
(Trillion Btu)

Facility Characteristics	Total Outputs	Steam	Hot Water	Chilled Water	Electricity
	Industrial Sector				
All Facilities	2,955	Q	Q	Q	Q
Census Region					
Northeast	Q	Q	Q	Q	Q
Midwest	385	302	Q	Q	Q
South	Q	Q	Q	Q	Q
West	Q	Q	Q	Q	Q
Energy Inputs					
Fuel Oil	Q	Q	Q	Q	Q
Natural Gas	1,043	879	Q	Q	112
Coal	Q	Q	Q	Q	Q
Electricity	806	630	Q	Q	Q
Energy Outputs					
Steam	2,906	Q	Q	Q	Q
Hot Water	Q	Q	Q	Q	Q
Chilled Water	Q	Q	Q	Q	Q
Electricity	Q	Q	Q	Q	Q

Q = Data withheld because the Relative Standard Error (RSE) was greater than 50 percent, or fewer than 20 buildings were sampled.

Notes: •"All Sectors" estimates include multibuilding residential facilities. •See the "Glossary" for definitions of terms used in this report. •Totals may not equal sum of components because of independent rounding.

Source: Energy Information Administration, Office of Energy Markets and End Use, Form EIA-871B, "Facility Form" of the 1989 Commercial Buildings Energy Consumption Survey.

Central Physical Plant Inputs

Natural gas was the most common energy input used to produce steam, hot water, chilled water, and onsite-generated electricity (used at 64 percent of the 30,729 multibuilding facilities). Fuel oil and electricity were each used at about half of the facilities. Few central physical plants used coal as an input, and the limited amount of data resulted in estimates that were unpublishable even at the national level (Table 11).

- An estimated 9,444 facilities (31 percent) used both fuel oil and natural gas. This overlap in fuel use may reflect either separate pieces of equipment, or use of both fuels in equipment with multiple fuel capability.

- Ninety percent of the plants that used fuel oil as an input produced steam, versus 79 percent of those that used natural gas. Of plants that produced chilled water, 81 percent used natural gas and 85 percent used electricity.

- In commercial facilities, 68 percent of the central plants used natural gas, but only 26 percent used fuel oil. Natural gas was used by 68 percent of the central plants using fuel oil.

Table 11. Number of Multibuilding Facilities by Types of Central Physical Plant Energy Inputs

Facility Characteristics	Number of Facilities	Types of Energy Inputs			
		Fuel Oil	Natural Gas	Coal	Electricity
	All Sectors				
All Facilities	30,729	14,332	19,693	Q	14,983
Census Region					
Northeast	4,739	Q	Q	Q	1,034
Midwest	5,472	Q	3,264	275	Q
South	16,637	8,611	9,512	Q	7,984
West	3,881	Q	2,980	Q	2,614
Energy Inputs					
Fuel Oil	14,332	14,332	9,444	Q	Q
Natural Gas	19,693	9,444	19,693	386	11,279
Coal	Q	Q	386	Q	332
Electricity	14,983	Q	11,279	331	14,983
Energy Outputs					
Steam	23,131	12,941	15,608	Q	10,518
Hot Water	7,570	1,344	4,746	Q	4,593
Chilled Water	5,655	Q	4,574	Q	4,789
Electricity	7,395	Q	3,886	Q	Q
	Commercial Sector				
All Facilities	12,790	3,355	8,691	Q	5,559
Principal Facility Activity					
College and University	2,267	Q	1,769	Q	1,347
Other School	6,244	Q	3,486	Q	1,334
Office	947	Q	516	Q	Q
Hospital	2,146	1,020	1,905	Q	1,502
Other	1,185	Q	1,014	Q	711
Census Region					
Northeast	1,691	1,179	Q	Q	584
Midwest	2,379	Q	2,347	Q	1,092
South	6,048	Q	3,477	Q	2,038
West	2,672	Q	1,962	Q	1,845
Energy Inputs					
Fuel Oil	3,355	3,355	2,280	Q	1,875
Natural Gas	8,691	2,280	8,691	Q	4,410
Coal	Q	Q	Q	Q	Q
Electricity	5,559	1,875	4,410	Q	5,559
Energy Outputs					
Steam	8,567	2,613	5,419	Q	3,454
Hot Water	4,127	832	3,575	Q	1,891
Chilled Water	4,259	1,069	3,337	Q	3,411
Electricity	1,481	Q	1,441	Q	1,358

See footnotes at end of table.

Table 11. Number of Multibuilding Facilities by Types of Central Physical Plant Energy Inputs (Continued)

Facility Characteristics	Number of Facilities	Types of Energy Inputs			
		Fuel Oil	Natural Gas	Coal	Electricity
	Industrial Sector				
All Facilities	17,241	10,491	10,318	Q	9,121
Census Region					
Northeast	Q	Q	Q	Q	Q
Midwest	Q	Q	Q	118	Q
South	10,521	Q	Q	Q	Q
West	Q	Q	Q	Q	Q
Energy Inputs					
Fuel Oil	10,491	10,491	Q	Q	Q
Natural Gas	10,318	Q	10,318	Q	Q
Coal	Q	Q	Q	Q	Q
Electricity	9,121	Q	Q	Q	9,121
Energy Outputs					
Steam	14,180	10,151	9,819	Q	Q
Hot Water	Q	Q	Q	Q	Q
Chilled Water	Q	Q	Q	Q	Q
Electricity	Q	Q	Q	Q	Q

Q = Data withheld because the Relative Standard Error (RSE) was greater than 50 percent, or fewer than 20 buildings were sampled.

Notes: •"All Sectors" estimates include multibuilding residential facilities. •See the "Glossary" for definitions of terms used in this report. •Totals may not equal sum of components because of independent rounding.

Source: Energy Information Administration, Office of Energy Markets and End Use, Form EIA-871B, "Facility Form" of the 1989 Commercial Buildings Energy Consumption Survey.

- Some regional differences were evident. Seventy percent of the commercial plants in the Northeast used fuel oil, while 99 percent of the plants in the Midwest used natural gas.
- Ninety-seven percent of the commercial plants that produced electricity used natural gas as an input.
- In the industrial sector, roughly equal proportions of plants used fuel oil (61 percent) and natural gas (60 percent). Nearly all of the industrial plants that used either fuel oil or natural gas produced steam.

Total inputs to central plants were estimated at 5.8 quadrillion Btu, 32 percent of which was natural gas (Table 12). The commercial sector accounted for 1.2 quadrillion Btu, 50 percent in the form of natural gas. Little detail on the quantities of central physical plant inputs was publishable.

Table 12. Central Physical Plant Energy Input Quantities
(Trillion Btu)

Facility Characteristics	Total Inputs	Fuel Oil	Natural Gas	Coal	Electricity
	All Sectors				
All Facilities	5,776	Q	1,827	Q	Q
Census Region					
Northeast	530	Q	Q	Q	Q
Midwest	916	Q	261	488	Q
South	Q	Q	985	Q	Q
West	299	Q	190	Q	92
Energy Inputs					
Fuel Oil	Q	Q	721	Q	Q
Natural Gas	2,876	69	1,827	364	592
Coal	Q	Q	Q	Q	Q
Electricity	2,316	72	989	Q	Q
Energy Outputs					
Steam	5,503	Q	1,697	Q	Q
Hot Water	508	27	Q	Q	Q
Chilled Water	Q	Q	357	Q	Q
Electricity	Q	Q	477	Q	Q
	Commercial Sector				
All Facilities	1,153	Q	575	Q	211
Principal Facility Activity					
College and University	602	Q	217	Q	Q
Other School	71	Q	48	Q	Q
Office	78	Q	39	Q	32
Hospital	331	37	223	Q	Q
Other	72	Q	49	Q	Q
Census Region					
Northeast	216	Q	121	Q	20
Midwest	452	Q	161	Q	Q
South	272	Q	136	Q	Q
West	213	Q	157	Q	Q
Energy Inputs					
Fuel Oil	560	Q	309	Q	59
Natural Gas	1,046	29	575	Q	188
Coal	Q	Q	Q	Q	Q
Electricity	863	33	364	Q	211
Energy Outputs					
Steam	991	Q	462	Q	171
Hot Water	307	Q	169	Q	Q
Chilled Water	623	21	267	Q	166
Electricity	434	Q	141	Q	Q

See footnotes at end of table.

Table 12. Central Physical Plant Energy Inputs (Continued)
(Trillion Btu)

Facility Characteristics	Total Inputs	Fuel Oil	Natural Gas	Coal	Electricity
	Industrial Sector				
All Facilities	Q	Q	1,213	Q	Q
Census Region					
Northeast	Q	Q	Q	Q	Q
Midwest	450	Q	Q	Q	Q
South	Q	Q	849	Q	Q
West	Q	Q	Q	Q	Q
Energy Inputs					
Fuel Oil	Q	Q	Q	Q	Q
Natural Gas	1,778	Q	1,213	Q	Q
Coal	Q	Q	Q	Q	Q
Electricity	Q	Q	593	Q	Q
Energy Outputs					
Steam	Q	Q	1,202	Q	Q
Hot Water	Q	Q	Q	Q	Q
Chilled Water	Q	Q	Q	Q	Q
Electricity	Q	Q	Q	Q	Q

Q = Data withheld because the Relative Standard Error (RSE) was greater than 50 percent, or fewer than 20 buildings were sampled.

Notes: •"All Sectors" estimates include multibuilding residential facilities. •"Total Inputs" includes inputs of other fuels, not shown separately. •See the "Glossary" for definitions of terms used in this report. •Totals may not equal sum of components because of independent rounding.

Source: Energy Information Administration, Office of Energy Markets and End Use, Form EIA-871B, "Facility Form" of the 1989 Commercial Buildings Energy Consumption Survey.

Central Physical Plant Output-Input Ratios

Although central physical plant input and output quantities are highly variable, the ratio between the two may be considerably less variable. The output-input ratios (Table 13) may be interpreted as measures of central physical plant efficiency. An output-input ratio of 0.5, for example, would indicate half of the Btu value of the primary energy was lost when it was converted to the form delivered to the rest of the facility (steam, hot water, chilled water, or electricity). Besides conversion losses, other losses are sustained in circulating the heating or cooling medium (steam, hot water, or chilled water), and in transmitting the medium through imperfectly insulated pipes to the serviced buildings. The arguments for and against the efficiency of district heating and cooling depend on whether these losses are offset by the efficiency advantages of being able to operate a large-scale, centralized, heating and cooling system.

Because these output-input ratios are subject to reporting errors in both inputs and outputs, the ratios in Table 13 must be interpreted carefully.

- Input totals and, to a lesser extent, output totals were contaminated by some reports that covered the entire facility, rather than just the central physical plant. In other words, some of the energy reported as a central plant input may instead have been consumed directly at other buildings on the facility. Electricity consumed directly at other buildings may also have been reported as an output (Appendix B, "Data Quality").

Table 13. Central Physical Plant Energy Output-Input Ratios

Facility Characteristics	Total Outputs (trillion Btu)	Total Inputs (trillion Btu)	Output/Input Ratios
	All Sectors		
All Facilities	3,776	5,776	0.66
Census Region			
Northeast	Q	530	.52
Midwest	631	916	.69
South	Q	Q	.68
West	241	299	.81
Energy Inputs			
Fuel Oil	Q	Q	.67
Natural Gas	1,744	2,876	.61
Coal	900	Q	.72
Electricity	1,386	2,316	.61
Energy Outputs			
Steam	3,556	5,503	.67
Hot Water	375	508	.74
Chilled Water	624	Q	.68
Electricity	Q	Q	.75
	Commercial Sector		
All Facilities	735	1,153	.64
Principal Facility Activity			
College and University	375	602	.63
Other School	38	71	.55
Office	54	78	.69
Hospital	208	331	.64
Other	60	72	.85
Census Region			
Northeast	131	216	.61
Midwest	236	452	.52
South	183	272	.68
West	186	213	.88
Energy Inputs			
Fuel Oil	371	560	.67
Natural Gas	660	1,046	.63
Coal	Q	Q	.49
Electricity	551	863	.64
Energy Outputs			
Steam	617	991	.63
Hot Water	221	307	.72
Chilled Water	408	623	.66
Electricity	266	434	.62

See footnotes at end of table.

Table 13. Central Physical Plant Energy Output-Input Ratios (Continued)

Facility Characteristics	Total Outputs (trillion Btu)	Total Inputs (trillion Btu)	Output/Input Ratios
	Industrial Sector		
All Facilities	2,955	Q	0.67
Census Region			
Northeast	Q	Q	Q
Midwest	385	450	.86
South	Q	Q	.68
West	Q	Q	Q
Energy Inputs			
Fuel Oil	Q	Q	.68
Natural Gas	1,043	1,778	.58
Coal	Q	Q	.81
Electricity	806	Q	.59
Energy Outputs			
Steam	2,906	Q	.68
Hot Water	Q	Q	Q
Chilled Water	Q	Q	.87
Electricity	Q	Q	.78

Q = Data withheld because the Relative Standard Error (RSE) was greater than 50 percent, or fewer than 20 buildings were sampled.

Notes: •"All Sectors" estimates include multibuilding residential facilities. •See the "Glossary" for definitions of terms used in this report. •Totals may not equal sum of components because of independent rounding.

Source: Energy Information Administration, Office of Energy Markets and End Use, Form EIA-871B, "Facility Form" of the 1989 Commercial Buildings Energy Consumption Survey.

- The point of measurement for outputs was not specified in the Facility Survey. For example, steam outputs could be measured (1) leaving the boiler, (2) leaving the central physical plant, or (3) entering a serviced building. Different efficiency ratios may be associated with each of these points. If the facility's steam pipes are poorly insulated, the output-input ratio measured at the central plant will be considerably higher than that measured entering the serviced building.

- From a building energy analysis perspective, measurements of energy entering serviced buildings would be most useful; however, steam meters are notoriously unreliable. Measurement problems would remain even if the Facility Survey had requested quantities of delivered steam.

The net effect of these reporting problems on the estimated output-input ratios is unclear. Unreliable meters would not have a systematic effect on the output-input ratios. The output-input ratios are decreased by reported input energy that instead was consumed directly at buildings, without offsetting reported central plant outputs. The output-input ratio is increased, however, by cases where the same electricity was reported as both an input and an output. From a building-delivered energy perspective, any reported outputs measured other than at the serviced building would increase the output-input ratio. The effects of these reporting errors may cancel out. Unfortunately, while there is some evidence on the amount of central plant versus facility-wide reporting (Appendix B), the point-of-measurement issue awaits the results of the 1992 CBECS District Heating and Cooling Suppliers Survey, which included questions on the point of measurement.

The overall output-input ratio was estimated to be 0.66 in all facilities, 0.64 in the commercial-sector facilities and 0.67 in the industrial-sector facilities. These ratios are most useful in conjunction with the CBECS district heating

and cooling data, which are collected from similar respondents under similar conditions. By using 0.66 as the ratio, it could be estimated that 798 trillion Btu of primary energy were required to produce the 527 trillion Btu of district heat consumed by commercial buildings on multibuilding facilities (Table 5).

The output-input ratios reported in Table 13 can be contrasted with the efficiency of 0.33 percent usually reported for electricity generation by electric utilities. The 0.33 percent is calculated by dividing the heat content of one kilowatthour of electricity (3,412 Btu) by an annual average amount of fossil fuel energy required to produce one kilowatthour at a fossil-fuel steam-electric power plant. In this calculation, any byproduct heat is ignored, regardless of whether the byproduct heat is used for some other purpose (such as heating buildings). If useful energy outputs other than electricity were accounted for in the efficiency calculations, the ratio would be larger than 0.33 percent.

Shortcomings of the output-input ratios in Table 13 include the measurement problems discussed above (non-central plant consumption included, uncertainty about the point of measurement, and unreliable steam meters), plus uncertainty about the coefficient of performance to use for chilled water. Direct comparison with fossil-fuel power plants is also not possible because some central physical plants may have contained a mix of processes, i.e., some cogeneration of steam and electricity along with a separate chilled water system. Nevertheless, the ratios in Table 13 did attempt to account for all usable outputs.

4. Recommendations

Original Objectives

The original objectives of the 1989 Facility Survey were:

- to provide improved estimates of district heat consumption for sample buildings that lacked building-level metering.

- to provide a basis for estimating primary fuel consumption by central plants in noncommercial buildings located on commercial facilities.

In terms of its original objectives, the 1989 Facility Survey was largely unsuccessful due to widespread data quality problems (Appendix B) and high variances. However, the facility characteristics by themselves, especially facility activity and size, turned out to be useful in describing energy consumption in the commercial sector. While improvements to the characteristics questions are called for, this portion of the Facility Survey can be regarded as generally successful, and worth continuing in some form on future CBECS. For example, the 1992 CBECS Building Questionnaire collected the facility activity for all multibuilding facilities, whether or not they provided district heating and cooling. Other questions included on the 1992 Building Questionnaire asked whether the facility had a central plant, and what its outputs were.

Building-Level Estimates of Outputs from Central Plants

The original design of the Facility Survey anticipated that good input-output relationships for central plants would serve as a basis for improved building-level estimates of delivered steam, hot water, and chilled water. However, given the erratic data received for central plant inputs and outputs, basing building-level imputations on input-output relationships derived from the Facility Survey is unlikely to be a reliable alternative to the current method. Furthermore, the Facility Survey found that cases lacking building-level data tended also to lack facility-level output data (Appendix B, Table B9).

Nonetheless, improvements to the CBECS district heating and cooling estimates have resulted from the Facility Survey. Some improvements were the result of changes in the 1989 building-level District Heating and Cooling Form that were made in the course of developing the complementary Facility Form. In addition, attention to the Facility Form appeared to result in better understanding, by both respondents and survey staff, of the relationships among the data items being collected. Shortcomings of the Facility Survey also led to a 1992 CBECS District Heating and Cooling Survey question on meter location (either at central plant or at sampled building). This question was needed to account for energy transfer losses, an issue which arose in the analysis of the Facility Survey data.

