Industrial Demand Module

The National Energy Modeling System (NEMS) Industrial Demand Module (IDM) estimates U.S. energy consumption by energy source (fuels and feedstocks) in the *Annual Energy Outlook* (AEO) for 15 manufacturing and 6 nonmanufacturing industries. The IDM subdivides manufacturing industries further into energy-intensive manufacturing industries and non-energy intensive manufacturing industries (Table 1). The IDM models manufacturing industries through either a detailed process-flow or end-use accounting procedure. The nonmanufacturing industries are modeled with less detail because processes are simpler and fewer data are available. The petroleum refining industry is not included in the IDM because it is modeled separately in the Liquid Fuels Market Module (LFMM) of NEMS. The IDM calculates energy consumption for the four census regions (Table 2) and disaggregates regional energy consumption to the nine census divisions based on fixed shares from the U.S. Energy Information Administration's (EIA's) *State Energy Data System* (SEDS). The IDM uses the latest published SEDS year (2019 for AEO2022) to determine these census division shares.[i] Overall, the IDM runs from model year 2018 through 2050.

Table 1. Industry categories and North American Industry Classification System (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 group[a]		Machinery	333	Coal mining	2121
Inorganic	325120, 325180	Computer and electronic products	334	Oil and natural gas extraction	211
Organic	325110, 325193, 325194, 325199	Electrical equipment and appliances	335	Metal and other non-metallic mining	2122-2123
Resins	325211, 325212, 325220	Transportation equipment	336	Construction	23
Agricultural chemicals	325311, 325312	Wood products	321		
Glass and glass products	327211, 327212, 327213, 327215, 327993	Plastic and rubber products	326		

Energy-intensive manufacturing		Non-energy-intensive manufacturing		Nonmanufacturing
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[b]			
Aluminum	3313			

Source: U.S. Energy Information Administration, *Annual Energy Outlook 2022* (AEO), based on U.S. Department of Commerce, U.S. Census Bureau, North American Industry Classification System (2017)—United States (Washington, DC, 2017).
[a]The AEO reports bulk chemicals energy consumption as an aggregate.
[b]NAICS 324199 contains merchant coke ovens, which the AEO considers part of the iron and steel industry.

Table 2. Census regions, census divisions, and states

Census region	Census divisions	States
1 (East)	1,2	Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont
2 (Midwest)	3, 4	Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, North Dakota, Nebraska, Ohio, South Dakota, and Wisconsin
3 (South)	5, 6, 7	Alabama, Arkansas, Delaware, District of Columbia, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and West Virginia
4 (West)	8, 9	Arizona, Alaska, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming

Source: U.S. Census Bureau, *2010 Census Regions and Divisions of the United States*—United States (Washington, DC, 2021).

The IDM models most industries as three separate, interrelated components:

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

The IDM calculates the PA component by end use for all but five manufacturing industries. These five industries are calculated by production process (process flow):

- Paper
- Glass
- Cement and lime
- Iron and steel

- Aluminum

The BSC component satisfies the steam demand from the PA and BLD components. In some industries, the PA component produces byproducts that are consumed in the BSC component. The iron and steel, paper, and aluminum industries determine boiler and combined-heat-and-power (CHP) fuel use within the PA step.

The IDM base year is currently 2018, which is the year of the latest available *Manufacturing Energy Consumption Survey* (MECS).[ii] EIA's Office of Energy Statistics conducts the MECS every four years, and we update the IDM base year when a new MECS becomes available.

The IDM does not model petroleum refining (NAICS 32411), which is modeled in detail in the LFMM, but the manufacturing total does contain the projected petroleum refining energy consumption. In addition, projections of lease and plant fuel, energy used for liquefaction of natural gas, and fuels consumed in cogeneration in the oil and natural gas extraction industry (NAICS 211) are calculated in modules other than the IDM.

Key assumptions—manufacturing

The IDM primarily uses a bottom-up modeling approach. An energy accounting framework traces energy flows from fuels to an industry's output. The IDM depicts the manufacturing industries, except for petroleum refining, with either a detailed process-flow or end-use approach. Generally, industries with homogeneous products use a process-flow approach, and those with heterogeneous products use an end-use approach. The following industries use a process-flow approach:

- Paper
- Glass
- Cement and lime
- Iron and steel
- Aluminum

The following industries use an end-use approach:

- Food
- Bulk chemicals
- The five metal-based durables industries (transportation equipment, machinery, computers, electrical equipment, and fabricated metals)
- Wood products
- Plastic and rubber products
- Balance of manufacturing (includes beverages, tobacco, furniture, other primary metals, pharmaceuticals, paints, soaps cleaning products, textiles, and other miscellaneous products)

Process and assembly component for end-use models

End-use industries measure energy consumption by activity, such as heating, cooling, or machine drive, instead of a process. These activities could be considered services. End-use industries usually have many different products, which makes specifying a manageable number of process steps impossible. Most manufacturing industries are end-use industries. The IDM models end-use process and assembly consumption at the census region level and aggregates to the national level.

For manufacturing industries modeled using an end-use approach, the process and assembly component modules model the end use for each major production end use. The IDM computes the throughput production for each end use and the energy required to produce it. The unit energy consumption (UEC) is defined as the amount of energy required to produce a unit of output—the energy intensity.

For end-use industries, the IDM base year (currently 2018) is an important assumption in calculating the UECs. The IDM calculates initial UECs in the base year by end use and region using the current MECS for that end use divided by shipments for that industry. Each UEC represents the energy required to produce one unit of the industry's output as measured by dollar value of shipments.

The module characterizes each major process end use by a UEC estimate and a technology possibility curve (TPC). A TPC represents the annual rate of change from the IDM base year to the end year of the projection period. For end-use industries, the TPC depicts the assumed average annual rate of change in energy intensity of an energy end use (for example, natural gas-fired heating or electricity-powered cooling). Each TPC for new and existing capacity varies by industry, vintage, and process. We developed these assumed rates using professional engineering judgments about energy characteristics, year of availability, and market adoption rates for new process technologies.

Table 3 shows median UEC values for existing equipment for 2018 as well as relative energy intensities (REIs), illustrating the magnitude of UECs and REI values. UECs and REIs are estimated for each industry, region, and end-use. The medians represent the median for a particular fuel and end use among all industries with that end use and fuel. The medians are estimated independently. The definitions of the columns in the table are:

- *UEC 2018* is the energy consumption for region, industry, and end use divided by regional shipments of that industry.
- *REI 2050 existing* is the ratio of 2050 energy intensity to 2018 energy intensity for existing facilities in the Reference case.
- *REI 2018 new* is the ratio of energy intensity for new, state-of-the-art facilities in 2018 to 2018 energy intensity for existing facilities in the Reference case.
- *REI 2050 new* is the ratio of energy intensity for new, state-of-the-art facilities in 2050 to 2018 energy intensity for existing facilities in the Reference case.

