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2014 Manufacturing Energy Consumption Survey Methodology and Data Quality: Survey Design, Implementation, and Estimates

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The *Manufacturing Energy Consumption Survey* (MECS) is the federal government's comprehensive source of information on energy use by U.S. manufacturers. The survey collects data on energy consumption and expenditures, fuel-switching capability, onsite generation of electricity, byproduct energy use, and other energy-related topics. Previous MECS surveys were conducted every three years for the years 1985 through 1994 and then every four years from the years 1994 through 2018.

The basic unit of data collection for this survey is the manufacturing establishment. A nationally representative sample of these establishments supplied the data through self-administered electronic questionnaires, although a subset of respondents supplied the data through conventional paper questionnaires. The U.S. Census Bureau, in consultation with the U.S. Energy Information Administration (EIA), selected the MECS sample, conducted fieldwork, and processed the data.

This document 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 MECS data tables and analysis.

Sample Design

The target population for the *2014 Manufacturing Energy Consumption Survey* (MECS), the most recently published survey data, consists of all manufacturing establishments in the United States that were active in 2014 with paid employees, except for small single-establishment companies that accounted for only about 2% to 3% of the total 2014 payroll for all U.S. manufacturing establishments. These small single-establishment companies are excluded to prevent response burden on these small companies, which are expected to consume only a very small amount of energy relative to the total energy consumption for six-digit industries in the Manufacturing Sector as classified in the 2012 North American Industry Classification System (NAICS). The sample design for the 2014 MECS involved selecting an initial sample from the 2012 Economic Census and a supplemental sample of 2013 births—when a new establishment is created—from the U.S. Census Bureau's Business Register.

The sampling frame for the initial sample was constructed from a list of establishments that were included in the Manufacturing portion of the 2012 Economic Census. These establishments included all manufacturing establishments in the United States that were active in 2012 with paid employees, except for small single-establishment companies with 2012 payroll below the 2012 Economic Census cutoffs that were used by the U.S. Census Bureau to determine the 2012 Census mailout. The frame included records for about 170,000 U.S. manufacturing establishments, which consisted of almost 58,000 establishments from multi-establishment companies and a little more than 112,000 single-establishment companies.

Each establishment represented on the sampling frame for the initial sample was assigned to one of 79 industry groupings in the manufacturing sector defined by the 2012 NAICS at the three-digit, four-digit, five-digit, or six-digit level. For a given industry, the level of NAICS detail was based on its relative energy intensity in terms of total annual energy consumption for the industry and average annual energy consumption for establishments classified in the industry. The more detailed five-digit and six-digit levels were used for the industries with the highest energy intensities. Similarly, each establishment on the frame was assigned to one of the four census regions—Northeast, Midwest, South, or West. Before sample selection, the sampling frame for the initial sample was stratified based on strata that were defined by 267 different combinations of 2012 NAICS industry groupings and the four census regions, and most of the industry groupings were broken out by census region. The strata were based on the desired publication levels that were defined by EIA. Each establishment represented on the initial sampling frame was assigned to only one stratum before sample selection.

The initial sample of about 14,100 establishments consisted of about 6,400 certainties, which were selected in the sample with a probability of 1, and a probability sample of about 7,700 noncertainties, which were selected in the sample with a probability less than 1. Of the certainties, about 2,500 establishments met at least one of the following four certainty criteria (the other certainties were the result of the noncertainty sample allocation):

Establishments classified in the following six-digit NAICS industries were selected with certainty: Paper (Except Newsprint) Mills (NAICS 322121), Paperboard Mills (NAICS 322130), Petroleum Refineries (NAICS 324110), and Iron and Steel Mills and Ferroalloy Manufacturing (NAICS 331110).

Establishments classified in industry groupings having 100 or fewer establishment records on the initial sampling frame were selected with certainty.

Establishments classified in strata having fewer than 30 establishment records on the initial sampling frame were selected with certainty.