Facility Inputs and Outputs

Although the 1989 Facility Survey provided some information on the types of energy used and produced in central plants, the central plant consumption (inputs) and production (outputs) data collected in the 1989 Facility Survey were much less satisfactory.

The most serious problem for inputs was that the some Facility Survey respondents reported facility-wide consumption rather than central physical plant consumption. The most serious problem for outputs was that the data were unavailable (Appendix B, Table B4). Actually, the problem may have been that the facilities lacked information on *both* inputs and outputs; for inputs the facility managers reported the only data available, facility-wide

data. The CBECS Energy Suppliers Survey remains the best source for estimates of district heating and cooling supplied to commercial buildings.

The abundance of inconsistent, implausible, and missing responses indicated that many respondents misunderstood the type of information that was requested, or simply could not provide it. This was the main reason that a separate Facility Survey was not included with the 1992 CBECS. Unless changes can be made to the Facility Survey that will substantially improve the quality of the data on quantities of energy input and output, it is highly questionable whether this component of the Facility Survey should be repeated.

Data Collection at the Facility Level

Improving the Data Collection Form

If a version of the Facility Survey is repeated in future CBECS (1995 and beyond), several improvements should be made to the Facility Form. Most improvements are needed to clarify for the respondent what information is requested. An overriding problem with the Facility Form is the need for the respondent to adhere to several bounding rules. These include the definitions of a building, an in-scope (for CBECS) commercial building, a central physical plant, and the relationship between the Facility Form and the District Heating and Cooling Form. Even if the language of the form can make the survey definitions clear, it may be unrealistic to expect a respondent to read through all the material and interpret all the rules as intended. For the Building Questionnaire, the boundaries of a building and whether it is in scope are determined by listers and interviewers who have been trained in the definitions.

It would be very helpful to develop a general accounting scheme for interim or sequential outputs, including cogeneration, and transmission and generation losses. This could be exhibited as a simple schematic of an energy balance, accounting for all inputs and outputs. This would help to obtain more consistent reporting of cogenerated electricity, or steam or electricity used to generate chilled water. As indicated in Appendix B, the term "cogeneration" was not consistently interpreted by respondents. It would also help determine whether outputs were measured at the point of departure from the plant, at the point of delivery to buildings, or somewhere in between.

To develop a better Facility Form, it might be necessary to conduct a more in-depth pilot study of a smaller number of facilities. The 1989 Facility Survey was useful in determining the size and broad characteristics of the population; this pilot study would be used to develop a more effective and useful line of questioning for subsequent surveys.

Any redesigned Facility Survey would have to address the fundamental fact that many central plants currently do not maintain records of inputs and outputs required. In response to this fact, the Facility Survey could collect more detailed information on plant characteristics, which could then be used in conjunction with engineering estimates to impute for missing inputs and outputs.

Alternate Design Approaches

An alternative to revising the 1989 adjunct Facility Survey would be to move toward a more facility-oriented data collection in CBECS. Such a change was not made for the 1992 CBECS (which did not have a facility component), but might be for a later CBECS, as part of a general survey redesign. A facility-based approach would target facilities, and try to collect facility-level consumption, as well as other energy-related data. Considerable work would be required to develop such an approach, which could constitute a major departure from the existing CBECS design. That approach would therefore need to be considered in the context of the broad goals of EIA's end-use data collection activities.

There are benefits in using facilities as a unit of data collection. To the extent that the facility, rather than the individual building, coincides with the economic decision-making unit, facilities represent a fruitful area for future work on conservation and energy management. Facilities are often natural economic units, unlike buildings, and buildings on facilities account for a large fraction of total commercial energy consumption. In terms of adoption of conservation features or participation in demand-side management (DSM) programs, the decision makers operate at the facility level. Also, buildings could be subselected from facilities to get characteristics data and building-specific energy use data for the traditional consumption benchmarking and analysis purposes.

The quality of the facility-based estimates could be improved by collecting data from a larger number of facilities, since a major data quality problem was the high variance of the estimates. Facilities are larger and more heterogeneous than commercial buildings. The sample of 393 facilities, yielding 237 respondents, was sufficient to support gross estimates for a pilot study, but not for a detailed substantive analysis within population subgroups. However, it is not altogether clear how to get a larger facility sample. Currently, the facility sample is derived from the building sample. One strategy might be to shift the building sample design to favor buildings on multibuilding facilities, such that a larger number of distinct facilities would be included.

Another possibility might be to target facilities directly at the sampling stage. The CBECS sample already has a list component, presently used solely to generate lists of large buildings. However, many of the elements on the multiple lists used in sampling are facilities: colleges, hospitals, and federal installations. If these elements were sampled as facilities specifically for a Facility Survey, the resulting sample would probably yield better results than the network estimator (Appendix C) used in the 1989 Facility Survey to translate the building-based CBECS sample to provide facility-level estimates. The special facility list would supplement the facilities drawn into the facility sample via the CBECS Building Characteristics Survey (as done in 1989).

Two additional advantages of a special facilities sample are:

- Measures of size are available on the special lists, so that eligibility cutoffs could be set. The CBECS has a minimum size of 1,001 square feet for the building survey, but had no minimum facility size for the 1989 Facility Survey. A minimum size would allow concentration of resources on the larger facilities.

- Sampling facilities might provide a method of measuring the overlap between the building-based CBECS and the facility-based Manufacturing Energy Consumption Survey (MECS). If facilities sampled for CBECS could be identified as existing on the frame for the MECS, or perhaps, even more simply, as being in-scope for the MECS, then their weighted contribution would overlap the MECS. This process might also allow coordination with other EIA surveys of nonutility generators. Such coordination will be more difficult if CBECS continues to sample only buildings.

The facilities sample would not replace the CBECS area sample (required for coverage of small-to-medium sized buildings) or list sample (required for coverage of large buildings not contained in multibuilding facilities). Rather, the facilities sample would supplement the area and list samples, just as the CBECS list sample does.

Mode of Data Collection

Despite the fact that CBECS had interviewers on site at each of the facilities in the 1989 Facility Survey to collect information on the CBECS sampled building(s), the facility data collection was completed by mail. The Facility Survey data might have been of much higher quality if trained interviewers had administered at least part of the Facility Form while at the site. In particular, the interviewer could have assisted in some of the bounding questions, such as defining buildings, defining what constitutes a commercial building, and determining the energy sources delivered to the central plant versus delivered to other buildings on the facility. The interviewer could also have identified, for later (mail) follow-up, the appropriate respondents for other parts of the Facility Survey, such as questions dealing with PURPA, DSM participation, or purchasing arrangements for natural gas.

The development of the Facility Survey and analysis of the data from the 1989 survey have already reshaped EIA's approach to collecting data for district heating and cooling, and have raised awareness of multibuilding facilities in general. Whether or not a Facility Survey is continued, the insights from the 1989 Facility Survey will help guide the future CBECS survey efforts.

Appendix A

The Facility Survey

The Need for Facility-Level Data

The CBECS is designed to measure consumption of individual fuels in individual commercial buildings. Data are collected on buildings' consumption of electricity, natural gas, fuel oil, and district heating and cooling. Each fuel is measured in terms of the amount consumed at, or delivered to, the building, rather than in terms of the primary fuels that may have been consumed at the earlier point of generation.

In this framework, district heat is an important fuel type. The total energy delivered in this form to commercial buildings is of the same magnitude as the total energy delivered from fuel oil. CBECS estimates of the amount of district heat provided to commercial buildings have been increasing since the first CBECS was conducted in 1979, largely as a result of improvements in coverage due to better understanding of this form of energy. In 1989, 13 percent of heated commercial floorspace was in buildings served by district steam or hot water. Six percent of air-conditioned commercial floorspace was cooled by district chilled water.[10]

For purposes of the CBECS, district heat is steam or hot water piped into a building from a central source that is located outside the building and serves more than one building. Similarly, district cooling is chilled water piped into a building from a central source that is located outside the building and serves more than one building. The central source may be a utility, or else a central physical plant that serves the entire multibuilding facility of which the building is a part. Typical examples of multibuilding facilities are university campuses and hospital complexes.

When district heating or cooling is provided by a utility or similar vendor, the amounts delivered are usually metered and billed, much as electricity, natural gas, or water service would be. Consumption for purchased district heating and cooling are relatively easy to obtain from billing records.

Of the commercial floorspace served by district heating and cooling, roughly three-quarters is served, not by a utility, but by a central physical plant on the same facility. Often in such cases, there is no metering of individual buildings' steam, hot water, or chilled water use. There may be metering records for a loop that serves several buildings, a record of total plant output only, or even no record of the overall output. In the latter case, the total facility inputs may be the only data available. For these reasons, it has been difficult for the CBECS to provide accurate estimates of total district heating and cooling consumption by commercial buildings.

Another difficulty with the CBECS district heating and cooling estimates has been reconciling the CBECS consumption totals, based on aggregating deliveries to individual buildings, with EIA's commercial-sector sales totals from energy suppliers. CBECS consumption totals can be compared with EIA commercial sales totals for electricity, natural gas, and fuel oil. However, EIA does not collect data on sales of steam, hot water, or chilled water to the commercial sector. Most of the energy consumed at the building level as cooling (via chilled water) or as heat (via steam or hot water) is reflected in sales of coal, natural gas, or fuel oil. Thus, accurate accounting of district heating consumption is needed to account for discrepancies between total sales and total building consumption of fossil fuels.

[10]Energy Information Administration, Office of Energy Markets and End Use, *Commercial Buildings Characteristics 1989*, DOE/EIA-0246(89) (Washington, DC, June 1991), Tables 79 and 80.

Generally, the primary fuels consumed on commercial facilities to generate district heating and cooling are excluded from the CBECS consumption totals. The primary fuel is typically excluded because the central plant that consumed the primary fuel is usually in a building classified as industrial, not commercial. Energy consumption in noncommercial buildings is explicitly outside the scope of the basic CBECS.

The CBECS designation of a building as commercial (in-scope) or noncommercial (out-of-scope) depends on the activity within the individual building, not the activity of the facility to which the building belongs. If the central physical plant occupies most of the building, the building is classified as industrial. Though awkward in relation to the central plant issues, the building classification scheme was developed for sound methodological reasons, and is fundamental to the design of the CBECS. The CBECS is a commercial *buildings* survey, and not a commercial *establishments* survey, because most energy consumption in the commercial sector is building related, that is, for space conditioning and lighting. To understand commercial energy consumption, it is therefore necessary to focus on characteristics of commercial buildings. In the field, CBECS interviewers devote a considerable amount of effort to defining building boundaries and determining whether the use of the building meets CBECS definitions of commercial activity.

The Facility Survey was added to the 1989 CBECS for two main reasons:

- To provide a better basis for imputing district heat consumption for sample buildings with no building-level metering. Previously, CBECS might have obtained building-specific records when available, total loop or system output when building records were not available, and total system input when output records were not available. It was hoped that collecting all types of information available from each site would provide a better basis for developing input-output relationships to be applied to cases where only limited information is available.

- To provide a basis for estimating primary fuel consumption by central plants in noncommercial buildings on commercial facilities. This would help to reconcile discrepancies between CBECS consumption totals and EIA's commercial-sector sales totals. The data collection was designed for a size-based network estimator of facility consumption totals.[11]

Because central plant outputs include chilled water and electricity as well as steam and hot water, any sound analysis of input-output relationships will need to account for chilled water and electricity generated or cogenerated onsite. It was therefore anticipated that this analysis effort would result in improved estimates not only for district heating consumption, but also for chilled water consumption and for electricity generation and cogeneration. However, the improved estimates for chilled water and electricity were secondary, not primary, purposes of the Facility Survey. The amounts of district chilled water and electricity produced are smaller in magnitude than district heat, and good data have been more difficult to obtain.

Identifying and Surveying Facilities

The facilities were sampled via the 1989 CBECS buildings sample.[12] During the interview at the building, the respondent was asked if the building was part of a multibuilding facility or complex. If the building was part of such a facility, the respondent was then asked if the facility had a central physical plant that produced district heating, district cooling, or electricity.

[11]Miriam L. Goldberg, "An Adjunct Facilities Survey for a Complex Buildings Survey," *Proceedings of the Section on Survey Research Methods of the American Statistical Association,* (1989).

[12]Energy Information Administration, Office of Energy Markets and End Use, *Commercial Buildings Characteristics 1989*, DOE/EIA-0246(89) (Washington, DC, June 1991), Appendix A.

The definition used for a multibuilding facility was purposefully made broad. A multibuilding facility was defined as "two or more buildings on the same site owned or operated by a single organization, business, or individual." The scope of the Facility Survey was restricted to facilities with central physical plants that produced district heating, district cooling, or electricity. If steam, hot water, or chilled water was piped in from one building to another (such as a boiler in a main hospital building supplied steam to an annex) then the building providing the steam, hot water, or chilled water was considered the central plant.

The Facility Form (Form EIA-871B) was then sent to all central physical plants so identified. The Facility Form (Appendix F) asked for the following:

- the principal activity of the facility;
- the number of buildings on the facility and their total square footage;
- whether the facility was designated a qualifying facility under the Public Utilities Regulatory Act of 1978 (PURPA);
- verification that there was a central physical plant;
- whether the plant had a cogeneration system and, if so, the total nameplate capacity and whether the system was interconnected with an electric utility;
- information on plant inputs (fuels, amount consumed, and expenditures);
- information on outputs from the plant to the district system (output fuels, yearly plant output, number and floorspace of buildings served).

Facility Survey cases were identified when respondents to the Building Questionnaire indicated that the building was both part of a facility and had a central physical plant. Forms were mailed in January 1990 with the rest of the Energy Suppliers Survey forms. Half of the returns were received within 2 months of the original request. A second mailing and reminder letters resulted in a limited number of additional responses. Telephone prompting, begun in late August, was much more effective at converting nonresponses. During these calls, survey staff members were able to answer questions and to encourage respondents to return their survey questionnaires even if they were unable to provide all of the requested data. The survey close-out date was November 10, 1990.

A total of 393 survey forms were mailed to managers of central physical plants identified on the Building Questionnaire. However, 24 of these responded that there was no central physical plant and an additional 8 reported that there was only one building on the facility. The overall response rate for the facility form was 68 percent (Table A1). This rate is based on all responses from eligible facilities, including those containing data (complete or partial) and those indicating they did not have a central plant. Nonrespondents included those who refused to answer the questionnaire (6 cases), those who indicated they would not respond because they do not maintain the necessary records to provide the requested information (3 cases), those that had not provided any information by survey closeout date (113 cases), and two "problem" cases which could not be classified. A total of 136 of the 385 eligible facilities (35 percent) responded with complete data that passed the critical item edit. Another 125 facilities provided some information, but what they provided was missing critical data needed for a response to be complete.

The problem of nonresponse, and its implications for the quality of the Facility Survey data, is discussed more fully in Appendix B, "Data Quality."

Table A1. Facility Form Responses by Disposition

Survey Disposition	Total Forms	Percent
	112	28
A. Complete, Usable Data		
B. Complete, No Central Plant	24	6
C. Partially Complete	125	32
D. Nonresponse	124	32
E. Not a Facility	8	2
F. Total Cases (sum of A through E)	393	100
G. Some Facility Data Present (A+B+C)	261	--
H. Response Rate (G/F-E)	--	68

-- = Data not applicable.

Source: Energy Information Administration, Office of Energy Markets and End Use, Form EIA-871B, "Facility Form" of the 1989 Commercial Buildings Energy Consumption Survey.

Appendix B

Data Quality

The Facility Survey was added to the 1989 CBECS to provide better information on district heating and cooling. As a pilot survey, the 1989 Facility Survey may be the precursor to a more refined data collection effort that will become an ongoing component of the CBECS. On the other hand, the Facility Survey may be valuable only for the one-time insights gained, and prove to be impractical to continue.

The quality of the Facility Survey data is a critical factor in determining whether the survey should be continued, modified, or discontinued. This appendix examines the quality of the Facility Survey data from two perspectives: respondents' ability to provide the requested data, and the apparent accuracy of the responses received.

Nonresponse rates (both unit and item) are important indicators of survey success. Unit nonresponse occurs when a sampled unit fails to cooperate with the survey by the end of the survey field period. (Outright refusal was rare.) Item nonresponse occurs when a respondent does not provide data for a particular survey item that is known to be applicable for that respondent.

Unit Nonresponse

The Facility Form was mailed to 393 multibuilding facilities identified from the CBECS Building Questionnaire as having central physical plants that produced steam, hot water, chilled water, or electricity. Of the 393 that received the form, 8 responded that the facility was not a multibuilding facility, 24 reported that they did not have a central physical plant, and 124 did not respond at all. Thus, of the 393 potential respondents initially identified, 60 percent (237 cases) provided some data, 8 percent were ineligible (either not a multibuilding facility or not served by a central plant), and the remaining 32 percent did not respond.

Calculation of an overall response rate is complicated by the fact that the eligibility of the 124 nonrespondents could not be determined, since some of the 124 may be single-building facilities, or may not have central plants. Nevertheless, the Facility Survey response was considerably poorer than the 92.5 percent response obtained in the 1989 CBECS Building Characteristics Survey, or the approximately 90 percent response obtained in the 1989 Electricity Suppliers Survey or the Natural Gas Suppliers Survey. However, the response is comparable to that obtained from the Fuel Oil Suppliers Survey or the District Heating and Cooling Suppliers Survey. As would be expected, there was a considerable overlap between the respondents to the latter survey and those to the Facility Survey.