Table 3. Median unit energy consumptions (UECs) and relative energy intensities (REIs)

End use	Fuel	UEC 2018 (trillion British thermal units per billion 2012$ of shipments)	REI 2050 existing	REI 2018 new	REI 2050 new
Heat	Natural gas	0.171	0.844	0.965	0.815
Heat	Electricity	0.026	0.919	0.984	0.895
Heat	Steam	0.408	0.844	0.964	0.812
Refrigeration	Electricity	0.049	0.911	0.977	0.890
Machine drive	Natural gas	0.021	0.945	0.997	0.923
Machine drive	Electricity	0.198	0.917	0.984	0.896
Electro Chemical Processes	Electricity	0.040	0.940	0.993	0.924
Other	Natural gas	0.022	0.837	0.945	0.833
Other	Electricity	0.008	0.911	0.982	0.892

Source: U.S. Energy Information Administration calculations, based on Manufacturing Energy Consumption Survey 2018 (Washington, DC, August 2021).

The first row of Table 3, shows the values for the end use “Heat” and fuel “Natural gas.” The median UEC is 0.171 trillion British thermal units per billion 2012 dollars in shipments for existing equipment in 2018. The REI for existing equipment in 2050 is 0.844. In 2050, existing equipment with median relative energy intensity uses 84.4% as much energy as existing equipment in 2018. REIs for new equipment are interpreted similarly relative to existing equipment in 2018. To simulate technological progress and adoption of more energy-efficient technologies, the IDM adjusts each UEC every projection year based on the assumed TPC for each end-use step. A TPC is derived from assumptions about the REI of productive capacity by vintage (new capacity relative to existing stock in a given year) or over time (new or surviving capacity in 2050 relative to the 2018 stock). Over time, each UEC for new capacity changes, and the TPC provides the rate of change. The module also assumes every UEC of the surviving 2018 capital stock changes over time because of retrofitting but not as rapidly as for new capital stock.

The concepts of REI and TPC embody assumptions about new technology adoption in the manufacturing industry and the associated change in energy consumption without characterizing individual technologies in detail. This approach reflects the assumption that industrial plants will change energy consumption when owners do the following:

- Replace old equipment with new, more efficient equipment
- Add new capacity
- Add new products
- Upgrade their energy management practices

The increased efficiency cannot be directly attributed to technology choice decisions because of the complexity of these industries. Instead, the module uses the REI and TPC to characterize intensity trends for bundles of technologies available for end-use industries. The Appendix contains the values for REI and TPC by end use, process, and census region. TPC and REI calculations for industries can either decline at a fixed percentage or can be vary over time, reflecting how changes in fuel price over time might affect the rates at which energy intensities declines.

The module distinguishes each UEC by three vintages of capital stock. The amount of energy consumption reflects the assumption that new vintage stock will consist of state-of-the-art technologies that have different efficiencies from the existing capital stock. Consequently, the amount of energy required to produce a unit of output using new capital stock is often less than that required by the existing capital stock. The old vintage consists of capital that exists in the IDM base year and continues to operate after adjusting for assumed retirements each year (Table 4). The IDM adds new production capacity in a given projection year to ensure that sufficient surviving and new capacity is available to meet the level of an industry's regional output as determined in the NEMS Macroeconomic Analysis Module (MAM). Middle vintage is capital added after 2018 through the year before the current projection year.

Table 4. Annual retirement rates for end-use industries

Industry	Retirement rate (x100)	Industry	Retirement rate (x100)
Food products	1.7	Wood products	1.3
Bulk chemicals	1.7	Plastics and rubber products	1.3
Metal-based durables	1.3	Balance of manufacturing	1.3

Source: SAIC, Industrial Demand Module base year update with Manufacturing Energy Consumption Survey 2006 data, unpublished data prepared for the Office of Integrated Analysis and Forecasting, U.S. Energy Information Administration (Washington, DC, August 2010).

Electric motor stock model

For calculating energy consumed in the machine-drive end use, the IDM uses an end-use electric motor technology choice module instead of a UEC and TPC. For a number of industries, the IDM calculates machine-drive electricity consumption using a motor stock model:[iii]

- Bulk chemicals industry
- Food industry
- Metal-based durables industries
- Wood
- Plastics
- Rubber products
- Balance of manufacturing

The module modifies the beginning stock of motors during the projection period. Motors are added to accommodate growth in shipments for each industry or industry group as motors are retired and replaced and as failed motors are rewound. When an old motor fails, the model determines whether it would be more economical to repair the motor or replace it. When a new motor is added, either to accommodate growth or replace a retiring motor, it must meet the minimum efficiency standard. Table 5 provides the beginning stock efficiency for seven motor size groups in each of the three industry groups, as well as efficiencies for replacement motors. The module assumes all replacement motors to be premium high-efficiency motors because of current efficiency regulations.

Table 5. Cost and performance parameters for industrial motor choice model

Industry/horsepower (hp) range	Average efficiency	Replacement motor efficiency	Rewind cost (2002$)	Replacement cost (2002$)
Food				
1–5 hp	81.3	89.5	230	442
6–20 hp	87.1	93.0	427	1,047
21–50 hp	90.1	94.5	665	1,889
51–100 hp	92.7	95.4	1,258	5,398
101–200 hp	93.5	96.2	2,231	10,400
201–500 hp	93.8	96.2	4,363	20,942
> 500 hp	93.0	96.2	5,726	28,115
Bulk chemicals				
1–5 hp	82.0	89.5	230	442
6–20 hp	87.4	93.0	427	1,047
21–50 hp	90.4	94.5	665	1,889
51–100 hp	92.4	95.4	1,258	5,398
101–200 hp	93.5	96.2	2,231	10,400
201–500 hp	93.3	96.2	4,363	20,942
> 500 hp	93.2	96.2	57,26	28,115
Metal-based durables[1]				
1–5 hp	82.2	89.5	230	442
6–20 hp	87.3	93.0	427	1,047
21–50 hp	90.1	94.5	665	1,889
51–100 hp	92.4	95.4	1,258	5,398
101–200 hp	93.5	96.2	2,231	10,400
201–500 hp	94.5	96.2	4,363	20,942
>500 hp	94.4	96.2	5,726	28,115
Wood, plastic, and balance of manufacturing				
1–5 hp	81.8	89.5	230	442
6–20 hp	86.6	93.0	427	1,047
21–50 hp	89.9	94.5	665	1,889
51–100 hp	92.1	95.4	1,258	5,398
101–200 hp	93.2	96.2	2,231	10,400
201–500 hp	93.1	96.2	4,363	20,942
>500 hp	93.1	96.2	5,726	28,115

Source: U.S. Energy Information Administration, *Model Documentation Report*, Industrial Sector Demand Module of the National Energy Modeling System (Washington, DC, September 2013).
Note: The efficiencies listed in this table are operating efficiencies based on average part-loads. Because the average part-load is not the same for all industries, the listed efficiencies for the different motor sizes vary across industries.
[1]The metal-based durables group includes five industries that are modeled separately: fabricated metals, machinery, computers and electronics, electrical equipment, and transportation equipment.

