Industrial Demand Module

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The NEMS Industrial Demand Module (IDM) estimates energy consumption by energy source (fuels and feedstocks) for 15 manufacturing and 6 non-manufacturing industries. The manufacturing industries are subdivided further into the energy- intensive manufacturing industries and non-energy-intensive manufacturing industries (Table 6.1). The manufacturing industries are modeled through the use of a detailed process-flow or end-use accounting procedure. The non-manufacturing industries are modeled with less detail because processes are simpler and there is less available data. The petroleum refining industry is not included in the Industrial Demand Module, as it is simulated separately in the Liquid Fuels Market Module (LFMM) of NEMS. The IDM calculates energy consumption for the four Census Regions (see Figure 5) and disaggregates regional energy consumption to the nine Census Divisions based on fixed shares from the U.S. Energy Information Administration (EIA) *State Energy Data System* [1]. The model base year for the IDM was updated to 2010 for AEO2014.

Table 6.1. Industry categories and NAICS codes

Energy-Intensive Manufacturing		Non-energy-Intensive Manufacturing		Non-Manufacturing	
Food products	(NAICS 311)	**Metal-based durables**		Agricultural crop production	(NAICS 111)
Paper and allied products	(NAICS 322)	Fabricated metal products	(NAICS 332)		
Bulk chemicals		Machinery	(NAICS 333)		
Inorganic	(NAICS 32512-32518)	Computer and electronic products	(NAICS 334)	Other agricultural production	(NAICS 112, 113, 115)
Organic	(NAICS 32511, 32519)	Electrical equipment and appliances	(NAICS 335)	Coal mining	(NAICS 2121)
Resins	(NAICS 3252)	Transportation equipment	(NAICS 336)	Oil and gas extraction	(NAICS 211)
Agricultural Chemicals	(NAICS 3253)	**Other**		Metal and other non-metallic mining	(NAICS 2122-2123)
Glass and glass products	(NAICS 3272), 327993	Wood products	(NAICS 321)		
Cement and Lime	(NAICS 32731, 32741)	Plastic and rubber products	(NAICS 326)	Construction	(NAICS 23)
Iron and steel	(NAICS 3311-3312)	Balance of manufacturing	(NAICS 31-33 not already classified)		
Aluminum	(NAICS 3313)				

NAICS = North American Industry Classification System (2007).
Source: Office of Management and Budget, North American Industry Classification system (NAICS) - United States (Springfield, VA. National Technical Information Service).

The energy-intensive manufacturing industries, consisting of food products, paper and allied products, bulk chemicals, glass and glass products, cement and lime, iron and steel, and aluminum, are modeled in considerable detail. Each industry is modeled as three separate but interrelated components: the Process and Assembly (PA) Component, the Buildings (BLD) Component, and the Boiler, Steam, and Cogeneration (BSC) Component. 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. For the manufacturing industries, the PA Component is separated into the major production processes or end uses. Petroleum refining (NAICS 32411) is modeled in detail in the LFMM of NEMS, and the projected energy consumption is reported in the manufacturing total.

Projections of refining energy use, lease and plant fuel, and fuels consumed in cogeneration in the oil and gas extraction industry (NAICS 211) are exogenous to the Industrial Demand Module, but endogenous to the NEMS modeling system.

Key assumptions - manufacturing

The NEMS Industrial Demand Module primarily uses a bottom-up modeling approach. An energy accounting framework traces energy flows from fuels to the industry's output. An important assumption in the development of this system is the use of 2010 baseline Unit Energy Consumption (UEC) estimates based on analysis and interpretations of the 2010 Manufacturing Energy Consumption Survey (MECS) which is conducted by EIA on a four-year survey cycle [2]. The UECs represent the energy required to produce one unit of the industry's output. A unit of output may be defined in terms of physical units (e.g., tons of steel) or in dollar value of shipments

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The Industrial Demand Module 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. Industries that use a process flow approach are paper, glass, cement and lime, iron and steel, and aluminum. Industries that use an end-use approach are food, bulk chemicals, the five metal based durables industries, wood, plastic and rubber products, and balance of manufacturing. The dominant process technologies are characterized by a combination of unit energy consumption estimates and Technology Possibility Curves (TPC). With the exception of the cement and lime industries, the aluminum industry, and the glass industry, the TPC depicts the assumed average annual rate of change in energy intensity of either a process step or an energy end use (e.g., heating or cooling). The TPCs for new and existing plants vary by industry, vintage and process. These assumed rates were developed using professional engineering judgments regarding the energy characteristics, year of availability, and rate of market adoptions of new process technologies.