Facility activity was the first item on the Facility Form. By using information from the Building Questionnaires of the associated buildings, EIA staff were able to code facility activities for the 124 nonresponding cases and the 8 cases that were not multibuilding facilities. No pattern of response outcome by facility activity was obvious (Table B1). It had been thought that industrial facilities would be less likely to complete the survey than commercial facility respondents. However, the response from industrial facilities was comparable to that from colleges and hospitals.

Unit nonresponse was also examined in terms of information from the Building Characteristics Survey (Table B2). Two crude facility size measures were available: the number and floorspace of the buildings sampled from each facility for the Building Characteristics Survey. All cases that turned out to be single building facilities had only one building sampled, while none of the cases without central plants had 4 or more sampled buildings. However, the majority of cases were respondents, regardless of the number of sampled buildings. No clear relationships were found between unit nonresponse rate and the sampled buildings' floorspace.

Table B1. Facility Survey Outcome by Principal Facility Activity

Principal Facility Activity	All Facilities	Facility Survey Outcome				Percent Non-respondent
		Respondent	Non-respondent	No Central Plant	Not Multi-building	
All Facilities	393	237	124	24	8	31.6
College and University	75	50	23	2	0	30.7
Other Schools	48	27	17	3	1	35.4
Office	51	27	16	7	1	31.4
Hospital	89	56	26	4	3	29.2
Industrial	85	55	25	5	0	29.4
Other	45	22	17	3	3	37.8

Source: Energy Information Administration, Office of Energy Markets and End Use, Form EIA-871B, "Facility Form" of the 1989 Commercial Buildings Energy Consumption Survey.

Table B2. Facility Survey Outcome by Size Measures from the Building Characteristics Survey

Size Measure	All Facilities	Facility Survey Outcome				Percent Non-respondent
		Respondent	Non-respondent	No Central Plant	Not Multi-building	
All Facilities	393	237	124	24	8	31.6
Number of Sampled Buildings						
1	216	119	72	17	8	33.3
2 or 3	141	97	37	7	0	26.2
4 or More	36	21	15	0	0	41.7
Floorspace of Sampled Buildings (square feet)						
10,000 or Less	37	19	16	2	0	43.2
10,001 to 100,000	137	85	42	7	3	30.7
100,000 to 500,000	125	73	40	10	2	32.0
500,000 to 1,000,000	53	33	16	3	1	30.2
Over 1,000,000	41	27	10	2	2	24.4
Central Plant Sampled						
Yes	116	58	39	12	7	33.6
No	277	179	85	12	1	30.7

Source: Energy Information Administration, Office of Energy Markets and End Use, Forms EIA-871A, "Building Questionnaire," and EIA-871B, "Facility Form," of the 1989 Commercial Buildings Energy Consumption Survey.

An additional piece of information obtained from the Building Characteristics Survey respondent was whether any of the sampled buildings contained the central plant. The unit nonresponse rates were about the same regardless of whether the central plant had been sampled. However, the "central plant" had been sampled in seven of the eight cases where the Facility Survey discovered that the supposed facility was not a multibuilding facility. Apparently, in these seven cases, the Building Characteristics Survey respondent had not understood the survey concepts of "multibuilding facility" or "central plant."

Further evidence that the concept of a "central plant" was not made clear is provided by the fact that in half of the 24 cases resolved not to have a central plant, the Building Characteristics Survey respondent had reported the central plant to be located in the sampled building. The survey concept was that of a plant located in one building providing district heating, cooling, or electricity to other buildings on the facility. Nevertheless, some respondents used the term to refer to any heating or cooling plant, regardless of whether the plant served several buildings, or just the building in which it was located.

Item Nonresponse

Of the 237 eligible and responding facilities, many were missing one or more items (Tables B3 and B4). The nonresponse rates in Tables B3 and B4 were calculated by dividing the number of facilities missing the item by the number of facilities to which the item applies. As in the case of the Building Characteristics Survey questions regarding multibuilding facilities and central plants, the nonresponse rates can indicate whether questions were phrased clearly to the respondents. The item nonresponse rates can also identify items where the requested information is not available. The items in Table B3 are general questions about the facility, while Table B4 focuses on the input and output energy sources.

In Tables B3 and B4, the varying number of "Not Applicable" responses are due to questionnaire skip patterns. For example, all facilities were eligible for Questions 1 through 6, but only facilities reporting the presence of a cogeneration system were eligible for Questions 7 and 8. Similarly, only facilities reporting steam as an output were eligible for any further steam-related items.

Table B3. Facility Form Response by Questionnaire Item, Facility Characteristics

Item and Description	Reported	Missing	Percent Missing	Not Applicable
Facility Characteristics				
2a Number of buildings on facility	235	2	0.8	0
2b Square footage on facility	209	28	11.8	0
3a Number of in-scope buildings	216	21	8.9	0
3b In-scope square footage	199	38	16.0	0
4 Qualifying facility (PURPA)	59	178	75.1	0
5 Central plant on facility	237	0	0.0	0
6 Cogeneration system	231	6	2.5	0
7 Cogeneration capacity	28	0	0.0	209
8 Cogeneration system connected to grid	28	0	0.0	209

Source: Energy Information Administration, Office of Energy Markets and End Use, Form EIA-871B, "Facility Form" of the 1989 Commercial Buildings Energy Consumption Survey.

With one exception, the nonresponse rates in Table B3 are fairly low, indicating that the Facility Survey respondents felt knowledgeable about facility characteristics. The exception was that the Facility Survey respondents tended not to know whether their facility was a Qualifying Facility under PURPA (Public Utilities Regulatory Policy Act). Of the 261 respondents (including the 24 without central plants), 66 were able to answer this question, 178 didn't know, and 17 left the item blank. Apparently, questions regarding status under PURPA should have been directed to someone at the facility other than the central plant manager.

Table B4. Facility Form Response by Questionnaire Item, Input and Output Energy

Item and Description	Reported	Missing	Percent Missing	Not Applicable
Input and Output Energy Description				
9 Fuel oil used as input	237	0	0.0	0
Input fuel oil type	85	23	21.3	129
Natural gas used as input	237	0	0.0	0
Coal used as input	237	0	0.0	0
Input coal type	23	7	23.3	207
Electricity used as input	237	0	0.0	0
Other fuel used as input	237	0	0.0	0
Input other fuel type	14	4	22.2	219
10 Steam output	218	19	8.0	0
Hot water output	218	19	8.0	0
Chilled water output	218	19	8.0	0
Electricity output	218	19	8.0	0
Cogenerated electricity output	218	19	8.0	0
Input Quantities				
9 Input fuel oil consumed	100	8	7.4	129
Input natural gas consumed	160	16	9.1	61
Input coal consumed	28	2	6.7	207
Input electricity consumed	143	11	7.1	83
Input other fuel consumed	9	9	50.0	219
Input fuel oil expenditures	95	13	12.0	129
Input natural gas expenditures	160	16	9.1	61
Input coal expenditures	28	2	6.7	207
Input electricity expenditures	140	14	9.1	83
Input other fuel expenditures	9	9	50.0	219
Output Quantities				
10 Output steam amount	120	55	31.4	62
Output hot water amount	11	44	80.0	182
Output chilled water	50	49	49.5	138
Output total electricity	34	12	26.1	191
Output cogen. electricity	12	1	7.7	224
# of bldgs. served by steam	144	31	17.7	62
# of bldgs. served by hot water	38	17	30.9	182
# of bldgs. served by chilled water	80	19	19.2	138
# of bldgs. served by total elec.	41	5	10.9	191
# of bldgs. served by cogen. elec.	11	2	15.4	224
Sq.ft. served by steam	138	37	21.1	62
Sq.ft. served by hot water	34	21	38.2	182
Sq.ft. served by chilled water	75	24	24.2	138
Sq.ft. served by chilled water	41	5	10.9	138
Sq.ft. served by cogen. elec.	11	2	15.4	224

Source: Energy Information Administration, Office of Energy Markets and End Use, Form EIA-871B, "Facility Form" of the 1989 Commercial Buildings Energy Consumption Survey.

Response rates tended to be significantly lower for energy outputs than for energy inputs (Table B4). Although all facilities with central plants reported at least one input energy source, 19 provided no output energy source. Part of this omission may have stemmed from the design of the survey form: the outputs section was on a back page that may not have been seen by some respondents. A redesigned survey form would need to make clear that the type(s) of output energy needs to be identified, even if the amounts produced cannot be provided. For the 1989 data, all output energy sources were treated as missing for the 19 cases where inputs were reported but no outputs.

For all input energy sources except "other", more than 90 percent of the central plants that reported having the input reported the amount of the input. On the other hand, all of the output energy forms, except electricity, had the output amount missing for at least 30 percent of the eligible cases. Response rates for the number of buildings and the floorspace served by the outputs were somewhat better, suggesting that the nonresponse was due to inability to provide the information, not noncooperation. The implication is that in many cases, district output quantities are not just unmeasured at the building level, but are also unmeasured at the facility level as well. Sixty-nine percent of the facilities producing steam were able to provide steam amounts, but only 20 percent of the facilities producing hot water were able to provide hot water amounts, so that the overall response rate for district heat was 55 percent. Fifty percent of the facilities producing chilled water were able to provide chilled water amounts.

Quality of Responses

Data Editing

As the facility forms were received, they were screened for accuracy and completeness. Forms were then keyed and computer edits were performed. The first edits were range and basic logic checks, followed by consistency checks among data items. Edit failures at these levels were most often due to coding or data entry error. If the causes of the error were not apparent to the technical reviewer, it was referred to supervisory staff for resolution.

EIA specified three technical edit checks to be performed on the facility data.

1. The number and floorspace of all buildings should be greater than or equal to the number and floorspace of in-scope buildings.

2. Ranges were provided for the average prices of energy sources input to the central physical plant.

3. A range of 0.25 to 1.0 was given for acceptable ratios of total Btu of central physical plant outputs to total Btu of central physical plant output. However, due to uncertainty about a reasonable factor, no Btu conversion factor was provided for chilled water.

Error correction was routine for the first two levels of editing. The technical edits had more complicated decision rules and required more supervisory involvement. The data reviewers basically had three choices when confronted with a technical edit failure:

- Update the data to eliminate the error conditions due to errors made by the coder, data entry operator, or supplier for future rounds of the edit cycle;

- Override the edit failure by assigning an override code and eliminate the failure for future rounds of the edit cycle; or

- Flag the case with a Problem Card and send it for review by a supervisor.

During the update process, data analysts assigned a reason for each update. Of the updates to correct any type of edit failure, the majority were due to a clerical error by the facility respondent, data keyer, data coder, or data editor. Following the technical edits, updates were made either as a result of telephone contacts with the respondents or due to the data analysts' decision. In many cases, telephone contacts were able to resolve problems, but in some instances the problem remained unresolved.

Size of Facility

The Facility Form requested four measures of facility size: the total number and total square footage of all buildings on the facility (Questions 2a and 2b), and of those totals, the number and square footage of buildings in-scope for CBECS (Questions 3a and 3b). In-scope buildings were defined in the questionnaire as "excluding (1) buildings 1000 square feet or smaller and (2) those whose primary purpose is agricultural, industrial, or residential."

All responses to the size questions on the Facility Survey were internally consistent, in that no respondent reported more in-scope buildings or floorspace than total buildings or floorspace. However, inconsistencies were detected when Facility Survey responses were compared with Building Characteristics Survey responses from sampled buildings on the facilities.

On any facility, the number of buildings sampled for the Building Characteristics Survey, and the sum of their floorspace, should be less than or equal to the amounts reported as in-scope from the Facility Survey. However, the sampled floorspace was greater than the reported in-scope floorspace (Question 3b) for 53 facilities, while there were more sampled buildings than the reported in-scope number of buildings (Question 3a) for 22 facilities. (Nineteen of the 22 facilities where the sampled number of buildings exceeded the reported in-scope number were also among the 53 with more sampled floorspace than the reported in-scope floorspace.) Fortunately, there was a sufficient amount of information available on the facilities, from listing materials and building interviews, to allow most of these discrepancies to be explained.

In some cases, the discrepancies were due to differences in perceptions of what was in-scope. For example, 14 of the 22 number-of-buildings discrepancies occurred on industrial facilities. In 10 of these 14 cases, the facility respondent reported no buildings to be in-scope. Apparently, the facility respondent perceived all buildings on the facility to be industrial in purpose, whereas the CBECS building interviewers were trained to distinguish between the principal activity of a building and the principal activity of the establishment or site. As a result, some buildings on an industrial facility, such as warehouses or offices, were identified as in-scope commercial buildings during the building interview, but not reported as such by the facility respondent.

Another type of discrepancy involved respondents who reported out-of-scope rather than in-scope buildings and floorspace in Questions 3a and 3b. An example was the 13,500,000 square foot college facility which reported only 1,001 square feet to be in-scope. If the Facility Survey is repeated, this question will need to be reworded to avoid this confusion.

Finally, some discrepancies were due to survey procedures, including (1) differences in the rounding of floorspace, (2) the Building Characteristics Survey practice of substituting regional averages for the square footage of buildings over 1,000,000 square feet, and (3) building-level imputation of floorspace for the Building Characteristics Survey.

In resolving these discrepancies, the Building Characteristics Survey responses were deemed to be the more accurate, more carefully ascertained values. The Building Characteristics Survey responses were systematically collected by interviewers trained in the CBECS definition of what constituted an in-scope building. If the quantity (number

or floorspace) from the Building Characteristics Survey was greater than the reported in-scope quantity from the Facility Survey, the following rules were used:

•If the facility was industrial, it was assumed that the respondent had treated buildings that were actually in scope as industrial. In this case, the in-scope quantity was changed to equal the Building Characteristics Survey sum.

•If the facility was not industrial, it was assumed that the respondent had reported out-of-scope rather than in-scope quantities.

(a)If the facility total was reported, the in-scope quantity was subtracted from the facility total. If this difference exceeded the Building Characteristics Survey sum, then the reported in-scope quantity was replaced by its complement (the difference between the total reported quantity and the originally reported in-scope quantity). However, if the Building Characteristics Survey quantity was greater than this difference, the in-scope quantity was set equal to the Building Characteristics Survey quantity.

(b)If the facility totals were missing, or the facility totals were less than the Building Characteristics Survey quantities, the in-scope quantities were set equal to the Building Characteristics Survey quantities;

(c) Finally, in any case where the in-scope value was changed so that it exceeded the total value, the total was set equal to the in-scope value, to preserve the relationship between in-scope and total values.

The sum of Building Characteristics Survey responses was a minimum value for in-scope quantities, and its use would tend to understate the number and floorspace of in-scope buildings on facilities. Given the large proportion of facilities (over one-fifth) affected by these changes, it might be preferable to have the CBECS interviewer ask these size questions in the future, just as it seems preferable to have the interviewer ascertain facility activity.

Cogeneration

The Facility Survey appeared to be a useful vehicle for obtaining information about cogeneration in the commercial sector. Earlier efforts had been stymied by the fact that large physical plant buildings, where cogeneration might take place, were classified as industrial buildings, and were therefore out of scope for CBECS.

In the Facility Survey, 28 facilities reported cogeneration systems. Ten of these facilities were colleges or universities, eight were industrial, and six were hospitals. All were able to provide their cogeneration capacities; which ranged from 150 kilowatts (a hospital) to 104,000 kilowatts (an industrial facility). Twenty facilities reported that they were connected to the local utility grid.

Problems arose when the outputs were examined. Seven of the "cogenerators" produced steam or hot water but no electricity, one produced electricity but not steam or hot water, and one did not report any outputs.

Furthermore, the Facility Form had asked for outputs of "Electricity--Total" and "Electricity--Cogenerated." It was expected that cogenerated electricity would be a subset of total electricity. However, six facilities reported cogenerated electricity, but not total electricity. One facility reported 174 million kilowatthours of cogenerated electricity but only 4 million kilowatthours of total electricity. In these seven cases, the values for the cogenerated electricity were copied over to total electricity.

Originally, there had been concern about double-counting cogenerated energy. Given the dubious quality of the cogeneration responses, this issue was not addressed.

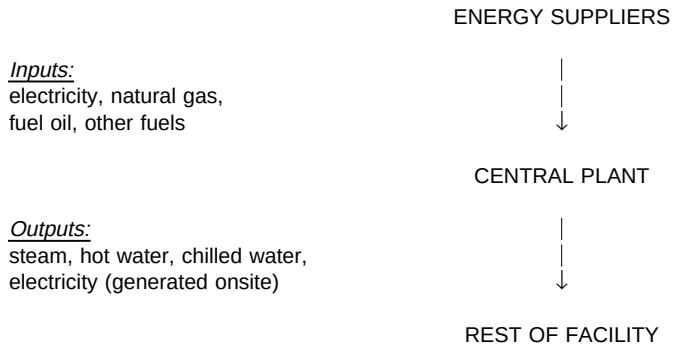
Central Plant Versus Facility-Wide Consumption

The Facility Form was designed to collect data on central plant consumption and output. However, it appears that some respondents reported not just central plant consumption, but the entire facility's consumption. Modifications to the Facility Form are needed to avoid this confusion in any future Facility Survey. There are two types of evidence for facility-wide reporting.

The first type of evidence involves electricity, which could be reported both as a system input and as a system output. In 39 cases, facilities reported both inputs and outputs of electricity. The amounts reported were the same, or virtually the same, in 16 of these cases. In these cases, it is almost certain that the "inputs" and "outputs" represented the total amount of electricity consumed by the entire facility, not just the central plant. In at least some of these cases, the breakdown between central plant energy consumption and noncentral plant energy consumption may be unknown.

The second type of evidence came from comparisons between the fuels and amounts reported on the Facility Form and the fuels and amounts reported by sampled buildings on the facility. In the idealized facility (for which the Facility Form was designed), fuels such as fuel oil and natural gas would be input to the central plant. The inputs would be used to produce outputs such as steam and chilled water, and these outputs would be the energy sources used by buildings on the facility. Central plants would receive fuel oil, coal, natural gas, and electricity, while other buildings on the facility would receive the outputs from the central plant (and perhaps some of the same fuels input to the central plant). The central plant would rarely be the sole source of electricity, and some buildings would not be included on district heating and cooling loops.