Establishments were selected with certainty if they were large users of feedstocks, natural gas, distillates, residual, or other fuels combined, based on data from the 2010 MECS.

These four certainty criteria resulted in 23 industry groupings being selected with certainty, including the four pre-specified six-digit NAICS industry groupings.

Each establishment represented on the sampling frame for the initial sample was assigned a measure of size that represented the combined annual cost of purchased fuels and electricity. EIA used reported or imputed data from the 2012 Economic Census to calculate this measure of size. For each stratum in which not all of the establishments were selected with certainty, Pareto sampling[1] was used to select a sample of a fixed size in which a given establishment's probability of selection was proportional to its measure of size. The Pareto sampling method results in weighted estimates that are slightly biased. However, the variance estimates associated with these weighted estimates have good properties, and the method is easy to implement compared with some other common probability-proportional-to-size sampling methods.

Target reliability constraints and maximum bounds on the sampling weights between 20 (high energy-intensive industries) and 100 (low energy-intensive industries with large numbers of establishment records on the sampling frame) were used to select the initial sample.

[1] Rosén, Bengt. (1997). "On sampling with probability proportional to size." *Journal of Statistical Planning and Inference*: **62**, 159-191.

The initial sample had a supplemental sample of about 800 births that were identified after the 2012 Economic Census was conducted, based on a list of about 5,650 newly identified in-scope establishments that was constructed from the U.S. Census Bureau's 2013 Business Register. Because information on the measure of size was not available for most of these births, their measure of size was set to 1. The top 150 establishments from multi-establishment companies in terms of 2013 payroll were selected with certainty, and separate random samples for two strata—single-establishment companies and establishments from multi-establishment companies—were selected from the about 5,500 noncertainty establishments. The supplemental sample increased the overall size of the 2014 MECS sample to 14,900 establishments.

Estimation

To produce the estimated totals from the 2014 MECS sample that are published or used in the calculation of ratios, the data from the respondents in the sample are weighted and then aggregated. The final weight is the sampling weight multiplied by an adjustment factor that corrects for unit nonresponse and coverage changes. The sampling weight for an establishment is the inverse of its probability of being selected for the sample. The sampling weight for a certainty is 1, while the sampling weight for a noncertainty is larger than 1 but is no greater than its maximum bound that was set during the sample design. The sampling weight for an establishment in the 2014 MECS sample that responds to the survey is then adjusted using a factor that is multiplied by the sampling weight. This adjustment also corrects for unit nonresponse to the survey, 2014 births that were not subjected to sampling in the initial sample or the supplemental sample, and deaths in the sample that ceased operation during 2014.

Separately, for certainties and noncertainties for a given stratum, the adjustment factor is a ratio computed as follows, using records for only establishments that were active in 2014. The numerator of the adjustment factor is the sum of the measure of size used for sampling that is weighted by the sampling weight for establishments in the sample (survey respondents and nonrespondents) and weighted by 1 for 2014 births. For deaths in the sample that ceased operation during 2014, an additional weight of 0.5 is applied to represent the average portion of the year that deaths were in business during 2014. The 2014 births were identified from the *2014 Annual Survey of Manufactures* (ASM) birth processing, and their measure of size was based on reported and imputed values for cost of fuels and cost of purchased electricity in the 2014 ASM. The denominator of the adjustment factor is the sum of the measure of size for only the survey respondents weighted by the sampling weight.

Before publication, the estimated establishment counts from the 2014 MECS sample were post-stratified as follows. The NAICS code for establishment records on the supplemental frame was updated using the U.S. Census Bureau's 2014 Business Register, and more than 400 records with an incomplete or out-of-scope NAICS code were removed from the updated supplemental frame. For a given industry grouping, the estimated establishment count was then set equal to the corresponding establishment count from the combined initial and updated supplemental frames. During this calibration procedure, the final weight for each respondent was adjusted while ensuring that the adjusted final weight was not less than 1. A published estimated establishment count was then calculated by summing the adjusted final weights after post-stratification for the respondents having the characteristics of interest.

