Concepts, Data Sources, and Techniques

Handbook of Energy Modeling Methods

NEMS Industrial Demand Module

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1. Introduction

The NEMS Industrial Demand Module (IDM) projects industrial energy consumption by energy source, as well as industrial combined heat and power (CHP) capacity, CHP generation, and CO2 emissions from the industrial sector. The industrial sector comprises energy-intensive manufacturing, non-energy-intensive manufacturing, and nonmanufacturing industries.

The IDM projects industrial consumption of the following energy types:

- Fuel consumption
  - Petroleum
  - Natural gas
  - Coal
  - Purchased electricity
  - Renewables
- Nonfuel consumption (the energy source is not burned, that is, it can be consumed as a chemical feedstock)
  - Liquids (for example, hydrocarbon gas liquids (HGL)),
  - Natural gas

The IDM projects annual energy consumption in each of the four census regions for the 21 industries and industry groups shown in **Table A-1** on page 27. It also projects total industrial sector consumption by energy source for each of the nine census divisions.

The IDM projects energy consumption based primarily on the following drivers:

- Value of shipments
- Energy intensity, which is assumed to decline over the projection period because of efficiency improvements of old capacity and installation of new capacity
- Energy prices

Capacity is defined as *machines only*, and prices are assumed to have less impact on energy consumption than value of shipments or energy intensity.

2. Historical Input Data

The *IDM base year*, the reference year for IDM input data, is the sample year of the most recent quadrennial Manufacturing Energy Consumption Survey (MECS). This MECS sample year is usually three to seven years before the first Annual Energy Outlook (AEO) projection year. The IDM uses MECS data for initial energy consumption calculations for manufacturing industries.

Because EIA does not have a survey of industrial non-manufacturing energy consumption, EIA cannot directly calculate nonmanufacturing energy consumption for the IDM base year. Instead, we estimate total non-manufacturing energy consumption in the IDM base year based on the difference between total industrial energy consumption from the latest State Energy Data System update and the manufacturing energy consumption, estimated from MECS data. We then use supplemental information from other sources, such as the *Fuel Oil and Kerosene Sales* report (FOKS), the Economic Census, and

U.S. Department of Agriculture (USDA) surveys, to disaggregate nonmanufacturing energy consumption among six industries and to improve base year estimates of nonmanufacturing energy consumption.

3. Overview of IDM Components

The IDM has three components, each representing one component of industrial energy demand:

- Process and assembly (PA)
- Buildings (BLD)
- Boiler/steam/cogeneration (BSC)

The PA component projects the amounts of energy and steam needed to produce goods; this energy accounts for most industrial energy consumption. The BLD component projects the energy used in buildings for certain applications (for example, lighting) in the industrial sector. The BSC component projects the fuel quantities consumed in producing steam for industrial use (both PA and BLD) from CHP or boilers.

3.1. Process and Assembly

Most industrial energy consumption modeled in the IDM is for process and assembly (PA). All energy projected in the PA component is used directly to make goods. PA component projections exclude projected energy used in buildings and usually exclude energy used to produce steam.

EIA assumes that energy consumption is a function of industrial capacity (machines) required to produce goods. Examples of real-world capacity include ovens used to bake bread or kilns used to manufacture cement. For the IDM base year, the IDM assumes that output is equal to capacity. This assumption implies that capacity must increase when output increases.

The IDM projects that as demand for goods increases, industries add new capacity and improve old capacity to meet the increased demand. Capacity is also retired over time and replaced by new capacity. The IDM assumes that, owing to technological advances, the added capacity is more energy efficient than the old capacity. It also assumes that the old capacity becomes more efficient over time, due to upgrades, while remaining less efficient than the new capacity.

3.2. Buildings Component

Buildings are estimated to account for a small percentage of total heat and power consumption in energy-intensive manufacturing industries. However, the IDM estimates that buildings energy consumption for some non-energy-intensive manufacturing industries is as much as 40% of total energy consumption.

For manufacturing, the IDM's estimates of initial buildings energy consumption are based on MECS energy consumption data for several activities:

- Lighting, from electricity only
- Heating, ventilation, and air conditioning (HVAC) from electricity, natural gas, and steam
- Facility support (such as office machines or water heating), mostly from electricity and natural gas

Projected steam demand is passed to the BSC component, which projects energy used for steam production.

After EIA analysts estimate IDM base year energy consumption, the IDM projects buildings energy consumption for manufacturing as a function of employment and shipments growth for each industry, as well as a price factor that reduces projected energy consumption growth in response to projected energy price increases. The module assumes that building energy consumption is sensitive to employment and shipments growth, because lighting and HVAC are designed primarily for workers. Also, shipments growth is correlated with floor space growth, another determinant of energy consumption in buildings.

3.3. Boiler/Steam/Cogeneration Component

The boiler/steam/cogeneration (BSC) component projects the energy necessary to meet projected steam demand in the PA and BLD components of the IDM. Cogeneration is also known as combined heat and power (CHP). To project energy consumption demand in British thermal units (Btu), the BSC first attempts to find a suitable CHP system from a candidate slate of representative CHP technologies for each industry's steam load and then evaluates the candidate CHP system for economic feasibility. If, for a particular industry, a candidate CHP system is not economically feasible, the BSC will assume that a boiler will fulfill steam demand for that industry. The boiler's projected fuel and efficiency characteristics are based on EIA analyst assumptions.

Unlike the PA and BLD components, the BSC uses projections of one form of energy—steam demand—to project boiler and CHP fuel consumption as well as CHP electricity generation. The BSC does not project energy consumed to produce steam for the iron and steel industry, the pulp and paper industry, or the aluminum industry. For these industries, the PA component projects steam requirements based on a slate of EIA analyst-specified technologies.

4. Projections for Nonmanufacturing Industries

Although the concepts discussed above also apply to nonmanufacturing industries, the projection process for these industries differs from those in the manufacturing industries, because EIA does not have a comparable survey to MECS for nonmanufacturing energy consumption. Broadly, EIA analysts estimate nonmanufacturing energy consumption in the IDM base year as the difference between estimated *total industrial* energy consumption, as reported in the State Energy Data System and *manufacturing* energy consumption, as estimated from MECS data. Using additional information from the Economic Censuses for Agriculture, Mining, and Construction and USDA surveys, EIA analysts allocate nonmanufacturing energy consumption among the nonmanufacturing industries.

Nonmanufacturing process and assembly energy consumption projections depend on input from other NEMS modules:

- The IDM uses input from the Commercial Demand Module (CDM) to project building energy consumption in the nonmanufacturing sector.
- Input from the Transportation Demand Module (TDM) helps project energy consumption of off-road vehicles, such as tractors in agriculture.

- Mining energy consumption depends on the following projected inputs:
    - The Oil and Gas Supply Module (OGSM) projects oil and natural gas well energy consumption.
    - The Coal Market Module (CMM) projects energy consumed in coal mines.
    - The Natural Gas Market Module (NGMM) projects natural gas consumption in the oil and natural gas sector (for lease and plant fuel) and natural gas consumed during liquefaction in LNG facilities.

5. Detailed Descriptions of IDM Components

5.1. Process and Assembly Component

The IDM projects that process and assembly (PA) of goods uses more energy than what the other two IDM components project. Although the IDM projects PA consumption for end-use industries differently than for process flow industries (defined below), the basic premise for both methods is that energy consumption is a function of the capacity required to produce goods.

The IDM assumes that industrial capacity increases over time as output increases; that is, as demand for goods increases, industries add new capacity or improve old capacity to serve the additional demand. The IDM also assumes that the added capacity is more energy efficient than the old capacity and that, because of retrofits and retirements of less-efficient capacity, existing capacity becomes more efficient over time while remaining less efficient than new capacity. The IDM represents two types of industries:

- **End-use industries:** End-use industries are industries the IDM projects energy consumption for by energy services used to produce goods (for example, heating, cooling, machine drive). Most manufacturing and all nonmanufacturing industries are end-use industries. Because end-use industries produce many different products, the IDM cannot model every industrial process step used to produce each product. The IDM projects end-use PA consumption for each census region based on the values of product shipments and aggregates to the national level.
- **Process flow industries:** A process flow is a series of distinct steps of a manufacturing process. Process flow industries include the paper, cement and lime, glass, iron and steel, and aluminum industries. For these industries, the IDM projects energy consumption by process step, based on physical output. Examples of process steps include direct heating for glassmaking or casting for steel. Unlike for end-use industries, the IDM projects energy consumption at the national level and then disaggregates energy projections to the census region level, based on the regional distribution of these industries' shipments, as projected by the Macroeconomic Activity Module (MAM).

