Appendix B

Survey Design, Implementation, and Estimates

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Introduction

The 1994 Manufacturing Energy Consumption Survey is the Energy Information Administration's latest survey of the manufacturing sector. Previous manufacturing surveys were conducted for reporting years 1985, 1988, and 1991 in 1986, 1989, and 1992, respectively. The next MECS survey will be conducted for reporting year 1998, with subsequent MECS being conducted every 4 years thereafter.

Overview of Changes from Previous Surveys

Sample Design. The MECS has increased its sample size by roughly 40 percent since the 1991 survey, increasing the designed sample size from 16,054 establishments to 22,922. This increase in size and change in sampling criteria required a departure from using the Annual Survey of Manufactures (ASM) as the MECS sampling frame. For 1994, establishments were selected directly from the 1992 Census of Manufactures (CM) mail file, updated by 1993 ASM.

Sample Frame Coverage. The coverage in the 1994 MECS is 98 percent of the manufacturing population as measured in total payroll. The sampling process itself provided that level of coverage, and no special adjustments were used to increase it. The 1991 survey had identical coverage, whereas the 1988 survey was statistically adjusted to cover 100 percent of the population. Therefore, many of the potential sources of bias that pertained to the 1988 survey estimates are not relevant to either the 1991 or 1994 survey. *Because of the difference in sample coverage, care must be exercised when comparing absolute quantities among the three surveys--small differences might be correctly attributable to coverage rather than real change.*

New Industry Estimates. The nearly 7,000 increase in the number of establishments sampled has allowed EIA to publish separate estimates for 52 industries and industry groups, in addition to the 20 larger major groups (2-digit SIC). In 1991, there were 42 industries and industry groups published; and in 1988, the sample design permitted only 10 industries for which separate estimates were publishable beyond the 20 major groups. Also, for the first time, this latest report presents estimates relating to the number of manufacturing establishments.

Additional Data Items for Improved Estimation. In 1991, EIA recognized a potential for overestimating energy source quantities in industries that produce and sell energy sources; it corrected for such overestimation by collecting energy shipments from sample establishments. The correction is required when a manufacturer uses an energy source as an input to a process (i.e, feedstock), produces another energy source as a result of that process, and then sells or transfers the produced energy source to another establishment. The quantity of the receipt in the second establishment would duplicate the feedstock use in the first. Part of the solution has been to estimate consumption in petroleum refineries differently from other industries (see section entitled "Feedstocks and Offsite-Produced Fuel at Petroleum Refineries" in this appendix). To correct the problem for other industries, the MECS, in 1991, began collecting shipments offsite of energy sources produced onsite (see "Development of the Data File" in this appendix). EIA has continued to correct for energy shipments from manufacturing establishments in 1994. In addition, estimates of energy shipments appear in Table A1, First Use of Energy, of this report.

New Data Collection Sections. Survey collection forms now include sections on natural gas industry restructuring—service rates of natural gas purchases; supply, transportation, and other costs associated with non-local distribution company natural gas purchases—actual fuel switching occurring between natural gas and residual fuel oil, types of cogeneration technology in use by manufacturers, square footage of manufacturing floorspace, and energy management activities (sponsored by electric utility; self; and Federal, State, and local governments). As a one-time collection of establishment activities, EIA investigated the methods that manufacturers most commonly used to purchase, and to make modifications to, electric motor systems.

New Geography Level. In part, the nearly 7,000-establishment increase in sample size provides for reliable estimation of energy consumption at the nine Census divisions (see glossary for a definition of Census division and Appendix E for a division-level map).

The basic unit of data collection for this survey is the manufacturing establishment. A nationally representative sample of these establishments supplied the information through mailed questionnaires. The Manufacturing and Construction Division of the Bureau of the Census, in consultation with EIA, selected the MECS sample, conducted fieldwork, and processed the data.

This appendix presents a summary of the design and implementation procedures for the survey, highlights differences between reporting periods, and describes the types of estimates included in this report. For more detailed design, methodology, and background information, refer to the EIA publication *Manufacturing Energy Consumption Survey: Methodological Report*, DOE/EIA-0514 (Washington, DC, 1988).

Description of the Manufacturing Sector

The manufacturing sector consists of all manufacturing establishments in the 50 States and the District of Columbia. The working definition of a manufacturing establishment is the definition stated in the Office of Management and Budget's *Standard Industrial Classification Manual*:

> [Manufacturing establishments are]... engaged in the mechanical or chemical transformation of materials or substances into new products. These establishments are usually described as plants, factories, or mills and characteristically use power driven machines and materials handling equipment. Establishments engaged in assembling component parts of manufactured products are also considered manufacturing if the new product is neither a structure nor other fixed improvement. Also included is the blending of materials such as lubricating oil, plastics, resins, or liquors.[26]

The SIC manual contains a hierarchial classification system that groups establishments according to their primary economic activities. This system divides the manufacturing sector (referred to as "manufacturing division" in the SIC manual) into 20 major industrial groups that are relatively homogeneous with respect to primary output. Each of these major industrial groups is assigned a two-digit code. The two-digit codes for the manufacturing sector range from SIC 20, Food and Kindred Products, through SIC 39, Miscellaneous Manufacturing Industries. Each major group is subdivided into three-digit groups, which are further divided into four-digit industries. For example, SIC 20 includes SIC 201, Meat Products, which, in turn, is subdivided into SIC 2011, Meat Packing Plants; SIC 2012, Sausages and Other Prepared Meat Products; SIC 2016, Poultry Dressing Plants; and SIC 2017, Poultry and Egg Processing.

The SIC category is the single most important classification variable in the MECS data system, both for selecting the survey sample and analyzing the tabulated data. The categories of primary interest for the MECS are the 20 major industrial groups (SIC 20 through 39) and the 52 three- and four-digit industries that consumed the most energy, demonstrated high growth, or had a special programmatic interest. A description of these 20 major industrial groups and 52 industry groups and industries appears in Appendix F of this report.

The 1994 MECS, as well as the 1988 and 1991 surveys, used the SIC classification system that is presented in the 1987 edition of the SIC manual. The 1985 MECS was based on the 1972 SIC manual. For the most part, the revisions were minor and had a negligible effect on the MECS estimates. However, there were some revisions that would affect comparisons between 1985 and subsequent years.

Among the more significant revisions was the one concerning the way certain petrochemical plants were classified for the 1988, 1991, and 1994 MECS, as opposed to the 1985 survey. If the primary product of a petrochemical plant in 1985 was a liquefied petroleum gas (LPG), the plant was classified in SIC 2911 as Petroleum Refining, regardless of how the LPG was produced. For the later survey years (including the 1994 survey), the establishment was classified in SIC 2911 only if the LPG was produced by a refinery process. If the LPG was produced by a chemical process, the establishment

[26]Office of Management and Budget, *Standard Industrial Classification Manual, 1987* (Washington, DC, 1987), p. 67.

was classified as an organic chemical industry (SIC 2865 or 2869). Thus, when comparing the estimates for SICs 2911, 2865, and 2869 between the 1985 and later MECS reports, the reader is cautioned to take the classification differences into account.[27]

The Sampling Frame and Its Relationship to the Manufacturing Sector

As mentioned in the Introduction to this appendix, the Census Bureau serves as the collecting and compiling agent for the MECS. In addition to the MECS, a major responsibility of the Manufacturing and Construction Division of the Census Bureau is to conduct the Census of Manufactures (CM) and the Annual Survey of Manufactures (ASM). MECS uses those surveys to construct a sampling frame, as well as to provide economic data for establishments common to both systems.

Census of Manufactures

The CM is conducted for years ending in "2" or "7" (for example, 1992) and obtains economic data for the complete universe of approximately 380,000 manufacturing establishments in the United States. For the purposes of data collection, the manufacturing universe is divided into two major subsets as follows.

1. **Small Single-Establishment Companies Not Sent a Report Form.** Generally, companies with fewer than five employees are excused from filing a CM report. Those with 5 through 20 employees are excused or sent a report form based on the magnitude of their annual payroll and shipments data. In 1992, approximately 143 thousand establishments were excused from filing due to this criterion.

2. **Establishments Sent a Report Form.** All companies with 20 or more employees are mailed a CM report form. In 1992, approximately 237 thousand establishments fell into this subset of the CM manufacturing universe, which represents all multi-establishment firms and single-establishment firms with payrolls above a pre-determined cutoff level.

Annual Survey of Manufactures

The ASM is conducted during non-CM years to provide estimates of economic characteristics for the universe of manufacturing establishments. As with the CM, the ASM contains two components. The first component is the mail portion, a probability sample of manufacturing establishments selected from the list of establishments that are sent the CM report form (see above). Those establishments are weighted so that they represent the mail portion of the CM universe. The second component of the ASM is the nonmail portion of the CM. These small establishments are not sent an ASM questionnaire, but their contribution to economic statistics is estimated based on selected information obtained annually from other Federal agencies. For the 1994 ASM, approximately 55 thousand questionnaires were mailed to manufacturing establishments that had been selected from an updated 1992 CM mail file.