Energy Flows for an Idealized Facility with a Central Plant



The comparison between the facility data and the building data showed a large amount of inconsistency of inputs between the central plants and the sampled buildings, even considering the fact that some of the sampled buildings were the central plants (Table B5). For example, 108 facilities reported using fuel oil as an energy input to the central plant. However, in 6 of the 18 cases in which the central plant was included in the Building Characteristics Survey sample, *no* sampled building claimed to be supplied with fuel oil. Furthermore, fuel oil *was* supplied in 29 of the 90 cases in which the central plant was not sampled. In the latter case, it is possible that either (1) the sampled building was not part of the district heating and cooling loop or (2) the fuel oil was supplied to meet some end use other than heating or cooling. More likely, the building survey respondent was reporting energy supplied to the central plant, even when the central plant was in a different building.

The output comparisons show that many facilities report outputs, especially of hot water and chilled water, which the sampled buildings did not claim to receive (Table B6). In many such cases, the sampled buildings were parking garages or warehouses, which would not necessarily be expected to use district heating or cooling even if other buildings on the facility did. More surprising were facilities where buildings reported receiving district heating and cooling sources that were not reported on the Facility Form as a product of the central plant. There were eight such cases for steam, four for hot water, and seven for chilled water. These findings may be real, but they were not expected.

Table B5. Comparison of Energy Sources Supplied to Sampled Buildings (Reported on the Building Characteristics Survey) with Energy Inputs Reported to the Facility Survey

Energy Sources Supplied to Sampled Buildings, as Reported on the Building Characteristics Survey	Energy Inputs Reported to the Facility Survey					
	Fuel Oil		Natural Gas		Electricity	
	Yes	No	Yes	No	Yes	No
	All Facilities					
All Facilities	108	129	176	61	154	83
Fuel Oil						
Supplied	41	19	47	13	49	11
Not Supplied	67	110	129	48	105	72
Natural Gas						
Supplied	54	87	126	15	96	45
Not Supplied	54	42	50	46	58	38
Electricity						
Supplied	107	129	175	61	154	82
Not Supplied	1	NC	1	NC	NC	1
	Facilities with Sampled Central Plant Building					
All Facilities	18	40	43	15	38	20
Fuel Oil						
Supplied	12	8	16	4	18	2
Not Supplied	6	32	27	11	20	18
Natural Gas						
Supplied	13	36	43	6	31	18
Not Supplied	5	4	NC	9	7	2
Electricity						
Supplied	18	40	43	15	38	20
Not Supplied	NC	NC	NC	NC	NC	NC
	Facilities Without Sampled Central Plant Building					
All Facilities	90	89	133	46	116	63
Fuel Oil						
Supplied	29	11	31	9	31	9
Not Supplied	61	78	102	37	85	54
Natural Gas						
Supplied	41	51	83	9	65	27
Not Supplied	49	38	50	37	51	36
Electricity						
Supplied	89	89	132	46	116	62
Not Supplied	1	NC	1	NC	NC	1

NC = No cases in sample.

Source: Energy Information Administration, Office of Energy Markets and End Use, Forms EIA-871A, "Building Questionnaire," and EIA-871B, "Facility Form," of the 1989 Commercial Buildings Energy Consumption Survey.

Table B6. Comparison of Energy Sources Received by Sampled Buildings (Reported on the Building Characteristics Survey) with Energy Outputs Reported to the Facility Survey

Energy Sources Supplied to Sampled Buildings, as Reported on the Building Characteristics Survey	Energy Outputs Reported to the Facility Survey							
	Steam		Hot Water		Chilled Water		Electricity	
	Yes	No	Yes	No	Yes	No	Yes	No
	All Facilities							
All Facilities	175	43	55	163	99	119	46	172
Steam								
Supplied	112	8	13	107	40	80	23	97
Not Supplied	63	35	42	56	59	39	23	75
Hot Water								
Supplied	8	13	17	4	12	9	3	18
Not Supplied	167	30	38	159	87	110	43	154
Chilled Water								
Supplied	40	20	20	40	53	7	19	41
Not Supplied	135	23	35	123	46	112	27	131
Electricity								
Supplied	174	43	55	162	99	118	45	172
Not Supplied	1	NC	NC	1	NC	1	1	NC
	Facilities with Sampled Central Plant Buildings							
All Facilities	39	15	24	30	34	20	9	45
Steam								
Supplied	11	2	3	10	6	7	2	11
Not Supplied	28	13	21	20	28	13	7	34
Hot Water								
Supplied	NC	3	3	NC	1	2	NC	3
Not Supplied	39	12	21	30	33	18	9	42
Chilled Water								
Supplied	2	4	2	4	6	NC	2	4
Not Supplied	37	11	22	26	28	20	7	41
Electricity								
Supplied	39	15	24	30	34	20	9	45
Not Supplied	NC	NC	NC	NC	NC	NC	NC	NC
	Facilities Without Sampled Central Plant Buildings							
All Facilities	136	28	31	133	65	99	37	127
Steam								
Supplied	101	6	10	97	34	73	21	86
Not Supplied	35	22	21	36	31	26	16	41
Hot Water								
Supplied	8	10	14	4	11	7	3	15
Not Supplied	128	18	17	129	54	92	34	112
Chilled Water								
Supplied	38	16	18	36	47	7	17	37
Not Supplied	98	12	13	97	18	92	20	90
Electricity								
Supplied	135	28	31	132	65	98	36	127
Not Supplied	1	NC	NC	1	NC	1	1	NC

NC = No cases in sample.

Source: Energy Information Administration, Office of Energy Markets and End Use, Forms EIA-871A, "Building Questionnaire," and EIA-871B, "Facility Form," of the 1989 Commercial Buildings Energy Consumption Survey.

Input amounts from the Facility Forms were also compared with the total consumption of these energy sources at sampled buildings on the facility. The Facility Form input amount was within 25 percent of the sum of the sampled buildings' amount for 6 of the 41 fuel oil cases, 26 of the 126 natural gas cases, and 26 of the 154 electricity cases reported by both the facility and the building respondents. In most of these cases, the floorspace of the sampled buildings represented a large majority of the facility floorspace. In about half of these cases, the sampled buildings included the building containing the central physical plant.

For situations like these, where the input fuel consumption reported on the Facility Form is approximately equal to the sum of the sampled buildings' energy consumption, and the facility floorspace is approximately equal to the sum of the sampled buildings' floorspace, it is difficult to disentangle central plant consumption from buildings' consumption. In cases where it appears that the same facility consumption is being reported for the buildings as well as for the central plant, the solution is not obvious. The consumption either (1) all belongs to the central plant, (2) all belongs to the buildings, or (3) should be allocated between central plant consumption and consumption at buildings. In the latter case, the allocation proportions cannot be determined from the survey data. Furthermore, if the appropriate records are not maintained, the allocation may also be unknown at the facility. The inability to distinguish central plant from facility-wide consumption for a significant proportion of facilities is a serious shortcoming of the Facility Survey data.

Output/Input Ratios

The ratio of the total Btu value of outputs to the total Btu value of inputs is a measure of district system efficiency. Conversion factors for inputs were taken from the *Monthly Energy Review*.[13] Steam outputs were either reported in thermal units (Btu), or a conversion factor of 1,000 Btu per pound was used.[14] Hot water was always reported in thermal units. No attempt was made to adjust for possible double-counting involving district heat and cogenerated electricity since, as discussed earlier, the validity of the cogeneration data was uncertain.

Chilled water Btu conversions were a problem. Respondents reported chilled water output in ton-hours. One ton-hour is equivalent to 12,000 Btu of cooling. The coefficient of performance (COP) relates Btu of cooling to Btu of energy input as

COP = Rate of heat removal (Btu of cooling) / Rate of energy input (Btu).

Since no data on the actual COP or type of central plant equipment were collected, it was necessary to assume COPs to make chilled water Btu conversions. The distributions of output/input ratios corresponding to different assumed COPs are given in Table B7. A COP of 4.3 is reasonable for a large central plant chiller. With transmission losses of 50 percent, that COP would be reduced to 2.15. A COP of 1.00 would be appropriate for a steam absorption chiller.

For output/input ratios, 0.425 to 0.900 represents the range of reasonable values. A ratio of 0.425 is the minimum central plant efficiency required to be a qualifying facility under PURPA, while 0.900 is about the maximum. Ratios were calculated for the 115 facilities that had inputs and outputs completely reported. For this group, about half of the ratios fell in the range, 0.425 to 0.900. Most of the remaining ratios were either just above or just below this range. The distributions corresponding to assumed COPs of 4.30 and 2.15 were similar, but the distribution of ratios for a COP of 1.0 resulted in a notable increase in the number of unreasonably high ratios.

[13]Energy Information Administration, Office of Energy Markets and End Use, *Monthly Energy Review*, DOE/EIA-0035(91/06) (Washington, DC: June 1991).

[14]Dwight K. French, *Methodological Issues in the Nonresidential Buildings Energy Consumption Survey*, Energy Information Administration, Office of Energy Markets and End Use (September 1983).

Table B7. Distribution of Output/Input Ratios, Assuming Different Values for the Coefficient of Performance

Output/Input Ratio	Assumed Coefficient of Performance		
	1.00	2.15	4.30
Less than 0.100	4	5	5
0.100 to 0.425	16	19	23
0.425 to 0.900	54	55	59
0.900 to 1.5	27	29	23
1.5 to 3.5	12	7	5
Over 3.5	2	0	0

Source: Energy Information Administration, Office of Energy Markets and End Use, Form EIA-871B, "Facility Form" of the 1989 Commercial Buildings Energy Consumption Survey.

Another problem was related to the apparent confusion between central plant versus facility-wide consumption. Electricity which was not consumed at the central plant could show up as both an input and an output, equal in size. "Inputs" of other fuels which were not actually consumed at the central plant would not be represented at all on the output side. To attempt to compensate for misreported electricity, two sets of facility-level output/input ratios (Table B8) were calculated. One set of ratios used the electricity data as reported by the facility respondent. The other set of ratios were calculated after the net electricity (output minus input) had been calculated. If the net electricity was positive, electricity was deleted as an input, and the net value assigned to the output. If negative, electricity was deleted as an output, and the absolute difference was assigned to the input. The net electricity calculation did not affect the distribution of output/input ratios very much (Table B8).

Table B8. Distribution of Output/Input Ratios, Using Electricity as Reported and Net Electricity

Output/Input Ratio	Calculated Using Electricity as Reported	Calculated Using Net Electricity
Less than 0.100	5	6
0.100 to 0.425	23	23
0.425 to 0.90	59	61
0.900 to 1.5	23	18
1.5 to 3.5	5	6
Over 3.5	0	1

Source: Energy Information Administration, Office of Energy Markets and End Use, Form EIA-871B, "Facility Form" of the 1989 Commercial Buildings Energy Consumption Survey.

Reporting Dates

The dates reported for energy inputs and outputs are used to determine if the reported amounts correspond to substantially more or less than the targeted one-year period. The Facility Form had requested that respondents provide information on total input fuels and total output fuel for the period from January 1, 1989 through December 31, 1989, or the closest time period for which data were available. For each type of input or output, respondents were asked to indicate the month, day, and year for the beginning and the end of the reporting period. Two types of reporting date problems were considered, missing dates and reporting periods less than 300 or more than 450 days in length.

Missing dates were either missing the day (but had the month and year) or completely missing. Most of those missing just the day appeared to be covering a 12-month period, for example, from "1/89" to "12/89". Only 4 inputs and 6 outputs had completely missing dates.

Period lengths less than 300 days were mainly found for inputs of fuel oil and outputs of chilled water. The former could be the dates of deliveries, while the latter seemed to be dates of the cooling season. It was decided that the date problems were minor, and could be ignored. That is, all reported fuel amounts were treated as representing the total for that fuel over a one-year period.

Expenditures Data

The expenditures information was used to calculate the average prices (total expenditures divided by total consumption) for the input fuels. The prices were used to edit the consumption amounts, chiefly to look for misreported units of measure. A few such cases were identified in electricity and fuel oil inputs. A number of very low natural gas prices, less than the wellhead price, were found. These prices were in the range charged for transportation of natural gas when natural gas is purchased directly from the producer. Multibuilding facilities, such as the industrial complexes, colleges, and hospitals covered by the Facility Survey are known to be heavily involved in the direct purchase of natural gas.

The direct purchase natural gas expenditures problem also affected the 1989 Natural Gas Suppliers Survey data.[15] One suggestion made for the 1992 CBECS Natural Gas Suppliers Survey was that expenditures for direct-purchase natural gas should be collected from the end-user, rather than from the local utility company, since only the end-user would know the full price. It appears that not all of the 1989 Facility Survey respondents had ready access to their facility's natural gas expenditures data. The expenditures provided to the Facility Survey may have been copied by respondents from local utility bills, which often include only transportation charges, but not the cost of the natural gas or any other charges.

Due to the incomplete reporting of natural gas expenditures, this report does not deal substantively with expenditures for fuels at facilities. Instead, attention is limited to the inputs and outputs of energy.

Building-Level Estimates

An important aim of the Facility Survey was to investigate the use of facility-level data to improve imputations for buildings missing consumption of district steam, hot water, or chilled water. There are two parts to this investigation: (1) are facility-level data available in cases where building-level data are missing? and (2) where facility-based building-level estimates are available, are they an improvement?

A considerable amount of data is missing from the building file for district heating and cooling energy sources. About half of the district steam, and 70 percent of the district hot water and chilled water are missing (Table B9). For the CBECS reports, steam and hot water are combined, while chilled water is considered unpublishable because of high relative standard errors for the estimates. About three-quarters of the buildings supplied with steam, and over 90 percent of the buildings supplied with hot water and chilled water are located on multibuilding facilities with central plants.

If the facility was able to provide the total output amount and the floorspace of the loop served by each district energy source, this information could be used in conjunction with the building floorspace (from the Building Characteristics Survey) to prorate outputs in proportion to square footage. Unfortunately, less than half of the

[15]Energy Information Administration, Office of Energy Markets and End Use, *Commercial Buildings Energy Consumption and Expenditures 1989*, DOE/EIA-0318(89) (Washington, DC, April 1992), pp. 325-326.

facilities supplying district steam, and only about one-quarter of the facilities supplying district hot water or chilled water, were able to report the necessary items. Those that were able to provide these items tended to be those for which the amounts delivered to sample buildings were already reported.

In an effort to answer the second question, namely, whether the facility-based estimates are an improvement, the facility-based building-level estimates were made and compared to the building data. Comparisons were made separately for cases where the building data were reported and for cases where the building data were missing. In the latter case, the building values had been imputed via multiple regression.

The sum of the building data was compared with the sum of the facility-based prorated estimates for the same buildings. The sums were simple, unweighted sums over all buildings in the sample for which both estimates were available. For the set of buildings that had reported values for building data, the sums of facility-based estimates were all slightly higher: 8.4 percent for steam, 1.3 percent for hot water, and 7.7 percent for chilled water. However, for the set of buildings where the building data had been imputed, the sums of facility-based estimates were considerably higher: 210.2 percent for steam, 44.9 percent for hot water, and 34.0 percent for chilled water. On the one hand, this discrepancy could indicate that, although the regression was fit using reported data, somehow the regression is underestimating district heating amounts. On the other hand, CBECS district heat intensities already seem high (over 90,000 Btu per square foot). More analysis is needed to explain these discrepancies.

Table B9. Relationship Between Energy Suppliers Survey Reporting and Facility Survey Reporting for District Heating and Cooling

Energy Source and Result of Energy Suppliers Survey	All Buildings		Buildings on Central Plant Facilities			
			All		Able to Estimate	
	Number	Percent	Number	Percent	Number	Percent
Steam						
All Buildings	451	100.0	334	100.0	140	100.0
Reported	231	51.2	146	43.7	98	70.0
Missing	220	48.8	188	56.3	42	30.0
Hot Water						
All Buildings	60	100.0	56	100.0	14	100.0
Reported	17	28.3	17	30.4	12	85.7
Missing	43	71.7	39	69.6	2	14.3
Chilled Water						
All Buildings	168	100.0	149	100.0	41	100.0
Reported	52	31.0	42	28.2	30	73.2
Missing	116	69.0	107	71.8	11	26.8

Source: Energy Information Administration, Office of Energy Markets and End Use, Forms EIA-871A, "Building Questionnaire," and EIA-871B, "Facility Form," of the 1989 Commercial Buildings Energy Consumption Survey.

Appendix C

Estimation

Estimation refers to the process by which national (population) estimates are made based on the responses received from a sample. Estimation for the Facility Survey had to deal with three problems, each of which will be described in a separate section of this appendix.

The first estimation problem was that, although the Facility Survey was targeted at multibuilding facilities, the basic CBECS sample was designed for inferences about individual buildings. The following section, "The Network Estimator," describes how estimates and their variances were produced. The theory of network estimation guided the overall design of the Facility Survey.

The second estimation problem was that not all sampled units responded to the Facility Survey, and not all respondents completed all items. The section, "Imputing for Missing Responses," describes the procedures used to compensate for missing responses.

The third estimation problem was that of producing estimates and variances which accounted for the effects of imputation. The inference from sample to population introduced sampling variance, due to the fact that a small part of the population was selected to represent the whole. The imputation procedures introduced imputation variance, since the responses received were used to guess how the nonrespondents would have responded. Since a large portion (over a third) of the units were completely imputed, the effects of imputation could not be ignored. The third section, "Estimation With Multiple Imputation," describes the method chosen to produce both point estimates and variances from the Facility Survey data.