For the aluminum, glass, and combined cement and lime industries, energy projections are endogenously derived based on data obtained from the technology estimates (e.g., expenditures, energy coefficients, utility needs) in the Consolidated Impacts Modeling System (CIMS) database prepared by the Pacific Northwest National Laboratory, as calibrated using inputs from the U.S. Geological Survey (USGS) of the U.S. Department of the Interior, Portland Cement Association and MECS 2010 released by EIA [3,4,5].

Process/assembly component

The PA Component models each major manufacturing production step or end use for the manufacturing industries. The throughput production for each process step is computed, as well as the energy required to produce it. The unit energy coefficient (UEC) is defined as the amount of energy to produce a unit of output; it measures the energy intensity of the process or end use.

The module distinguishes the UECs 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 existing in 2010 and surviving after adjusting for assumed retirements each year (Table 6.2). New production capacity is assumed to be added in a given projection year such that sufficient surviving and new capacity is available to meet the level of an industry's output as determined in the NEMS Regional Macroeconomic Module. Middle vintage capital is that which is added after 2010 up through the year prior to the current projection year.

To simulate technological progress and adoption of more-efficient energy technologies, the UECs are adjusted each projection year based on the assumed TPC for each step. The TPCs are derived from assumptions about the relative energy intensity (REI) of productive capacity by vintage (new capacity relative to existing stock in a given year) or over time (new or surviving capacity in 2040 relative to the 2010 stock). For example, state-of-the-art additions to steel hot rolling capacity in 2010 are assumed to require only 80 percent as much energy as does the average existing plant, so the REI for new capacity in 2010 is 0.80 (see Table 6.3). Over time, the UECs for new capacity change, and the rate of change is given by the TPC. The UECs of the surviving 2010 capital stock are also assumed to change over time, but not as rapidly as for new capital stock because of retrofitting. For example, with hot rolling, the TPC for new facilities is -0.804% per year, while the TPC for existing facilities is -0.699% per year. Table 6.3 provides more examples, including alternative assumptions used to reflect an advanced, "high tech" case.

Table 6.2. Retirement rates

Industry	Retirement Rate (percent)	Industry	Retirement Rate (percent)
Iron and Steel			
Blast Furnace and Basic Steel Products	1.5	Food Products	1.7
Electric Arc Furnace	1.5	Pulp and Paper	2.3
Coke Oven	2.5	Metal-Based Durables	1.3
Other Steel	2.9	Other Non-intensive Manufacturing	1.3
Bulk Chemicals	1.7		

Note: Except for the Blast Furnace and Basic Steel Products Industry, the retirement rate is the same for each process step or end-use within an industry.
Source: Energy Information Administration, Model Documentation Report: Industrial Sector Demand Module of the National Energy Modeling System, (Washington, DC, September 2013).

For the new submodules cement and lime, aluminum, and glass baseline capacity (as of year 2008 or 2009) is assumed to retire at a linear rate over a fixed period of time (20 years). Incremental, or added, capacity is assumed to retire according to a logistic survival function. In addition, for the cement industry, retirement of existing wet process kiln technology is assumed to be permanent; only dry process kilns can be added to replace retired wet kilns or to satisfy needed additional capacity.