Manufacturing Energy Consumption Survey

In 1994, the MECS improved its sampling procedure. For the first time, the survey sample was drawn directly from the updated 1992 CM mail file, rather than subsampled from the ASM mail file. While this change in sampling frame has no effect on the coverage of the manufacturing universe by the MECS—sample establishments, when weighted, still cover 98 percent of the manufacturing universe, as measure by total payroll—this improvement permits the MECS to target directly those industries that are of significant interest to data users, as well as to control subnational sampling (see Sample Design

[27] An effort was made to account for the SIC revisions by reclassifying the 1985 MECS estimates according to the 1987 SIC codes. The revised consumption estimates were used to form energy intensity change estimates. See EIA, *Manufacturing Energy Consumption Survey: Changes in Energy Intensity in the Manufacturing Sector, 1985-1991*, DOE/EIA-0552(85-91) (Washington, DC, 1995). Future MECS samples will conform to the North American Industrial Classification System (NAICS) developed by the Office of Management and Budget. The NAICS will replace the 1987 SIC.

section in this appendix).[28] Of the 239,000 eligible establishments in the CM mail file, 22,922 were selected for the 1994 MECS sample, of which 22,173 were mailed a questionnaire and 749 were identified as out of scope (e.g., out of business).

Coverage Differences Between MECS 1988 and 1985, 1991, and 1994

Due to an adjusted coverage difference between the 1988 survey design and 1985, 1991 and 1994 designs, the coverage of manufacturing estimates varied slightly from the 1988 survey to the other surveys. Therefore, EIA urges that comparisons of estimates produced from these surveys and analysis of trends be done with caution.

The 1994 MECS estimates cover 98 percent of the manufacturing sector as measured by total payroll. The 2 percent of the payroll not covered is known to be represented by a subgroup of relatively small but numerous manufacturing establishments. When taken as a whole, they account for roughly 2 percent of a number of different economic measures, including energy consumption. Because of the cost and difficulty of accurately surveying this subgroup, it was excluded from the survey and, thus, from the estimates presented in this report.

In contrast, the 1988 MECS estimates represent the *entire* manufacturing sector. Small establishments excluded from the other MECS surveys were accounted for by means of a population adjustment factor, applied to each establishment's sampling weight (by stratum) after the sample was drawn. Coverage adjustment was necessary for the 1988 survey because the coverage of the population had degraded over time, and Census procedures for population updates could not entirely compensate for the coverage loss. Also, EIA wanted to retain the active portion of the 1985 sample, rather than select an entirely new sample. This method meant that establishments had to be classified according to very specific definitions. For example, establishments that had ceased operation since 1985 had to be distinguished from those that merely underwent a change of ownership. To counteract the coverage loss, as well as the operational errors that might have occurred while maintaining a sample built in this way, a ratio adjustment was selected to adjust selected MECS economic estimates to control totals from the 1987 Census of Manufactures. By necessity, that adjustment also included the portion of the manufacturing sector that was not originally intended for estimation, the 2 percent of certain economic measures represented by the smallest establishments.[29] The 1994 and other MECS surveys did not use an adjustment factor because: (1) there was no readily available population adjustment for 1991 estimates, and (2) the relative simplicity of the sample design yielded fewer operational errors.

The 1985 estimates excluded the smallest establishments from coverage. That exclusion tends to make 1985 coverage comparable with the 1991 and 1994 coverages. Due to Census' updating procedures that were in place during the 1985 survey, the coverage might have been slightly less than the 98 percent of the 1991 and 1994 surveys, but exact estimates of coverage are difficult to estimate. Therefore, caution must be exercised by readers who wish to compare 1985, 1988, 1991, and 1994 estimates.[30]

Sample Design

Sample Size

The expected size of the MECS sample was 23,000 establishments. Because of the randomness of sampling, the actual sample size differed. Of the approximately 239 thousand eligible establishments, exactly 22,922 establishments were selected, of which 22,173 were mailed a questionnaire.

[28]Establishments that were first eligible for the MECS in calendar year 1994 were not mailed a questionnaire. Rather, their contribution was accounted for in the nonresponse adjustment. See section entitled "Estimation Process" in this appendix.

[29]For a more detailed explanation of the population adjustment factor, see Appendix A, EIA, *Manufacturing Energy Consumption Survey: Consumption of Energy, 1988*, DOE/EIA-0512(88), op. cit.

[30]Comparisons among the survey years can be more appropriately made by using internal ratios (e.g., quantity of offsite-produced energy per value of shipments) because the coverage differences that will appear affect both energy consumption and value of shipments equivalently in a given year. See EIA, *Manufacturing Energy Consumption Survey: Changes in Energy Intensity in the Manufacturing Sector, 1985-1991*, DOE/EIA-0552 (85-91) (Washington , DC, 1995).

In selecting the sample, the MECS had specific target criteria by SIC stratum and Census division. The targeted sampling errors in terms of relative standard errors (RSE) for the MECS sample were:

- zero for total energy expenditures in heavy energy-consuming industries, with all eligible establish-ments being selected, resulting in a census of these industries (see text box);
- no more than 3 percent for total energy expenditures in nonfuel-intensive SIC industries (2819, 2821, and 2869); and
- no more than 5 percent for total energy expenditures in each of the remaining groups and industries.

Because data users requested more precise subnational estimates (i.e., four Census regions and nine divisions), the 1994 MECS sample was highly controlled at sub-national levels, as defined by SIC and Census divisions (see Table B1 in this appendix). This represented a change from previous samples.

Not all industries or industry groupings were controlled at the Census-division level. To target each industry and Division, a much larger sample, exceeding the expected 23,000 establishment target set for the 1994 MECS, would have been required. Instead, only 150 cells (as defined by SIC and Census division) were controlled. These cells represent the industries-division groupings that account for the largest expenditures for energy. A detailed sampling table is provided in Table B1 of this appendix. In addition to the 150 controlled cells, the table also shows the cell totals for those industries for which a census of all establishments was included in the sample.

The major purpose of increasing the sample size was to be able to produce separate energy estimates for more industries than before, as well as to produce more precise sub-national estimates. The first two surveys—in 1985 and 1988—published estimates for the 20 two-digit major groups that comprise manufacturing and 10 four-digit industries. Those 10 four-digit industries were the most energy-consuming in manufacturing. The 1991 MECS published 40 four-digit industries, 2 three-digit industry groups, and 20 two-digit major groups. The 1994 MECS has 49 four-digit industries, 3 three-digit industry groups, and 20 two-digit major groups. These industry additions come from three groups: (1) industries not in the top 10, but with high energy consumption; (2) certain high-growth industries, such as computers and medical instruments; and (3) industries for which there are identifiable policy interests or conservation opportunities.

Industries Where All Eligible Establishments Were Selected

Food industries include:

2046 Wet Corn Milling
2061 Cane Sugar, Except Refining
2062 Cane Sugar Refining
2063 Beet Sugar
2075 Soybean Oil Mills.

Paper industries include:

2611 Pulp Mills
2621 Paper Mills
2631 Paperboard Mills.

Chemical industries include:

2812 Alkalies and Chlorine
2816 Inorganic Pigments
2822 Synthetic Rubber
2823 Cellulosic Manmade Fibers
2824 Organic Fibers, Noncellulosic
2861 Gum and Wood Chemicals
2873 Nitrogenous Fertilizers
2874 Phosphatic Fertilizers
2895 Carbon Black.

Petroleum industries includes:

2911 Petroleum Refining.

Stone, Clay and Glass industries include:

3211 Flat Glass
3221 Glass Containers
3274 Lime.

Primary Metal industries include:

3312 Blast Furnaces and Steel Mills
3313 Electrometallurgical Products
3331 Primary Copper
3334 Primary Aluminum
3339 Primary Nonferrous Metals, nec
3353 Aluminum Sheet, Plate, and Foil.

Remaining industries are represented by a survey sample of eligible establishments.