The Network Estimator

The facility data can be used to derive estimates of national totals across all facilities. As described by Goldberg,[16] the estimator used is a network estimator, based on the basic CBECS sample design. For any aggregate quantity Q defined as the sum of facility quantities Q_f, the estimator is

$$\hat{Q} = \sum_f Q_f \sum_{b \in F_f} (s_b/S_f) d_b w_b \qquad \textbf{(1)}$$

where

F_f = the set of multibuilding facilities with central physical plants,

s_b = square footage of sample building b,

S_f = total square footage of in-scope buildings on facility f,

d_b = 0/1 indicator variable for whether building b is in the responding sample, and

w_b = sampling weight for building b (including unit nonresponse adjustment).

[16]Miriam L. Goldberg, "An Adjunct Facilities Survey for a Complex Buildings Survey," *Proceedings of the Section on Survey Research Methods of the American Statistical Association*, (1989).

Nonsampled and nonresponding buildings do not contribute to the sum $\hat{Q}$, since $d_b = 0$ for these buildings. Likewise, a facility f with no responding buildings does not contribute to the sum, since the multiplier for the quantity Q_f is zero.

The estimator $\hat{Q}$ can also be expressed as

$$\hat{Q} = \sum_f Q_f W_f \quad \textbf{(2)}$$

where

$$W_f = \sum_{b \in F_f} (s_b/S_t) d_b w_b \quad \textbf{(3)}$$

is the derived facility sample weight for facility f.

Alternatively, the estimator can be expressed as a sum over all sample buildings:

$$\hat{Q} = \sum_b (Q_{f(b)} s_b/S_{f(b)}) d_b w_b, \quad \textbf{(4)}$$

or

$$\hat{Q} = \sum_b (Q_{f(b)}/S_{f(b)}) s_b d_b w_b, \quad \textbf{(5)}$$

where f(b) indicates the facility f to which building b belongs. For example, $Q_{f(b)}$ is the quantity for the facility to which building b belongs.

Equation (4) indicates that the facility total Q_f is allocated among sample buildings b on the facility in proportion to the buildings' floorspace. This allocation is not intended as an accurate estimate of the individual buildings' proportion of central plant outputs. Indeed, the building may receive no outputs from the central plant, in which case this proportion is known to be zero. Rather, the allocation implied by the estimator $\hat{Q}$ is a statistical apportionment that yields an unbiased estimate for the aggregate Q.

Equation (5) shows that the estimator does not require explicit values for the facility consumption Q_f and the facility eligible floorspace S_f, only for the ratio of the two. Thus, for facilities where both the consumption amounts and the eligible floorspace are missing, it is less critical to impute these items separately than to get a reasonable imputation for their ratio. For instance, it may be more stable to hot-deck the consumption per square foot than to impute consumption and floorspace separately.

Ignoring unit nonresponse adjustments[17], the building sampling weight w_b is simply the reciprocal of the sampling probability. With the inflation for unit nonresponse, we can consider the adjusted weight w_b as the reciprocal of the probability p_b that a building both is sampled and responds to the survey.

This probability can be partitioned as the product of the probability P_f that at least one building from the facility is in the (responding) sample and the conditional probability $p_{b|f}$ that the building b is sampled, given that facility f is in the sample. This partition is valid even though the two components are not separately known in general.

[17]The response rate for the 1989 CBECS was 92.5 percent, so that the effects of the nonresponse adjustments are small.

The derived sampling weight W_f (Equation (3)) estimates the reciprocal of the facility probability P_f. This approach provides an unbiased estimator of the facilities aggregate q using building sampling weights only, without explicit calculation of exact facility sampling probabilities.

Given that the facility f is in the responding sample, the conditional expectations are $E_{|f}(d_b) = p_{b|f}$, and

$$E_{|f}(W_f) = 1/P_f. \quad \textbf{(6)}$$

Over all possible samples, $E(d_b) = p_b = 1/w_b$, so that $E(W_f) = 1$. Thus, each facility f has expected contribution Q_f to the facility aggregate estimator $\hat{Q}$, and

$$E(\hat{Q}) = \sum_f Q_f \, E(W_f) = \sum_f Q_f = Q. \quad \textbf{(7)}$$

Therefore, $\hat{Q}$ is unbiased.

Imputing for Missing Responses

As described in Appendix B, the Facility Survey experienced two types of nonresponse, unit and item. If the sole purpose of the Facility Survey were to improve the quality of estimates from the District Heating and Cooling Suppliers Survey, then nonresponse would be a problem only insofar as it limited the amount of data verification that could be accomplished. However, the Facility Survey was also designed to provide population estimates of inputs and outputs of central plants. If untreated, unit and item nonresponse could lead to serious biases in these estimates.

Imputation Versus Reweighting

Unit nonresponse to the Facility Survey could be handled either as unit nonresponse or as item nonresponse. In the CBECS, nonresponse to the Building Characteristics Survey is considered unit nonresponse. Sampling weights are adjusted for unit nonresponse within cells defined by sampling information. On the other hand, nonresponse by a building's energy supplier to the Energy Suppliers Survey is treated as item nonresponse. The missing items are imputed using data from the Building Characteristics Survey.

It seemed preferable to treat Facility Survey unit nonresponse as item nonresponse, as with unit nonresponse to the CBECS Energy Suppliers Surveys. From the Building Characteristics Survey, there is abundant information about the characteristics of the sampled buildings on the facility, which can be used to impute facility information. In addition, the facility activity is known for all sampled facilities, including unit nonrespondents. These activities were obtained by examining and coding the questionnaires of the sampled buildings on the facility.

There would be several problems associated with a reweighting approach to unit nonresponse adjustment. Both nonresponse adjustment and variance estimation would be difficult if Facility Survey nonresponse were treated as unit nonresponse. The usual unit nonresponse reweighting adjustment is based on sampling stratification cells. The adjustment cells used by CBECS are based on building-level characteristics. Each facility could have several sampled buildings, each one in a different cell, making the assignment of a facility to a cell problematic.

The building-based sampling stratification has similar consequences for variance estimation. CBECS variances are estimated using a jackknife procedure, with buildings assigned to replication units based on the sample stratification cells. It is conceivable that buildings associated with the same facility could be assigned to different replication units.

Finally, it would be desirable for each building that belonged to a multibuilding facility with a central plant to have the associated Facility Form information on the final building data file. Using nonresponse adjustment factors would leave a substantial fraction of applicable buildings without these data.

For all the above reasons, nonresponse to the Facility Form was treated as item nonresponse.

The Hot-deck Procedure

The two basic CBECS techniques for handling item nonresponse are regression modeling and hot-decking. Regression modeling is used for missing energy consumption. The CBECS estimates for consumption of electricity, natural gas, fuel oil, and district heat are the most important estimates provided by the entire survey. Hot-decking is used to impute for missing building characteristics, which include a large number of less critical items. Developing separate models for each item with missing values would be time consuming, without having a major impact on data quality.

About 50 Facility Survey items, some more important than others, required imputation. Some items, such as the quantities of energy input and output, might have been modeled individually. However, the process would have been time consuming, with no guarantee of success. Therefore, hot-decking, the easier of the two techniques to implement, was chosen to impute for all missing Facility Survey data.

In the hot-deck method, cases are divided into two groups: "donors" (with reported values for the items of interest) and "receivers" (with missing values for the item of interest). The separation into donors and receivers is usually done within "cells" formed by cross-tabulating items known for both groups. Within cells, values are considered to be missing at random, and imputation is performed by randomly selecting a donor and copying its value onto the receiver.

Facilities are matched on some or all of the relevant characteristics, such as facility activity, size, types of input and output energy, power generation characteristics, and the type of fuels listed as being delivered to sampled buildings on the facility. Numeric items are not hot-decked directly. Instead, hot-decking was performed on ratios between nonmissing quantities and missing quantities, such as outputs to inputs or in-scope square footage to total square footage.

In hot-deck imputation, the definition of cells constitutes an implicit form of modeling. Cell variables, analogous to main effects in the analysis of variance, are chosen for their relationship with the target item, and all interactions between cell effects are included.

Some facilities with reported data for particular items were discovered during data editing to have impossible or implausible answers for those items. Those cases were disqualified as donors for the items in question.

The CBECS uses a vector hot-deck procedure. With this procedure, the facility that donates a particular item to a receiver also donates related items (up to 5) if any of these are missing. Thus, a vector of values, rather than a single value, is copied from the donor to the receiver. This procedure helps to keep the hot-decked values internally consistent, and avoids implausible combinations of facility responses.

The Facility Survey data were organized into four data groups for imputation: (1) facility characteristics, (2) input and output fuels, (3) output amounts, and (4) input amounts. These four groups will be discussed in turn.

Facility Characteristics

The first facility characteristic to be imputed was whether the facility was a multibuilding facility. The matching variables for this critical item were (1) whether there was more than one sampled building on the facility, (2) whether the sampled building(s) reported receiving any energy from the central plant, and (3) whether the facility was industrial. The remaining items imputed in the first group were items 2 through 8 from the Facility Form, facility size and power production characteristics.

The facility size items (total and in-scope number of buildings and floorspace) were not imputed directly. Instead, the following four ratios were imputed:

- the ratio of the floorspace of sampled buildings from the Building Characteristics Survey to the in-scope floorspace from the Facility Survey;
- the ratio of the in-scope floorspace to the total facility floorspace;
- the ratio of the number of sampled buildings to the number of in-scope buildings;
- the ratio of the number of in-scope buildings to the total number of buildings on facility.

Since the number and floorspace of the sampled buildings was known (or previously imputed), the imputed ratios could be used to fill in whichever items were missing. Matching variables used to impute these ratios included whether the facility was industrial, as well as categorical versions of the ratios.

The facility power production characteristics were imputed matching on each other, and also on information from the Building Characteristics Survey on energy sources used in the sampled buildings.

Input and Output Fuels

The second group consisted of the input and output fuel use indicators (binary variables indicating whether a fuel was used or produced). Output fuel indicators were imputed first, using building data on the energy sources supplied to the buildings by central plants. Also used were a categorical version of the ratio of sampled to total buildings on the facility (an indicator of how complete the sampled buildings' energy sources might be) and whether the facility had a cogeneration system. Input fuel indicators were imputed using the output fuels, plus the Census region (to reflect regional availability of fuels).

Once imputations for input and output fuel indicators were completed, input and output amounts could be imputed.

Output Amounts

The third group comprises the facility output quantities. Output amounts were imputed before input amounts because available information on the size of the loop served by outputs could help establish the demand for the outputs. Input amounts could then be sized based on the outputs required.

As was the case for the facility size items in the first group, output amounts were not imputed directly. Instead, the following two ratios were imputed for each output energy source:

- the ratio of the output loop floorspace to the total facility floorspace;
- the ratio of the output amount to the output loop floorspace.

These ratios were imputed using the input and output fuel use indicators, as reported or imputed in the second group of items. For output amount per loop floorspace, climate zone was an additional variable. Since the value of total facility floorspace was either reported or had been imputed in the first group, these ratios could be used to obtain the output amount.

Input Amounts

Finally, the fourth group consisted of the facility input quantities. For inputs, two types of ratios were used:

- overall: the ratio of the total input Btu to the total output Btu;
- for each input fuel: the ratio of the Btu of the input fuel to the total input Btu.

Values less than 0.1 or greater than 1.5 were excluded as donors. Both input and output fuel use indicators were used to impute these ratios.

Estimation with Multiple Imputation

Because of the high Facility Form nonresponse rates, the final facility data set was heavily imputed. Final estimates were based on responses for about one-half to two-thirds of the in-scope Facility Survey cases. This limitation would exist regardless of what strategy was adopted for handling the Facility Form nonresponse. The imputation strategy used was multiple imputation.

Multiple imputation is defined as "the technique that replaces each missing or deficient value with two or more acceptable values representing a distribution of possibilities."[18] The multiple imputation method involves two or more independent replications of the imputation methodology. Each replication completes the full-sample data set by imputing once for each missing value. The analysis and variance estimation then proceeds using standard survey methods. The multiple full-sample estimates are combined to obtain the overall survey error, including the contribution due to imputation effects.

In reflecting the "distribution of possibilities," multiple imputation offers two main advantages. First, for point estimates, multiple imputation makes better use of the available data than does single imputation. Second, multiple imputation allows variances to include uncertainty due to item imputation in overall estimates of survey error. Previously, multiple imputation had been used in CBECS for the 1989 building characteristics data in a limited evaluation of the imputation procedure and its effect on variances.[19]

There are two stages in the implementation of multiple imputation: (1) the imputation phase, in which two or more independent imputations are made for each missing value, and (2) the estimation phase, in which the multiple imputations are used to estimate the quantities of interest and their variances.

[18]Donald B. Rubin, *Multiple Imputation for Nonresponse in Surveys*, (New York, Wiley, 1987), p. 2.

[19]Eugene M. Burns, "Multiple Imputation in the 1989 Commercial Buildings Energy Consumption Survey: Building Characteristics," CBECS Technical Note 86, Energy Information Administration, Office of Energy Markets and End Use (April 8, 1991); Energy Information Administration, Office of Energy Markets and End Use, *Commercial Buildings Characteristics 1989*, DOE/EIA-0246(89) (Washington, DC, June 1991), Appendix B.

Imputation

The first step in multiple imputation is generating of multiple, independently drawn, imputed values. To ensure that imputations are independent, both within and between sets of imputations, CBECS employs a type of hot-decking known as approximate Bayesian bootstrapping.[20]

In a cell with n_d potential donors and n_r receivers, the approximate Bayesian bootstrapping first requires a random draw of size n_d, with replacement, from the set of donors. (The only restriction on cell size was that n_d must be greater than or equal to 2.) If the hot-deck cell definition constitutes a satisfactory implicit model, then the quality of the resulting imputed value is not affected by this randomization within cells. Next, n_r imputed values are randomly drawn, with replacement, from the pool of sampled donor values.

Multiple imputation was accomplished simply by repeating the procedure using different seeds for the random number generator. The result was multiple sets of imputed values, which could be used to form multiple completed versions of the full data set. In all, 10 sets of imputed values were produced, the upper range of the 2 to 10 suggested as a reasonable number by Rubin.[21]

Estimation

The second part of multiple imputation is incorporating the m sets of imputed values into the estimation process. The m sets of imputed values update the unimputed file to form m completed data sets. With multiple imputation, the survey's standard methods of producing point estimates and variances can be applied to each completed data set. The resulting sets of estimates and variances are then combined into an overall set of estimates and variances which incorporate imputation effects.

In the standard CBECS methods, a completed full-sample data set is used to obtain point estimates of totals as follows:

$$\hat{X} = \sum_{i=1}^{n} w_i x_i, \qquad \textbf{(8)}$$

where w_i is the overall full-sample adjusted weight for the i^{th} building, x_i is the value of the variable of interest for the i^{th} building (ignoring distinctions between reported and imputed values), and n is the number of buildings included in the cell. Estimates for the number of buildings are formed by summing the sampling weights, i.e., by letting x_i=1 for all n buildings.

Due to the complexity of the sample design, the CBECS uses the jackknife replication method (with 40 collapsed strata) for variance estimation. To capture variation due to unit nonresponse, weight adjustment is performed separately within each replicate, as well as overall. The 40 sets of replicate weights are used to compute mean square errors about the full-sample point estimates, as follows:

$$\hat{S}^2 = \sum_{k=1}^{40} (X_k - \hat{X})^2, \qquad \textbf{(9)}$$

where X_k is the point estimate based on the k^{th} replicate, and $\hat{X}$ is the point estimate based on the full-sample data set. The replicate totals are calculated as

$$X_k = \sum_{i=1}^{n} I_{ki} w_{ki} x_i, \qquad \textbf{(10)}$$

[20]Donald B. Rubin and Nathaniel Schenker, "Multiple Imputation for Interval Estimation From Simple Random Samples With Ignorable Nonresponse," *Journal of the American Statistical Association* 81, 394 (June 1986), pp. 366-374.

[21]Donald B. Rubin, *Multiple Imputation for Nonresponse in Surveys*, (New York, Wiley, 1987), p. 15.

where w_{ki} is the k^{th} replicate adjusted weight for the i^{th} building, and the replicate inclusion indicator, I_{ki}, takes the value

0, if the i^{th} building is in the k^{th} stratum in the unit omitted from the k^{th} jackknife replicate,

2, if the i^{th} building is in the k^{th} stratum in the unit included in the k^{th} jackknife replicate, and

1, for all buildings not belonging to the k^{th} stratum.

The standard methods described above are applied to each of the m completed data sets. The combined overall point estimate for each item is obtained as the mean of the full-sample estimates, $\bar{X}_m$, as follows

$$\bar{X}_m = \sum_{r=1}^{m} \hat{X}_r / m, \qquad \textbf{(11)}$$

where m is the number of completed full-sample data sets, and $\hat{X}_r$ is the full-sample point estimate for the r^{th} completed full-sample data set (Equation (2)).

The combined overall variances are estimated as the sum of two components:

- a within-completed data set component, $\bar{W}_m$, calculated as the mean of the full-sample variances,

$$\bar{W}_m = \sum_{r=1}^{m} \hat{S}^2_r / m, \qquad \textbf{(12)}$$

  where $\hat{S}^2_r$ is the mean square error estimate (Equation 9) for the r^{th} completed full-sample data set, and

- a between-completed data set component, B_m, estimated as the variance of the full-sample point estimates,

$$\mathbf{B}_m = \sum_{r=1}^{m} (\hat{X}_r - \bar{X}_m)^2 / (m-1). \qquad \textbf{(13)}$$

The total variance, V_m is

$$V_m = \bar{W}_m + (1 + m^{-1})\mathbf{B}_m. \qquad \textbf{(14)}$$

where the factor $(1 + m^{-1})$ is an adjustment for the use of a finite number of imputations.