The IDM assumes capacity is equal to output (both measured in dollar values) in the IDM base year, even though real-world capacity utilization is typically less than 100%. The IDM implicitly assumes that capacity utilization is the same in the projection years as it is in the IDM base year. If the IDM base year occurs in a time of economic expansion, the IDM's assumption that capacity grows with output is reasonable. However, if the IDM base year occurs during or just after a recession, EIA analysts may estimate that a certain amount of capacity is idle in the IDM base year and project that industries will return the idle capacity to service before adding new capacity.

5.1.1. Projecting for End-Use Industries

5.1.1.1. Estimating capacity

EIA analysts estimate IDM base year capacity for end-use industries as equal to the dollar amount of shipments multiplied by a judgment-based normalizing constant, assuming capacity is equal to output. The following equations describe the relationships among output, shipments, and capacity for each industry and census region in the IDM base year:

$$\text{Output in Dollars} = \text{Normalizing Constant} \times \text{Shipments in Dollars.} \quad (1)$$

$$\text{Capacity} = \text{Output in Dollars.} \quad (2)$$

Establishing the relationships among shipments, output, and capacity in the IDM base year allows projection of energy consumption for future years: growth in projected shipments causes growth in projected capacity. The IDM projects three types of capacity: old capacity, new capacity, and added capacity.

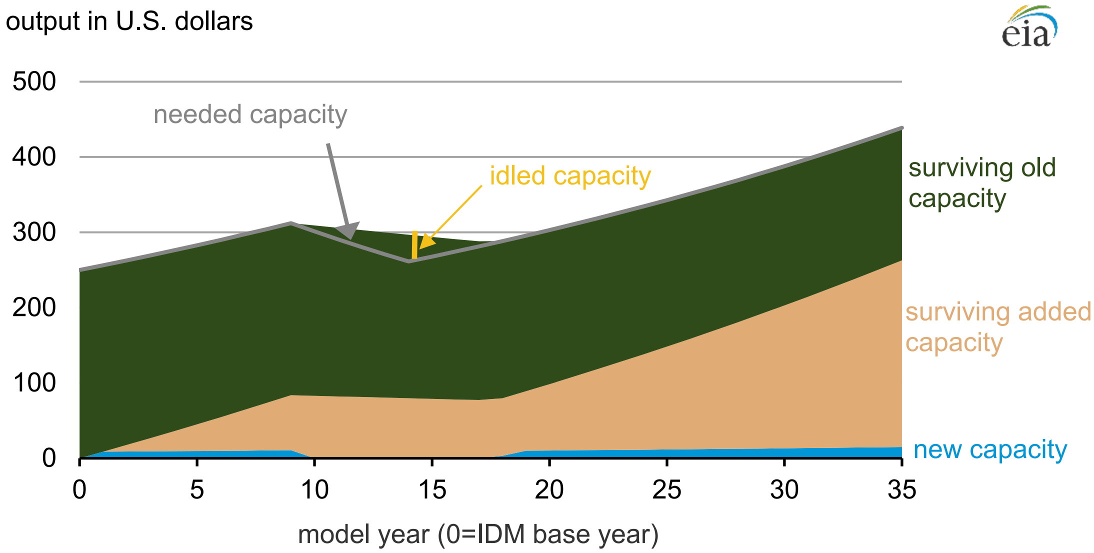
- **Old capacity** is the estimated capacity in the IDM base year still in service in a projection year.
- **New capacity** is capacity added in the current projection year to meet demand.
- **Added capacity** is cumulative capacity, added in years before the current projection year, that is still in service. This year's new capacity will be counted in next year's added capacity.

The capacity existing in any projection year is the sum of surviving old capacity, surviving added capacity, and new capacity. Capacity is retired as it wears out or becomes too inefficient to use. Old capacity and added capacity are not necessarily retired at equal rates.

- **Surviving old capacity** is old capacity existing in a projection year, which is equal to old capacity less cumulative retirements.
- **Surviving added capacity** is added capacity in a projection year, which is equal to cumulative capacity added between the base year and the year before the projection year less cumulative retirements of old and added capacity.

The IDM projects new capacity both to serve economic growth and to replace retired capacity. No capacity is added if shipments growth minus retirements is less than or equal to zero.

Figure 1. Example: End-use capacity changes over time, by type



Source: example based on input file itech.txt

Figure 1 illustrates capacity changes over time and the various types of capacity for an industry and census region. Needed capacity, which is the amount of capacity needed to produce shipments in a particular projection year, is usually the sum of surviving old capacity, added capacity, and new capacity.

When shipments decline as a result of a recession and projected needed capacity is less than total capacity, the IDM assumes that existing old capacity is idled and that no new capacity enters service. For example, needed capacity falls lower than total capacity between years 10 and 17 in **Figure 1**. The vertical distance between needed capacity and total capacity is idled capacity. The IDM assumes that only surviving old capacity is idled, because old capacity is assumed less efficient than surviving added capacity. In **Figure 1**, idled capacity is illustrated for Year 14. The IDM assumes that industries return old idled capacity to service before adding new capacity after gross output starts to increase again. In **Figure 1**, projected needed capacity starts increasing in Year 15, but projected new capacity is not added until Year 18.

For most end-use industries, EIA analysts assume a retirement factor between 1.0% and 1.5% of either old or added capacity. To calculate the projected retirement rate, the IDM multiplies the retirement factor by a function of cumulative projected energy price increases since 1990, which is the first historical year considered in NEMS. Therefore, when projected energy prices increase by a certain amount, the IDM assumes that industries retire old capacity more rapidly in order to add more energy efficient capacity, which reduces the projected fuel expenditure.

The IDM models electricity consumption for machine drive differently from other end uses. Electricity consumption for machine drive is calculated using a motor model that tracks installed motors, which comprise intact motors, new motors, and rewound (overhauled) motors (details are on page 11).

5.1.1.2. Projecting industrial energy consumption based on changes in capacity

After the IDM projects capacity, it can project energy consumption for each census region, industry, and energy source. The IDM cannot project energy consumption of capacity directly for end-use industries, because the number of products these industries produce is too great and energy use cannot be broken down to individual processes. Instead, the IDM projects energy use by projecting the energy services—or end uses—the capacity consumes: heating; cooling; and in some industries, electrochemical processes.

From estimated energy consumed for each end use, along with value of shipments in the IDM base year, EIA analysts estimate an initial energy intensity for each region, industry, end-use, and fuel, known as base year Unit Energy Consumption (UEC), or the *base UEC*. The UEC is the amount of energy needed to produce one unit of output and is therefore a measure of energy intensity. For end-use industries, output is defined as the dollar value of shipments. The IDM calculates the UEC as the energy consumed, by industry, fuel, region, and end-use divided by value of shipments for the industry and region:

$$\text{IDM Base Year UEC for End Use} = \frac{\text{IDM Base Year Energy Consumption for End Use}}{\text{IDM Base Year Shipments}}. \qquad (3)$$

EIA analysts use MECS data to estimate IDM base year manufacturing energy consumption. For nonmanufacturing consumption, they use additional data sources, as explained on page 4. For years after the IDM base year, the IDM projects the energy intensity of surviving old, surviving added, and new capacity relative to the UEC for the IDM base year by multiplying the base year UEC by the Relative Energy Intensity (REI).

The REI is a judgment-based ratio of energy intensity in a new or improved existing process to the base UEC. REIs are between 0 and 1 and are unitless. EIA analysts estimate three REIs for each fuel, end-use, industry, and census region:

- Energy intensity of old capacity in the final projection year relative to old capacity in the IDM base year
    - Multiplying this REI by the base UEC yields old capacity UEC for the final projection year.
- Energy intensity of new capacity relative to old capacity in the IDM base year
    - Multiplying this REI by the base UEC yields the UEC of new capacity in the IDM base year.
- Energy intensity of new capacity in the final projection year relative to new capacity in the IDM base year
    - Multiplying this REI by the base UEC yields the UEC of new capacity in the final projection year.