Petrochemical feedstock requirement

The IDM estimates feedstock requirements for the major petrochemical olefin products such as ethylene, propylene, and butadiene. The primary feedstocks used to produce the olefins are hydrocarbon gas liquids (HGLs) (ethane, propane, and butane) and heavier oil-derived petrochemical feedstocks (naphtha and other oils). These feedstocks are converted to olefins, primarily ethylene, in a chemical process known as cracking. The IDM also models natural gas feedstock demand for the production of methanol, ammonia, hydrogen, and other chemical products. Biomass is a potential raw material source for chemicals, but the module assumes biomass-based capacity is unavailable during the projection period because of economic barriers. The type of feedstock determines the energy requirements for heat and power to produce the chemicals, as well as the product yield.

We base historical HGL and heavy petrochemical feedstock consumption on SEDS data, and 2020–23 feedstock consumption on *Short-Term Energy Outlook* forecasts and external data sources. From 2024 on, the sum of HGL and heavy feedstock consumption grows or declines with the shipments of resins, synthetic rubber, and fibers (in the current model there is no incorporation of additional plastic or chemical recycling capacity). We assume all new olefin production capacity in the United States is light-feedstock-based. However, under certain price conditions, some amount of light feedstocks consumption is allowed to switch over to heavy feedstocks consumption. This represents the ability of certain cracking facilities to switch between cracking HGL and cracking heavy feedstock.

This light/heavy feedstock switching is represented in the model as switching between use of ethane (light) and naphtha (heavy) feedstock in the production of ethylene (the desired olefin product). Ethane/naphtha switching is a function of the relative price of each feedstock (derived from linear regressions of historical chemical price data and WTI price), the chemical cracking efficiencies of each feedstock, and the prices of the coproducts from the respective cracking reactions. The chemical mass yields from cracking ethane and naphtha are shown in Table 6. The IDM calculates the net feedstock cost of ethane needed to produce one tonne of ethylene, and subtracts the value of the side products produced from that reaction to get the net feedstock cost of producing ethylene from ethane. The same value is calculated for naphtha by subtracting the value of the side products produced from cracking one tonne of ethylene from the cost of the naphtha used to produce one tonne of ethylene. The net costs of each feedstock are compared against each other, and the feedstock with the lower net feedstock cost is considered more economic. We assume differences in process and capital costs are negligible.

Table 6. Chemical mass yields for cracking ethane and naphtha

tonnes of product per tonne of feedstock

Products	Ethane	Naphtha
Hydrogen	0.0591	0.0097
Methane	0.0704	0.1694
Ethylene	0.8091	0.3867
Propylene	0.0194	0.1547
Butadiene	0.0178	0.0476

Products	Ethane	Naphtha
Butylenes/butanes	0.0081	0.0507
Benzene	0.0081	0.0437
Toluene	0.0008	0.0166
Xylene	0	0.0224
Other aromatics	0.0073	0.0735
Fuel oil	0	0.0251

Source: U.S. Energy Information Administration, based on *Ethylene Product Stewardship Manual*, December 2004.

The amount of capacity that can switch between ethane and naphtha is based on a few assumptions. First, it is assumed there is a baseline naphtha feedstock demand that is constant from 2024 on, equal to 90% of 2019 naphtha feedstock consumption, or about 550 trillion British thermal units (tBtu). All of this capacity is in the West South Central census division. Second, some cracking capacity can quickly switch between cracking ethane and naphtha, depending on the relative net feedstock costs. The baseline *quick flex* capacity is 2011 ethylene produced from naphtha minus the ethylene produced from the nonflexible (naphtha-only) capacity, or about 2.605 million tonnes ethylene. Quick flex capacity is also all in the West South Central division. In a given year where either ethane or naphtha is more economic, 50% of existing flex capacity (after capacity additions) will change to the most economic feedstock (with no change if that feedstock is already being used in 100% of the quick flex capacity). Some flex capacity, which cracks only ethane to begin with, can switch more slowly. Given a sustained price signal where the net feedstock costs for ethane are higher than the net feedstock costs for naphtha for three consecutive years, some of the *slow flex* capacity will switch over to quick flex capacity after a construction period of two more years. This represents cracking facilities that need substantial investment to be able to crack naphtha. The baseline slow flex capacity is the 2004 ethylene produced from naphtha minus the 2011 ethylene produced from naphtha, or about 5.513 million tonnes ethylene. Slow flex capacity is converted to quick flex capacity in increments of 1.102 million tonnes ethylene capacity. We assume no new slow flex capacity will be built.

For 2020–23, EIA uses an exogenous, analyst-based natural gas feedstock forecast based on project-level methanol and ammonia/urea capacity estimates, as well as changes in shipments in select sectors. Ethylene cracker project-level data were similarly employed for both the HGL (light) and naphtha (heavy) feedstock forecast for 2020–23. In addition, the IDM breaks down HGL feedstock into its components (ethane, propane, propylene, butanes, and natural gasoline). Propylene consumption is held constant at about 300,000 barrels per day throughout the projection period, close to current U.S. refinery propylene production levels.

We determine baseline feedstock intensities from the 2018 MECS. For chemical feedstock, intensity does not change over time: the IDM assumes every feedstock TPC is zero. Unlike most other processes represented in manufacturing PA components, chemical yields follow basic chemical stoichiometry that allows for specific yields under set conditions of pressure and temperature.

Process/assembly component for process-flow models

The IDM models five energy-intensive manufacturing industries using a process-flow approach instead of an end-use approach:

- Paper
- Glass
- Cement and lime
- Iron and steel
- Aluminum

These modules, completed in AEO2016, use a suite of detailed technology choices for each process flow. Instead of the energy intensity for each process and end use evolving according to a TPC, the process-flow models use technology choice for each process flow. We derive technology characteristics (for example, expenditures, energy intensities, and utility needs) from the Consolidated Impacts Modeling System (CIMS) database that the Pacific Northwest National Laboratory prepares. These characteristics define the energy requirements for each technology.[iv] Depending on the industry, these data are calibrated using inputs from the U.S. Geological Survey (USGS) of the U.S. Department of the Interior, the Portland Cement Association, and our latest MECS.[v,vi]

The process-flow models calculate surviving capacity based on retirement and needed capacity, which in turn is based on shipments and surviving capacity. The IDM assumes baseline capacity (as of 2018) to retire at a linear rate over a fixed period of 20 years and incremental, or added, capacity to retire according to a logistic survival function with a potential maximum life of 30 years. The analyst can adjust parameters to obtain the exact shape of the logistic S-curve. EIA obtained equipment characteristics used for investment decisions (capital and operating costs, energy use, and emissions) for new-built equipment from the CIMS database. Each step of the process flow allows for several technology choices whose fuel type and efficiency are known at the national level because regional fuel breakouts are fixed using available EIA data.

We benchmark the process flow models to the 2018 MECS data for each fuel in each of the five process flow industries. This process ensured a historically accurate fuel consumption baseline for industries modeled in the IDM.