Types of Potential Survey Errors in Estimates Published from the MECS Sample

Estimates produced from the MECS sample are subject to both sampling and nonsampling errors. Potential nonsampling errors include various response and operational errors, such as errors during data collection, reporting errors, transcription errors, and bias as a result of nonresponse. These are all types of errors that could also occur if a census had been conducted under the same conditions as the sample survey. Most of the important operational errors were detected and corrected during the course of reviewing data for reasonableness and consistency. Although nonsampling error is not measured directly, quality control procedures are employed throughout the survey process to minimize this type of error. The unweighted unit response rate for the 2014 MECS based on response to total onsite consumption of electricity was about 72%, and the quantity response rate based on weighted measure of size was about 83%.

Sampling error is the error caused by observing a sample instead of the entire sampling frame. Statistics based on the sample (such as totals and ratios) generally differ from statistics on the entire frame because the sample includes only a subset of the frame.

Statisticians use measures of sampling variability, such as the standard error (SE) and the relative standard error (RSE), to measure the sampling error. These measures of sampling variability are typically estimated from the sample that was selected. The standard error, which is measured in the same units as the estimate, is a measure of the sampling variability of the estimate based on all possible samples that could have been selected using the chosen sample design. The RSE, which may also be referred to as the coefficient of variation (CV), is the standard error expressed as a fraction of the estimate and is displayed as a percentage. For MECS, the estimated RSEs associated with a given data table are published in a separate table and in a similar format as the corresponding data table. An estimate for which the corresponding RSE is greater than 50% is replaced by the *Q* symbol in the data table, unless the value of the estimate is less than half the unit of measure in the table. Note that for both the standard error and the relative standard error, the estimated value for an aggregate level may not be computed by summing the corresponding estimated values for its individual components.

The estimated standard error can be used to compute a confidence interval centered about the corresponding published estimate with a desired level of confidence. Only one of many possible samples was selected for MECS. If a confidence interval were constructed for each of these possible samples, then the percentage of confidence intervals containing the frame value (if EIA had surveyed a census of the entire sampling frame under the same conditions as the sample) would be expected to equal the level of confidence. For example, if EIA could construct a 95% confidence interval for each possible sample that could be selected, then it would expect that 95% of these confidence intervals would contain the value obtained from taking a census of the sampling frame.

To determine the half-width of the confidence interval for a given published estimate, EIA computes the margin of error (MOE) defined as the estimated standard error of the estimate multiplied by the standard normal percentile for the level of confidence, rounded up to the nearest unit used in publishing the corresponding estimate. The lower bound of the confidence interval is the estimate minus the MOE, and the upper bound of the confidence interval is the estimate plus the MOE. For the standard normal percentile, EIA uses 1.645 for a 90% confidence interval and uses 1.96 for a 95% confidence interval.

For example, suppose that the published estimate of total fuel consumption for the United States is 2,000 trillion British thermal units (Btu) and its published estimate of the RSE is 0.6%, which implies that its estimated SE is about 2,000 x 0.6% = 12 trillion Btu. The MOE for a 95% confidence interval would be 1.96 x 12 trillion Btu, or about 24 trillion Btu, and the 95% confidence interval would be 2,000 +/- 24 trillion Btu, or 1,976 to 2,024 trillion Btu.

Disclosure Protection

The U.S. Census Bureau, the MECS collection agent for EIA, is required by Title 13 United States Code, Section 9, to keep the survey data confidential and use the survey data only to produce aggregate statistics. The U.S. Census Bureau is not permitted to publicly release survey data in a way that could identify a business, organization, or institution. Following the Federal Cybersecurity Enhancement Act of 2015, the survey data are protected from cybersecurity risks through screening of the systems that transmit the data.