Table B1. Sample Size by Census Division, Industry Group and Selected Industry, 1994

SIC Code	Industry Group and Industry	Controlled Census Division									No Controls	Total
		New England	Middle Atlantic	East North Central	West North Central	South Atlantic	East South Central	West South Central	Mountain	Pacific		
2011	Meat Packing Plants	-	-	-	37	-	-	-	-	-	80	117

Table B1. Sample Size by Census Division, Industry Group and Selected Industry, 1994

SIC Code	Industry Group and Industry	Controlled Census Division									No Controls	Total
		New England	Middle Atlantic	East North Central	West North Central	South Atlantic	East South Central	West South Central	Mountain	Pacific		
2033	Canned Fruits and Vegetables	-	-	-	-	-	-	-	-	57	106	163
2037	Frozen Fruits and Vegetables	-	-	-	-	-	-	-	-	44	54	98
2046	Wet Corn Milling	2	0	13	17	2	6	4	4	6	0	54
2051	Bread, Cake, and Related Products	-	-	-	-	-	-	-	-	-	183	183
2061	Cane Sugar, Except Refining	0	0	0	0	7	0	25	0	12	0	44
2062	Cane Sugar Refining	1	3	1	0	7	1	4	0	2	0	19
2063	Beet Sugar	0	1	7	11	0	0	1	10	10	0	40
2075	Soybean Oil Mills	0	2	25	28	14	9	5	1	10	0	94
2082	Malt Beverages	-	-	-	-	-	-	-	-	-	30	30
20	Balance of Food and Kindred Products	113	184	218	188	204	146	172	109	216	0	1550
21	Tobacco Products	-	-	-	-	18	-	-	-	-	17	35
22	Textile Mill Products	82	147	-	-	222	84	-	-	-	101	636
23	Apparel and Other Textile Products	-	271	-	-	204	171	-	-	268	198	1112
2421	Sawmills and Planing Mills, General	-	-	-	-	140	-	-	-	121	213	474
2436	Softwood Veneer and Plywood	-	-	-	-	-	-	-	-	-	68	68
2493	Reconstituted Wood Products	-	-	-	-	-	-	-	-	-	80	80
24	Balance of Lumber and Wood Products	-	-	189	-	222	-	-	-	209	268	888
2511	Wood Furniture, Except Upholstered	-	-	-	-	-	-	-	-	-	161	161
25	Furniture and Fixtures	-	-	129	-	-	-	-	-	-	278	407
2611	Pulp Mills	1	3	12	1	11	9	0	0	10	0	47
2621	Paper Mills	58	55	74	7	27	22	21	4	30	0	298
2631	Paperboard Mills	18	34	51	5	40	19	19	4	24	0	214
26	Balance of Paper and Allied Products	85	157	168	-	142	-	94	-	124	132	902
27	Printing and Publishing	173	235	236	171	218	96	172	144	202	0	1647
2812	Alkalies and Chlorine	3	4	3	3	8	3	11	3	6	0	44
2813	Industrial Gases	-	22	33	-	26	-	27	-	27	43	178
2816	Inorganic Pigments	1	22	16	7	19	5	3	0	8	0	81
2819	Industrial Inorganic Chemicals, nec.	-	-	18	-	28	19	29	11	33	63	201
2821	Plastics Materials and Resins	-	25	30	-	30	20	33	-	-	40	178
2822	Synthetic Rubber	5	5	11	1	9	8	18	1	4	0	62
2823	Cellulosic Manmade Fibers	0	1	0	0	2	5	1	0	0	0	9
2824	Organic Fibers, Noncellulosic	6	2	0	0	51	11	0	0	0	0	70
2861	Gum and Wood Chemicals	3	4	3	13	9	5	16	1	2	0	56
2865	Cyclic Crudes and Intermediates	-	-	-	-	11	-	13	-	-	44	68
2869	Industrial Organic Chemicals, nec.	-	51	39	-	39	17	46	-	-	57	249
2873	Nitrogenous Fertilizers	3	11	13	15	15	4	25	14	18	0	118
2874	Phosphatic Fertilizers	0	4	5	7	33	4	7	6	1	0	67
287	Balance of Agricultural Chemicals	-	-	-	-	-	-	-	-	-	40	40
2895	Carbon Black	0	0	4	1	2	1	15	0	0	0	23
28	Balance of Chemicals and Allied Products	46	99	97	62	82	-	-	-	82	91	559
2911	Petroleum Refining	4	27	31	12	12	13	85	29	50	0	263
29	Balance of Petroleum and Coal Products	-	110	99	-	-	-	-	-	-	187	396
3011	Tires and Inner Tubes	-	-	-	-	-	16	-	-	-	30	46
308	Miscellaneous Plastics Products, nec.	118	211	235	113	162	123	125	80	193	0	1360
30	Balance of Rubber and Misc. Products	-	-	116	-	77	-	-	-	-	168	361
31	Leather and Leather Products	-	-	-	-	-	-	-	-	-	145	145
3211	Flat Glass	2	9	9	1	8	7	7	2	9	0	54
3221	Glass Containers	3	17	15	2	16	0	10	1	14	0	78
3229	Pressed and Blown Glass, nec.	-	15	-	-	-	-	-	-	-	33	48
3241	Cement, Hydraulic	-	12	16	12	13	-	16	-	16	21	106
3274	Lime	1	10	24	9	10	13	9	5	6	0	87
3296	Mineral Wool	-	-	-	-	-	-	-	-	-	42	42
32	Balance of Stone, Clay, and Glass Products	-	107	178	104	105	95	117	-	156	215	1077
3312	Blast Furnaces and Steel Mills	4	75	81	11	31	29	27	5	25	0	288
3313	Electrometallurgical Products	0	10	15	1	4	2	1	0	2	0	35
331	Balance of Blast Furnace and Steel Products	-	-	63	-	-	-	-	-	-	78	141
3321	Gray and Ductile Iron Foundries	-	-	54	-	-	-	-	-	-	72	126
3331	Primary Copper	0	0	4	0	1	0	4	10	1	0	20
3334	Primary Aluminum	3	2	5	1	7	5	3	2	15	0	43
3339	Primary Nonferrous Metals, nec.	5	24	14	5	4	8	5	8	15	0	88
3353	Aluminum Sheet, Plate, and Foil	3	5	14	2	8	10	5	1	6	0	54
33	Primary Metal Industries	86	90	156	-	49	72	70	-	82	78	683
34	Fabricated Metal Products	162	197	287	145	171	135	193	104	223	0	1617
357	Computer and Office Equipment	-	-	-	-	-	-	-	-	44	76	120
35	Balance of Industrial Machinery and Equipment	160	164	259	157	171	130	166	121	227	0	1555
36	Electronic and Other Electric Equipment	101	103	147	85	133	80	68	47	155	0	919
3711	Motor Vehicles and Car Bodies	-	-	28	-	-	-	-	-	-	25	53
3714	Motor Vehicle Parts and Accessories	-	20	70	-	-	53	-	-	-	128	271
37	Balance of Transportation Equipment	27	43	90	24	65	46	57	20	53	0	425
3841	Surgical and Medical Instruments	-	-	-	-	-	-	-	-	-	120	120
38	Balance of Instruments and Related Products	77	86	110	-	68	-	-	-	107	114	562
39	Miscellaneous Manufacturing Industries	-	121	-	-	-	-	-	-	-	254	375
	Total	1356	2800	3515	1258	2957	1502	1729	747	2925	4133	22922

The increase in sample size also allowed for greater precision and reliability of existing estimates, especially among the major groups (two-digit SICs). For example, SIC 20 in the current sample design includes eight four-digit industries for which estimates were publishable. Previously, in the 1985 and 1988 designs, no four-digit industries in SIC 20 were published separately. The addition of the eight industries in 1991 and its continuation in 1994 yielded greater reliability of the SIC 20 major group estimates by having more sample cases in the publishable four-digit industries that comprise SIC 20. Thus, overall reliability in SIC 20 was improved without adding sample cases for that express purpose.

Sampling Methodology

For the first time, the MECS sample was selected directly from the 1992 CM mail file, updated for 1992 and 1993 manufacturing "birth" establishments. In doing so, the MECS discontinued the two-stage sampling process that existed for the previous surveys.

Pre-1994 MECS Sampling Methodology

Prior to 1994, MECS sample selection was a two-stage selection process, with the first stage being the selection of the ASM mail sample from the CM frame. The second stage was the subselection of the MECS sample from the ASM mail sample. Thus, a MECS sample establishment was selected conditionally upon its having been selected into the ASM mail sample, which means that its probability of selection from the ASM sample was conditional. Therefore, the overall probability of selection into the MECS sample was represented by the product of this conditional probability and its ASM selection probability. The probabilities for selection into the MECS sample were proportional to an energy measure of size (MOS).

Calculations of the MOS changed for the 1991 survey from those of previous years but maintained a close relationship. Actually, two MOSs were computed for each establishment. The first was based on the 1990 ASM purchased electricity quantity. The other was based on the ASM cost of purchased fuels (excluding electricity). The probability of selection would be the maximum of the two probabilities computed by using the two different MOSs.

The energy MOS for the 1985 and 1988 surveys was formed by taking a previous total Btu measure per cost of fuels and electric energy at the establishment updated by multiplying that ratio by a more current measure of average cost of fuels and electric energy. If the establishment had come into existence since the time of the last energy data available, industry averages would be employed for the ratio of Btu to cost of fuels. Neither MOS in the 1991 MECS was as highly correlated with energy consumption as the MOS used in the 1985 and 1988 sample designs. However, one advantage of the 1991 method was the fact that ASM data were used directly. Thus, each establishment had its own MOS and industry averages were no longer needed.[31]

1994 MECS Sampling Methodology

In 1994, the selection process was completed as a single-stage sampling process, bypassing the ASM and drawing directly from the CM universe. Therefore, the probability of selection was proportional to the MOS, not conditional on the ASM selection probability.