The concepts of REI and TPCs are a means of embodying assumptions regarding new technology adoption in the manufacturing industry and the associated change in energy consumption of capital without characterizing individual technologies in detail. The approach reflects the assumption that industrial plants will change energy consumption as owners replace old equipment with new, sometimes more-efficient equipment, add new capacity, add new products, or upgrade their energy management practices. The reasons for the increased efficiency are not likely to be directly attributable to technology choice decisions, changing energy prices, or other factors readily subject to modeling. Instead, the module uses the REI and TPC concepts to characterize intensity trends for bundles of technologies available for major process steps or end use.

There are two exceptions to the general approach in the PA component. The first is for electric motor technology choice implemented for 9 industries to simulate their electric machine drive energy end use. Machine drive electricity consumption in the bulk chemicals industry, the food industry, the five metal-based durables industries, wood, plastics and rubber products, and balance of manufacturing is calculated by a motor stock model. The beginning stock of motors is modified over the projection horizon as motors are added to accommodate growth in shipments for each sector, as motors are retired and replaced, and as failed motors are rewound. When an old motor fails, an economic choice is made on whether to repair or replace the motor. When a new motor is added, either to accommodate growth or as a replacement, the motor must meet the minimum efficiency standard and a premium efficiency motor is also available. Table 6.4 provides the beginning stock efficiency for seven motor size groups in each of the three industry groups, as well as efficiencies for EPACT minimum and premium motors [7]. As the motor stock changes over the projection horizon, the overall efficiency of the motor population changes as well.

The second exception in the PA component is the Cement and Lime, Aluminum, and glass submodules. The methodology is described below.

The addition of the cement and lime submodule, the aluminum submodule, and the glass submodule are among several enhancements of the energy-intensive industries within the Industrial Demand Module. Instead of the aggregate energy intensity evolving according to TPCs for both new and vintage equipment for the process flows, the new submodules utilize detailed technology choice for each process flows. The new modules calculate surviving capacity based on retirement and needed capacity based on shipments and surviving capacity. Existing capital equipment retires linearly and new capital equipment retires according to a non-linear "S" curve over the useful life of the equipment. The exact shape of the "S" curve can be obtained by parameters adjusted by the user. New capital equipment information (capital and operating costs, energy use, and emissions) were obtained from the Consolidated Impacts Modeling System (CIMS) database. Each step of the process flow allows for multiple technology choices whose fuel type and efficiency are known at the national level, as regional fuel breakouts are fixed using available EIA data.

Combined cement and lime industry

For the cement process flow, each step (raw material grinding, kiln – both rotation and burner, finished grinding) allows for multiple technology choices whose fuel type and efficiency are known at the national level, as regional fuel breakouts are fixed using available EIA data.

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

1. Raw materials grinding: ball mill, roller mill
2. Kilns (rotators): rotary long with preheat, precalcining, and computer control (dry process only), rotary preheat with high-efficiency cooler (dry only), rotary preheat, precalcine with efficient cooler (dry process only), rotary wet standard with waste heat recovery boiler and cogeneration (wet process only)
3. Kilns (burners): standard fired by natural gas, efficient fired by natural gas, standard fired by oil, efficient fired by oil, standard fired by coal, standard fired by petroleum coke, standard fired by hazardous waste, standard fired by residue-derived fuel
4. Finished grinders: standard ball mill, finishing ball mill with high-efficiency separator, standard roller mill, finishing roller mill with high-efficiency separator

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 base year technology slate is determined from the latest CIMS database and calibrated for the year 2008 with dry and wet mill capacity cement fuel use data from the Portland Cement Association, the USGS, and the 2010 MECS. All new cement capacity, both for replacement and increased production, is assumed 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 thus “displace” a certain amount of domestic clinker production, and therefore energy use.

Lime shipments are estimated using a fixed percentage of stone, clay and glass shipments. Lime shipments, plus cement shipments, are presented together as the consolidated cement and lime output. Energy consumption and technology evolution in the lime industry are driven by the same methods implemented for cement, with different, industry-specific equipment choices.

Aluminum industry

For the aluminum process flow, each step (alumina production, anode production, and electrolysis for primary aluminum production, and melting for secondary production), allows for multiple technology choices whose fuel type and efficiency are known, as well as other operating characteristics. Technology shares are known at the national level, with regional fuel breakouts based on fixed allocations using available EIA data.

