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.

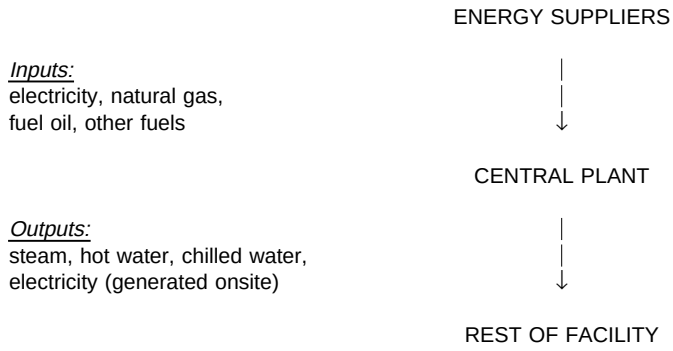
Central Plant Versus Facility-Wide Consumption

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.