The judgment-based technology possibility curve (TPC) is the annual rate of decline in industrial energy intensity. The IDM projects the UEC for old capacity in an industry, region, end use, and projection year as follows:

$$\text{UEC for Old Capacity} = (1+ \text{Old Capacity TPC})^{(\text{Years since IDM Base Year})} \times \text{IDM Base Year UEC}. \qquad (4)$$

Similarly, the UEC for surviving capacity added in a year before the current projection year is

$$\text{UEC for Added Capacity} = (1+ \text{Old Capacity TPC})^{(\text{Previous Year - IDM Base Year})} \times \text{IDM Base Year UEC.} \quad (5)$$

For end use industries, typical unit energy consumption covers these end uses and fuels:

- Heating: natural gas, coal, electricity, and steam
- Cooling: natural gas and electricity
- Machine drive: electricity (calculated in the motor model; see page 11) and natural gas
- Electrochemical processes: electricity
- Other processes: electricity and natural gas

Table 1 shows actual base UECs, REIs, and TPCs (TPCs are multiplied by 100 for easier readability) for each industry and census region. Three REI numbers denote declines in energy intensity over time. Energy intensity declines occur by improving old capacity, installing new capacity, or retiring (presumably less-efficient) capacity.

For example, in **Table 1**, the REI for old capacity (column 2) for "*process cooling—electricity* in the final projection year is 0.842. This means that old cooling capacity in the last projection year uses 84.2% as much electricity as old cooling capacity does in the IDM base year. The improvement is a result of improving old capacity and retiring less efficient capacity when it wears out or becomes uneconomical.

Table 1. Example: Base UEC and REIs for old and new capacity

	(1) UEC IDM base year (Base UEC)	(2) REI old capacity, final projection year	(3) TPC old x100	(4) REI new capacity, base year	(5) REI new capacity, final projection year	(6) TPC new capacity X100
Process heating—electricity	0.0356	0.873	-0.376	0.900	0.774	-0.420
Process heating—natural gas	1.66	0.762	-0.751	0.720	0.532	-0.840
Process heating—coal	0.0128	0.873	-0.376	0.900	0.773	-0.420
Process heating—steam	5.44	0.580	-1.502	0.720	0.391	-1.679
Process cooling—electricity	0.137	0.842	-0.476	0.850	0.724	-0.446
Process cooling—natural gas	0.0458	0.762	-0.751	0.720	0.532	-0.840
Machine drive—electricity	0.595	0.873	-0.376	0.960	0.809	-0.476
Machine drive—natural gas	0.508	0.873	-0.376	0.900	0.774	-0.420
Electro-chemical process—electricity	0.0687	0.974	-0.072	0.950	0.823	-0.396
Other—electricity	0.00763	0.891	-0.321	0.915	0.782	-0.434
Other—natural gas	0.623	0.762	-0.751	0.720	0.532	-0.840

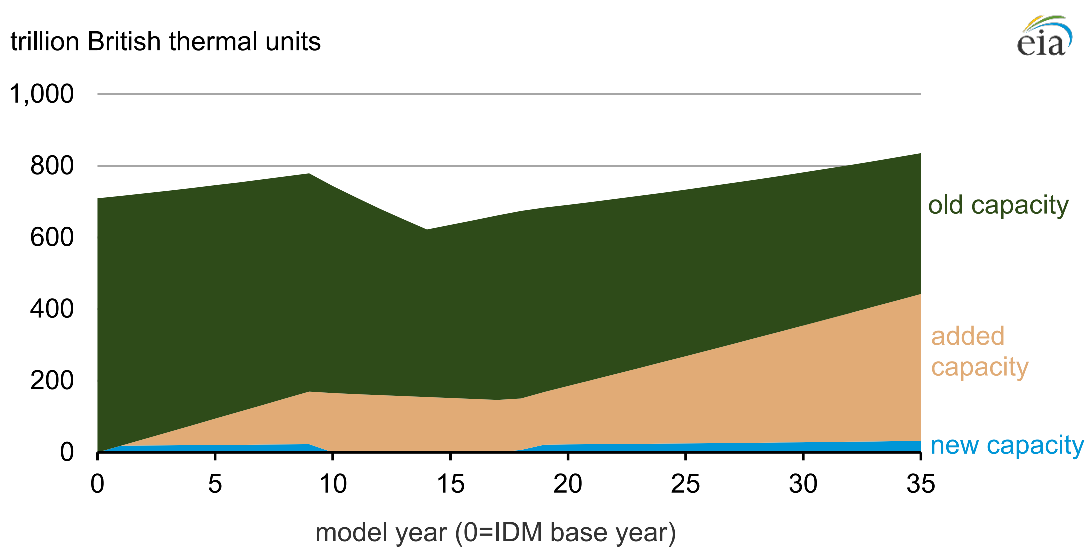
Source: IDM input file itech.txt

The REI for new capacity in the IDM base year (column 4) for *process cooling—natural gas* is 0.720. This calculation means that new cooling capacity in the IDM base year uses 72.0% as much natural gas as old capacity in the IDM base year, because capacity added in the IDM base year is more advanced and presumably more energy-efficient than the old capacity in the IDM base year. In the final projection year, *process cooling—natural gas* uses 53.2% as much energy as old capacity in the IDM base year (column 5).

The base UEC and REIs for steam in **Table 1** have different interpretations. The UEC for *process heating—steam* is the volume of steam used, not the energy of that steam, per dollar of shipments. The REI (column 5) for *process heating—steam* is 0.391 for new capacity in the last projection year. This calculation means that new capacity installed in the final projection year uses 39.1% as much steam as old capacity in the IDM base year. Projected steam use can decline because projected design improvements decrease the amount of water used, steam is recycled more effectively, or the industrial process uses lower-temperature technologies in the future and needs less steam and more water. The PA component projects the amount of steam required for heating, and the BSC projects energy needed to produce steam.

Figure 2 shows energy consumption for direct (non-boiler) natural gas consumption. To project energy consumption, the IDM multiplies the capacity from Figure 1 by the UECs for natural gas for all end uses. Because the IDM assumes that old capacity is the first to be idled, projected energy consumed by old capacity declines significantly between Year 10 and Year 14. As old capacity is retired, projected energy use for cumulative added capacity increases relative to projected energy used by old capacity. However, the share of energy used by added capacity is about the same in 2050 as the share used by old capacity in 2050, even though there is more cumulative added capacity in 2050 than old capacity. The energy used is the same, because the UEC for added capacity is lower than the UEC for old capacity.

Figure 2. Example: Direct natural gas energy consumption by capacity type



Source: example based on input file itech.txt

5.1.1.3. Motor Model for Projecting Machine Drive Energy Consumption

The IDM uses a different method to project electricity consumption in the machine drive end use. Instead of using the TPC approach described above, it uses a motor stock model, based on the motor size groups shown in **Table 2**, to project machine drive electricity consumption for motors in end-use manufacturing industries.

Table 2. Motor categories by horsepower

horsepower (hp)
1–5
6–20
21–50
51–100
101–200
201–500
>500

Source: IDM input file indmotorx.xlsx

The IDM projects electricity consumption for motors based on the projected size and composition of the motor fleet. EIA analysts initially estimate projected motor fleet electricity consumption based on estimated statistics on actual motors in use. These estimated statistics include horsepower, motor cost, motor efficiency, motor energy consumption, motor vintage, and motor failure rate. EIA analysts estimate the percentage of failed motors that are rewound (overhauled and returned to service) or replaced when they fail. The decision to replace or rewind motors that fail determines vintage and efficiency of the motor fleet, because current regulations require new motors to be more efficient than previous regulations have required.

EIA analysts derive the data for the basic motor stock model from the *United States Industrial Electric Motor Systems Market Opportunities Assessmen*t,[1] a report produced for the U.S. Department of Energy's Advanced Manufacturing Office. Section 313 of The Energy Independence and Security Act of 2007 (EISA2007) required manufacturers to increase the minimum efficiency of motors to reflect the National Electrical Manufacturers Association's Premium Efficiency requirements, effective for motors manufactured after June 1, 2016.

The motor stock model assumes that failed motors will be replaced if the total energy savings from the new motor over a certain time period (for example, five years) is greater than the cost difference between the new motor and rewinding the existing motor. This period of time is the *payback period*.

The IDM projects, for each projection year, the composition of the motor fleet and electricity consumption in each industry. First, for each projection year, it projects the number of failed motors, based on the previous year's motor fleet and an assumed rate of failure. The model then projects the share of the failed motors that are rewound or replaced, based on a cost-benefit function (rewound

[1] U.S. Department of Energy, United States Industrial Electric Motor Systems Market Opportunities Assessment (Burlington, MA, December 1998).

motors are less efficient than they were before they failed). Once the numbers of intact existing, rewound, and replaced motors are estimated, the IDM projects electricity consumption, based on the energy consumption and efficiency of all types of motors.