Pulp and paper industry

The pulp and paper industry converts wood fiber to pulp, and then it manufactures paper, paperboard, and consumer products that are generally sold in the domestic marketplace. The industry produces a full line of paper and board products, as well as dried pulp, which is sold as a commodity product to domestic and international paper and board manufacturers. This industry includes several manufacturing steps and technologies:

- Wood preparation removes bark and chips logs into small pieces.
- Pulping removes fibrous cellulose in the wood from the surrounding lignin. Pulping can occur with a chemical or a mechanical process.
- Pulp washing means washing the pulp with water to remove the cooking chemicals and lignin from the fiber.
- Drying, liquor evaporation, effluent treatment, and other miscellaneous steps are part of the pulping process. Pulp is sent to a pressing section to squeeze out as much water as possible by mechanical means. The pulp is compressed between two rotating rolls, and the amount of water removed depends on the design and speed of the machine. When the pressed pulp leaves the

pressing section, it has about a 65% moisture content. It is then heat-dried. Various techniques for drying are available, and each has different energy consumption characteristics.
- Bleaching is required to produce white paper stock.

Paperboard, newsprint, coated paper, uncoated paper, and tissue paper are final products. Producing final products requires drying, finishing, and stock preparation.

Glass industry

For the glass industry model, each step of the three glass product processes modeled in the IDM (flat glass, pressed and blown glass, and glass containers) allows for several technology choices with known fuel type and efficiency, as well as other known operating characteristics.

For flat glass (NAICS 327211), the process steps consist of batch preparation, furnace, form and finish, and tempering. For pressed and blown glass (NAICS 327212), the process steps are preparation, furnace, form and finish, and fire polish. For glass containers (NAICS 327213), the process steps are preparation, furnaces, and form and finish. For fiberglass (mineral wool–NAICS 327993), the process steps are preparation, furnaces, and form and finish. The final category (glass from glass products–NAICS 327215) was not modeled as a process flow with technology choice but instead is modeled as an end-use industry and thus employs a UEC and TPC for each fuel to capture energy intensity changes over time.

The glass submodule uses several technologies. Not all of the technologies below are available to all processes:

- The preparation step (collection, grinding, and mixing of raw materials including recycled glass known as cullet) uses either a standard set of grinders and motors or an advanced set that is computer-controlled.

- The furnaces, which melt the glass, are air-fueled or oxy-fueled burners that use natural gas. Electric-boosting furnace technology is also available. Direct-electric (or Joule) heating is available for fiberglass production.

- The form and finish process is used for all glass products, and the technologies can be selected from high-pressure, natural gas-fired, computer-controlled technology or basic technology.

- No technology choice exists for the tempering step (flat glass) or the polish step (blown glass). Placeholders for more efficient future technology choices were implemented, but their introduction into these processes was rather limited.

As with the other submodules, the technology slate in each of these process steps evolves over time and depends on the relative cost of equipment, cost of fuel, and fuel efficiency. Oxy-fueled burners were added as a retrofit to the burner technologies, and their additive impact is determined by the relative price of natural gas and electricity.

Combined cement and lime industry

For the cement process flow, each step (raw material grinding, kiln, and finish grinding) can choose several technologies, and each step’s fuel types and efficiency levels are known at the national level because regional fuel breakouts are fixed using EIA data.

Cement has both dry and wet mill processes. Some technologies are available for both processes, but others are available for only one process. The technology choices within each group are:

- Raw materials grinding
    - Ball mill or roller mill
- Kilns (rotators)
    - Dry process only
        - Rotary long with preheat, precalcining, and computer control
        - Rotary preheat with high-efficiency cooler
        - Rotary preheat and precalcine with efficient cooler
    - Wet process only: rotary wet standard with waste heat recovery boiler and cogeneration
- Kilns (burners)
    - Coal-fired: standard or efficient
    - Natural gas-fired: standard or efficient
    - Petroleum coke-fired: standard
    - Alternative fuel such as municipal solid waste (MSW): standard
- Finish grinding
    - Ball mill: standard or with high-efficiency separator
    - Roller mill: standard or with high-efficiency separator

The technology slate in each process step evolves over time and depends on the relative cost of equipment, cost of fuel, and fuel efficiency. The IDM assumes retirement of existing wet process kiln technology to be permanent; only dry process kilns can be added to replace retired wet kilns or to satisfy needed additional capacity.

The latest CIMS database determines and calibrates the IDM base year technology slate for the year 2008 with dry and wet mill capacity cement fuel data from the Portland Cement Association, the USGS, and the 2018 MECS. The IDM assumes all new cement capacity, both for replacement and increased production, to be dry cement capacity. Existing wet capacity is assumed to retire at a linear rate over 20 years with no replacement. Imported clinker, additives, and fly ash are assumed to make constant percentage contributions to the finished product and to displace a certain amount of domestic clinker production, which affects energy use.

The module estimates lime energy consumption separately from cement, but presents them together as the consolidated cement and lime energy consumption. The same methods implemented for cement drive energy consumption and technology evolution in the lime industry with different, industry-specific equipment choices.

Iron and steel industry

The iron and steel industry includes several major process steps:

- Coke production
- Iron production
- Steel production
- Steel casting

- Steel forming

Steel manufacturing plants are either integrated or non-integrated. The classification depends on the number of major process steps performed in the facility. Integrated plants perform all of the process steps, whereas non-integrated plants, in general, perform only the last three steps.

The IDM uses a process flow of five steps to estimate unit energy consumption values. Steps for making crude steel are different for steel made primarily from raw materials (primary steel) and scrap steel reformed into new steel (secondary steel).

These are the steps used to make crude primary steel:

- Coke ovens convert metallurgical coal into coke.
- Iron is reduced in a blast furnace (BF), which is then charged into a basic oxygen furnace (BOF) to produce crude steel.

To make secondary steel, an electric arc furnace (EAF) produces raw steel from an all-scrap (recycled materials) charge, which can be supplemented with direct-reduced iron (DRI). Like a BF, DRI reduces iron, but uses much lower temperatures than a BF. DRI can also supplement primary steel production.

The steps of turning crude steel into finished products is the same for primary and secondary steel:

- Crude steel is cast into blooms, billets, or slabs using continuous casting. Ninety-seven percent of all U.S. steel is produced using continuous casting.
- Steel is then hot-rolled into various mill products. Some of these are sold as hot-rolled mill products, while others are further cold rolled to impart surface finish or other desirable properties.

The technology slate in each of these process steps evolves over time and depends on the relative cost of equipment, cost of fuel, and fuel efficiency. The latest CIMS database determines and calibrates the IDM base year technology slate for the IDM base year 2018 MECS and USGS physical output for 2018.

Aluminum industry

For the aluminum industry model, each step (alumina production, anode production, electrolysis for primary aluminum production, and melting for secondary production) has several technology choices for new capacity with known fuel types and efficiencies, as well as other operating characteristics. Technology shares are known at the national level, and regional fuel breakouts are based on fixed allocations using available EIA data.

The aluminum industry has both primary and secondary production processes, which vary widely in their energy demands. Recently, the share of secondary aluminum has increased significantly higher than its historical share. A number of primary smelters have closed during the past few years and may not reopen. Therefore, experts expect the share of secondary aluminum to constitute at least 75% of total aluminum output through 2050. Consistent with assumptions in previous years, no new primary aluminum plants are assumed to be built in the United States before 2050, although very limited capacity expansion of existing primary smelters may occur.