The aluminum industry has both primary and secondary production processes, which vary greatly in their energy demands. As such, the extents of these processes are based on the aluminum industry’s projected production and its historical share of production processes attenuated by relevant regional energy prices. Therefore, the fraction of total throughput from each aluminum production process varies over the model projections. However, it is assumed based on expert judgment that no new primary aluminum plants will be built in the U.S. before 2040, although capacity expansion of existing primary smelters may occur.

Some technologies are available to both processes, while others are available to only one process. The technology choices within each production processing group are:

1. 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.
2. 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. Note that anodes are a major requirement for the Hall-Heroult process.
3. Alumina production (Bayer Process) is used in primary production only and selects between existing natural gas facilities and those with retrofits.
4. Secondary production selects between two natural gas-fired melters – i.e., a standard and a melter with 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. The base year technology slate is determined from the latest CIMS database and calibrated for the base year 2010 MECS and the USGS. All new capacities for aluminum production, both for replacement and increased production needs, are now assumed to be either pre-existing primary production or new secondary production, based on historical trend data and projected energy prices. Similar to the energy-intensive technology of the cement industry, the lifespan of existing and new production capacity is assumed to be 20 and 30 years, respectively. In addition, production that has been idled is allowed to re-enter production before new equipment is built.

Glass industry

For the glass process flow, each step of the three glass product processes modeled in the IDM (flat glass, pressed and blown glass, glass containers) allows for multiple technology choices whose fuel type and efficiency are known, as well as other operating characteristics.

For flat glass (NAICS 327211) the process steps include batch preparation, furnace, form & finish, and tempering. For pressed and blown glass (NAICS 327212), the process steps include preparation, furnace, form & finish, and fire polish. For glass containers (NAICS 327213), the process steps include preparation, furnaces, and form & finish. For fiberglass (“mineral wool” – NAICS 327993), the process steps include preparation, furnaces, and form & finish. The final category (“glass from glass products” – NAICS 327215) was not modeled as a process flow with technology choice but instead endowed with fuel-specific UECs which evolved over time via TPC.

Table 6.3. Coefficients for technology possibility curve for manufacturing industries and all industrial scenarios
applies to all fuels unless specified