5.1.2. Projecting for Process Flow Industries

5.1.2.1. Process Flows and Capacity

A process flow is a series of distinct steps in a manufacturing process. The IDM projects energy consumption for five process flow industries: paper, glass, cement and lime, iron and steel, and aluminum. The process flows for these industries are known, because the products are relatively homogeneous.

As with end-use industries, capacity (machines) is at the heart of the process flow models. For the IDM base year, EIA analysts estimate physical capacity for each modeled process. Projected energy consumption for a particular type of capacity depends on IDM base year energy consumption, physical capacity, capacity additions, capacity age, and the technology the IDM chooses for the capacity. Because energy consumption depends on physical output and technology choice, it is important to know how much capacity is available and how much is added in response to increases in demand. For the process flow industries, the following elements drive the IDM's annual projections of industrial capacity and energy consumption:

- Capacity measures
    - Base capacity: capacity from the IDM base year that is still in service in the projection year. The IDM assumes base capacity is retired linearly over a fixed period, usually 20 years.
    - Surviving capacity: base capacity plus previous capacity additions still in service in the projection year.
    - Needed capacity: output minus surviving capacity in a projection year. If surviving capacity exceeds demand, projected needed capacity is zero, and existing base capacity is idled. The module assumes that idled capacity will be returned to service before new capacity is added.
    - New capacity: the amount of projected capacity added in the projection year. New capacity is assumed to retire as a function of its useful life, specified by expert judgment, and a logistic retirement parameter.
- Technology choice
    - The technology the IDM chooses, from a slate of technologies, for projected new capacity. Technologies are different means of performing one process step. Examples of technologies include the continuous digester in the Kraft pulp process (paper industry) and the prebake anode in the primary smelting process (aluminum industry). The IDM uses a utility function that accounts for fuel consumption, fuel prices, capital costs, operation and maintenance costs, and CO_2 emissions.
- Ratio of physical output to value of shipments
    - A ratio that transforms the value of shipments, a dollar figure, into physical output in tons. The ratio is assumed fixed throughout the projection period.

The IDM assumes that each process step may have different physical output because of the nature of the processes. For example, the module assumes that the continuous casting process is used for all projected steel output, and it also assumes that two processes may be used to produce steel: a blast furnace/a basic oxygen furnace (BF/BOF), or an electric arc furnace (EAF).

5.1.2.2. Capacity and output

For the IDM base year, the U.S. Geological Survey provides data on physical output of all process flow industries except the paper industry. EIA analysts obtain data on the paper industry from trade group publications. The IDM assumes that capacity equals the physical output of each process step in each projection year. Therefore, the IDM implicitly assumes that capacity utilization is the same in the projection years as it is in the IDM base year. The following equations describe the modeled annual relationships among capacity, output, and the dollar value of shipments:

$$\text{IDM Base Year Capacity} = \text{IDM Base Year Output.} \qquad (6)$$

Therefore,

$$\text{IDM Base Year Capacity} = \left(\frac{\text{IDM Base Year Output}}{\text{IDM Base Year Shipments}}\right) \times \text{IDM Base Year Shipments.} \qquad (7)$$

For projection years, the IDM estimates capacity as

$$\text{Projection Year Capacity} = \left(\frac{\text{IDM Base Year Output}}{\text{IDM Base Year Shipments}}\right) \times \text{Projection Year Shipments.} \qquad (8)$$

For each projection year, the IDM projects *needed capacity* first. To project needed capacity for a projection year, the IDM starts with *surviving capacity*, which is the previous year's capacity less retirements. The IDM deducts surviving capacity from the current projection year's output, which is equal to shipments for the current projection year multiplied by the (assumed constant) ratio of physical output to the value of shipments in the IDM base year. *Added capacity* is only projected when needed capacity exceeds surviving capacity. For each projection year,

$$\text{Capacity} = \left(\frac{\text{IDM Base Year Value of Output}}{\text{IDM Base Year Shipments}}\right) \times \text{Projection Year Shipments} \qquad (9)$$

$$\text{Surviving Capacity} = \text{Surviving Base Capacity} + \text{Surviving Incremental Added Capacity.} \qquad (10)$$

$$\text{Needed Capacity} = \text{Capacity} - \text{Surviving Capacity.} \qquad (11)$$

If projected shipments decline sufficiently, the IDM sets projection year needed capacity to zero and assumes that base year capacity is idled. As with the end-use industries, no new capacity will be projected until all idled capacity is back in service.

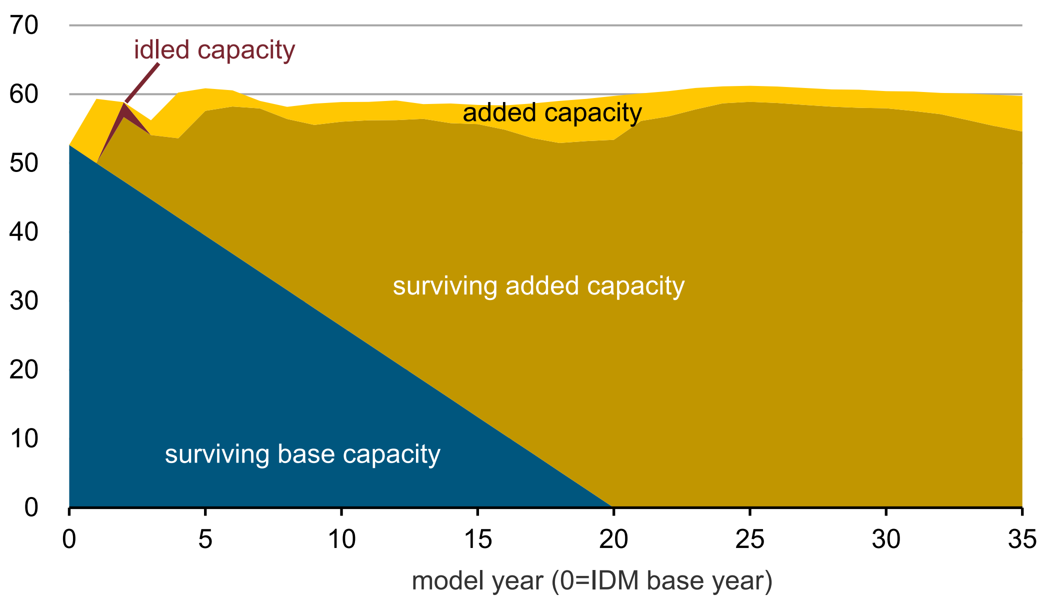
After the IDM projects new capacity for a projection year, it also projects technology choices for each process step. To obtain projection year capacity by process step, EIA analysts assign a *step factor* to each intermediate process step. Each step factor is a measure of the physical input necessary to produce the next step's output. For each projection year, the IDM estimates the capacity for each process step:

$$\text{Capacity for Process Step} = \left(\frac{\text{IDM Base Year Output}}{\text{IDM Base Year Shipments}}\right) \times \text{Step Factor} \times \text{Shipments} \qquad (12)$$

Figure 3 shows an example of projected capacity for the electric arc furnace (EAF) step, in which steel scrap and direct reduced iron are melted. The figure shows steel produced, in million metric tons, disaggregated by the type of capacity used to produce the steel: surviving base capacity, surviving added capacity, or new capacity. Needed capacity is the sum of these three types of capacity less any idled capacity. Capacity is idled in Year 1 and put back into service in Year 2.