Some technologies are available to both processes, and others are available to only one process:

- Primary smelting (Hall-Heroult electrolysis cell) is represented as smelting in four pre-bake anode technologies that denote standard and retrofitted choices and one inert anode-wetted cathode choice.
- Anode production, used in primary production only, is represented by three natural gas-fired furnaces under various configurations in forming and baking pre-bake anodes and the formation of Söderberg anodes. Anodes are a requirement for the Hall-Heroult process.
- Alumina production (Bayer Process) is used in primary production only and selects between existing natural gas facilities and those with retrofits.
- Secondary production selects between two natural gas-fired melters: standard and high efficiency.

The technology slate in each of these process steps evolves over time and depends on the relative cost of equipment, cost of fuel, and fuel efficiency, subject to the constraint that the secondary production share is at least 75% of all aluminum production. We calibrate the latest IDM base year technology slate to CIMS bandwidth studies from the Department of Energy's Advanced Manufacturing Office[vii], the 2018 MECS, and the USGS physical production of primary and secondary aluminum. The module assumes all new capacities for aluminum production, both for replacement and increased production needs, to be either pre-existing primary production or new secondary production, based on historical trend data and projected energy prices.

Buildings component

The total buildings energy demand by industry for each region is a function of regional industrial employment and output. The IDM estimates building energy consumption for building lighting, HVAC (heating, ventilation, and air conditioning), facility support, and onsite transportation. Space heating was further divided to estimate the amount provided by direct combustion of fossil fuels and by steam (Table 7). The module also estimates energy consumption in the BLD component for an industry based on regional employment and output growth for that industry using the 2018 MECS as a basis.

Table 7. Buildings component energy consumption inputs

trillion British thermal units

Industry	Census region	Lighting—electricity	HVAC—electricity	HVAC—natural gas	HVAC—steam	Facilities support total	Onsite transportation total
Food	1	0.5	3.1	3.1	1.0	2.0	0.2
	2	1.7	10.9	14.3	4.5	9.3	1.4
	3	2.2	14.4	28.5	9.0	15.6	1.1
	4	0.7	4.7	7.1	2.2	4.1	0.3
Paper	1	0.9	1.0	1.1	0.0	0.4	0.1

Industry	Census region	Lighting—electricity	HVAC—electricity	HVAC—natural gas	HVAC—steam	Facilities support total	Onsite transportation total
	2	3.3	3.7	4.8	0.0	1.6	2.2
	3	4.3	4.8	9.7	0.0	2.5	2.6
	4	1.4	1.6	2.4	0.0	0.7	0.2
Bulk chemicals	1	1.1	1.8	1.2	0.0	0.7	0.0
	2	3.7	6.2	5.4	0.0	3.0	0.8
	3	4.9	8.2	10.8	0.0	5.4	0.2
	4	1.6	2.7	2.7	0.0	1.4	0.0
Glass	1	0.3	0.4	0.4	0.0	0.0	0.0
	2	1.0	1.3	1.6	0.0	0.0	0.0
	3	1.3	1.7	3.2	0.0	0.0	0.0
	4	0.4	0.6	0.8	0.0	0.0	0.0
Cement and lime	1	0.1	0.1	0.0	0.0	0.0	0.0
	2	0.3	0.3	0.0	0.0	0.0	1.6
	3	0.4	0.4	0.0	0.0	0.0	0.4
	4	0.1	0.1	0.0	0.0	0.0	0.0
Iron and steel	1	0.7	0.6	1.1	0.0	0.3	0.0
	2	2.3	2.0	4.8	0.0	1.1	3.1
	3	3.1	2.6	9.7	0.0	2.1	0.9
	4	1.0	0.9	2.4	0.0	0.5	0.0
Aluminum	1	0.3	0.2	0.5	0.0	0.3	0.0
	2	1.0	0.7	2.2	0.0	1.3	0.8
	3	1.3	0.9	4.3	0.0	1.8	0.2
	4	0.4	0.3	1.1	0.0	0.6	0.0
Fabricated metal products	1	1.2	1.6	1.8	0.5	0.4	0.1
	2	4.3	5.6	8.3	2.2	1.5	0.6
	3	5.6	7.3	16.7	4.5	2.4	2.1
	4	1.8	2.4	4.1	1.1	0.7	0.1
Machinery	1	0.8	1.2	1.5	0.3	0.3	0.1
	2	3.0	4.3	6.7	1.2	1.3	0.5
	3	3.9	5.7	13.5	2.4	1.8	1.3
	4	1.3	1.8	3.3	0.6	0.6	0.1
Computer products	1	0.6	1.8	0.9	0.4	0.5	0.0
	2	2.0	6.3	4.0	1.6	1.9	0.0
	3	2.6	8.3	8.1	3.3	2.8	0.0
	4	0.8	2.7	2.0	0.8	0.8	0.0
Transportation equipment	1	1.9	2.9	3.4	1.1	0.7	0.2
	2	6.6	10.3	15.6	5.0	2.8	1.7

Industry	Census region	Lighting—electricity	HVAC—electricity	HVAC—natural gas	HVAC—steam	Facilities support total	Onsite transportation total
	3	8.7	13.5	31.2	10.1	4.2	2.8
	4	2.8	4.4	7.8	2.5	1.2	0.3
Electrical equipment	1	0.3	0.7	0.5	0.2	0.2	0.0
	2	1.0	2.3	2.4	0.9	0.6	0.1
	3	1.3	3.0	4.8	1.8	1.0	0.8
	4	0.4	1.0	1.2	0.4	0.3	0.0
Wood products	1	0.5	0.5	0.4	1.8	0.2	0.0
	2	1.7	1.7	1.6	8.1	0.6	5.1
	3	2.3	2.3	3.2	16.3	1.0	3.8
	4	0.7	0.7	0.8	4.0	0.3	0.0
Plastic products	1	1.2	1.6	1.2	0.2	0.5	0.2
	2	4.3	5.6	5.6	1.0	1.9	1.0
	3	5.7	7.4	11.3	2.0	2.7	2.6
	4	1.8	2.4	2.8	0.5	0.8	0.3
Balance of manufacturing	1	0.0	5.3	5.5	2.3	3.0	0.0
	2	0.0	18.8	25.0	10.4	14.0	0.0
	3	0.0	24.8	50.0	20.8	19.5	0.0
	4	0.0	8.1	12.4	5.2	5.2	0.0

Source: U.S. Energy Information Administration calculations, based on Manufacturing Energy Consumption Survey 2018 (Washington, DC, August 2021).
Note: HVAC = heating, ventilation, and air conditioning

Boiler, steam, and cogeneration component

Except for the iron and steel industry and the pulp and paper industry, the steam demand and by products from the PA and BLD components are passed to the BSC component, which applies a heat rate and a fuel share equation (Table 8) to the boiler steam requirements to compute the required energy consumption. The iron and steel industry and pulp and paper industry have independent BSC and cogeneration-related modeling that is calculated as part of the PA step.