Calculation of the MOS was simplified in the 1994 MECS. Rather than use two MOS (as done in the previous survey) a single MOS was calculated: total energy expenditures. This measure combines electric and fossil-based energy source expenditures. This change allowed for an increase in the precision of establishments that are served equally by both electricity and fossil-based energy sources.

Of the 52 separately published three- and four-digit SICs, 27 included 100 percent of the corresponding establishments in the CM universe. This was done to maximize reliability (minimize the standard errors) for those important energy-intensive and growth industries. The remaining 25 separately published three- and four-digit SICs were represented by a survey sample. Those industries came from major groups with large numbers of establishments (see Table B2), and the industries

[31]By using two different probabilities of selection, the expected sample size would be larger than would be expected by using only one. The sample allocations for each stratum were adjusted as necessary to stay close to the EIA targeted sample sizes.

themselves had such large numbers of establishments that it was impractical to include all of them. The overall probabilities for selection of the MECS sample establishments ranged from 0.010 to 1.000.

Table B2. Number of Establishments in the Census of Manufactures Universe by Major Group, 1994

SIC Code	Major Group	Number of Establishments
20	Food and Kindred Products	14,698
21	Tobacco Products	121
22	Textile Mill Products	4,428
23	Apparel and Other Textile Products	18,019
24	Lumber and Wood Products	21,623
25	Furniture and Fixtures	7,691
26	Paper and Allied Products	5,582
27	Printing and Publishing	37,384
28	Chemicals and Allied Products	9,565
29	Petroleum and Coal Products	1,971
30	Rubber and Miscellaneous Plastics Products	11,952
31	Leather and Leather Products	1,356
32	Stone, Clay, and Glass Products	11,970
33	Primary Metal Industries	5,171
34	Fabricated Metal Products	26,262
35	Industrial Machinery and Equipment	33,837
36	Electronic and Other Electric Equipment	11,264
37	Transportation Equipment	7,240
38	Instruments and Related Products	7,071
39	Miscellaneous Manufacturing Industries	9,994
	Total	247,199

To completely enumerate every two-digit SIC, the 1994 MECS would have required a collection of almost 250 thousand questionnaires. Given cost constraints of the MECS, a complete enumeration was not feasible. Instead, EIA constructed a sample design based on several factors, complying with legislatively mandated coverage, meeting user-need requests, and highlighting topic-related issues. Table B2 displays the sample targets.

For the 1994 MECS, the total sample size selected was 22,922. Of that sample, 749 establishments were determined to be out of scope or no longer in business prior to the MECS mailing, leaving a mail sample of 22,173. At the final closing, 19,292 questionnaires were received and subsequently keyed, a response rate of 87 percent.

Fieldwork, Editing, and Quality Control

The 1994 MECS continued the method that was started with the 1988 survey of using customized questionnaires for specific industries. The three questionnaires were:

- **Form EIA-846(A)**—This questionnaire was sent to the majority of the sample and collected the basic consumption, expenditure, fuel-switching, end-use, and technology information.

- **Form EIA-846(B)**—This questionnaire was sent exclusively to establishments in the Petroleum Refining Industry (SIC 2911). The design of the questionnaire took advantage of the fact that other EIA surveys collect certain consumption and expenditure data from the refinery population. Thus, the EIA-846(B) questionnaire did not require respondents to report on certain data items.

- **Form EIA-846(C)**—This questionnaire was sent to producers of Chemicals and Allied Products (SIC 28), producers of Petroleum and Coal Products other than Petroleum Refining (SIC 29 excluding SIC 2911), Lumber

and Wood Products (SIC 24), Paper and Allied Products (SIC 26), and selected Primary Metal Industries (in SIC 33). It is similar to the EIA-846(A) questionnaire except that it collects additional information on shipments of energy sources produced onsite and a different set of specific technologies related to energy efficiency.

The questionnaires were mailed to the in-scope MECS sample establishments in May of 1995.[32] Returned questionnaires were subjected to initial screening procedures for completeness, and incomplete forms or responses with obvious inconsistencies were set aside for review by industry specialists. Valid returned questionnaires were forwarded directly to check-in and then to data entry.

All forms that were incomplete or failed the initial screening procedures were carefully reviewed by the industry specialists from the Bureau of the Census and EIA. Those specialists retrieved missing data and verified questionable items by telephone contact with the individual who completed the questionnaire. Once the forms were completed and verified, they were forwarded to check-in and to data entry.

The resulting MECS data file was then subjected to a series of computer edits. Those edits included consistency checks among data items from different parts of the MECS and between the MECS and the 1994 ASM, as well as checks for outliers in the distribution of individual variables. Records with failed edits were reviewed and followed up by industry specialists.

Development of the Data File

The estimates in this report were developed from a data file consisting of both directly reported values and more complex items derived from a combination of directly reported values. Reported values consist of responses to the 1994 MECS questionnaires (see Appendix D). Those values were supplemented by estimates of energy consumption for nonfuel purposes and offsite-produced fuel consumption at petroleum refineries from another EIA questionnaire.[33] Additionally, the responses to the questionnaire for each responding establishment were supplemented by the following economic data:

- Value of shipments and receipts
- Value added by manufacturing
- Total employment.

Those economic data were not collected by the 1994 MECS but were provided by the Census Bureau by linking the 1994 ASM economic data and MECS energy data at the establishment level. Since the MECS was selected from the updated 1992 CM mail file, nearly 7 thousand establishments had economic data imputed (see Appendix C, Quality of the Data).

The reported energy values were used to construct several derived values, which, in turn, were used to prepare the estimates appearing in selected tables in this report (see the Survey Estimates section in this appendix). Those derived values are defined as follows:

1. **Energy Produced Offsite and Consumed as Fuel.** This derived value represents onsite consumption of fuels that were originally produced offsite. That is, they arrived at the establishment as the result of a purchase, or were transferred to the establishment from outside sources. As such, this derived value is equivalent to "consumption of purchased" fuels as reported by the Census Bureau for the years 1974 through 1981. The Census Bureau defines "purchased" fuels to include those actually purchased plus those transferred in from other establishments.[34]

2. **Energy Produced Offsite and Consumed for Nonfuel Purposes.** This derived value also represents energy that was originally produced offsite. This energy was used at the establishment site as raw material inputs and feedstocks.

[32]The MECS sample is selected according to establishment characteristics. However, the central administrative offices of multi-establishment companies were the addressees of the questionnaires and were responsible for distributing them to their establishments.

[33]The calculations for those quantities are discussed in the Consumption for Nonfuel Purposes at Refineries section and in the Offsite-Produced Fuel Use at Refineries section in this appendix.

[34]U.S. Department of Commerce, Bureau of the Census, *Annual Survey (Census) of Manufactures*, "Fuels and Electric Energy Consumed," 1974-1982 (Washington, DC).

3. **Energy Produced Onsite from Nonenergy Inputs and Consumed Onsite as Fuel.** This derived value covers materials such as wood chips, bark, and wood waste and pulping liquor. These fuels are produced primarily in pulp and paper mills as a byproduct of wood used in the pulping process. Wood for pulping is not classified as energy in the MECS, and, therefore, would not have been included as an input. This derived value also covers waste materials, biomass, and hydrogen that was produced from the electrolysis of brine. Energy sources such as petroleum and coal that were consumed as fuel and originated onsite from captive mines or wells (an unusual occurrence) are included here also.

4. **Energy Produced Onsite from Nonenergy Inputs and Consumed for Nonfuel Purposes.** Most onsite-produced energy that is used for nonfuel purposes is derived from other types of energy. The major exception is hydrogen that is produced from the electrolysis of brine. The consumption of hydrogen for nonfuel purposes that is produced from the electrolysis of brine is the major example of this derived value. Energy sources such as petroleum and coal that were consumed as a nonfuel and originated onsite from captive mines or wells are included here also.

5. **Energy Produced Onsite from Energy Inputs and Consumed as Fuel.** This derived value covers a wide range of fuels consumed onsite that are produced onsite as direct products or byproducts of other types of energy.

6. **Energy Produced Onsite from Energy Inputs and Consumed Onsite for Nonfuel Purposes.** This derived value includes all petrochemical feedstocks and other raw material inputs that were produced onsite from existing energy or from other onsite-produced energy.