Figure 3. Example: Projected capacity for EAF-produced steel by capacity type

million metric tons



Source: calculation based on input file ironstlx.xlsx
Note: EAF = electric arc furnace

5.1.2.3. Technology Choice

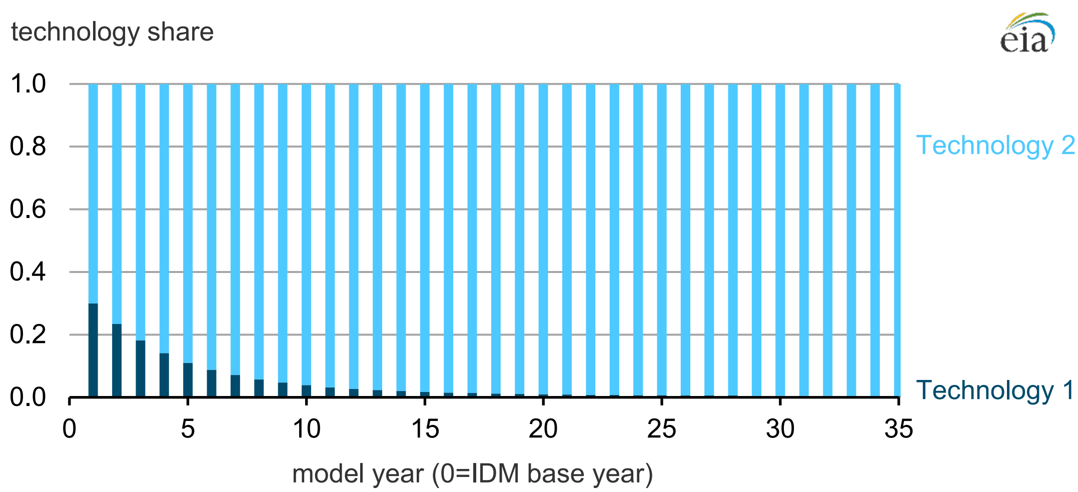
The choice of technologies for each process step depends on the following data inputs and assumptions for the IDM base year:

- Technology costs
    - Fixed costs and operation and maintenance costs (all per kiloton), which EIA analysts assume based on the Consolidated Impacts Modeling System (CIMS) and EIA research
- Energy consumption in dollars per kiloton of output, including fuel and steam
- Energy prices
- Consumption of other resources (for example, steam) that require energy to produce them

- Carbon penalty (only for the iron and steel industry and the aluminum industry)
- Parameters that determine the relative weight of the various factors used in selecting a technology

Projected technology shares for electric arc furnace capacity additions are shown in **Figure 4**. Projecting technology shares occurs in two steps. First, the IDM uses the technology choice characteristics above to calculate an exponential function for each technology. As the value of each variable increases, the value of the exponential function declines, and that technology is less likely to be chosen. Second, the IDM calculates technology shares. Each technology share is proportional to the value of that technology's exponential function. For example, if for a particular projection year, the exponential function for EAF-produced steel has a value of 2.20 for one technology and a value of 0.94 for a second technology, the sum of the values is 3.14. The shares of the two technologies are approximately 0.7 (2.20/3.14) and 0.3 (0.94/3.14), respectively. In that year, the IDM projects that 70% of new EAF steel output is manufactured using the first technology and that 30% is manufactured using the second technology.

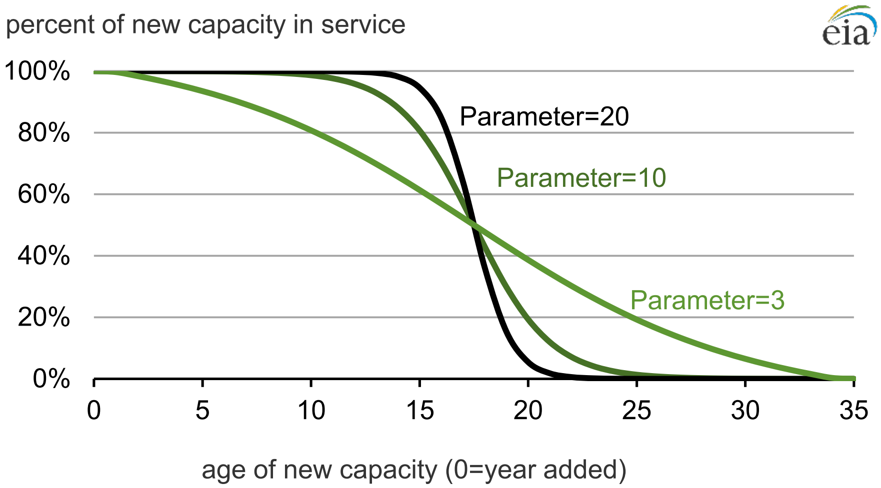
Figure 4. Example: Electric Arc Furnace capacity additions by technology share



Source: calculation based on input file ironstlx.xlsx

The IDM's method of projecting capacity retirements for the process flow industries differs from the method used for the end-use industries. The IDM assumes a useful life for baseline (old) and added capacity. Baseline capacity is projected to retire linearly over its service life. For added capacity, the IDM uses a logistic curve to project capacity retirement over its useful life. Projected retirements are close to linear with lower values of the logistic curve parameter, as shown in **Figure 5**. EIA analysts can set useful life and retirement parameters common to all industries or separately by industry. If one industry is expected to experience quick technical change, EIA analysts may project that capacity is retired more quickly in that industry than in others.

Figure 5. Example: Useful life parameters and retirement behavior in process flow models



Source: calculation based on input file ironstlx.xlsx

5.1.2.4. Projecting energy consumption in process flow industries

After the IDM projects in-service capacity and technology shares for the process flow industries, it projects energy consumption for each of the three vintages of capacity:

- Energy consumption from base capacity
  - Energy intensity of base capacity, multiplied by the projected amount of base capacity in service
- Energy consumption from surviving added capacity
  - Projected energy intensity of capacity in the current projection year, multiplied by the cumulative added capacity still in service in the year before the current projection year
- Energy consumption from new capacity
  - Projected energy intensity of the new capacity added in the projection year, multiplied by the projected new capacity

Total energy consumption for the projection year is the sum of the consumption by these three vintages of capacity.

Details of process flow energy consumption projections

EIA analysts estimate capacity energy use for the IDM base year for each industry, step, and technology. IDM base year capacity and energy consumption are input from historical data. Base year technology shares are derived from data from the Consolidated Impacts Modeling System (CIMS) and MECS.

Energy consumption for all types of capacity has two components:

- Direct: energy consumption by equipment to produce a good
- Indirect: energy used in producing steam and oxygen, which are used in some, though not all, process steps

For each technology, process step, and industry, the IDM estimates total energy consumption (in million Btu) for a technology in the IDM base year as

$$\text{Energy Use} = (\text{Technology Share} \times \text{Base Year Capacity}) \times (\text{Direct Energy Use} + \text{Indirect Energy Use}). \quad (13)$$

Projecting new capacity energy use

The IDM projects energy use for new capacity for each technology, process step, energy source, and projection year. Energy used directly in the process step (for example, direct heating), as well as energy used to create steam and oxygen are included where applicable. Energy consumption for new capacity is projected as described above for the IDM base year.

Initial steam demand for the IDM base year is estimated based on MECS data. The CHP and boiler shares of steam demand for the IDM base year and for the final projection year are estimated based on expert judgment. After EIA analysts have estimated steam demand and chosen CHP and boiler shares for the steel and paper industries, they choose specific CHP and boiler technology shares for the IDM base year and final projection year from a slate of analyst-assumed boiler and CHP technologies with different energy sources. For the intervening projection years, the IDM interpolates these values.

The process flow models project energy use for steam demand for each step and technology by summing energy used over CHP technologies and boiler technologies. CHP and boiler technologies differ from technologies that produce goods by direct energy use, and each industry has a separate set of CHP and boiler technologies. For the steel and paper industries, the IDM projects steam energy use by step and technology. Annual CHP energy use for each technology, in million Btu per kiloton of output, is projected as follows:

$$\begin{aligned}&\text{CHP Energy Use for Technology}\\&= \text{Total Steam Use for Technology}\\&\times (\text{CHP Share}) \times \sum_{\text{CHP Technologies}} \text{CHP Technology Share} \times \text{Energy Use of CHP Technology} \quad (14)\end{aligned}$$

Boiler energy use for each technology is projected similarly to CHP energy use.

For the aluminum industry, the structure is slightly different. The IDM assumes boilers and CHP are a distinct process step in the manufacture of alumina from bauxite; alumina manufacturing is the only step that requires steam. For the IDM base year, EIA analysts estimate CHP technology and boiler technology shares by expert judgment. For the projection years, the IDM projects CHP and boiler technologies using the technology choice method described above.

For the glass industry and for the cement and lime industries (which the IDM treats as one industry) any steam energy use is calculated in the IDM's Boiler/Steam/Cogeneration (BSC) component described starting on page 20. Neither industry uses a large amount of steam.

The IDM assumes that a gigajoule of oxygen requires a constant amount of electricity to produce, and this constant is estimated by expert judgment. To project energy consumed in the production of oxygen (in million Btu per kiloton of output), the IDM multiplies the projection year oxygen energy use in gigajoules of oxygen per kiloton of output by this constant.