The boiler fuel shares apply only to the fuels that are used in boilers for steam-only applications. The next section describes fuel use for the share of the steam demand associated with combined heat and power (CHP). The IDM assumes some fuel switching for the remainder of the boiler fuel use and calculates it with a logit-sharing equation where fuel shares are a function of fuel prices; the module also assumes the logit parameter to be -2 for all regions and industries.

The IDM assumes byproduct fuels, production of which the PA component estimates, to be consumed without regard to price, independent of purchased fuels. The boiler fuel share equations and calculations are based on the 2018 MECS and information from the Council of Industrial Boiler Owners[viii].

Table 8. Boiler steam cogeneration component energy inputs, 2018

trillion British thermal units

Industry	Census region	Natural gas	Coal	Renewables	Petroleum
Food	1	23.0	6.2	4.8	0.1
	2	104.3	21.2	6.5	2.2
	3	208.8	6.8	41.8	6.6
	4	51.9	2.8	4.9	0.1
Bulk chemicals	1	65.2	16.4	0.3	6.7
	2	295.5	56.3	0.4	21.4
	3	591.4	17.9	2.9	332.5
	4	146.9	7.4	0.3	5.4
Glass	1	0.1	0.0	0.0	0.0
	2	0.3	0.0	0.0	0.0
	3	0.5	0.0	0.0	0.0
	4	0.1	0.0	0.0	0.0
Cement and lime	1	0.0	0.0	0.1	0.0
	2	0.0	0.0	0.1	0.0
	3	0.0	0.0	0.7	0.0
	4	0.0	0.0	0.1	0.0
Fabricated metal products	1	0.8	0.0	0.0	0.0
	2	3.5	0.0	0.0	0.0
	3	7.0	0.0	0.0	0.0
	4	1.7	0.0	0.0	0.0
Machinery	1	0.4	0.0	0.0	0.0
	2	1.9	0.0	0.0	0.0
	3	3.8	0.0	0.0	0.0
	4	0.9	0.0	0.0	0.0
Computer products	1	0.7	0.0	0.0	0.0
	2	3.0	0.0	0.0	0.0
	3	5.9	0.0	0.0	0.0
	4	1.5	0.0	0.0	0.0
Transportation equipment	1	1.5	0.0	0.0	0.4
	2	6.7	0.0	0.0	0.6
	3	13.5	0.0	0.0	2.1
	4	3.3	0.0	0.0	0.0
Electrical equipment	1	0.4	0.0	0.0	0.0
	2	1.6	0.0	0.0	0.0
	3	3.2	0.0	0.0	0.0
	4	0.8	0.0	0.0	0.0

Wood products	1	1.1	0.0	38.3	0.1
	2	5.1	0.0	51.2	0.3
	3	10.2	0.0	331.1	0.5
	4	2.5	0.0	38.5	0.1
Plastic products	1	1.8	0.0	0.0	0.0
	2	8.3	0.0	0.0	0.0
	3	16.7	0.0	0.0	0.0
	4	4.1	0.0	0.0	0.0
Balance of manufacturing	1	12.0	0.3	1.6	1.4
	2	54.3	1.1	2.1	7.8
	3	108.7	0.4	13.7	49.2
	4	27.0	0.2	1.6	1.6

Source: U.S. Energy Information Administration calculations, based on Manufacturing Energy Consumption Survey 2018 (Washington, DC, August 2021).

Combined heat and power

Combined heat and power (CHP) plants, which are designed to produce both electricity and useful heat, have been used in the industrial sector for many years. The CHP estimates in the module for end-use industries are based on the assumption that the historical relationship between industrial steam demand and CHP will continue in the future, and the rate of additional CHP penetration will depend on the economics of retrofitting CHP plants to replace steam generated from existing non-CHP boilers. The technical potential for CHP is based on supplying steam requirements. Capacity additions are then determined by:

- The interaction of CHP investment payback periods (with the time value of money included) derived using operating hours reported in EIA's published statistics
- Market penetration rates for investments with those payback periods
- Regional deployment for these systems as characterized by the collaboration coefficients in Table 9
- Assumed installed costs for the CHP systems in Table 10

Table 9. Regional collaboration coefficients for CHP deployment

Census region	Collaboration coefficient
1 (Northeast)	0.335
2 (Midwest)	0.175
3 (South)	0.235
4 (West)	0.255

Source: Calculated from American Council for an Energy-Efficient Economy, 2017 State Energy Efficiency Scorecard (Washington, DC, September 2017) and Form EIA-860, Annual Electric Generator Report, U.S. Energy Information Administration, Office of Energy Statistics (Washington, DC, October 2018).
Note: CHP = combined heat and power

Table 10. Cost characteristics of industrial CHP systems

System	Capacity (MW)	2018 overall heat rate (Btu/kWh)	2018 installed cost (2018$/kW)	2050 overall heat rate (Btu/kWh)	2050 installed cost (2018$/kW)
Reciprocating engine	1.2	8,713	$2,586	8,597	$2,553
	3.0	8,654	$2,010	8,538	$1,984
Gas turbine	4.6	9,768	$1,839	9,252	$1,741
	10.4	10,807	$1,842	10,236	$1,751
	23.2	10,276	$1,309	9,733	$1,245
	45.0	8,933	$1,162	8,461	$1,106
Combined cycle	117.0	6,789	$1,581	6,430	$1,482
	376.0	6,270	$1,267	5,992	$1,211

Source: Leidos, *Distributed Generation, Battery Storage, and Combined Heat and Power System Characteristics and Costs in the Buildings and Industrial Sectors* (Washington, DC, May 2020).
Note: CHP = combined heat and power, MW = megawatt, Btu = British thermal units, kW = kilowatt, kWh = kilowatthour

CHP for steel, paper, and aluminum industries

For steel and paper, the IDM computes boiler and CHP capacity and generation as part of the PA step. Steam demand for each process is a non-energy demand for each process step. The module calculates the initial steam and CHP in the IDM base year based on historical Form EIA-860 data through 2020, and a CHP share is assumed in the final projection year. Specific CHP and boiler technology shares in the IDM base year and final projection year are then chosen from a slate of user-assumed technologies with different fuels. In the intervening years, the share of CHP and boilers and the technology shares are interpolated.

For the aluminum industry, the structure is slightly different. The boilers step (including CHP) is a distinct process step in the manufacture of alumina from bauxite. Boiler and CHP technology shares are user-assumed in the IDM base year.

Key assumptions—nonmanufacturing

The nonmanufacturing sector consists of three industries: agriculture, mining, and construction. These industries all use electricity, natural gas, diesel fuel, and gasoline. The mining industry also uses coal and residual fuel oil; the construction industry uses propane and other petroleum products such as asphalt and road oil. Except for oil and natural gas extraction, almost all of the energy use in the nonmanufacturing sector takes place in the PA step. Oil and natural gas extraction uses a significant amount of residual fuel oil in the BSC component.