7. **Energy Produced Onsite from Energy Inputs and Shipped to Other Establishments.** This derived value is continued from the 1991 MECS. Data are now collected for certain industries that produce and sell energy sources to other establishments. Most notably, these industries include Blast Furnaces and Steel Mills (SIC 3312) and various industries in Chemicals and Allied Products (SIC 28). If an establishment converts an energy source into a fuel and then ships it offsite to another establishment, the total Btu quantity among the producing and receiving establishments would be duplicative and thus overstated. By deducting this derived value from the producing establishments, the amount consumed at the receiving establishments is not duplicative.

The first four of the derived values represent an addition to the energy consumed onsite and are described in this publication as First Use (formerly Primary Consumption); that is, either energy was produced offsite or was produced onsite from nonenergy inputs. The fifth derived value described above does not represent an addition because it was produced onsite from energy that is already reported as input. Such energy represents duplicate counting of the input energy content. It is, however, a useful measure of onsite-produced fuel consumption and is not duplicative with respect to an estimate of total fuel consumption. The sixth derived value is duplicative with respect to the consumption of energy for nonfuel purposes, and, therefore, was not used to prepare estimates. It was included only for computational purposes and completeness. The seventh derived value—appearing in Table A1 of this report—is used to adjust First Use of Energy (formerly Primary Consumption). This adjustment was also included in the detailed tables of Appendix A; hence, there is a disconnect in table calculations between the 1991 and 1994 MECS. This adjustment must be either excluded from 1994 estimates or included with 1991 estimates in order for the statistics from these two cycles to be totally comparable.

Assumptions Underlying Derived Values

Two basic assumptions are necessary to produce the derived values from the data reported on the MECS questionnaire. First, it is assumed that any energy produced onsite is disposed of as it is produced. That is, it is burned as fuel and/or consumed as input or feedstock; any excess is flared, dumped, transferred out, sold, or placed into inventory. For the purpose of computing the derived values, a quantity of an energy source produced onsite and placed into inventory *during the previous year* is not considered onsite production in the reporting year. A corollary of this assumption is that any energy source that was consumed onsite and originated offsite was acquired only if there was not sufficient onsite production to meet the establishment's needs of the energy source in the current year. Second, it is assumed that the priority use of onsite production is first as a shipment (if applicable), then as input or feedstock, and last as fuel. These assumptions are believed to reflect the energy use patterns at the vast majority of, but not all, establishments. The assumptions do provide a consistent method of determining an establishment's nonduplicative total energy consumption and its reliance on outside providers to supply it.

The Estimation Process

Estimates in this report represented 98 percent of the total of manufacturing payroll and shipments in the CM universe—coverage equivalent to the 1994 ASM mail file. The 2 percent not covered are the smallest manufacturing establishments, which were not sent an ASM form. ASM imputes those establishments' data for publications by using industry averages. As discussed previously, the MECS no longer covers the small establishments either directly or through a ratio adjustment.

Population representation is accomplished by weighting the data from the establishment records in the consumption data file. Weighting is the process of multiplying the reported or derived values by a case-specific constant designed to inflate the data from each sample case to that portion of the population that it represents. The first, basic component in the MECS weights is the sampling weight. The sampling weight for a MECS sample case is the reciprocal of its overall probability of selection into the MECS.

The second component of the MECS weights is an adjustment for nonresponse. Adjustment factors to account for nonresponse were calculated by using the known energy measures of size of the respondents and the total sample. Because an establishment is selected into the MECS sample with a probability proportional to the establishment's energy measure of size, that measure can be viewed as an establishment's estimated contribution to energy expenditures in 1994. A separate adjustment factor was computed for each of the 72 sampling strata[35] and took the form:

$$a_s = \frac{\sum_{j}^{Sample} MOS_{s,j}}{\sum_{i}^{Resp.} MOS_{s,i}}, \qquad \textbf{(1)}$$

where $MOS_{s,j}$ is the measure of size for MECS sample establishment j in stratum s, and $MOS_{s,i}$ is the measure of size for MECS respondent I in stratum s. The adjustment factor was then multiplied by the sampling weight to produce the final MECS weight.

Feedstock and Offsite-Produced Fuel at Petroleum Refineries

The basic function of a petroleum refinery (SIC 2911) is to manufacture a wide variety of petroleum products from crude oil and other liquid hydrocarbon inputs. Those products can be grouped into three classes of use. The largest portion of refinery output is in the form of fuels that are ultimately consumed strictly for their energy content (e.g., motor gasoline, kerosene, and diesel oil). Many refinery products, however, are consumed not for their energy content but for their chemical properties. This class of energy products is generally known as petrochemical feedstock. Finally, a third class of product consists of finished materials that are consumed for specific physical properties, rather than for their energy content or chemical properties. Those finished materials include asphalt, lubricants, waxes, and solvents, and are referred to as nonenergy products.[36]

The MECS was specifically designed to collect information on the consumption of energy for heat, power, and electricity generation, and as petrochemical feedstock and other raw material inputs. The consumption of energy was reported directly by the establishments in the MECS sample, and the estimates in this report reflect that consumption. For most industries,

[35]For the 1985 MECS, adjustment cells were defined by cross-classifying sampling stratum with levels of employment size category. Employment size proved not to be worthwhile for use as an adjustment factor and was discontinued for later surveys.

[36]Certain petroleum products can be classified according to the end user of the product. For example, propane might be a fuel or feedstock, depending on the needs of the receiving establishment.

the end result of energy inputs is manufactured products that are not considered energy products. However, fuels produced from refinery inputs are treated as energy products by their subsequent users[37] and are reported not only in other manufacturing industries, but also in EIA surveys of consumption in other end-use sectors (residential households, residential vehicles, and commercial buildings). In that sense, refineries do not "use up" the majority of their inputs. They merely convert them from one form of energy (for example, crude oil) to another more usable form (for example, motor gasoline). Therefore, classifying refinery inputs that go into fuels and certain petrochemical feedstocks as refinery consumption would have resulted in massive double counting of total energy consumption, both within the manufacturing sector and across other energy-consuming sectors in the U.S. economy.

The second and third class of refinery products, petrochemical feedstock and nonenergy products, must be treated differently. The creation of those products by the refinery also requires energy inputs, primarily crude oil. The products are combustible and have a known heat content expressed in British thermal units (Btu). Asphalt, for example, contains 6.636 million Btu per 42-gallon barrel. However, the products are not recognized as energy by their subsequent consumers, and no provision was made for collecting data on their consumption from the MECS respondents. Therefore, the transformation of energy inputs to feedstock and nonenergy products must be counted as refinery consumption, or it will never be accounted for anywhere in EIA's consumption surveys.

One characteristic of petroleum refineries is that, except for losses caused by spills, contamination, etc., the Btu content of the energy inputs exactly equals the Btu content of the outputs, both energy and nonenergy. As energy products will be declared energy inputs by receiving establishments, only the Btu quantity of the nonenergy products will not be duplicative of other establishments' consumption. Therefore, EIA includes the Btu value of the nonenergy products in the petroleum refinery nonfuel and first-use estimates as a surrogate for the portion of the energy inputs that were used to produce them. EIA produces such information for all refinery products from the "Monthly Refinery Report," Form EIA-810. This form collects information on the monthly shipments from the universe of refineries in the United States. Those data were the basis for estimating the input energy requirements for the nonenergy products.

The shipment quantities, adjusted for changes in annual inventories, of the nonenergy products and certain classifications of petrochemical feedstock, as reported on the "Monthly Refinery Report," were converted to Btu and summed to produce a monthly refinery total. Those totals were then summed across refineries and months to produce the total Btu value of refinery shipments of nonenergy products for 1994. That total was used to represent the total Btu value of the inputs used to produce the nonenergy products and was inserted directly into the appropriate tables of this report to represent nonfuel consumption in refineries (see Survey Estimates in this appendix). Because the individual energy inputs corresponding to these shipments were not identified, the Btu value was entered in the "Other" column.

The "Monthly Refinery Report" covers only the refinery part of an establishment, while the MECS Forms EIA-846(A) through (C) cover energy use at the entire site, as defined by the Bureau of the Census. This difference affects MECS estimation only for cases in which a MECS report reflects energy use at both a refinery and a co-located petrochemical plant. For these cases, establishment nonfuel use is not completely estimated by shipments of refinery nonenergy products as measured by the EIA-810. The format of the MECS refining report, Form EIA-846(B) (see Appendix D), allows respondents to report energy-related data from a petrochemical plant co-located with the refinery. Form EIA-846(B) collected nonfuel use at and shipments of energy sources from the co-located petrochemical plant (Columns 9 and 10 of Section II). The total Btu of the consumption as a nonfuel minus the petrochemical plant shipments of energy sources is added across energy sources and establishments to the previously discussed refinery shipments of nonenergy sources. Note that for the petrochemical plant, estimation of nonfuel use is measured directly, as the majority of that usage does not appear in products that will later be converted to fuel use by other manufacturing plants. The additional nonfuel use estimated for the adjoining petrochemical plants proved to be small relative to the refinery usage because the majority of petrochemical plants report separately on the MECS. Because the resulting quantities were unreliable[38] and quite small compared to refinery shipments of nonenergy sources, they were excluded from the total refinery nonfuel estimates.