	Existing Facilities					New Facilities			
Industry/Process Unit	Reference REI2040[1]	High Tech REI 2040[1]	Reference TPC%[2]	High Tech TPC%[2]	REI 2010[3]	Reference REI2040[4]	High Tech REI 2040[4]	Reference TPC%[2]	High Tech TPC%[2]
Food Products- Milling									
Process Heating-Electricity	0.900	0.987	-0.351	-0.045	0.900	0.800	0.875	-0.392	-0.094
Process Heating-Steam	0.810	0.947	-0.701	-0.182	0.900	0.711	0.804	-0.784	-0.375
Process Cooling-Electricity	0.900	0.983	-0.351	-0.057	0.900	0.800	0.873	-0.392	-0.100
Process Cooling-Natural Gas	0.900	0.987	-0.351	-0.045	0.900	0.800	0.875	-0.392	-0.094
Other-Electricity	0.900	0.993	-0.351	-0.024	0.900	0.800	0.875	-0.392	-0.093
Other-Natural Gas	0.950	0.987	-0.171	-0.045	0.950	0.850	0.924	-0.370	-0.094
Food Products-Dairy									
Process Heating-Electricity	0.980	0.987	-0.067	-0.045	0.970	0.950	0.943	-0.069	-0.094
Process Heating-Steam	0.930	0.947	-0.242	-0.182	0.950	0.850	0.849	-0.370	-0.375
Process Cooling-Electricity	0.900	0.983	-0.351	-0.057	0.900	0.800	0.873	-0.392	-0.100
Process Cooling-Natural Gas	0.980	0.987	-0.067	0.045	0.970	0.950	0.943	-0.069	-0.094
Other-Electricity	0.930	0.993	-0.242	0.024	0.960	0.850	0.934	-0.405	-0.093
Other-Natural Gas	0.980	0.987	-0.067	-0.045	0.970	0.950	0.943	-0.069	-0.094
Food Products-Animal Processing									
Process Heating-Electricity	0.980	0.987	-0.067	-0.045	0.970	0.950	0.943	-0.069	-0.094
Process Heating-Steam	0.950	0.947	-0.171	-0.182	0.950	0.900	0.849	-0.180	-0.375
Process Cooling-Electricity	0.930	0.983	-0.242	-0.057	0.950	0.850	0.922	-0.370	-0.100
Process Cooling-Natural Gas	0.980	0.987	-0.067	-0.045	0.970	0.950	0.943	-0.069	-0.094
Other-Electricity	0.950	0.993	-0.171	-0.024	0.980	0.900	0.953	-0.283	-0.093
Other-Natural Gas	0.980	0.987	-0.067	-0.045	0.970	0.950	0.943	-0.069	-0.094
Food Products-Other									
Process Heating-Electricity	0.980	0.987	-0.067	0.045	0.970	0.950	0.943	-0.069	-0.094
Process Heating-Steam	0.930	0.947	-0.242	-0.182	0.950	0.850	0.849	-0.370	-0.375
Process Cooling-Electricity	0.930	0.983	-0.242	-0.057	0.950	0.850	0.922	-0.370	-0.100
Process Cooling-Natural Gas	0.980	0.987	-0.067	-0.045	0.970	0.950	0.943	-0.069	-0.094
Other-Electricity	NA	NA	-0.171	-0.024	NA	NA	NA	-0.215	-0.097
Other-Natural Gas	0.980	0.987	-0.067	-0.045	0.970	0.950	0.943	-0.069	-0.094
Paper & Allied Products									
Wood Preparation	0.785	0.990	-0.802	-0.033	0.882	0.696	0.990	-0.790	-0.386
Waste Pulping-Electricity	0.934	0.953	-0.228	-0.161	0.936	0.936	0.874	0.000	-0.228
Waste Pulping-Steam	0.872	0.908	-0.456	-0.322	0.936	0.936	0.816	0.000	-0.456
Mechanical Pulping-Electricity	0.794	1.006	-0.767	0.021	0.931	0.613	1.215	-1.380	0.893
Mechanical Pulping-Steam	0.629	1.013	-1.533	0.043	0.931	0.402	1.583	-2.760	1.787
Semi-Chemical-Electricity	0.949	0.983	-0.173	-0.025	0.971	0.929	0.956	-0.149	-0.052
Semi-Chemical-Steam	0.901	0.985	-0.346	-0.051	0.971	0.888	0.941	-0.297	-0.105
Kraft, Sulfite, Misc. Chemicals	0.856	0.928	-0.519	-0.249	0.914	0.807	0.786	-0.415	-0.502
Kraft, Sulfite, Misc Chemicals-Steam	0.731	0.861	-1.037	-0.498	0.914	0.712	0.675	-0.830	-1.004
Bleaching-Electricity	0.773	0.927	-0.853	-0.252	0.878	0.674	0.913	-0.878	0.129
Bleaching-Steam	0.597	0.859	-1.706	-0.504	0.878	0.516	0.949	-1.756	0.259
Paper Making	0.864	0.830	-0.485	-0.621	0.885	0.851	0.584	-0.132	-1.376
Paper Making-Steam	0.747	0.687	-0.969	-1.242	0.885	0.818	0.383	-0.264	-2.753

Table 6.3. Coefficients for technology possibility curve for industries and all industrial scenarios (cont.)
applies to all fuels unless specified