Unlike the manufacturing sector, the nonmanufacturing sector does not have a single source of data for energy consumption estimates. Instead, EIA derives UECs for the nonmanufacturing sector from various sources of data collected by a number of government agencies.

Nonmanufacturing data were revised using EIA and U.S. Census Bureau sources to provide more realistic projections of diesel and gasoline for off-road vehicle use and to allocate natural gas, HGLs, and electricity consumption. EIA used Fuel Oil and Kerosene Sales (FOKS),[ix] the U.S. Department of Agriculture's *Agricultural Resource Management Survey* (ARMS),[x] and the U.S. Census Bureau's 2017 Economic Census for Mining[xi] and Census for Construction.[xii]

Agriculture subsector

U.S. agriculture consists of three major industries:

- Crop production, which depends primarily on regional environments and crops demanded
- Animal production, which largely depends food demands and feed accessibility
- Forestry, logging, and all other agricultural activities

These subindustries have historically been tightly grouped as a result of competing uses for land. For example, crops produced for animal feed cannot be consumed by humans. Similarly, forests provide the feedstock for the paper and wood industries, but they are not good for growing crops and limit or prevent animals from grazing. Forestry and logging are not modeled within NEMS.

Energy consumption in the agricultural sectors modeled in NEMS—crops and other—are disaggregated into three activities: irrigation, buildings, and vehicles. EIA derives the TPC for each activity from the Commercial Demand Module (CDM) and the Transportation Demand Module (TDM). Each TPC for irrigation depends on the relative change in energy intensity for ventilation from the CDM. Similarly, each TPC for buildings depends on a weighted average of the change in intensity for heating, lighting, and building shells from the CDM. Each TPC for vehicles changes over time depending on the relative intensity change of trucks from the TDM.

We extract baseline energy consumption data for the two agriculture sectors (crops and other agriculture) from the Census of Agriculture and a special tabulation from the U.S. Department of Agriculture, National Agricultural Statistics Service (NASS). Expenditures for four energy sources are collected from crop farms and livestock farms as part of the ARMS. We convert these data from dollar expenditures to energy quantities using fuel prices from NASS and EIA.

Mining subsector

The mining sector comprises three industries: coal mining, metal and nonmetal mining, and oil and natural gas extraction. Energy use is based on the equipment and onsite vehicles used at the mine. All mines use extraction equipment and lighting, but only coal and metal mines and nonmetal mines use grinding and ventilation. As with the agriculture module described above, efficiency changes in buildings and transportation equipment influence each TPC.

The Coal Market Module (CMM) provides coal mining production data. Currently, we assume 70% of coal is mined at the surface and the rest is mined underground. As these shares change, however, so does the energy consumed because surface mines use less energy overall than underground mines. In addition, the energy consumed for coal mining depends on coal mine productivity, which is also obtained from the CMM. Diesel fuel and electricity are the predominant fuels used in coal mining.

Electricity used for coal grinding is calculated using the raw grinding process step from the cement submodule. In metal and nonmetal mining, energy use is similar to coal mining. Output used for metal and nonmetal mining is derived from the MAM's variable for other mining that also provides the shares of each type of mining.

For oil and natural gas extraction, natural gas used as lease and plant fuel makes up the majority of fuel used for extraction and processing and is computed in the Oil and Gas Supply Module (OGSM). In addition, natural gas fuel used for liquefaction to produce LNG is computed by the Natural Gas Market Module (NGMM). Both of these uses of natural gas are considered industrial consumption in the aggregate, but are not computed by the IDM. The other (lesser) fuels in the oil and gas sector, including fuel oil, diesel, and electricity, are computed by the IDM based on oil and natural gas production data from OGSM. Energy use depends on the fuel extracted, whether the well is conventional or unconventional (for example, extraction from tight and shale formations), percentage of dry wells, and well depth.

Construction subsector

The construction sector uses diesel fuel, gasoline, electricity, and propane as energy sources. Construction also uses asphalt and road oil as a nonfuel energy source. Asphalt and road oil use is tied to state and local government real investment in highways and streets. This investment is derived from the MAM. Each TPC for diesel and gasoline fuels is directly tied to the TDM's heavy- and medium-duty vehicle efficiency projections. For non-vehicular construction equipment, each TPC is a weighted average of vehicular TPC and highway investment.

Legislation and regulations

Consolidated Appropriations Act, 2021 (CAA2020)

CAA2020 extended the combined heat and power (CHP) investment tax credit (ITC) from the Bipartisan Budget Act of 2018 through the end of 2023. It now applies for all qualifying CHP facilities for which construction begins before January 1, 2024.[xiii]

Bipartisan Budget Act of 2018 (BBA2018)

BBA2018 retroactively extended the combined heat and power (CHP) investment tax credit (ITC) from the Energy Improvement and Extension Act of 2008 (EIEA2008) through the end of 2021. The ITC in EIEA2008 originally went from 2008 through the end of 2016, but BBA2018 applied the ITC to all qualifying CHP facilities for which construction begins before January 1, 2022.[xiv]

The Energy Independence and Security Act of 2007 (EISA2007)

EISA2007 suspends motor efficiency standards established under the Energy Policy Act of 1992 (EPACT1992) for purchases made after 2011. Section 313 of EISA2007 increases or creates minimum efficiency standards for newly manufactured and imported general-purpose electric motors. The efficiency standards are raised for general-purpose, integral-horsepower induction motors, except for fire pump motors. Minimum standards were created for seven types of poly-phase, integral-horsepower induction motors and National Electrical Manufacturers Association (NEMA) design B motors (201–500 horsepower) that were not previously covered by EPACT standards. In 2013, the Energy Policy and Conservation Act was amended (Public Law 113-67), and efficiency standards were revised in a subsequent U.S. Department of Energy (DOE) rulemaking (10 CFR 431.25). For motors manufactured after June 1, 2016, efficiency standards for current regulated motor types[xv] were expanded to include 201–500 horsepower motors. In addition, special- and definite-purpose motors from 1–500 horsepower and NEMA design A motors from 201–500 horsepower were subject to efficiency standards. The AEO2017 modeled 2014 regulations by modifying the specifications for new motors in the electric motor technology choice module and the 2014 regulations are unchanged in AEO2021.

Energy Policy Act of 1992 (EPACT1992)

EPACT1992's efficiency standards for boilers, furnaces, and electric motors affect the Industrial Demand Module (IDM). The IDM assumes efficiency of 80% and 82% for natural gas and oil burners, respectively. These efficiencies meet the EPACT1992 standards. EPACT1992 requires minimum efficiencies for all motors up to 200 horsepower purchased after 1998. The choices offered in the motor efficiency assumptions are all at least as efficient as the EPACT minimums.

Clean Air Act Amendments of 1990 (CAAA1990)

CAAA1990 contains numerous provisions that affect industrial facilities. Three major categories of such provisions are process emissions (for example, a chemical reaction that releases carbon), emissions related to hazardous or toxic substances, and sulfur dioxide (SO2) emissions. Process emissions requirements were specified for several industries and activities (40 CFR 60). Similarly, 40 CFR 63 requires limitations on emissions of almost 200 hazardous or toxic substances. These requirements are not explicitly represented in the NEMS Industrial Demand Module because they are not directly related to energy consumption projections.