For MECS, the U.S. Census Bureau uses cell suppression to protect against the disclosure of identifiable information before releasing the data tables to EIA for publication. The software used by the U.S. Census Bureau to identify the table cells to be suppressed has been approved by the U.S. Census Bureau's Disclosure Review Board. For a given cell in a data table, a suppression of an estimate involves replacing the value of the estimate with a *W*. However, suppressed data at detailed publication levels are included in published higher-level aggregates in the data table.

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 2014 MECS questionnaires. Those values were supplemented by estimates of energy consumption for nonfuel purposes and offsite-produced fuel consumption at petroleum refineries based on responses to Form EIA-810, *Monthly Refinery Report*. In addition, 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 number of employees

Those economic data were not collected by the MECS but were provided by the U.S. Census Bureau by linking the economic data found on the Manufacturing portion of the Economic Census or the Annual Survey of Manufactures with the MECS energy data at the establishment level. When necessary, the values were imputed using ratio or other adjustments. The reported energy values were used to construct several derived values, which, in turn, were used to prepare the estimates in selected tables in the MECS. Those derived values are defined as the following categories.

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

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.

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 the wood used in the pulping process. Wood for pulping is not classified as energy in the MECS, and, therefore, it would not have been included as an input. This derived value also covers waste materials, biomass, and hydrogen that are produced from the electrolysis of brine. Energy sources such as petroleum and coal that are consumed as fuel and originate onsite from captive mines or wells (an unusual occurrence) are also included here.

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. Energy sources such as petroleum and coal that were consumed as a nonfuel and originated onsite from captive mines or wells are also included here.

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 petrochemical feedstocks and other raw material inputs that were produced onsite from existing energy or from other onsite-produced energy. This derived value is duplicative with respect to the consumption of energy for nonfuel purposes and therefore was not used to prepare estimates.

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 Iron and Steel Mills (NAICS 331111) and various industries in Chemicals and Allied Products (NAICS 325). 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.

Assumptions Underlying Derived Values

Two basic assumptions are necessary to produce the derived values from the data reported on the MECS questionnaire. First, EIA assumes 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, EIA does not consider a quantity of an energy source produced onsite and placed into inventory during the previous year as 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 the establishment did not have sufficient onsite production to meet its needs of the energy source in the current year. Second, EIA assumes 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.

Tabular Estimates

The derived values described above are used to form the estimates found in the published tables. Along with data for electricity, steam, and hot water, the derived variables together form four different measures of energy consumption.

Table 1.1 through 1.5 (Consumption of Energy for All Purposes (First Use))

These tables sum the first four derived values described above. They exclude derived values 5 and 6 because they would duplicate the consumption of nonfuel use of energy in values 2 and 4. Derived value 7 is also subtracted when applicable to eliminate duplication among establishments. The net electricity (and steam and hot water) shown in these tables, does not duplicate the combustible fuel shown elsewhere.

Tables 2.1 through 2.4 (Energy Used as a Nonfuel (Feedstock))

These tables include nonfuel use and exclude fuel use. As such, they are the sum of derived values 2 and 4. Derived value 6 is *not* included because it would be duplicative of the other energy already counted.

Tables 3.1 through 3.6 (Energy Consumption as a Fuel)

The combustible fuel estimates in these tables are based on the reported data from respondents after editing. They are also equivalent to the sum of derived values 1, 3, and 5. The net electricity (and steam and hot water) shown in these tables does not duplicate the combustible fuel use shown elsewhere.

Tables 4.1 through 4.4 (Offsite-produced Fuel Consumption)

These tables show fuel consumption coming from either purchases or other outside sources. Derived value 1 is the only quantity used in these estimates. Electricity, steam, and hot water are only from purchases or outside sources.