	Existing Facilities				New Facilities				
Industry/Process Unit	Reference REI2040[1]	High Tech REI 2040[1]	Reference TPC%[2]	High Tech TPC%[2]	REI 2010[3]	Reference REI2040[4]	High Tech REI 2040[4]	Reference TPC%[2]	High Tech TPC%[2]
Iron and Steel									
Coke Oven-Electricity	0.932	0.879	-0.233	-0.429	0.902	0.868	0.652	-0.128	-1.216
Coke Oven-Steam	0.869	0.772	-0.467	-0.858	0.902	0.835	0.470	-0.257	-2.152
BF/BPF-Electricity	0.993	0.950	-0.022	-0.172	0.987	0.987	0.882	NA	-0.375
BF/BOF-Steam	0.987	0.902	-0.045	-0.345	0.987	0.987	0.787	NA	-0.751
EAF-Electricity	0.912	0.901	-0.308	-0.346	0.990	0.825	0.775	-0.606	-0.813
Hot Rolling[7]	0.810	0.902	-0.699	-0.344	0.800	0.628	0.596	-0.804	-0.978
Hot Rolling-Steam[7]	0.656	0.813	-1.397	-0.687	0.800	0.492	0.442	-1.608	-1.956
Cold Rolling[7]	0.709	0.947	-1.141	-0.183	0.924	0.422	0.851	-2.580	-0.273
Cold Rolling-Steam[7]	0.500	0.896	-2.281	-0.365	0.924	0.189	0.784	-5.160	-0.546
Bulk Chemicals									
Process Heating-Electricity	0.893	0.965	-0.376	-0.120	0.900	0.793	0.861	-0.420	-0.149
Process Heating-Steam	0.798	0.866	-0.751	-0.478	0.990	0.699	0.752	-0.840	-0.597
Process Cooling-Electricity	0.867	0.951	-0.476	-0.168	0.850	0.743	0.810	-0.446	-0.159
Process Cooling-Natural Gas	0.893	0.965	-0.376	-0.120	0.900	0.793	0.861	-0.420	-0.149
Electro-Chemicals	0.979	0.993	-0.072	-0.025	0.950	0.843	0.911	-0.396	-0.141
Other-Electricity	0.908	0.967	-0.321	-0.113	0.915	0.803	0.873	-0.434	-0.155
Other-Natural Gas	0.893	0.965	-0.376	-0.120	0.900	0.793	0.861	-0.420	-0.149
Metal-based Durables									
Fabricated Metals									
Process Heating-Electricity	0.712	0.642	-1.427	-1.468	0.675	0.406	0.329	-1.679	-2.370
Process Cooling-Electricity	0.650	0.576	-1.427	-1.820	0.638	0.371	0.299	-1.784	-2.493
Process Cooling-Natural Gas	0.712	0.642	-1.127	-1.468	0.675	0.406	0.329	-1.679	-2.370
Electro-Chemical Process	0.937	0.887	-0.216	-0.398	0.713	0.441	0.359	-1.586	-2.261
Other-Electricity	0.748	0.681	-0.962	-1.274	0.686	0.406	0.327	-1.737	-2.439
Machinery									
Process-Heating-Electricity	0.712	0.642	-1.427	-1.468	0.675	0.314	0.329	-2.519	-2.370
Process Cooling-Electricity	0.650	0.576	-1.427	-1.820	0.638	0.283	0.299	-2.676	-2.493
Process Cooling-Natural Gas	0.712	0.642	-1.127	-1.468	0.675	0.314	0.329	-2.519	-2.370
Electro-Chemicals	0.937	0.887	-0.216	-0.398	0.713	0.346	0.359	-2.379	-2.251
Other-Electricity	0.748	0.681	-0.962	-1.274	0.686	0.311	0.327	-2.606	-2.439
Computers and Electronics									
Process Heating-Electricity	0.798	0.744	-0.751	-0.979	0.720	0.559	0.504	-0.840	-1.185
Process Cooling-Electricity	0.751	0.693	-0.952	-1.213	0.680	0.520	0.467	-0.892	-1.247
Process Cooling-Natural Gas	NA	NA	-0.751	-0.979	NA	NA	NA	-0.840	-1.185
Electro-Chemical Process	0.958	0.923	-0.144	-0.265	0.760	0.599	0.540	-0.793	-1.130
Other-Electricity	0.824	0.774	-0.641	-0.850	0.732	0.563	0.507	-0.869	-1.219
Electrical Equipment									
Process Heating-Electricity	0.798	0.744	-0.751	-0.979	0.720	0.559	0.504	-0.840	-1.185
Process Heating-Steam	NA	NA	-1.502	-3.914	NA	NA	NA	-1.679	-4.740
Process Cooling-Electricity	0.751	0.693	-0.952	-1.213	0.680	0.520	0.467	-0.892	-1.247
Process Cooling-Natural Gas	0.798	0.744	-0.751	-0.979	0.720	0.559	0.504	-0.840	-1.185
Electro-Chemical Process	0.958	0.923	-0.144	-0.265	0.760	0.599	0.540	-0.793	-1.130
Other-Electricity	0.824	0.774	-0.641	-0.850	0.732	0.563	0.507	-0.869	-1.219