After the IDM projects energy use for each technology, it projects energy use of new capacity by process step. For fuels except electricity, it projects total energy use for each energy source (for example, natural gas) and step as

$$\text{Energy Use by Step} = \sum_{\text{Technologies}} (\text{Direct Energy Use} + \text{Steam Energy Use}). \qquad (15)$$

For electricity, which includes electricity used in the production of oxygen, total energy consumption for new capacity is similar:

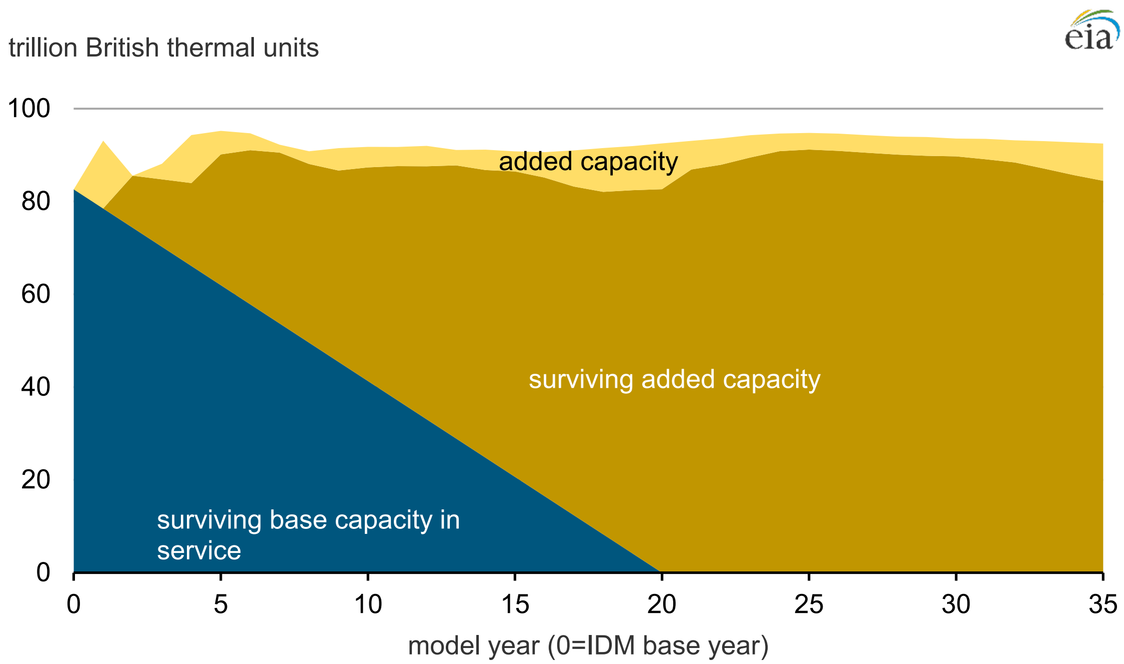
$$\text{Electricity Use by Step} = \sum_{\text{Technologies}} (\text{Direct Electricity Use} + \text{Oxygen Energy Use}). \qquad (16)$$

The IDM projects total energy consumption by energy source for each industry and projection year by summing projection year energy source use across process steps and converting the result to trillion Btu.

Projecting energy use by surviving added capacity is quite similar to projecting energy use by new capacity, because surviving capacity was new capacity in a previous projection year. Therefore, energy use from surviving added capacity is the sum of new capacity energy use in previous years for surviving capacity still in service. The process flow models assume no improvement in the energy efficiency of existing capacity. Energy efficiency projected by the process flow models increases when the models project the use of more energy-efficient technologies over time.

Figure 6 shows total energy consumption by capacity type for electric arc furnaces (EAF). The IDM projects total energy consumption by energy source per technology by summing energy consumption by energy source for each type of capacity.

Figure 6. Example: Energy consumption of EAF-produced steel by capacity type



Source: calculation based on input file ironstlx.xlsx
Note: EAF = electric arc furnace

The IDM projects the idling of base capacity during the early years of the projection period, owing to a decline in EAF production. Idling surviving base capacity decreases the amount of surviving base capacity in service, which lowers energy consumption of this type of capacity.

5.1.2.5. Projecting regional capacity and energy use for process flow industries

For the process flow industries, the IDM first projects national-level industrial capacity and energy consumption and then disaggregates the national-level totals to the four census regions. For regional projections of capacity in each industry, the IDM assigns shares based on the assumed regional share of output for each process flow industry in each projection year. For example, if 50% of projected glass furnace output in 2025 is in Region 3, the IDM will assign 50% of glass furnace capacity in 2020 to Region 3. In the manufacturing sector, many process steps must be performed on the same site. Consequently, when the IDM assigns one industry's process step to a region, it often assigns the entire process flow for that industry to that region. Some exceptions exist (for example, BOF and EAF capacity have different regional distributions).

5.2. Buildings Component

EIA analysts estimate that buildings account for a small percentage of allocated heat and electric power in the manufacturing sector. However, some non-energy-intensive manufacturing industries use a significant percentage of their total energy consumption in buildings.[2] IDM base year energy includes energy consumption for several building end uses, such as lighting and heating, ventilation, and air conditioning (HVAC).

For the manufacturing industries, the IDM uses historical buildings energy consumption data from the MECS. For the projection period, the IDM projects that energy consumption in the manufacturing-sector buildings grows (or declines) at the average of the growth rates of employment and shipments for the industry, because HVAC and lighting are designed primarily for workers rather than for machines. The IDM also uses growth rates in shipments to project buildings energy consumption, because shipments growth tends to increase total commercial building floor space, which also leads to an increase in total building energy use.

Of the non-manufacturing industries, the IDM represents only buildings energy consumption in the two agriculture industries, *crops* and *other agricultural*. It treats buildings energy consumption as part of process and assembly for these industries. For the IDM base year, total agricultural energy consumption is shared out to the two agricultural industries, based on USDA Farm Production Expenditures survey data for the IDM Base Year. The IDM estimates buildings energy consumption in the IDM base year as equal to each agricultural industry's total consumption less consumption for irrigation and off-road vehicles. For the projection years, the IDM projects energy consumption for buildings from a buildings index that indicates change in average efficiency of heat, light, and building shell (the physical structure of a building, including roof, walls, and foundation). The IDM receives these average efficiencies from the Commercial Buildings Module.

5.3. Boiler Steam Cogeneration (BSC) Component

5.3.1. Boiler Steam Cogeneration in the IDM Base Year

The BSC component of the IDM projects energy consumed to meet the projected steam demand from the process and assembly and buildings components, disaggregated into combined heat and power (CHP)-served steam demand and boiler-served steam demand. For the IDM base year, CHP generation and capacity are determined from historical data. The IDM assumes all remaining steam demand in the IDM base year is served by boilers. For the projection years, the BSC projects the fuel consumption for CHP and boilers to serve steam demand projected in the PA and BLD components. The BSC doesn't project steam demand for the iron-and-steel, pulp-and-paper, or aluminum industries, because fuel consumption for steam used in these industries is projected in the PA step.

The BSC component projects energy (natural gas, coal, distillate/residual fuel oil, or renewables/waste) needed to meet steam demand as projected by the PA and BLD components. The energy necessary to produce steam will always exceed the energy in the steam produced, because CHP units and boilers are not 100% efficient.

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[2] U.S. Energy Information Administration, 2014 *Manufacturing Energy Consumption Survey*, (http://www.eia.gov/consumption/manufacturing/), September 2018. Note that byproduct and non-energy use of combustible fuels are excluded from the computation because they are not allocated in the MECS tables.

EIA analysts use several data sets to estimate the fuel used to meet steam demand in the IDM base year. For manufacturing, they use MECS data to estimate energy use in the IDM base year for boilers and CHP. CHP capacity and generation for historical CHP years, as well as planned generation and capacity for the early projection years, are available from EIA Form 860, *Annual Electric Generator Report*, and EIA Form 923, *Power Plant Operations Report*, respectively. Any projected steam in the projection years not allocated to CHP is allocated to boilers.

For non-manufacturing industries, information on steam is sparse. EIA analysts assume there is no steam used in construction. For buildings in agriculture, they use steam intensities from the Commercial Buildings Demand module, and they assume that mining and construction consume little or no energy in buildings. As for manufacturing, EIA analysts use data from EIA Forms 860 and 923 to determine historical CHP capacity and generation and to estimate CHP capacity and generation for the early projection years.