Feedstock and Offsite-Produced Fuel at Petroleum Refineries

The basic function of a petroleum refinery (NAICS 324110) 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, and waxes and are referred to as nonenergy products.[2]

The MECS was specifically designed to collect information on the consumption of energy for heat, power, and electricity generation as well as for 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, 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[3] and are reported not only in other manufacturing industries but also in EIA surveys of consumption in other end-use sectors. 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). Until the 2014 MECS, all of these products, such as asphalt, petrochemical feedstocks, lubricants, and solvents, were counted as refinery consumption by including their Btu value because the products would not be recognized as energy by their subsequent consumers. In addition, 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 had to be counted as refinery consumption, or it would never have been accounted for anywhere in EIA's consumption measurement. The method that EIA introduced starting with the 2014 MECS uses shipments of the nonenergy products as a surrogate for the energy used to produce them. EIA produces such information for all refinery products based on responses to Form EIA-810, *Monthly Refinery Report*. This form collects information

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[2] 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.

[3] 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, EIA assumes 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, EIA assumes that respondents would not report it as an energy source receipt.

on the monthly shipments from U.S. refineries. These data were the basis for estimating the input energy requirements for the nonenergy products.

Asphalt (i.e., bitumen) and two petrochemical feedstocks categories identified in Form EIA-810 are now being asked for directly starting with the 2014 MECS and are counted the same as other energy sources. Although the use for these substances would mostly be as nonfuel, the added value of the data along with the importance of the substances to the industries most likely to report the consumption made the collection both feasible and advantageous. Consumption data on other refinery nonfuel products (lubricants, waxes, solvents) are not widely known by MECS respondents. For that reason, they are accounted for by including their published Product Supplied numbers as a line item in Table 1 as *Miscellaneous Nonfuel Products*. As a result, consumption from refineries is removed but not assigned to any individual consuming industry.

Because of these changes, the energy use at petroleum refineries (NAICS 324110) is now defined as solely its own fuel use (including net electricity and steam). Nonfuel use has been moved into consuming industries and miscellaneous nonfuel products. As such, total consumption quantities in refineries as shown in Table 1 will appear smaller in 2014 than in previous years. Likewise, it is likely that the chemicals industry (NAICS 325) would show an increase over previous years (Table 1 below). Users should take into account the methodological changes when comparing total consumption in 2014 to other years.

Table 1: Comparison of total consumption of fuel and feedstock for petroleum and coal products and chemicals

Year	NAICS code	Subsector and industry	Total consumption (trillion British thermal units)
2010	324	Petroleum and coal	6,137
	324110	Petroleum refineries	5,922
	325	Chemicals	4,995
	325110	Petrochemicals	860
2014	324	Petroleum and coal	4,168
	324110	Petroleum refineries	3,372
	325	Chemicals	6,297
	325110	Petrochemicals	1,110

The Form EIA-810 data are also used to calculate the offsite-produced fuel use at the refinery establishment. Because the MECS petroleum refinery questionnaire, Form EIA-846(B), collects only total fuel use of petroleum products (regardless of their origin), EIA uses the Form EIA-810 data to calculate the offsite-produced fuel ratio for those products. Estimation of the ratio used the same assumptions described in the section on Assumptions Underlying Derived Values**,** except that Form EIA-810 data were used instead of data reported on the MECS questionnaire. This ratio is then applied to the MECS estimated value of total fuel. [10] The estimator takes the form:

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

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 NAICS industries.

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. *Total consumption of energy* (formerly, *first use*) 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 other types of manufacturers also 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, the energy source would be double-counted when it arrived at the receiving establishment. Total *consumption of energy* 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. For the 2014 MECS, the estimates can be found in Table 1.

The coal used to make coke has the greatest effect on total energy consumption. A steel mill processes bituminous coal to make coke for later use in the steel making process. Total consumption counts the quantity of coal as the original nonfuel input. Any onsite consumption of coke produced from the coal is not included in total consumption because it duplicates the coal use. If the steel mill sells and ships some of the coke to another establishment, it will show up as an input of an offsite-produced energy source in the second establishment and will be included in that establishment's consumption data. By subtracting the Btu value of the shipments from the producing establishment, the MECS avoids the double counting of the Btu of the input coal in the first establishment with the consumed coke in the second establishment.