The standard CBECS estimation methods have been incorporated into an EIA modification of TPL, TPL/VARIANCE, which produces publication-quality tables of estimates and their associated relative standard errors.[22] Incorporating multiple imputation in estimation would require further modification of TPL/VARIANCE. The estimates presented in this report were programmed in SAS using WESVAR[23]1 to produce the standard survey estimates.

[22]Paul M. Gargiullo, *TPL-VARIANCE: System Documentation*, Energy Information Administration, Office of Energy Markets and End Use; Paul M. Gargiullo and Miriam L. Goldberg, "A Modified Table Producing Language (TPL) System for Producing Tables of Survey Statistics with Variances," *Proceedings of the Bureau of the Census Fifth Annual Research Conference*, (Washington, DC: Bureau of the Census, 1989).

[23]Paul Flyer and Leyla Mohadjer, *The Wesvar Procedure* (Rockville, MD: Westat, Inc., 1988).

Appendix D

Relative Standard Errors

Table D1. Relative Standard Errors for Estimates of District Heat Consumption by CBECS Survey Year, for Buildings Constructed Before 1980
(Percent)

CBECS Survey Year	Floorspace Served by District Heat	District Heat Consumption	Consumption per Square Foot
1979	19.6	15.6	7.7
1983	18.1	26.4	15.5
1986	15.8	23.6	16.0
1989	23.1	22.8	15.2

Note: The 1979 and 1983 CBECS asked for purchased steam; the 1986 CBECS asked for purchased and nonpurchased steam and hot water; the 1989 CBECS asked for district steam or district hot water piped into the building.

Source: Energy Information Administration, Office of Energy Markets and End Use, 1979, 1983, 1986 and 1989 Commercial Buildings Energy Consumption Surveys.

Table D2. Relative Standard Errors for Principal Activity of Multibuilding Facility and Principal Activity of Commercial Buildings, Number of Buildings and Floorspace
(Percent)

Commercial Building Characteristics	All Buildings on Facilities	Principal Facility Activity				
		College and University	Other School	Office	Shopping Center and Mall	Hospital
	Buildings					
All Buildings on Facilities	3.7	16.8	10.8	12.3	11.4	17.7
Principal Building Activity						
Assembly	9.5	32.0	20.1	43.6	54.4	68.2
Education	11.6	24.5	12.4	100.0	NC	51.7
Food Sales and Service	16.4	51.6	29.7	NC	38.8	NC
Health Care	21.4	48.6	NC	43.8	NC	18.5
Lodging	10.2	19.6	53.9	75.4	84.6	53.6
Mercantile and Service	9.0	38.9	94.1	36.3	12.5	73.2
Office	9.2	40.6	42.8	14.1	57.1	26.2
Parking Garage	24.3	57.5	64.4	43.5	92.7	50.9
Warehouse	8.7	75.5	77.9	49.8	41.1	43.4
Other	27.1	43.5	0.3	45.4	NC	96.5
Vacant	14.5	67.2	76.4	22.3	49.6	87.2
Ownership and Occupancy						
Nongovernment Owned						
Owner Occupied	5.7	25.1	21.0	14.1	16.4	21.5
Nonowner Occupied	11.3	49.5	74.1	18.5	15.4	44.8
Government Owned	7.7	20.4	12.1	25.5	3.2	30.0
	Floorspace					
All Buildings on Facilities	5.4	21.9	10.7	18.0	13.8	20.0
Principal Building Activity						
Assembly	13.8	38.6	22.5	54.6	60.8	80.0
Education	10.3	33.1	11.2	100.0	NC	54.1
Food Sales and Service	17.3	50.5	23.4	NC	37.3	NC
Health Care	21.2	54.3	NC	49.2	NC	22.5
Lodging	12.2	18.4	73.1	70.8	70.9	34.5
Mercantile and Service	11.7	43.3	83.4	34.9	16.0	73.0
Office	13.2	39.5	39.2	21.4	55.2	23.4
Parking Garage	23.2	51.8	63.8	38.1	71.4	56.8
Warehouse	11.8	67.8	68.3	52.2	47.5	30.8
Other	23.2	52.0	0.3	41.6	NC	98.1
Vacant	26.2	59.0	82.9	19.0	43.5	63.9
Ownership and Occupancy						
Nongovernment Owned						
Owner Occupied	6.0	24.0	26.7	13.2	21.8	28.7
Nonowner Occupied	12.1	44.9	70.7	19.3	16.0	57.2
Government Owned	9.3	26.3	11.2	40.0	3.2	20.2

See footnotes at end of table.

Table D2. Relative Standard Errors for Principal Activity of Multibuilding Facility and Principal Activity of Commercial Buildings, Number of Buildings and Floorspace (Continued)
(Percent)

Commercial Building Characteristics	Principal Facility Activity					
	Industrial	Hotel and Motel	Entertainment Complex	Warehouse	Religious	Other
	Buildings					
All Buildings on Facilities	17.6	16.5	17.2	11.4	14.4	12.5
Principal Building Activity						
Assembly	89.9	99.0	17.7	1.9	18.0	42.9
Education	82.4	NC	NC	0.0	34.8	NC
Food Sales and Service	99.1	54.8	48.8	98.4	70.6	58.4
Health Care	NC	NC	NC	NC	NC	0.3
Lodging	NC	16.6	96.6	NC	78.9	70.3
Mercantile and Service	41.6	99.2	34.6	32.4	NC	17.8
Office	19.8	88.7	54.0	33.5	62.7	37.8
Parking Garage	87.2	NC	70.7	62.2	2.1	64.1
Warehouse	31.0	100.3	37.6	11.4	NC	25.5
Other	39.9	NC	8.2	98.7	NC	40.1
Vacant	33.2	100.3	74.7	29.8	63.3	39.2
Ownership and Occupancy						
Nongovernment Owned						
Owner Occupied	18.4	18.8	22.6	14.2	14.7	14.8
Nonowner Occupied	32.1	47.0	58.0	19.6	55.0	38.2
Government Owned	34.9	NC	21.6	51.4	NC	24.0
	Floorspace					
All Buildings on Facilities	16.5	13.7	16.8	15.0	16.6	17.6
Principal Building Activity						
Assembly	76.1	91.1	16.3	1.9	19.3	46.9
Education	75.3	NC	NC	NC	36.6	NC
Food Sales and Service	98.2	60.9	43.7	98.4	72.2	64.6
Health Care	NC	NC	NC	NC	NC	0.3
Lodging	NC	13.6	96.6	NC	73.9	71.5
Mercantile and Service	48.4	99.2	36.5	29.8	NC	21.5
Office	25.0	62.1	63.9	35.7	63.5	35.9
Parking Garage	75.1	NC	57.5	70.6	2.1	65.0
Warehouse	27.1	100.3	44.4	16	NC	32.3
Other	38.5	NC	8.2	98.7	NC	30.5
Vacant	29.1	100.3	80.7	57.2	68.3	47.0
Ownership and Occupancy						
Nongovernment Owned						
Owner Occupied	17.0	15.7	24.6	18.9	16.8	14.4
Nonowner Occupied	25.6	44.1	60.5	22.6	57.8	40.5
Government Owned	35.5	NC	27.9	49.2	NC	29.8

NC = No cases in sample.

Source: Energy Information Administration, Office of Energy Markets and End Use, Forms EIA-871A, "Building Questionnaire," and EIA-871B, "Facility Form" of the 1989 Commercial Buildings Energy Consumption Survey.

Table D3. Relative Standard Errors for Census Region of Commercial Buildings on Multibuilding Facilities, Number of Buildings and Floorspace
(Percent)

Commercial Building Characteristics	All Buildings on Facilities	Census Region			
		Northeast	Midwest	South	West
	Buildings				
All Buildings on Facilities	3.7	9.9	11.2	7.6	6.0
Principal Facility Activity					
College and University	16.8	17.6	34.3	17.1	35.1
Other School	10.8	40.7	26.0	18.5	14.2
Office	12.3	26.9	30.9	20.7	12.7
Shopping Center and Mall	11.4	16.0	25.3	22.1	30.0
Hospital	17.7	35.7	30.5	42.8	35.9
Industrial	17.6	29.5	18.1	30.1	36.9
Hotel and Motel	16.5	41.6	57.1	29.7	25.5
Entertainment Complex	17.2	32.8	35.5	27.9	40.7
Warehouse	11.4	29.7	18.6	21.5	29.2
Religious	14.4	19.1	32.8	22.9	34.1
Other	12.5	29.7	21.0	21.6	34.8
	Floorspace				
All Buildings on Facilities	5.4	14.6	12.0	10.4	10.3
Principal Facility Activity					
College and University	21.9	29.3	28.6	29.3	47.5
Other School	10.7	27.7	15.8	19.2	18.8
Office	18.0	31.2	31.1	31.9	19.3
Shopping Center and Mall	13.8	52.8	22.2	17.2	28.9
Hospital	20.0	30.2	43.0	22.5	33.7
Industrial	16.5	22.9	33.7	27.5	37.4
Hotel and Motel	13.7	47.8	65.5	27.8	17.5
Entertainment Complex	16.8	31.1	35.4	37.4	19.5
Warehouse	15.0	41.3	22.1	25.0	29.0
Religious	16.6	23.9	29.0	27.6	34.1
Other	17.6	41.4	16.9	28.6	37.8

Source: Energy Information Administration, Office of Energy Markets and End Use, Forms EIA-871A, "Building Questionnaire," and EIA-871B, "Facility Form" of the 1989 Commercial Buildings Energy Consumption Survey.

Table D4. Relative Standard Errors for Commercial Buildings by Presence of a Central Physical Plant on Multibuilding Facilities, Number of Buildings and Floorspace
(Percent)

Commercial Building Characteristics	All Buildings on Facilities	with Central Plant on Facility	Without Central Plant on Facility
	Buildings		
All Buildings on Facilities	3.7	10.9	3.8
Principal Facility Activity			
College and University	16.8	22.3	21.5
Other School	10.8	25.9	11.1
Office	12.3	34.6	13.2
Shopping Center and Mall	11.4	36.9	11.4
Hospital	17.7	18.8	37.2
Industrial	17.6	25.0	22.3
Hotel and Motel	16.5	48.3	18.4
Entertainment Complex	17.2	91.3	17.3
Warehouse	11.4	NC	11.4
Religious	14.4	59.7	14.6
Other	12.5	42.4	12.3
	Floorspace		
All Buildings on Facilities	5.4	13.0	6.3
Principal Facility Activity			
College and University	21.9	26.6	20.4
Other School	10.7	24.9	10.6
Office	18.0	24.3	20.4
Shopping Center and Mall	13.8	47.0	13.7
Hospital	20.0	26.6	29.0
Industrial	16.5	19.1	22.4
Hotel and Motel	13.7	47.3	14.7
Entertainment Complex	16.8	87.0	20.9
Warehouse	15.0	NC	15.0
Religious	16.6	54.5	16.7
Other	17.6	36.9	14.3

NC = No cases in sample.

Source: Energy Information Administration, Office of Energy Markets and End Use, Forms EIA-871A, "Building Questionnaire," and EIA-871B, "Facility Form" of the 1989 Commercial Buildings Energy Consumption Survey.

Table D5. Relative Standard Errors for Energy Consumed at Commercial Buildings on Multibuilding Facilities (Percent)

Commercial Building Characteristics	Major Fuels	Electricity	Natural Gas	Fuel Oil	District Heat
All Buildings on Facilities	11.2	11.1	12.7	26.4	24.3
Principal Facility Activity					
College and University	33.4	34.5	51.1	59.4	44.3
Other School	17.1	15.5	19.3	40.1	75.5
Office	12.4	12.6	21.5	62.0	37.7
Shopping Center and Mall	16.0	17.3	21.6	48.9	NC
Hospital	27.0	16.5	28.9	51.1	46.0
Industrial	25.7	29.4	43.9	94.9	40.3
Hotel and Motel	21.0	20.0	26.7	64.0	75.1
Entertainment Complex	22.1	19.0	32.0	27.3	NC
Warehouse	25.5	29.6	33.1	43.8	NC
Religious	15.4	16.5	18.9	35.4	3.0
Other	24.9	36.1	23.1	57.2	75.7
Central Physical Plant					
Present on Facility	19.6	20.8	24.8	43.9	25.3
Not Present on Facility	8.1	9.2	9.0	19.6	39.0

NC = No cases in sample.
Note: "District Heat" includes district steam and district hot water.
Source: Energy Information Administration, Office of Energy Markets and End Use, Forms EIA-871A through EIA-871F of the 1989 Commercial Buildings Energy Consumption Survey.

Table D6. Relative Standard Errors for Number and Floorspace of Multibuilding Facilities with Central Physical Plants (Percent)

Facility Characteristics	Number of Facilities	Facility Floorspace		Floorspace per Facility	Percent Commercial Floorspace
		Total	Commercial		
	All Sectors				
All Facilities	19.6	17.6	14.1	19.7	11.9
Census Region					
Northeast	45.6	23.2	22.0	25.9	11.4
Midwest	43.6	24.0	28.1	32.6	15.5
South	30.6	31.4	17.6	30.3	25.9
West	39.7	37.6	32.8	39.5	5.0
Total Floorspace (square feet)					
200,000 or Less	29.8	34.2	24.3	15.5	18.6
200,001 to 500,000	30.3	30.4	20.9	3.9	25.2
500,001 to 1,000,000	28.4	27.3	24.8	4.6	11.2
1,000,001 to 5,000,000	23.2	24.0	21.1	9.3	16.8
Over 5,000,000	42.1	46.8	37.5	17.9	32.6
	Commercial Sector				
All Facilities	20.1	17.2	15.6	21.5	2.7
Census Region					
Northeast	30.8	24.0	24.3	29.7	4.5
Midwest	29.6	30.0	30.7	28.9	2.2
South	40.9	20.9	22.1	32.1	4.0
West	24.1	38.4	32.0	36.7	5.7
Principal Facility Activity					
College and University	28.4	31.2	27.3	31.4	4.0
Other School	41.0	26.2	26.4	26.6	5.4
Office	42.4	27.0	27.1	44.1	.5
Hospital	28.2	28.3	29.7	26.1	4.9
Other	35.1	32.2	32.3	27.4	4.7
Total Floorspace (square feet)					
200,000 or Less	36.2	27.5	27.9	15.9	3.8
200,001 to 500,000	28.9	29.3	28.8	5.2	4.2
500,001 to 1,000,000	26.8	25.3	25.8	4.3	4.7
1,000,001 to 5,000,000	25.9	21.9	22.4	7.8	1.8
Over 5,000,000	44.5	43.5	38.4	4.7	7.0

See footnotes at end of table.

Table D6. Relative Standard Errors for Number and Floorspace of Multibuilding Facilities with Central Physical Plants (Continued)
(Percent)

Facility Characteristics	Number of Facilities	Facility Floorspace		Floorspace per Facility	Percent Commercial Floorspace
		Total	Commercial		
	Industrial Sector				
All Facilities	30.6	31.0	20.5	30.2	27.1
Census Region					
Northeast	76.4	51.1	29.4	32.4	31.2
Midwest	71.7	42.4	42.0	57.1	30.8
South	41.4	46.0	34.8	38.8	34.5
West	120.0	53.1	60.6	68.4	15.5
Total Floorspace (square feet)					
200,000 or Less	42.2	49.7	48.0	20.5	14.8
200,001 to 500,000	45.8	46.2	36.7	5.3	35.9
500,001 to 1,000,000	125.4	120.5	93.0	10.1	47.8
1,000,001 to 5,000,000	48.4	57.3	42.6	28.9	70.8
Over 5,000,000	71.6	86.6	80.3	41.0	46.8

Note: "All Sectors" estimates include multibuilding residential facilities.
Source: Energy Information Administration, Office of Energy Markets and End Use, Form EIA-871B, "Facility Form" of the 1989 Commercial Buildings Energy Consumption Survey.

Table D7. Relative Standard Errors for Number of Buildings on Multibuilding Facilities with Central Plants, Number of Facilities
(Percent)

Facility Characteristics	All Facilities	Number of Buildings on Facility				
		4 or Less	5 to 10	11 to 25	26 to 100	Over 100
	All Sectors					
All Facilities	19.6	33.1	39.5	41.5	42.1	38.4
Total Floorspace (square feet)						
200,000 or Less	29.8	42.0	46.7	84.3	122.1	NC
200,001 to 500,000	30.3	38.4	48.8	55.2	65.0	88.5
500,001 to 1,000,000	28.4	45.5	74.8	52.7	52.6	96.3
1,000,001 to 5,000,000	23.2	91.1	63.1	45.8	29.9	67.0
Over 5,000,000	42.1	110.8	91.7	70.3	133.7	47.7
	Commercial Sector					
All Facilities	20.1	38.1	27.7	31.0	25.7	44.3
Principal Facility Activity						
College and University	28.4	78.0	86.5	57.1	39.8	51.9
Other School	41.0	59.2	40.4	96.9	76.9	98.3
Office	42.4	56.2	62.0	95.5	81.2	74.4
Hospital	28.2	50.3	63.4	44.7	29.2	72.3
Other	35.1	55.2	64.8	83.9	101.3	94.1
Total Floorspace (square feet)						
200,000 or Less	36.2	48.0	38.9	79.5	155.9	NC
200,001 to 500,000	28.9	52.2	51.6	46.4	143.5	NC
500,001 to 1,000,000	26.8	45.8	78.4	62.7	48.2	99.2
1,000,001 to 5,000,000	25.9	60.2	70.2	44.0	25.6	67.2
Over 5,000,000	44.5	110.8	100.9	128.4	73.5	50.0
	Industrial Sector					
All Facilities	30.6	61.0	53.0	69.4	60.5	70.3
Total Floorspace (square feet)						
200,000 or Less	42.2	80.5	55.3	106.8	128.2	0.0
200,001 to 500,000	45.8	59.1	142.6	97.0	69.5	88.5
500,001 to 1,000,000	125.4	28.9	177.7	83.6	142.1	146.3
1,000,001 to 5,000,000	48.4	135.9	128.7	102.8	128.5	159.9
Over 5,000,000	71.6	0.0	20.4	70.8	1.0	134.1

NC = No cases in sample.
Note: "All Sectors" estimates include multibuilding residential facilities.
Source: Energy Information Administration, Office of Energy Markets and End Use, Form EIA-871B, "Facility Form" of the 1989 Commercial Buildings Energy Consumption Survey.