The EIA-810 data are also used to calculate the offsite-produced fuel use at the refinery establishment (see Derived Values in this appendix). Because Version A of Section II of Form EIA-846(B) collects only total fuel use of petroleum products (regardless of their origin), it was necessary to use the EIA-810 data to calculate the offsite-produced fuel ratio for those products. Estimation of the ratio utilized the same assumptions described in the section in this appendix on Assumptions

[37]Whether a respondent reports petrochemical feedstock as an energy source receipt often depends on the type of feedstock received. If the feedstock received is commonly used as a fuel, such as distillate fuel oil or ethane, then it is assumed that respondents will report it as an energy source receipt. If the refinery product received for petrochemical feedstock use is not normally considered a fuel, the assumption is made that respondents would not report it as an energy source receipt.

[38]Examination of the MECS refinery reports showed evidence that reporting for the adjoining petrochemical operations in the last two columns caused considerable respondent confusion.

Underlying Derived Values, except that EIA-810 data were used instead. This ratio is then applied to the MECS estimated value of total fuel.[39] The estimator takes the form:

$$O_{p,MECS} = \left(\frac{O_{p,EIA-810}}{F_{p,EIA-810}} \right) \bullet F_{p,MECS} \quad \textbf{(2)}$$

where $O_{p,MECS}$ is the MECS estimate of the amount of petroleum product *p* produced offsite and consumed as fuel, $O_{p,EIA-810}$ is the EIA-810 estimate of the amount of petroleum product *p* produced offsite and consumed as fuel, $F_{p,MECS}$ is the MECS estimate of total fuel use of petroleum product *p*, and $F_{p,EIA-810}$ is the EIA-810 estimate of the total fuel use of petroleum product *p*.

Estimates of the contribution to fuel consumption of offsite-produced nonpetroleum products are calculated directly from MECS data, applying the same estimation method employed in other SICs.

Shipments of Energy Sources Produced Onsite

Manufacturers who produce energy sources do so not only for their own consumption but often sell or transfer the products to other establishments. The most notable example in manufacturing is petroleum refineries. Energy consumption for those establishments is estimated by using a special method as has been explained in the immediately preceding section. The principal products of petroleum refineries are energy sources. First Use (formerly primary consumption) in petroleum refineries, by virtue of the special method already described, does not need to account for outgoing energy products because it excludes incoming energy sources used for raw materials. Yet there are other types of manufacturers that produce and sell energy sources as secondary products. If the energy content of the sold energy source materials from the secondary products are counted at the producing establishment, there would be double counting when the energy source is counted at the receiving establishment. First Use consumption, as currently defined, avoids double counting of *intra*-establishment use of an energy source that results from an onsite transformation from another energy source. In addition, it avoids double counting of *inter*-establishment use of such transformed energy sources. In 1991, the MECS included a table in the appendix that could be used to adjust First Use by deducting the amount of sold energy sources that were produced onsite. For the 1994 MECS, the estimates can be found in Table A1.

The example that has the greatest effect on total energy consumption is coal used to make coke. A steel mill processes coal to make coke for later use in the steel making process. For example, First Use consumption counts the quantity of coal as the original nonfuel input. Any onsite consumption of coke is not included in First Use consumption as it duplicates the coal use. If the steel mill sells and ships some of the coke to another establishment, it will show up as a shipment of an offsite-produced energy source in the second establishment and will be included in first use consumption. That would result in double counting.

First Use (formerly primary consumption) eliminates double counting of *inter*-establishment energy shipments by subtracting the energy equivalent of coke shipments from First Use of energy. In 1994, the total shipments adjustment was 587 trillion Btu. This means that a better estimate of total first use consumption is 21,663 trillion Btu. If the purpose is to compare with previous years, then the 587 trillion Btu needs to be added back in. The 22,250 trillion Btu for total first use can then be compared to the amounts used in earlier MECS years.

[39]The MECS value for total fuel would also include the amount used at the adjoining petrochemical plant if one were present. Using a ratio based on refinery-only data from the EIA-810 on that portion of the establishment is a source of error. However, refinery fuel use will usually dominate the petrochemical fuel use, especially for petroleum products.

Concept of Fuel-Switching Capability

EIA continues to employ the concept of fuel switching that was developed prior to the 1985 survey. After extensive consultation with potential data users and data providers for the 1985 survey, EIA developed a tightly specified concept of fuel-switching capability based on the following set of principles:

- Switching data would cover consumption of energy for heat, power, and onsite electricity generation only. Switching of energy consumed as feedstock or raw material inputs would not be considered.
- Switching data would focus on capability (what could be done) rather than actual performance (what was, or is being done) or future possibilities (what might be possible).
- Switching capability would be collected for a closed historical reference period, rather than the present or some future reference period.
- Switching capability would be collected for the 1-year reference period used for MECS consumption data to tie in with the consumption data and avoid seasonal bias.
- The survey would measure short-term response capability: that is, actions that could have taken place within 30 days of a decision to switch.
- Switching capability would reflect the total flexibility provided by an establishment's equipment configuration. Both multiple-fired equipment and redundant or backup equipment could contribute to capability.
- The survey would measure in-place capability: that is, capability provided by equipment that was already installed or was available at the establishment for installation during the reference period. Major modifications to the design capabilities of equipment and major capital expenditures were not to be considered in assessing capability.
- Switching capability would be valid only if, following the switch from one type of energy to another, the establishment would have been able to maintain its actual production schedule during the reference period.
- Switching capability provided by an establishment's equipment configuration could be limited or negated by legal or practical constraints, such as binding supply contracts, interruptible service, environmental regulations, or unavailability of supply or delivery systems for a potential alternative.
- Economic considerations were *not* to be considered a practical constraint in evaluating switching capability. The survey was designed to measure potential response to changes in economics or supply patterns.

The MECS obtained fuel-switching data by asking respondents to determine the amounts of 1994 input energy consumption of six major types of energy that could have been switched to one or more alternatives in accordance with the previously listed principles. The six types of energy were purchased electricity, natural gas, distillate oil, residual oil, coal (excluding coke),[40] and LPG. Respondents were directed to provide the quantities of switchable consumption by subtracting the quantities that were not switchable from the quantities that were actually consumed during 1994. Such an approach is clear and saves burden because it starts with a previously reported quantity and allows the respondent to subtract quantities known to be nonswitchable because of any one of the various conditions discussed above. The alternative would be to force the respondent to add up quantities for all energy uses for which all aspects of the concept are satisfied. Once the total switchable quantities had been determined, the remaining task was to determine how much of each switchable quantity could have been replaced by specific alternatives.

In 1994, for the first time, EIA expanded on the base of fuel-switching capabilities and investigated actual fuel switching. That investigation targeted the decision-making process of actually switching energy. Based on user-need studies and past fuel-switching capabilities, investigation of actual fuel switching was limited to switches between residual fuel oil and natural gas.

[40]Coke was excluded because it was found to be virtually nonswitchable in its most common use, the production of steel. Integrated steel mills, for a variety of reasons, have traditionally attempted to minimize the amount of coke required to produce hot metal. Hence, the capability of switching coke is more related to minimizing its use, than to the capacity to switch.

How To Measure Discretionary Fuel Use

One of the more interesting summary statistics that can be developed from the estimates of actual consumption, minimum consumption, and maximum consumption is the **discretionary-use rate**. The discretionary-use rate is a measure, in percent, of the extent to which manufacturers elected to consume discretionary quantities of a given energy source.

The discretionary-use rate is calculated as:

$$USE = \frac{ACT - MIN}{MAX - MIN} \times 100 \quad \textbf{(3)}$$

where USE is the discretionary-use rate of a given energy source,
ACT is the actual consumption of that energy source,
MIN is the minimum consumption, which would have been achieved if all ascertained switching *from* that type of energy had occurred.
and MAX is the maximum consumption, which would have been achieved if all ascertained switching *into* that type of energy had occurred.

Thus, the discretionary-use rate is a measure, in percent, of the depth into the discretionary range of consumption to which manufacturers chose to go, given their fuel-switching capabilities and production levels of 1994.

If manufacturers had chosen to minimize their consumption of a given energy source by using alternative energy sources whenever possible, then ACT = MIN, and the discretionary-use rate would be 0 percent. At the other extreme, if manufacturers had chosen to maximize the consumption of a given energy source by using that energy source whenever possible, then ACT = MAX, and the discretionary-use rate would be 100 percent.

Note that (ACT - MIN) is equivalent to the "switchable" amount of the given energy source that was consumed, that is, the amount of the energy source that was consumed even though it could have been switched to another energy source.