Duplication in Fuel Use of Coal Coke and Blast Furnace Gas in the Iron and Steel Industry

MECS analysts have assumed for purposes of estimation that all energy sources used for fuel are completely consumed in the process. That means that an energy source used as fuel will not be transformed into another substance that can later be used for fuel or nonfuel purposes. The assumption holds well enough in most cases even though waste substance that was not consumed in the heater or boiler may accumulate. In the case of a blast furnace used in the iron making process (NAICS 331111), the effect of not completely consuming the blast furnace fuel inputs may be a significant cause of duplication. Literature reviews and consultation have revealed that most of the formation of the blast furnace gas would arise from the input fuel use of coke. Other sources may contribute to the generation of blast furnace gas, but they appear to be minor compared with coke.

One possible solution to adjusting the MECS data so that the energy flows in NAICS 331111 appear reasonable is to adjust the fuel use of coal coke downward by the heat content of the blast furnace gas consumed in that industry. As implied in the preceding paragraph, this adjustment would be imperfect because not all of the blast furnace gas would necessarily arise from the incomplete combustion of coal coke. Another complication is that the MECS has historically published only a combined estimate for coke oven gas and blast furnace gas to meet publication requirements. However, the proportion of blast furnace gas in those combined estimates has been about two-thirds. Therefore, for 2014, an estimate for coal coke fuel use in NAICS 331111 in 2014 may be computed as:

Coke and Breeze Fuel Use for NAICS 331110 as reported in MECS: 290 trillion Btu (Table 3.2 in 2014 MECS).
Coke and Blast Furnace Gas Combine Estimate in NAICS 331110: 234 trillion Btu. (Table 3.5 in 2014 MECS)
Adjusted Estimate for Coke and Breeze Fuel Use in NAICS 331110: 290 - 2/3(234) = 134 trillion Btu.

Concept of Fuel-Switching Capability

EIA continues to employ the concept of fuel switching that was developed before the first survey for 1985. After extensive consultation with potential data users and data providers, 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 one-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, which 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 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* 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 2014 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),[4] and hydrocarbon gas liquids—formerly liquefied petroleum gas. 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 2014. 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 is to determine how much of each switchable quantity could have been replaced by specific alternatives.

How to Measure Discretionary Fuel Use

One of the summary statistics that can be developed from the estimates of actual consumption, minimum consumption, and maximum consumption is the *discretionary-use rate* (Table 10.1). The discretionary-use rate is a measure, as a percentage, of the extent to which manufacturers elected to consume discretionary quantities of a given energy source. The discretionary-use rate is calculated as:

$$USE = \frac{ACT - MIN}{MAX - MIN}$$

where USE is the discretionary-use rate of a given energy source;

ACT is the actual consumption of that energy source;

[4] 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.

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, as a percentage, of the depth into the discretionary range of consumption to which manufacturers chose to go, given their fuel-switching capabilities and production levels in 2014.

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%. 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%.

Note that (ACT - MIN) is equivalent to the *switchabl*e 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.

The Heat Content of Energy Sources

Many of the estimates of individual energy sources are presented in physical units (kilowatthours, barrels, and short tons). Summary totals need to be in terms of a common unit of measurement, so tables are also given where Btu is the common unit.

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 and have no regard for efficiency of use. Because no energy consumption process is 100% efficient (although some are considerably more energy efficient than others), Btu figures must be considered as the maximum available heat content. The following table presents the Btu conversion factors of major types of energy.

Table 2. 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)	1,033
Hydrocarbon gas liquids (42 gallon barrel)	3,439
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)	28,458

Source: EIA, Annual Energy Review