5.3.2. Steam Projections for Manufacturing Industries

For the manufacturing industries, EIA analysts use regional boiler and CHP fuel consumption data from the MECS for the IDM base year, along with national shares of boiler or CHP fuel use, to estimate regional fuel demand for steam production.

After analysts have estimated steam consumption for all fuels and census regions in the IDM base year, they estimate the initial UEC for steam for old capacity as a census region's steam (in trillion Btu) divided by the value of the census region's shipments (in dollars). The IDM uses TPCs and REIs to project energy consumption for the projection years. TPCs and REIs for steam have a different interpretation from REIs in the process and assembly step and are discussed on page 10.

EIA analysts assume that boilers consume byproduct and waste fuels, such as wood chips, before any fuels are purchased. After the BSC component projects quantities of steam produced from byproduct fuels, it allocates the remaining steam demand to purchased fuels such as natural gas.

To calculate IDM base year fuel demand for process steam by census region for the non-manufacturing industries, EIA analysts first estimate, by expert judgment, the steam intensity for agriculture and mining at the national level and assume this intensity is constant across regions. All steam intensity estimates must be consistent with the total amount of non-manufacturing energy consumption estimated for the IDM base year. EIA analysts then use data on existing CHP capacity, generation, fuel use, thermal output, and planned additions (from EIA surveys EIA-860 and EIA-923), from the IDM base year to the last historical year for which data are available, to estimate existing CHP capacity and generation disaggregated by region and industry. They also use information on planned capacity to help estimate CHP additions for the first few projection years. Steam demand not met by CHP is assumed to be met by analyst-selected boilers.

The IDM projects that the following industries use the most CHP: bulk chemicals; pulp and paper; and to a lesser extent, food and iron-and-steel. Other industries are projected to use much less CHP. The IDM models iron-and-steel, pulp-and-paper, and aluminum steam demand and energy consumption in the PA component.

To project CHP capacity additions for the projection years, the IDM first projects additional steam demand for a year not currently served by existing or planned capacity. After the IDM has projected byproduct-fuel-produced steam, it allocates the remainder of the steam demand to CHP or boilers. The IDM first considers whether CHP can be used to meet projected steam demand. It assumes a variety of candidate CHP systems available at the national level, by industry, based on research on CHP units in service. Several candidate CHP systems are needed, because each industry has a variety of steam demands, as shown in **Table 3**.

Based on heat content of the steam produced per hour, EIA analysts estimate CHP unit deployment for a variety of steam demands in the manufacturing sector. Each candidate CHP system is usually associated with only one steam heat content, although a few candidate CHP systems are associated with two steam heat contents. All candidate CHP systems in the BSC component are natural gas-fired, because almost all CHP units installed in the recent past are natural gas-fired.

Table 3. Sample steam load shares by industry

	Steam demand in MMBtu/hour							
Industry	**1.5–3.0**	**3.0–6.5**	**6.5–10**	**10–50**	**50–100**	**100–250**	**250–500**	**500**
Food	5%	5%	5%	30%	20%	25%	5%	5%
Chemicals	5%	5%	5%	20%	15%	20%	15%	25%
All other manufacturing	1%	2%	2%	30%	20%	25%	10%	10%

Source: Based on IDM input file indcogenx.xlsx
Note: MMBtu=million British thermal units

To project CHP, the IDM evaluates the candidate CHP units for economic feasibility. Economic feasibility depends on the projected capital costs of the candidate CHP units, projected fuel expenditures, interest rates, and payback acceptance periods (the lengths of time the industry is willing to wait for the CHP to pay for itself). Higher capital costs, fuel expenditures, and interest rates, or less willingness to wait for a return on investment, will make CHP units less likely to be selected.

For each industry, the amount of projected CHP adopted in each projection year is the total economical CHP projected at the national level, multiplied by an EIA analyst-assumed penetration factor. For example, a penetration factor of 4% means that it takes 25 years for all projected economical CHP to be adopted. To project adopted CHP by region, the IDM multiplies CHP adopted nationally by a regional coefficient. This coefficient is a function of already-installed regional CHP, planned regional CHP, and regional scores derived from the American Council for an Energy Efficient Economy. These scores denote how conducive state policies are to installing CHP.

The IDM assumes that any steam demand not served by CHP will be served by boilers. Boiler efficiency is projected based on expert judgment.

5.3.3. Byproduct Fuels

Some manufacturing industries produce byproducts that can be burned, such as renewable fuels or waste gases. The IDM projects that byproduct fuels are burned for steam before purchased fuels are used and that byproduct fuels are burned the year they are produced. The IDM classifies byproduct fuels as either primary fuels, intermediate fuels (created only in the production process), or renewable fuels.

The IDM assumes that, for the IDM base year, the total quantity of byproduct fuel produced (intermediate fuel) for each capacity vintage, end-use, and fuel is the rate of byproduct fuel production (in heat units per dollar of shipments) multiplied by the capacity (in dollar value of shipments). For projection years, the IDM projects that the byproduct production rate is constant for all fuels except biomass. For biomass, the IDM projects the byproduct production rate as the previous year's byproduct production rate multiplied by a variable representing *price response,* that is, the effect of price changes on the quantities produced.

6. IDM Interaction with Other NEMS Modules

6.1. Data Exchanges During a NEMS Run

The IDM projects long-term industrial sector energy demand and passes it to the other NEMS modules. For each projection year, the IDM receives from other NEMS modules the projected value of shipments, energy prices, and employment. Based on the values of these variables, the IDM projects the following series and passes them back to NEMS:

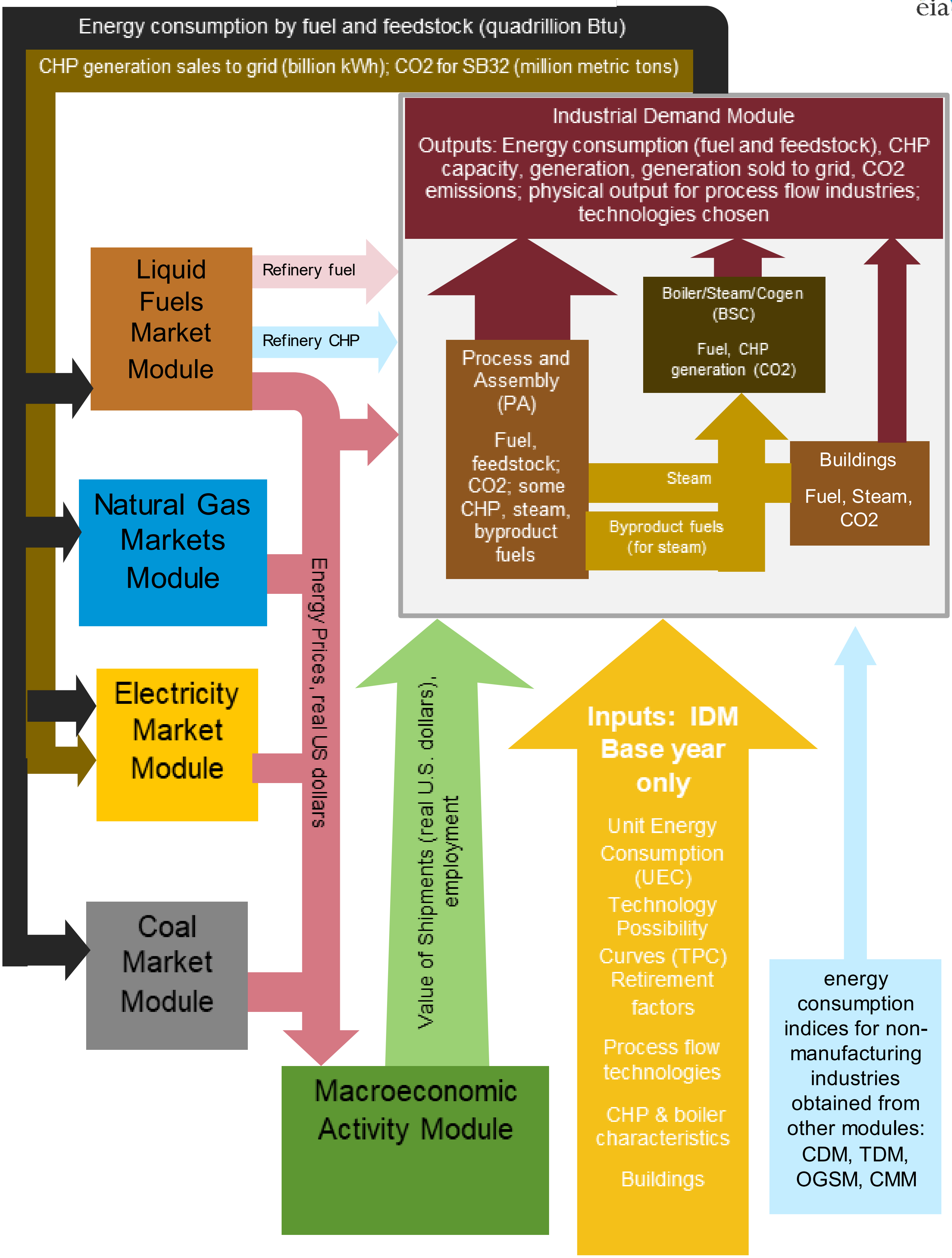
- Industrial energy consumption
- CHP electricity generation
- CO2 for all 21 industry groups
- Quantities of combusted fuels and non-combusted fuels, including feedstocks in the bulk chemicals industry and asphalt in the construction industry.