Section 406 of the CAAA1990 requires the U.S. Environmental Protection Agency (EPA) to regulate industrial SO2 emissions when total industrial SO2 emissions exceed 5.6 million tons per year (42 USC 7651). Because industrial coal use (the main source of SO2 emissions) has been declining, EPA does not anticipate that specific industrial SO2 regulations will be required (U.S. Environmental Protection Agency, National Air Pollutant Emission Trends: 1900–1998, EPA-454/R-00-002, March 2000, Chapter 4). Further, because industrial coal use is not projected to increase, the industrial cap is not expected to affect industrial energy consumption projections. The electric power sector includes emissions from coal-to-liquids CHP plants because they are subject to the separate emission limits of large electricity-generating plants.

Maximum Achievable Control Technology for Industrial Boilers (Boiler MACT)

Section 112 of the Clean Air Act (CAA) requires regulation of air toxics through the National Standards for Hazardous Air Pollutants (NESHAP) for industrial, commercial, and institutional boilers. The AEO2022 models final regulations, known as Boiler MACT. Pollutants covered by Boiler MACT include the following hazardous air pollutants: hydrogen chloride, mercury, dioxins/furans, carbon monoxide, and particulate matter. Generally, industries comply with the Boiler MACT regulations by including regular maintenance and tune-ups for smaller facilities and emission limits and performance tests for larger facilities. In line with natural gas area source boilers being exempt from regulation under Boiler MACT, the IDM penalizes coal and fuel oil fired boilers relative to natural gas boilers.

Finally, the MAM models Boiler MACT as an upgrade cost. These upgrade costs are classified as nonproductive costs, which are not associated with efficiency improvements. The effect of these costs in the MAM is a reduction in shipments coming into the IDM.

California Assembly Bill 32: Emissions Cap-and-Trade as Part of the Global Warming Solutions Act of 2006 (AB32) as Amended by California Senate Bill 32, 2016 (SB32)

AB32 established a comprehensive, multiyear program to reduce greenhouse gas (GHG) emissions in California, including a cap-and-trade program.[xvi] In addition to the cap-and-trade program, AB32 authorizes the low carbon fuel standard (LCFS); energy efficiency goals and programs in transportation, buildings, and industry; combined-heat-and-power goals; and renewable portfolio standards.

The AEO2022 models the cap-and-trade provisions for industrial facilities, refineries, and fuel providers. The NEMS Electricity Market Module models allowance price, representing the incremental cost of complying with AB32 cap-and-trade, by a region-specific emissions constraint. This allowance price, when added to market fuel prices, results in higher effective fuel prices in the demand sectors. NEMS also models limited banking and borrowing of allowances, as well as a price containment reserve and offsets. AB32 is not modeled explicitly in the IDM, but it enters the module implicitly through higher effective fuel prices and macroeconomic effects of higher prices, all of which affect energy demand and emissions primarily in census region 9 (the Pacific).

SB32 was enacted in September 2016 and requires California regulators to plan for a 40% reduction in GHG emissions to lower than 1990 levels by 2030.[xvii] The AEO2022 models emissions goals in the cap-and-trade program assuming a ceiling on CO2 allowance prices to prevent infeasible solutions or extremely high allowance prices. Further cost-effective emissions reductions are not available, and consequently, the allowance price is at the price ceiling. The IDM assumes this price ceiling to be slightly higher than the price of the Tier 3 Allowance Price Containment Reserve.

The cap-and-trade program is only one part of California’s GHG reduction strategy. According to the California Air Resources Board, the cap-and-trade program is assumed to comprise less than 30% of total GHG emissions reductions targets.[xviii] Emissions reductions targeted by the other GHG reduction programs described above affect the industrial sector only indirectly.

Notes and sources

[i] U.S. Energy Information Administration, State Energy Data System (SEDS), based on energy consumption by state 2019, (Washington, DC, June 25, 2021).

[ii] U. S. Energy Information Administration, Manufacturing Energy Consumption Survey 2018, (Washington, DC, August 2021).

[iii] U.S. Department of Energy (2007). Motor Master+ 4.0 software database; available at updated link http://www.eere.energy.gov/manufacturing/downloads/MM41Setup.exe (paste into browser). User manual: https://www.energy.gov/sites/prod/files/2014/04/f15/motormaster_user_manual.pdf.

[iv] Roop, Joseph M., "The Industrial Sector in CIMS-US," Pacific Northwest National Laboratory, 28th Industrial Energy Technology Conference, May 2006.

[v] U.S. Department of the Interior, U.S. Geological Survey, Minerals Yearbooks 2019 and 2020.

[vi] Portland Cement Association, U.S. and Canadian Portland Cement Industry Plant Information Summary, cement data were made available under a non-disclosure agreement.

[vii] U.S. Department of Energy, Advanced Manufacturing Office, Bandwidth Study on Energy Use and Potential Energy Saving Opportunities in U.S. Aluminum Manufacturing, (Washington, DC, September 2017).

[viii] Personal correspondence with the Council of Industrial Boiler Owners, April 18, 2011.

[ix] U.S. Energy Information Administration, Adjusted Fuel Oil and Kerosene Sales (FOKS), (Washington, DC, January 2021).

[x] U.S. Department of Agriculture, Economic Research Service, Agriculture Research Management Survey (ARMS) Farm Production Expenditures 2020 Summary, July 30, 2021 (cornell.edu).

[xi] U.S. Census Bureau, 2017 Economic Census Mining: Industry Series: Selected Supplies, Minerals Received for Preparation, Purchased Machinery, and Fuels Consumed by Type for the United States: 2017 (Washington, DC, December 15, 2020).

[xii] U.S. Census Bureau, 2017 Economic Census; Construction: Industry Series: Detailed Statistics by Industry for the United States: 2017 (Washington, DC, October 8, 2021).

[xiii] U.S. Congress, "H.R.133 - Consolidated Appropriations Act, 2021", Division EE, Title I, Subtitle C-- Extension of Certain Other Provisions, Sec. 132, 116th Congress (2019-2020), became Public Law No: 116-260 on December 27, 2020.

[xiv] U.S. Congress, "H.R.1892 - Bipartisan Budget Act of 2018", Division D, Title I, Subtitle C-- Extension and phaseout of energy credit, Sec. 40411, 115th Congress (2017–2018), became Public Law No: 115-123 on February 9, 2018.

[xv] Federal Register 79 FR 103, pp. 30934-31014, Washington, DC, May 29, 2014.

[xvi] California Air Resources Board "California Code of Regulations, Title 17, Division 3, Chapter 1, Subchapter 10, Article 5 §95800 - §96022" (Sacramento, California, June 14, 2014).

[xvii] California Global Warming Solutions Act §38566 as amended (Sacramento, California, September 8, 2016).

[xviii] Based on personal communication with CARB staff and calculations of Table II-3, page 43, of California Air Resources Board "The 2017 Climate Change Scoping Plant Update," (Sacramento, California, January 20, 2017).