Survey Estimates Presented in Appendix A

Except for some estimates of energy consumption for nonfuel purposes at petroleum refineries, all energy consumption and energy-related statistics produced from MECS data are calculated by inflating the data collected from the responding establishments with the adjusted sampling weights. Those weights establish the relationship between the responding establishments and the manufacturing population as defined for the MECS. Three types of statistics are shown in this report: aggregates (for example, total natural gas consumption in the hydraulic cement industry), ratios (for example, the amount of fuel consumed per dollar of value added in the manufacturing sector), and number of establishments (for example, the number of establishments engaged in a certain activity). These statistics are based on the originally reported values, or the derived values discussed earlier, and appear in Tables A1 through A44.

In 1994, for the first time, a MECS consumption report presents number of establishment estimates. Conceptually, these table of estimates represent sister tables to consumption tables. In earlier surveys, limited sample size precluded the estimation of establishment numbers. With a nearly 7-thousand increase in sample size for 1994, *number of establishment* estimates have been derived by adjusting the Horvitz-Thompson estimator,[41]

$$\hat{U} = \sum_{i=1}^{n} u_i \cdot W_i, \quad \textbf{(4)}$$

[41]Steven K. Thompson, *Sampling* (New York: John Wiley & Sons, Inc., 1992).

where u_i is a binary variable--1 if the i^{th} establishment is in the domain of interest, 0 otherwise; and W_i is the nonresponse-adjusted sample weight of the i^{th} establishment. The adjusted Horvitz-Thompson estimator is as follows:

$$\hat{U}_s = \frac{N_s}{\hat{N}_s} \sum_{i=1}^{n_s} u_i \cdot W_i, \quad \textbf{(5)}$$

where N_s denotes the universe of the sample frame for SIC *s*; *u* is a binary variable—1 for establishments in the domain of interest, 0 otherwise--representing the i^{th} establishment's existence in the domain of interest (for example, consuming natural gas, participating in an energy-management program, and so on); *W* denotes the nonresponse-adjusted sample weight for the i^{th} establishment; n_s is the number of sampled establishments in SIC *s* that responded to the survey; and $\hat{N}_s$ represents the summation of the adjusted sample weights of all responding establishments at the *s* SIC level.

For higher levels of population-count totals, the number of establishment values at the SIC level were aggregated. This yields the expression:

$$\hat{U} = \sum_{s \in S} \hat{U}_s = \sum_{s \in S} \frac{N_s}{\hat{N}_s} \sum_{i=1}^{n_s} u_i \cdot W_i. \quad \textbf{(6)}$$

The sample frame (N_S) was assembled from both the 1992 CM and the 1993 ASM. Hence, it represents the best frame available. As with all frames, there are coverage errors. There exist some establishments (ineligible units) that should not have been included, as well as some establishments (missing units) that should have been included but were not. In survey processing, ineligible units can be ascertained. However, missing units are not identified.

For *number of establishment* estimates, the control count (*N*) is equal to the frame size. Hence, the control counts include the identified ineligible units. If one were to assume that no missing cases existed and that all ineligible units had been identified, then lowering of the control number (*N*) to account for those coverage errors could have been justified. Instead of lowering the control number, it was assumed that the weighted number of missing and ineligible cases negated each other--there were equal numbers of (weighted) missing and ineligible cases. Given that assumption, the control number obtained from the original sample frame was retained.

First Use (Formerly Primary Consumption) of Energy for All Purposes

In previous reports, the term "Primary Consumption" was unclear and misunderstood by data users. Instead of interpreting Primary Consumption as the first use of energy at the manufacturing site (as it was intended), some readers interpreted *primary* as accounting for energy losses in generating and transmitting electricity. To avoid future misunderstandings, the term *Primary* has been renamed *First Use* in this report and for all subsequent reports.

Table A1 presents estimates of the total First Use of Energy for All Purposes by the manufacturing sector. This measure is intended to represent total demand for energy by manufactures. Except for petroleum refineries, the estimates in Table A1 are based on the following derived values:

- Energy produced offsite and consumed as fuel
- Energy produced offsite and consumed for nonfuel purposes
- Energy produced onsite from nonenergy inputs and consumed as fuel
- Energy produced onsite from nonenergy inputs and consumed for nonfuel purposes
- Energy shipments offsite (as a subtraction from the first-use total per SIC).

Table A1 also includes estimates of net electricity and steam consumption: that is, purchases plus transfers in and generation from noncombustible renewable resources, minus quantities sold and transferred out. First use excludes quantities of energy that were produced from other energy inputs and, therefore, avoids intra-establishment double counting.

The estimates shown in the petroleum refinery row of Table A1 are conceptually different from the estimates in the other rows of that table. For all industries except petroleum refineries, each cell represents the total first use of energy for all purposes. In the petroleum refinery row, the cell entries for "net electricity" through "coke and breeze" represent only the quantities of given type of energy that was consumed as fuel. The "Other" cell of the petroleum refinery row includes other energy that was consumed as fuel plus the quantity of energy (mostly crude oil) that was consumed for the production of nonenergy products, as estimated by the Btu value of the shipments. Note that although the estimates shown in the refinery row are computed differently, the total Btu does represent a nonduplicative measure of first use. (For more information, refer to Feedstock and Offsite-Produced Fuel at Petroleum Refineries in this appendix.)

First Use (Formerly Primary Consumption) of Energy for Nonfuel Purposes

Table A3 presents the total first use of combustible energy for nonfuel purposes. This table is based upon aggregates of the derived values of energy produced offsite plus those produced onsite from nonenergy inputs, and consumed onsite for nonfuel purposes. Table A3 presents the nonfuel first use component of Table A1. The entry in the "Other" column of the petroleum refinery row of Table A3 represents the total inputs (mostly crude oil) for the production of nonenergy products. The other cells in the petroleum refinery row contain zeros because refinery inputs are available in aggregate form only.

Except for petroleum refineries (see Feedstock and Offsite-Produced Fuel at Petroleum Refineries in this appendix), the estimates in Table A3 are based on the following derived values:

- Energy produced offsite and consumed for nonfuel purposes
- Energy produced onsite from nonenergy inputs and consumed for nonfuel purposes.

Input Energy for Heat, Power, and Electricity Generation

Table A4 presents estimates of input energy for the production of heat, power, and electricity generation. For combustible energy, the estimates are based upon the reported MECS questionnaire responses to "quantity consumed onsite as fuel" (see Appendix D). That reported value is exactly equal to the sum of the following derived values:

- Energy produced offsite and consumed as fuel
- Energy produced onsite from nonenergy inputs and consumed as fuel
- Energy produced onsite from energy products and consumed as fuel.

Thus, the estimates of combustible energy in Table A4 represent total consumption as fuel, regardless of where the energy was produced.

The consumption estimates for fuel use are not duplicative. There is clearly no duplication for quantities that were produced offsite or for those produced onsite from nonenergy sources. Quantities produced onsite from other energy inputs result from consumption of an energy source as feedstock or raw material input. They do not result from the consumption of an energy as fuel.

Examples of energy produced onsite from other energy sources include

- Coke oven gas produced as a byproduct of the destructive distillation of coal to produce coke
- Petroleum coke produced in refineries as a result of the high-temperature treatment of petroleum fractions
- Still gas produced in refineries as a result of distillation, cracking, reforming, and other processes.

From those examples, it is clear that the input energy was not consumed as a fuel and would not have been included elsewhere in Table A4.

The estimates of electricity and steam (note that steam is included in the “Other” energy category) must conform to the same criteria as combustible energy. That is, they must represent inputs to produce heat and power and to generate electricity that do not duplicate energy content represented elsewhere in Table A4.

In the case of electricity, the quantities generated onsite by conventional generation or cogeneration must be excluded because the input fuels (coal, for example) to produce the electricity are already counted elsewhere in the table. Thus, the nonduplicative measure of electricity input for Table A4 is the same net electricity estimate that appeared in Table A1. The same rationale applies to steam. Onsite production is excluded because the input fuel would be counted elsewhere. Thus, the allocation of energy to the various sources shown in Table A4 is consistent with a concept of First Use of Energy for Heat, Power, and Electricity Generation.

Other Topics

Table A2 presents consumption estimates of selected petroleum products expressed in barrels per day rather than in barrels. Included are three estimates of consumption that have been described previously: (1) first use of energy (Table A1), (2) total inputs of energy (Table A4), and (3) consumption for nonfuel purposes (Table A3). These estimates are presented for the convenience of the data user and were derived simply by taking the annual consumption estimate and dividing by 365.

Table A5 presents the total consumption of offsite-produced energy sources as fuel. As noted, these estimates are conceptually equivalent to the Census Bureau's "purchased" fuels. The estimates in Table A5 are based on those estimates of energy produced offsite and consumed onsite as fuel.