Table D8. Relative Standard Errors for Qualifying Facilities and Cogeneration, Number of Multibuilding Facilities (Percent)

Facility Characteristics	Number of Facilities	Qualifying Facilities	Cogeneration System	
			Total	Connected to Grid
		All Sectors		
All Facilities	19.6	40.1	50.6	54.5
Total Floorspace (square feet)				
200,000 or Less	29.8	68.6	119.1	129.4
200,001 to 500,000	30.3	61.7	65.5	67.0
500,001 to 1,000,000	28.4	37.3	88.9	91.0
1,000,001 to 5,000,000	23.2	34.3	55.8	77.3
Over 5,000,000	42.1	65.2	37.3	47.9
		Commercial Sector		
All Facilities	20.1	52.6	118.0	144.0
Principal Facility Activity				
College and University	28.4	61.8	90.7	103.6
Other School	41.0	96.0	286.4	360.8
Office	42.4	63.1	103.5	110.2
Hospital	28.2	46.7	60.8	66.1
Other	35.1	80.1	129.4	147.7
Total Floorspace (square feet)				
200,000 or Less	36.2	79.9	238.1	319.6
200,001 to 500,000	28.9	62.9	166.3	202.3
500,001 to 1,000,000	26.8	40.9	112.0	111.6
1,000,001 to 5,000,000	25.9	36.4	46.0	47.6
Over 5,000,000	44.5	104.0	42.5	56.4
		Industrial Sector		
All Facilities	30.6	56.8	61.1	62.2
Total Floorspace (square feet)				
200,000 or Less	42.2	106.9	155.2	157.5
200,001 to 500,000	45.6	79.6	69.6	70.0
500,001 to 1,000,000	125.4	156.8	131.5	141.8
1,000,001 to 5,000,000	48.4	72.6	189.5	350.7
Over 5,000,000	71.6	67.5	61.3	69.5

Note: "All Sectors" estimates include multibuilding residential facilities.

Source: Energy Information Administration, Office of Energy Markets and End Use, Form EIA-871B, "Facility Form" of the 1989 Commercial Buildings Energy Consumption Survey.

Table D9. Relative Standard Errors for Number of Multibuilding Facilities by Types of Central Physical Plant Energy Outputs
(Percent)

Facility Characteristics	Number of Facilities	Types of Energy Outputs			
		Steam	Hot Water	Chilled Water	Electricity
	All Sectors				
All Facilities	19.6	23.4	34.2	22.1	39.9
Census Region					
Northeast	45.6	53.4	40.9	31.4	94.4
Midwest	43.6	28.2	69.9	41.4	57.2
South	30.6	34.8	56.5	34.8	52.3
West	39.7	45.7	77.2	55.1	115.0
Energy Outputs					
Steam	23.4	23.4	31.1	32.1	43.5
Hot Water	34.2	31.1	34.2	30.3	112.1
Chilled Water	22.1	32.1	30.3	22.1	67.1
Electricity	39.9	43.5	112.1	67.1	39.9
Energy Inputs					
Fuel Oil	33.3	36.5	42.2	58.3	54.4
Natural Gas	23.4	27.8	32.7	25.4	45.5
Coal	53.3	56.6	109.1	74.1	73.4
Electricity	27.1	34.5	45.5	24.9	51.2
	Commercial Sector				
All Facilities	20.1	26.7	35.1	19.1	41.7
Principal Facility Activity					
College and University	28.4	33.5	42.4	29.4	80.6
Other School	41.0	54.6	62.6	47.2	123.3
Office	42.4	42.3	61.7	50.4	66.5
Hospital	28.2	33.6	67.5	44.1	66.7
Other	35.1	44.8	56.3	49.2	96.0
Census Region					
Northeast	30.8	36.3	69.5	43.4	147.0
Midwest	29.6	35.8	55.9	47.6	60.6
South	40.9	53.4	59.6	34.3	60.7
West	24.1	32.0	44.7	36.4	85.6
Energy Outputs					
Steam	26.7	26.7	45.2	27.6	51.1
Hot Water	35.1	45.2	35.1	38.7	87.0
Chilled Water	19.1	27.6	38.7	19.1	51.9
Electricity	41.7	51.1	87.0	51.9	41.7
Energy Inputs					
Fuel Oil	24.0	26.2	45.8	41.1	70.8
Natural Gas	17.9	17.8	38.6	19.8	41.6
Coal	77.8	79.0	115.3	82.4	79.5
Electricity	18.7	24.2	35.9	23.6	44.9

See footnotes at end of table.

Table D9. Relative Standard Errors for Number of Multibuilding Facilities by Types of Central Physical Plant Energy Outputs (Continued)
(Percent)

Facility Characteristics	Number of Facilities	Types of Energy Outputs			
		Steam	Hot Water	Chilled Water	Electricity
	Industrial Sector				
All Facilities	30.6	33.6	78.3	97.7	50.9
Census Region					
Northeast	76.4	77.5	108.3	328.0	190.5
Midwest	71.7	62.3	98.5	96.5	83.3
South	41.4	42.9	198.7	122.9	60.3
West	120.0	143.9	166.3	175.0	186.8
Energy Outputs					
Steam	33.6	33.6	83.6	108.7	53.8
Hot Water	78.3	83.6	78.3	81.3	229.2
Chilled Water	97.7	108.7	81.3	97.7	287.8
Electricity	50.9	53.8	229.2	287.8	50.9
Energy Inputs					
Fuel Oil	43.9	44.4	168.1	187.7	61.2
Natural Gas	39.4	41.2	127.3	103.9	73.2
Coal	72.2	81.8	501.9	148.8	76.9
Electricity	44.7	52.5	81.4	98.2	101.6

Note: "All Sectors" estimates include multibuilding residential facilities.
Source: Energy Information Administration, Office of Energy Markets and End Use, Form EIA-871B, "Facility Form" of the 1989 Commercial Buildings Energy Consumption Survey.

Table D10. Relative Standard Errors for Central Physical Plant Energy Output Quantities
(Percent)

Facility Characteristics	Total Outputs	Steam	Hot Water	Chilled Water	Electricity
	All Sectors				
All Facilities	36.4	42.9	35.3	38.1	48.9
Census Region					
Northeast	52.9	62.8	63.5	68.1	81.5
Midwest	30.6	30.8	61.2	53.4	42.6
South	51.8	58.0	78.1	68.3	71.5
West	30.7	28.8	59.2	53.1	47.6
Energy Inputs					
Fuel Oil	53.9	63.2	67.5	70.3	62.4
Natural Gas	23.2	26.6	40.6	37.1	31.1
Coal	49.7	52.5	69.5	168.4	61.9
Electricity	24.7	29.2	43.8	33.7	35.5
Energy Outputs					
Steam	37.9	42.9	54.4	38.4	52.7
Hot Water	50.0	128.5	35.3	52.4	64.5
Chilled Water	40.0	57.4	52.1	38.1	54.2
Electricity	54.1	63.8	56.3	58.5	48.9
	Commercial Sector				
All Facilities	18.9	19.7	43.8	30.3	32.7
Principal Facility Activity					
College and University	31.8	32.7	65.6	49.0	52.3
Other School	28.2	38.6	55.2	61.9	139.5
Office	32.6	39.0	62.7	58.1	59.2
Hospital	26.0	30.9	53.9	43.8	38.2
Other	41.7	52.4	98.6	117.4	91.3
Census Region					
Northeast	36.9	39.4	69.2	69.1	79.8
Midwest	37.3	37.0	62.1	58.0	56.3
South	37.2	30.6	75.7	48.5	48.8
West	31.2	23.4	66.4	63.0	50.5
Energy Inputs					
Fuel Oil	24.7	24.5	71.5	39.6	41.9
Natural Gas	20.9	21.6	49.3	31.8	33.9
Coal	55.4	51.9	72.0	90.5	73.4
Electricity	23.2	22.9	53.6	31.5	35.0
Energy Outputs					
Steam	20.7	19.7	72.6	34.8	36.2
Hot Water	38.2	48.2	43.8	64.7	67.6
Chilled Water	28.7	34.0	58.6	30.3	39.7
Electricity	34.3	40.4	67.1	41.3	32.7

See footnotes at end of table.

Table D10. Relative Standard Errors for Central Physical Plant Energy Output Quantities (Continued)
(Percent)

Facility Characteristics	Total Outputs	Steam	Hot Water	Chilled Water	Electricity
	Industrial Sector				
All Facilities	45.7	50.5	112.3	118.5	59.6
Census Region					
Northeast	107.8	116.2	201.0	264.6	129.2
Midwest	43.5	43.0	126.7	88.3	56.9
South	55.8	60.3	237.5	172.4	76.7
West	59.0	109.0	81.3	68.9	93.9
Energy Inputs					
Fuel Oil	65.3	73.5	302.4	165.2	69.6
Natural Gas	35.0	37.0	151.1	131.8	49.1
Coal	56.9	60.6	105.8	453.0	67.8
Electricity	41.2	42.7	110.7	100.5	55.3
Energy Outputs					
Steam	46.1	50.5	160.6	109.0	62.4
Hot Water	147.0	236.4	112.3	78.4	104.7
Chilled Water	124.1	152.7	162.7	118.5	181.2
Electricity	61.8	69.8	117.1	267.1	59.6

Note: "All Sectors" estimates include multibuilding residential facilities.
Source: Energy Information Administration, Office of Energy Markets and End Use, Form EIA-871B, "Facility Form" of the 1989 Commercial Buildings Energy Consumption Survey.

Table D11. Relative Standard Errors for Number of Multibuilding Facilities by Types of Central Physical Plant Energy Inputs
(Percent)

Facility Characteristics	Number of Facilities	Types of Energy Inputs			
		Fuel Oil	Natural Gas	Coal	Electricity
	All Sectors				
All Facilities	19.6	33.3	23.4	53.3	27.1
Census Region					
Northeast	45.6	54.9	52.9	126.0	35.3
Midwest	43.6	55.8	26.4	40.6	59.9
South	30.6	47.4	41.8	59.6	44.4
West	39.7	82.9	45.4	81.2	46.5
Energy Inputs					
Fuel Oil	33.3	33.3	44.7	74.2	52.0
Natural Gas	23.4	44.7	23.4	48.4	32.6
Coal	53.3	74.2	48.4	53.3	49.8
Electricity	27.1	52.0	32.6	49.8	27.1
Energy Outputs					
Steam	23.4	36.5	27.8	56.6	34.5
Hot Water	34.2	42.2	32.7	109.1	45.5
Chilled Water	22.1	58.3	25.4	74.1	24.9
Electricity	39.9	54.4	45.5	73.4	51.2
	Commercial Sector				
All Facilities	20.1	24.0	17.9	77.8	18.7
Principal Facility Activity					
College and University	28.4	58.8	32.8	62.8	29.4
Other School	41.0	58.6	43.5	85.8	42.9
Office	42.4	82.8	38.2	306.0	53.6
Hospital	28.2	38.0	31.5	131.1	33.9
Other	35.1	61.3	38.3	205.3	48.7
Census Region					
Northeast	30.8	37.6	50.6	141.1	48.2
Midwest	29.6	60.3	29.8	60.1	36.6
South	40.9	51.5	39.0	91.7	32.2
West	24.1	51.6	27.7	82.0	30.4
Energy Inputs					
Fuel Oil	24.0	24.0	30.7	102.4	37.5
Natural Gas	17.9	30.7	17.9	74.8	20.2
Coal	77.8	102.4	74.8	77.8	68.1
Electricity	18.7	37.5	20.2	68.1	18.7
Energy Outputs					
Steam	26.7	26.2	17.8	79.0	24.2
Hot Water	35.1	45.8	38.6	115.3	35.9
Chilled Water	19.1	41.1	19.8	82.4	23.6
Electricity	41.7	70.8	41.6	79.5	44.9

See footnotes at end of table.

Table D11. Relative Standard Errors for Number of Multibuilding Facilities by Types of Central Physical Plant Energy Inputs (Continued)
(Percent)

Facility Characteristics	Number of Facilities	Types of Energy Inputs			
		Fuel Oil	Natural Gas	Coal	Electricity
	Industrial Sector				
All Facilities	30.6	43.9	39.4	72.2	44.7
Census Region					
Northeast	76.4	85.0	76.8	242.6	58.4
Midwest	71.7	53.8	75.2	41.3	96.2
South	41.4	52.4	57.6	76.4	58.2
West	120.0	278.1	128.9	NC	148.9
Energy Inputs					
Fuel Oil	43.9	43.9	59.8	79.5	70.9
Natural Gas	39.4	59.8	39.4	64.9	54.3
Coal	72.2	79.5	64.9	72.2	55.9
Electricity	44.7	70.9	54.3	55.9	44.7
Energy Outputs					
Steam	33.6	44.4	41.2	81.8	52.5
Hot Water	78.3	168.1	127.3	501.9	81.4
Chilled Water	97.7	187.7	103.9	148.8	98.2
Electricity	50.9	61.2	73.2	76.9	101.6

Note: "All Sectors" estimates include multibuilding residential facilities.
Source: Energy Information Administration, Office of Energy Markets and End Use, Form EIA-871B, "Facility Form" of the 1989 Commercial Buildings Energy Consumption Survey.

Table D12. Relative Standard Errors for Central Physical Plant Energy Input Quantities
(Percent)

Facility Characteristics	Total Inputs	Fuel Oil	Natural Gas	Coal	Electricity
	All Sectors				
All Facilities	42.8	79.1	24.8	96.5	63.1
Census Region					
Northeast	43.3	62.3	57.8	101.8	54.6
Midwest	28.8	58.7	35.8	42.1	54.1
South	60.5	92.4	42.9	172.4	92.8
West	33.3	84.5	36.2	135.0	44.8
Energy Inputs					
Fuel Oil	63.0	79.1	32.3	159.3	100.6
Natural Gas	22.3	27.7	24.8	48.5	42.6
Coal	108.3	177.4	69.9	96.5	263.8
Electricity	37.7	42.5	27.4	77.0	63.1
Energy Outputs					
Steam	44.3	79.3	26.7	97.0	68.7
Hot Water	41.5	48.4	62.7	80.7	67.7
Chilled Water	78.2	90.0	34.3	147.1	124.7
Electricity	70.0	92.6	39.8	113.4	185.9
	Commercial Sector				
All Facilities	21.3	59.2	19.7	60.5	38.0
Principal Facility Activity					
College and University	39.4	148.9	37.3	65.2	67.8
Other School	36.2	80.3	46.2	82.3	85.0
Office	34.2	62.7	43.2	125.9	48.3
Hospital	34.0	29.4	39.0	147.2	55.4
Other	39.2	57.3	44.9	132.6	70.5
Census Region					
Northeast	35.1	81.2	45.4	98.0	40.4
Midwest	41.8	60.5	44.0	67.4	75.8
South	41.6	54.6	35.1	79.4	65.2
West	32.1	84.7	40.0	106.8	57.8
Energy Inputs					
Fuel Oil	24.0	59.2	33.2	51.9	31.6
Natural Gas	22.7	32.0	19.7	66.9	39.1
Coal	60.5	60.3	79.3	60.5	57.0
Electricity	26.6	34.3	27.4	66.6	38.0
Energy Outputs					
Steam	24.2	61.6	21.3	61.6	44.6
Hot Water	41.3	60.5	45.2	74.0	71.0
Chilled Water	34.6	40.1	29.7	97.4	43.6
Electricity	44.4	59.6	40.1	75.7	57.6

See footnotes at end of table.

Table D12. Relative Standard Errors for Central Physical Plant Energy Inputs (Continued)
(Percent)

Facility Characteristics	Total Inputs	Fuel Oil	Natural Gas	Coal	Electricity
	Industrial Sector				
All Facilities	53.5	90.2	35.0	122.4	88.1
Census Region					
Northeast	77.0	61.7	88.4	112.4	103.8
Midwest	39.2	89.1	70.3	50.4	65.6
South	64.7	93.5	47.2	175.4	115.7
West	63.1	157.7	74.1	NC	72.1
Energy Inputs					
Fuel Oil	75.3	90.2	54.3	188.7	116.0
Natural Gas	31.3	52.9	35.0	60.0	58.5
Coal	133.3	178.6	110.2	122.4	286.7
Electricity	59.0	77.0	42.3	139.5	88.1
Energy Outputs					
Steam	53.9	90.1	35.6	122.6	92.5
Hot Water	122.5	171.1	211.8	173.3	129.3
Chilled Water	219.0	274.3	162.6	417.7	246.5
Electricity	80.6	94.4	61.2	142.5	264.7

Note: "All Sectors" estimates include multibuilding residential facilities. "Total Inputs" includes inputs of other fuels, not shown separately.

Source: Energy Information Administration, Office of Energy Markets and End Use, Form EIA-871B, "Facility Form" of the 1989 Commercial Buildings Energy Consumption Survey.