The IDM projects energy consumption at the census region level, by industry and fuel, and further disaggregates total industrial energy consumption to the census division level, based on data from EIA's State Energy Data System.

Figure 7 shows the interaction of the IDM with other NEMS modules, which follows these steps:

1. For the IDM base year only, the IDM estimates energy consumption from initial inputs such as UEC, prices, TPCs, buildings energy information, and a slate of boiler and CHP characteristics.
2. The IDM estimates energy demand and passes the energy demand values to NEMS.
3. For each subsequent year, the IDM receives variables from other modules, projects industrial energy demand for all energy sources, and passes these values to NEMS. The other modules from which the IDM receives variables are: the Macroeconomic Activity Module (MAM), the Liquid Fuels Market Module (LFMM), the Natural Gas Markets Module (NGMM), the Electricity Market Module (EMM), the Coal Market Module (CMM), the Commercial Demand Module (CDM), the Oil and Gas Supply Module (OGSM), and the Transportation Demand Module (TDM).

Figure 7: Industrial Demand Module Interactions with other NEMS modules



After the NEMS supply modules run, the results are passed to the integrating module (not shown) to check for convergence. If the NEMS run converges for a projection year, all projected values are the model results for the entire NEMS for that year, and the process begins for the next projection year. The NEMS model results may require several iterations to converge for a particular projection year.

Among the other NEMS modules, the Macroeconomic Activity Module (MAM) has the most influence on the IDM projections. For each IDM industry, the MAM supplies employment total and value of shipments, which affect industrial energy consumption over the projection years: projected energy intensity for all industries depends on shipments, and projected buildings energy consumption depends on both shipments and employment. The MAM also provides projections of state and local government expenditures, which are correlated with asphalt demand—a major energy demand. The sets of energy prices the other modules provide are also important for projecting equipment retirements and fuel switching. However, the IDM assumes limited fuel switching in the short run because MECS data indicate that the ability to switch fuels on existing equipment is limited.

6.2. Benchmarking to External Data

The IDM benchmarks energy demand projections to ensure consistency with historical data and other projections EIA publishes. First, the IDM benchmarks projections for the IDM base year and the most recent year for which historical data are available to historical data in EIA's *Monthly Energy Review*. EIA analysts use data from the State Energy Data System to allocate energy consumption among the nine census divisions. The allocation yields regional benchmark factors, which are applied through all projection years. For the first one or two projection years, the IDM benchmarks projections to the national-level forecasts in EIA's *Short-Term Energy Outlook* (STEO). For the remaining projection years, the IDM applies a composite STEO and SEDS benchmark factor. The STEO benchmark factor gradually approaches unity, while the SEDS benchmark factor remains constant through all projection years.

The IDM also benchmarks projections for individual industries, to ensure that the sum of projected energy consumption of each energy source for the individual industries equals total projected industrial consumption of that energy source. The only exception is coal consumption from gasification, which is part of the mining industry. To avoid double counting, the tables for all-industry consumption show coal industrial consumption net of coal gasification. However, the mining energy consumption table includes gasified coal to accurately capture supply and demand interactions in the coal market. The IDM passes coal consumption including gasified coal to the CMM for the same reason.

Model Data Sources

- EIA sources
    - Manufacturing Energy Consumption Survey (MECS)—quadrennial: Manufacturing energy consumption
    - State Energy Data System (SEDS)—annual: Historical energy consumption data disaggregated by state
    - Monthly Energy Review (MER)—monthly: Historical energy consumption data for benchmarking
    - Short-Term Energy Outlook (STEO)—monthly: Near-term projections of energy supply and disposition for benchmarking
    - Fuel Oil and Kerosene Sales (FOKS) survey—annual: Distillate consumption for agriculture and construction
    - Form EIA-923 and predecessor forms: Annual Electric Generator Report—annual: Combined heat and power (CHP) generation, existing and planned
    - Form EIA-860 and predecessor forms: Annual Electric Generator Report—annual: CHP capacity, existing and planned
- Non-EIA sources
    - U.S. Department of Agriculture (USDA)
        - Agriculture Research Management Survey (ARMS)
        - Census of Agriculture, USDA, National Agricultural Statistics Service—years ending in "2" and "7"
            - Fuel expenditures for agriculture
            - Electricity purchases and sales
            - Value of agricultural products sold
        - Farm Production Expenditures survey Fuel expenditures disaggregated by agriculture industries (crop and other agriculture)
        - Special tabulation—when requested: Estimated physical quantities of fuel
    - Census Bureau—Economic Census for construction and mining,—years ending in "2" and "7"
        - Fuel expenditures
        - Electricity consumption
    - Greenhouse Gas Reporting Program for facilities, Environmental Protection Agency—annual: Biogenic CO2 emissions to validate renewable emissions for process flow industries
    - Mineral Commodity Summaries, United States Geological Survey—annual: Physical output of the five process flow industries
    - State Energy Efficiency Scorecard, American Council for an Energy-Efficient Economy—annual: Indication of likelihood of state regulators to view CHP favorably

Appendix

Detailed List of IDM Output

Energy consumption by Census region and energy source for manufacturing and nonmanufacturing industries

- Liquids
    - Liquid Fuel uses (energy for heat and power)
        - Distillate (diesel)
        - Residual fuel
        - Gasoline
        - Hydrocarbon gas liquids (HGL) classified as liquefied petroleum gases (LPG) and other
        - Petroleum coke
        - Miscellaneous petroleum
    - Liquid Nonfuel uses
        - Asphalt and road oil
        - Chemical feedstocks (HGL, naphtha)
- Natural gas
    - Fuel uses (energy for heat and power)
    - Non fuel use: Chemical feedstocks
- Coal (steam and metallurgical)
- Purchased electricity
- Renewables, including nonbiogenic waste fuel

Other outputs

- Combined heat and power (CHP) capacity and generation
- CO2 emissions
- Projections of physical output for the five process flow industries (paper, glass, cement and lime, iron and steel, aluminum)
- Technologies chosen for the five process flow industries

Table A-1. IDM Industries and NAICS Codes

Energy-intensive manufacturing		Non-energy-intensive manufacturing		Nonmanufacturing	
Food products	311	Metal-based durables industries		Agriculture: crop production	111
Paper and allied products	322	Fabricated metal products	332	Other agricultural production	112, 113, 115
Bulk chemicals[2]		Machinery	333	Coal mining	2121
Inorganic	325120–325180	Computer and electronic products	334	Oil and natural gas extraction	211

Energy-intensive manufacturing		Non-energy-intensive manufacturing		Nonmanufacturing	
Organic	325110, 32519	Electrical equipment and appliances	335	Metal and other non-metallic mining	2122–2123
Resins	3252	Transportation equipment	336	Construction	23
Agricultural chemicals	3253	Wood products	321		
Glass and glass products	3272, 327993	Plastic and rubber products	326		
Cement and lime	327310, 327410	Balance of manufacturing	312–316, 323, 3254–3256, 3259, 3271, 327320, 327330, 327390, 327420, 3279 (except 327993), 3314, 3315, 337, 339		
Iron and steel	331110, 3312, 324199[1]				
Aluminum	3313				

NAICS=North American Industry Classification System (2012)

[1]NAICS 324199 contains merchant coke ovens, which are considered part of the iron and steel industry in the *Annual Energy Outlook.*

[2]Bulk chemicals energy consumption is reported as an aggregate in the *Annual Energy Outlook*.