Table A6 presents quantities of total inputs of byproduct and “Other” energy sources used as fuel. These estimates are components of the estimates of combustible energy sources found in the last column of Table A4. Net steam (see explanation for Table A4) is not included in Table A6 but is included in the “Other” column in Table A4.

Table A7 is a new table that provides the square footage of manufacturing floorspace in the United States.

Tables A8 through A10 present results obtained when respondents were asked to assign their total input energy consumption of selected major energy sources to various end uses in the establishment. The energy consumption measures used as a baseline for each combustible energy source are found in Table A4. The measures are shown in Tables A8 through A10 as the line item "Total Inputs." Electricity end-use data were collected on the MECS questionnaire as net demand for electricity (purchases plus transfers in plus onsite generation minus sales and transfers out). Those estimates first appear in Table A11 and were collected for end-use data because quantities of net demand represent the actual amount available for use at the establishment. Table A10 shows the results of using that measure of electricity consumption.

Net demand for electricity duplicates the fuel consumption of combustible energy sources used in the process of electricity generation. Tables A8 and A9 show the end-use estimates using the concept of net electricity. Net electricity, the concept used in conjunction with "First Use of Energy" and "Total Inputs of Energy for Heat, Power, and Electricity Generation," is defined as the sum of purchases and transfers in plus onsite generation from noncombustible renewable resources minus sales and transfers out. Unlike net demand for electricity, net electricity excludes onsite generation of electricity from combustible energy sources. Thus, it does not double count the energy content of combustible energy sources used to generate electricity. End-use consumption in terms of net electricity was calculated by forming ratios of net demand for electricity for each end use to total net demand for electricity at the establishment and multiplying those ratios by the quantity of net electricity at the establishment.

The total inputs rows in Tables A8 and A9 include the category “Other” to show how much of the total input energy is not accounted for by major energy sources. For some SICs it is a substantial amount. For example, coal coke and refinery off-gas are significant contributors to boiler fuel and process heat. Data are not available to break down the “Other” category by end-use. Further, steam (the major output from boilers) is excluded from these tables. Consequently, total input energy for any end-use category other than boiler fuel would be underestimated by the amount of steam that contributes to that end

use.[42] Therefore, summing consumption over the end-use categories for which data are available would give a misleading indication of the energy actually used.

For any individual energy source, the estimates in the end-use categories represent direct use. When electricity is considered independently of the combustible energy sources, the more meaningful amount would be in terms of net demand (Table A10) rather than net electricity (Tables A8 and A9).

Table A11 presents components of electricity demand. These quantities are calculated directly from responses to the MECS questionnaire. Note that the quantity "net demand for electricity" is not equivalent to "net electricity" shown in Tables A1 and A4. The latter quantity excludes onsite generation by combustible energy sources.

Table A12 presents components of onsite electricity generation. These components are cogeneration, generation using renewable energy sources, and conventional generation using combustible energy sources. These data are weighted totals of reported responses.

Table A13 is a new table that classifies electricity cogeneration by cogeneration technology.

Table A14 presents quantities of electricity sold to utility and nonutility purchasers. These data are weighted totals of reported responses.

Tables A15, A17, and A20 present purchases, expenditures, and average prices for energy sources. The purchased quantities shown in Tables A15 are *not* values of consumption. These data are the amounts actually purchased in the open market regardless of their later disposition. Quantities received through transfers or from a central purchasing office are excluded. The prices shown in Table A20 are the results of simple division of the expenditures presented in Table A17 by the purchased quantities in Table A15. Prices are shown in both dollars per physical unit and dollars per million Btu. Both the expenditures and quantities purchased were values estimated directly from responses to the MECS questionnaires.

Tables A16, A18, A19, A21, and A22 present purchases, expenditures, and prices for electricity and steam. These tables break down the gross purchases for these energy sources by the type of supplier. Electricity and steam suppliers are either utilities or nonutilities.

Table A23 presents estimates of several energy-related operating ratios. These estimates are computed from energy data reported by the MECS responding establishments and economic data reported on the ASM for the same establishments. The consumption values used in the formation of these ratios appear in Table A4. It is not possible to reconstruct exactly the 1994 ASM estimates of economic variables by dividing MECS consumption by corresponding ratios of consumption per economic unit. Due to different purposes of the MECS and ASM, the size and weighting scheme of the MECS and ASM samples are different. Therefore, a MECS estimate for an economic variable would be expected to be slightly different due to sampling error, especially for the entries representing a relatively small number of establishments.

Tables A24 and A25 present estimates of participation by establishments in energy-management activities. Total input energy is the measure of interest. If an establishment indicates participation in an activity, its energy consumption is counted in the appropriate category. If not, it is counted in "None Identified."[43] Table A24 also shows subcategories of participation: electric utility sponsorship (often referred to as demand-side management), self, government sponsorship, or third-party sponsorship.

Tables A26 and A27 present estimates of total input energy consumption broken down by employment size of establishment, value of shipments, and presence of selected energy-saving technologies. These technologies are known to save energy but may not have been installed for that purpose.

Tables A28 through A36, most of which are new tables, investigate the fuel-switching capability and actual switching of fuels between natural gas and residual fuel oil.

Tables A37 through A40 present estimates of the capability of substituting specific alternative types of energy for those actually consumed, holding production constant. Each table contains information for the specific type of energy that was

[42]In the case of cogeneration, the underestimation could be expressed in terms of an unknown amount of steam and electricity.
[43]Until the 1994 MECS, participation had to be shown as total inputs of energy. The 1994 MECS can also show establishment counts.

actually consumed for the production of heat, power, and generated electricity in 1994. It should be noted that the first column of Table A37 refers to "Total Receipts" of electricity, while the first column of Tables A29, A33, A38, A39, and A40 refers to "Total Consumed" natural gas, residual fuel oil, distillate fuel oil, coal, and LPG, respectively.

Thus, the quantities of electricity generated onsite are excluded, as are the quantities of electricity leaving the establishment site. When considering fuel-switching capabilities, total electricity receipts is a more meaningful quantity than total electricity consumption. A respondent who has onsite generation of electricity has, more than likely, used an additional amount of a combustible energy source to operate the generator. It is a valid question to ask, "How much of that self-generation is replaceable by electricity receipts?" However, it is more reasonable and of greater interest to collect the fuel-switching data for the fuel used to generate the electricity by asking respondents to show the quantity of electricity receipts that could replace the combustible fuel.

In Tables A29, A33, and A37 through A40 the estimates provided in each column under "Alternative Types of Energy" should be considered independently because respondents were instructed to enter the maximum amount of the quantity of the energy actually consumed that could have been replaced by a given alternative. Because each value represents the maximum quantity of electricity receipts that could have been replaced, their sum exceeds the total quantity of electricity that was ascertained as switchable. That difference indicates that some establishments had more than one type of energy that could have been substituted for electricity usage during 1994.

Tables A41 and A42 are new tables that tabulate information about electric motors.

Table A43 is a new table that gives the consumption of wood and related products, including biomass.

Table A44 is a new table that provides a more detailed classification of the “Other” category in Table A1.

Number of Establishments

For the first time, MECS presents estimates for number of manufacturing establishments. These estimates appear as companion tables to several of the consumption tables given above, where appropriate. These estimates use an adjusted Horvitz-Thompson estimator as the means to calculate number of establishments. For further details, see Survey Estimates Presented in Appendix A in this appendix.

The Heat Content of Energy Sources

Many of the estimates of individual energy sources in this report are presented in physical units (kilowatthours, barrels, and short tons). Row totals and combinations of types of energy are presented in Btu. Tables A1 through A5 are presented in physical units in Parts 1 and 2 and in Btu in Parts 3 and 4.

A Btu is the quantity of heat required to raise the temperature of 1 pound of water by 1 degree Fahrenheit. Thus, converting physical units of a given type of energy to Btu is a means of expressing the heat content of that energy source. All Btu quantities are in terms of higher heating value, with no regard for efficiency of use. Because no energy consumption process is 100-percent efficient (although some are considerably more energy efficient than others), Btu figures must be considered as the maximum available heat content. Table B3 presents the Btu conversion factors of major types of energy.

Table B3. Conversion of Physical Units to British Thermal Units

Type of Energy	British Thermal Units (thousands)
Electricity (1,000 kilowatthours)	3,412
Residual Fuel Oil (42 gallon barrel)	6,287
Distillate Fuel Oil (42 gallon barrel)	5,825
Natural Gas (1,000 cubic feet)	1,030
Liquefied Petroleum Gas (42 gallon barrel)	3,606
Coke and Breeze (short ton)	24,800
Bituminous Coal and Lignite Used as Fuel (short ton)	22,036
Anthracite Coal and Lignite Used as Fuel (short ton)	26,280
Coal Used for Coking (short ton)	26,800

Source: EIA, *Annual Energy Review 1994*, DOE\EIA-0383(94) (Washington, DC, July 1995), Appendix A.