Table D13. Relative Standard Errors for Central Physical Plant Energy Output-Input Ratios
(Percent)

Facility Characteristics	Total Outputs	Total Inputs	Output/Input Ratio
	All Sectors		
All Facilities	36.4	42.8	19.0
Census Region			
Northeast	52.9	43.3	22.4
Midwest	30.6	28.8	12.6
South	51.8	60.5	26.4
West	30.7	33.3	11.4
Energy Inputs			
Fuel Oil	53.9	63.0	27.7
Natural Gas	23.2	22.3	9.9
Coal	49.7	108.3	27.2
Electricity	24.7	37.7	18.0
Energy Outputs			
Steam	37.9	44.3	20.2
Hot Water	50.0	41.5	16.9
Chilled Water	40.0	78.2	26.7
Electricity	54.1	70.0	28.2
	Commercial Sector		
All Facilities	18.9	21.3	11.4
Principal Facility Activity			
College and University	31.8	39.4	16.2
Other School	28.2	36.2	26.1
Office	32.6	34.2	16.4
Hospital	26.0	34.0	23.3
Other	41.7	39.2	25.7
Census Region			
Northeast	36.9	35.1	28.2
Midwest	37.3	41.8	15.3
South	37.2	41.6	20.4
West	31.2	32.1	13.0
Energy Inputs			
Fuel Oil	24.7	24.0	14.9
Natural Gas	20.9	22.7	11.3
Coal	55.4	60.5	7.6
Electricity	23.2	26.6	12.5
Energy Outputs			
Steam	20.7	24.2	13.4
Hot Water	38.2	41.3	16.8
Chilled Water	28.7	34.6	13.6
Electricity	34.3	44.4	17.9

See footnotes at end of table.

Table D13. Relative Standard Errors for Central Physical Plant Energy Output-Input Ratios (Continued)
(Percent)

Facility Characteristics	Total Outputs	Total Inputs	Output/Input Ratio
	Industrial Sector		
All Facilities	45.7	53.5	23.4
Census Region			
Northeast	107.8	77.0	29.5
Midwest	43.5	39.2	11.3
South	55.8	64.7	27.6
West	59.0	63.1	17.3
Energy Inputs			
Fuel Oil	65.3	75.3	32.5
Natural Gas	35.0	31.3	15.7
Coal	56.9	133.3	29.2
Electricity	41.2	59.0	26.2
Energy Outputs			
Steam	46.1	53.9	24.1
Hot Water	147.0	122.5	28.3
Chilled Water	124.1	219.0	49.4
Electricity	61.8	80.6	32.0

Note: "All Sectors" estimates include multibuilding residential facilities.
Source: Energy Information Administration, Office of Energy Markets and End Use, Form EIA-871B, "Facility Form" of the 1989 Commercial Buildings Energy Consumption Survey.

Glossary

Agricultural: As used in this survey, activities involving the production, processing, sale, storage, or housing of agricultural products, including livestock. (See **Commercial**, **Manufacturing/Industrial**, **Residential**, and **Sector**.)

All Sectors: See **Sector**.

Barrel: A volumetric unit of measure for crude oil and petroleum products equivalent to 42 U.S. gallons. (See **Gallon**.)

Boiler: A type of space-heating equipment consisting of a vessel or tank where heat produced from the combustion of fuels such as natural gas, fuel oil, or coal is used to generate hot water or steam. Many buildings have their own boilers, while other buildings have steam or hot water piped in from a central plant. Steam or hot water piped into a building from a central plant is considered district heat. (See **District Heat**.)

British Thermal Unit: The amount of energy required to increase the temperature of 1 pound of water by 1 degree Fahrenheit, at standard conditions of temperature and pressure. Energy consumption is expressed in Btu in this report to allow for consumption comparisons among fuels that are measured in different units. (See **Btu Conversion Factors**, **Metric Conversion Factors**.)

Btu: See **British Thermal Unit**.

Btu Conversion Factors: The Btu conversion factors for this survey are as follows:

	Btu Equivalent	Unit
Electricity	3,412	kilowatthour
Natural Gas	1,030	cubic foot
Distillate Fuel Oils (Nos. 1,2, and 4)	138,690	gallon
Residual Fuel Oils (Nos. 5 and 6)	149,690	gallon
District Heat (Steam and Hot Water)	1,000	pound

Sources: Energy Information Administration, *Monthly Energy Review* (June 1991), pp. 125-129 for electricity, natural gas, distillate, and residual; and *Methodological Issues In the Nonresidential Buildings Energy Consumption Survey* (September 1983) pp. 173-175 for district steam.

For district chilled water conversions, see **Coefficient of Performance** and Appendix B, "Data Quality."

Building: For this survey, a structure totally enclosed by walls extending from the foundation to the roof, containing over 1,000 square feet of floorspace, and intended for human occupancy. Structures that were included in the survey as a specific exception were parking garages not totally enclosed by walls and a roof, as well as structures erected on pillars to elevate the first fully enclosed level, but leaving the sides at ground level open.

Excluded from the survey as nonbuildings were the following: structures (other than the exceptions just noted) that were not totally enclosed by walls and a roof (such as oil refineries, steel mills, and water towers); street lights, pumps, billboards, bridges, swimming pools, and construction sites; mobile homes and trailers, even if they housed commercial activity; and oil storage tanks. (See **Commercial Building**.)

Census Region: A geographic area consisting of several States defined by the U.S. Department of Commerce, Bureau of the Census. The States are grouped into four regions:

Region	States
Northeast	Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Vermont, and Rhode Island
Midwest	Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin
South	Alabama, Arkansas, Delaware, the District of Columbia, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and West Virginia
West	Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming

Central Physical Plant: A plant that is owned by, and on the grounds of, a multibuilding facility and that provides district heating, district cooling, or electricity to one or more other buildings on the same facility. The central physical plant may be by itself in a separate building or may be located in a building where other activities occur. In this report, the forms of energy provided by the central physical plant to the other buildings on the same facility are referred to as outputs. The forms of energy consumed at the central physical plant in order to provide the outputs are referred to as inputs. (See **District Heat**, **District Chilled Water**, and **Multibuilding Facility**.)

Coal: In this report, the term includes anthracite, bituminous, and subbituminous coal, as well as the derivative of coal known as coke.

Coefficient of Performance: The ratio of the rate of heat removal (Btu of cooling) to the rate of energy input (Btu). One ton-hour (district chilled water) is equivalent to 12,000 Btu of cooling. (See **Btu Conversion Factors** and **District Chilled Water**.)

Cogeneration: The sequential generation of electric power and useful heat by a single process. Neither generation of electricity without use of the byproduct heat, nor waste-heat recovery from processes other than electricity generation is included in the definition of cogeneration. (See **Electricity Generation**.)

Commercial Building: A building with more than 50 percent of its floorspace used for commercial activities. Commercial buildings include, but are not limited to, stores, offices, schools, churches, gymnasiums, libraries, museums, hospitals, clinics, warehouses, and jails. Government buildings were included except for buildings on site with restricted access, such as some military bases or reservations. Farms and buildings located on farms (such as silos, grain elevators, and barns) were excluded from the survey. (See **Building, Commercial, Residential, Manufacturing/Industrial, Agricultural**, and **Principal Building Activity.**)

Commercial: Neither residential, industrial, nor agricultural. (See **Residential**, **Manufacturing/Industrial**, **Agricultural,** and **Commercial Building**.)

Commercial Sector: See **Sector**.

Connected to the Grid: Electrically interconnected with an electric utility. (See **Electricity Generation**.)

Conversion Factors: See **Btu Conversion Factors** and **Metric Conversion Factors**.

COP: See **Coefficient of Performance**.

Cubic Foot: As a natural gas measure, the amount of gas contained in a cube with an edge that is 1 foot long at standard temperature and pressure conditions (60 degrees Fahrenheit and 14.73 pounds standard per square inch.) The thermal content varies by the composition of the gas. (See **Natural Gas** and **Btu.)**

District Chilled Water: Chilled water from an outside source used as an energy source for cooling in a building. The water is chilled in a central plant and piped into the building. Chilled water may be purchased from a utility or provided by a central physical plant in a separate building that is part of the same multibuilding facility (for example, a hospital complex or university). (See **Central Physical Plant** and **Multibuilding Facility**.)

District Heat: Steam or hot water from an outside source used as an energy source for space heating or another end use in a building. The steam or hot water is produced in a central plant and piped into the building. The district heat may be purchased from a utility or provided by a central physical plant in a separate building that is part of the same multibuilding facility (for example, a hospital complex or university). (See **Central Physical Plant** and **Multibuilding Facility**.)

District Hot Water: District heat in the form of hot water. (See **District Heat**.)

District Steam: District heat in the form of steam. (See **District Heat**.)

Electricity: Electric energy, usually measured in kilowatthours. In this report, electricity is reported both as energy supplied to a central physical plant by an electric utility via power lines and as electricity generated by a central physical plant on a multibuilding facility. (See **Central Physical Plant**, **Electricity Generation**, and **Kilowatthour**.)

Electricity Generation: The onsite production of electricity using electricity generators on either a regular or emergency basis. (See **Electricity** and **Cogeneration**.)

Facility: See **Multibuilding Facility**.

Floorspace: All the area enclosed by the exterior walls of a building, including indoor parking facilities, basements, hallways, lobbies, stairways, and elevator shafts. (See **Square Footage**.)

Fuel Oil: A liquid petroleum product less volatile than gasoline, used as an energy source. In this report, fuel oil includes distillate fuel oil (No. 1, No. 2, and No. 4,), residual fuel oil (No. 5 and No. 6), and kerosene.

Gallon: A volumetric measure equal to 4 quarts (231 cubic inches) used to measure fuel oil. One barrel equals 42 gallons. (See **Barrel**.)

Government Owned: Owned by a Federal, State, or local government agency. The building may be occupied by agencies of more than one government and may also be shared with nongovernment establishments.

Hot-Deck Imputation: An imputation procedure using random resampling from nonmissing cases to fill in values for missing cases. (See **Imputation** and Appendix C, "Estimation.")

Imputation: A statistical method used to fill in values for missing items, designed to minimize the bias of estimates based on the filled-in data set. (See **Hot-Deck Imputation,** and Appendix C, "Estimation.")

Industrial: See **Manufacturing/Industrial**.

Industrial Sector: See **Sector**.

Input: See **Central Physical Plant**.

In Scope: Meeting the requirements for eligibility in the CBECS, and, therefore, included in the population covered by the survey. For the 1989 survey, these eligibility requirements were (a) that the structure be a building, according to the CBECS definition; (b) that the building be larger than 1,000 square feet; and (c) that more than 50 percent of the floorspace be used for commercial activities. (See **Building, Commercial, Floorspace**.)

Kilowatthour: A unit of work or energy, measured as 1 kilowatt (1,000 watts) of power expended for 1 hour.

Manufacturing/Industrial: As used in this survey, activities involving the processing or procurement of goods, merchandise, raw materials, or food. These activities include: food processing; leather/textile mills; light assembly factories, such as those for apparel and electronic instruments; heavy assembly factories, such as those for machinery and other heavy equipment; paper processing; chemical or petroleum processing, metalworks, glassworks, and other similar manufacturing plants; printing and publishing; generation, transmission, or distribution of electricity, natural gas, steam, or other utility or sanitary service; and construction and natural resource procurement.

Metric Conversion Factors: In this report, estimates are presented in customary U.S. units. Floorspace estimates may be converted to metric units by using the relationship, 1 square foot is approximately equal to .0929 square meters. Energy estimates may be converted to metric units by using the relationship, 1 Btu is approximately equal to 1,055 joules. (See **Btu**.)

Multibuilding Facility: A group of two or more buildings on the same site owned or operated by a single organization, business, or individual. Examples include university campuses and hospital complexes. (See **Building** and **Facility**.)

Multiple Imputation: The independent imputation of two more acceptable value for each missing item. The multiple imputation estimates can be combined to obtain variance estimates which include the effects of the imputation. (See **Imputation**, **Variance**, and Appendix C, "Estimation.")

Natural Gas: Hydrocarbon gas (mostly methane) supplied as an energy source to individual buildings by pipelines from a central utility company. Natural gas does not refer to liquefied petroleum gas or to privately owned gas wells operated by a building owner.

Network Estimator: A statistical technique which allows analysis of units other than those that were directly sampled. In this report, the facility-level estimates are based on the 1989 CBECS building-level sample. (See **Sampling** and Appendix C, "Estimation.")

Out of Scope: Violating one or more of the requirements for eligibility in the survey, therefore not included in the population covered by the 1989 CBECS. (See **In Scope**.)

Output: See **Central Physical Plant**.

Output-Input Ratio: The ratio of the amount (in Btu) of energy output by a central physical plant to the amount (in Btu) of input energy required. (See **Btu** and **Central Physical Plant**.)

Owner Occupied: Having the owner or the owner's business represented at the site. A building is considered owner occupied if an employee or representative of the owner (such as a building engineer or building manager) maintains office space in the building. Similarly, a chain store is considered owner occupied even though the actual owner may not be in the building but headquartered elsewhere. Other examples of the owner's business occupying a building include State-owned university buildings, elementary and secondary schools owned by a public school district, and a post office where the building is owned by the U.S. Postal Service.

Pounds (District Heat): A weight quantity of steam, also used in this report to denote a quantity of energy in the form of steam. The amount of usable energy obtained from a pound of steam depends on its temperature and pressure at the point of consumption and on the drop in pressure after consumption.

Principal Building Activity: The activity or function occupying the most floorspace in the building. The categories were designed to group buildings that have similar patterns of energy consumption. (See **Building** and **Floorspace**.)

The principal building activity categories used in this report are described below.

Assembly: signifies buildings used for the gathering of people for social, recreational, or religious activities whether in private or nonprivate meeting halls.

Education: refers to buildings that house academic or technical classroom instruction.

Food Sales and Service: involves retail or wholesale of food, as well as activities that involve preparation and sale of food and beverages for consumption.

Health Care: covers diagnostic and treatment facilities for both inpatient and outpatient care. Excluded from this group are skilled nursing or other residential care facilities (nursing homes). These buildings are classified as "Lodging" buildings.

Lodging: refers to buildings that offer multiple accommodations for short-term or long-term residents (including nursing homes).

Mercantile and Service: refers to buildings containing sales and displays of goods or services (excluding food).

Office: refers to buildings used for general office space, professional offices, and administrative offices.

Other: covers buildings that do not fit into any of the other named categories.

Parking Garage: refers to buildings used to park cars. Buildings in this category need not be totally enclosed by walls.

Warehouse: describes buildings used to store goods, manufactured products, merchandise, or raw materials. This category includes both refrigerated and nonrefrigerated warehouses.

Vacant: designates buildings in which more floorspace was vacant than was used for any single activity (as defined above) at the time of interview. A vacant building may have some occupied floorspace.

Principal Facility Activity: The primary business, commerce, or function carried on within each multibuilding facility. (See **Multibuilding Facility**.)

The principal facility activity categories used in this report were the following:

College and University
Other School (secondary, elementary, and other schools)
Office
Shopping Center and Mall
Hospital
Industrial (includes agricultural)
Hotel and Motel
Entertainment Complex

Warehouse
Religious
Other

For tables of facility characteristics, "Other" also includes shopping centers and malls, hotels and motels, entertainment complexes, warehouse, and religious facilities.

Public Utilities Regulatory Policy Act (PURPA): A 1978 Act which guarantees that electric utilities will purchase any excess electricity generated onsite by a facility, provided that the facility meets certain criteria. A facility meeting the PURPA criteria is designated as a qualifying facility. (See **Electricity Generation**.)

PURPA: See **Public Utilities Regulatory Policy Act (PURPA)**.

Quadrillion Btu: Equivalent to 1,000,000,000,000,000 (10^{15}) Btu. (See **Btu**.)

Qualifying Facility: See **Public Utilities Regulatory Policy Act (PURPA)**.

Relative Standard Error: A measure of the reliability or precision of a survey statistic. The relative standard error is defined as the standard error of a survey estimate, expressed as a percent of the estimate. For example, a relative standard error of 10 percent means that the standard error is one-tenth as large as the survey estimate. (See **Standard Error** and Appendix C, "Estimation.")

Residential: As used in this survey, activities related to use as a dwelling for one or more households.

RSE: See **Relative Standard Error**.

Sampling: The procedure used to select cases (for the CBECS, buildings) for interview from the population (commercial buildings in the United States). (See **Network Estimator** and Appendix A, "The Facility Survey.")

Sector: A major component of the U.S. economy. The sector categories used in this report were defined based on the principal facility activity. (See **Principal Facility Activity**.)

All Sectors: includes commercial sector facilities, industrial sector facilities, and residential facilities.

Commercial Sector: encompasses colleges and universities, other schools, offices complexes, shopping centers and malls, hospitals, hotels and motels, entertainment complexes, warehouses, and religious facilities.

Industrial Sector: refers to industrial and agricultural facilities.

Square Footage: Floorspace, in units of square feet. One square foot is approximately equal to 0.0929 square meters. (See **Floorspace** and **Metric Conversion**.)

Standard Error: A measure of the precision of an estimate, equal to the square root of the variance. (See **Variance**, **Relative Standard Error**, and Appendix C, "Estimation.")

Steam: See **District Steam**.

Trillion Btu: Equivalent to 1,000,000,000,000 (10^{12}) Btu. (See **Btu**.)

Variance: A measure of the variability of a set of observations that are subject to some chance variation, equal to the expected squared difference between a single observation and the average of all possible observations obtained in the same manner. The variance is the square of the standard error of estimates. For statistics presented in this report, the variance indicates the likely difference between the value computed from the CBECS sample and the

average of the values that could have been computed from all possible samples that might have been obtained by the same sample selection process. (See **Standard Error** and Appendix C, "Estimation.")

Weight: The number of units (buildings or facilities) in the United States that a particular sampled unit represents. To estimate the total value of an attribute (such as floorspace contained in multibuilding facilities) in the U.S. as a whole, each sampled unit's value is multiplied by the unit's weight. Summing the weighted sample values provides an estimate of the nationwide total. (See Appendix C, "Estimation.")