Table 6.3. Coefficients for technology possibility curve for all industrial scenarios (cont.)
applies to all fuels unless specified

	Existing Facilities				New Facilities				
Industry/Process Unit	Reference REI2040[1]	High Tech REI 2040[1]	Reference TPC%[2]	High Tech TPC%[2]	REI 2010[3]	Reference REI2040[4]	High Tech REI 2040[4]	Reference TPC%[2]	High Tech TPC%[2]
Transportation Equipment									
Process Heating-Electricity	0.854	0.814	-0.526	-0.685	0.765	0.625	0.575	-0.672	-0.948
Process Heating-Steam	0.728	0.435	-1.052	-2.740	0.765	0.510	0.240	-1.343	-3.792
Process Cooling-Electricity	0.818	0.774	-0.666	-0.849	0.723	0.583	0.535	-0.714	-0.997
Process Cooling-Natural Gas	0.854	0.814	-0.526	-0.685	0.765	0.625	0.575	-0.672	-0.948
Electro-Chemical Process	0.970	0.946	-0.101	-0.186	0.808	0.667	0.615	-0.634	-0.904
Other-Electricity	0.874	0.836	-0.449	-0.595	0.778	0.631	0.580	-0.695	-0.975
Other-Non-Intensive Manufacturing									
Wood Products									
Process Heating-Electricity	0.712	0.654	-1.127	-1.452	0.630	0.379	0.308	-1.679	-2.358
Process Heating-Steam	0.505	0.166	-2.253	-5.807	0.630	0.226	0.032	-3.358	-9.432
Process Cooling-Electricity	0.650	0.579	-1.427	-1.804	0.595	0.347	0.280	-1.784	-2.481
Process Cooling-Natural Gas	0.712	0.645	-1.127	-1.452	0.630	0.379	0.308	-1.679	-2.358
Electro-Chemical Process	0.937	0.969	-0.216	-0.502	0.665	0.412	0.600	-1.586	-0.342
Other-Electricity	0.748	0.875	-0.962	-0.443	0.641	0.379	0.310	-1.737	-2.388
Plastic Products									
Process Heating-Electricity	0.798	0.747	-0.751	-0.968	0.675	0.524	0.473	-0.840	-1.179
Process Heating-Steam	0.635	0.306	-1.502	-3.871	0.675	0.406	0.158	-1.679	-4.716
Process Cooling-Electricity	0.751	0.696	-0.952	-1.203	0.638	0.487	0.438	-0.892	-1.241
Process Cooling-Natural Gas	0.798	0.747	-0.751	-0.968	0.675	0.524	0.473	-0.840	-1.179
Electro-Chemical Process	0.958	0.979	-0.144	-0.070	0.713	0.561	0.677	-0.793	-0.171
Other-Electricity	0.824	0.915	-0.641	-0.295	0.686	0.528	0.479	-0.869	-1.194
Balance of Manufacturing									
Process Heating-Electricity	0.844	0.804	-0.563	-0.726	0.675	0.551	0.508	-0.672	-0.943
Process Heating-Steam	0.712	0.627	-1.127	-1.546	0.675	0.450	0.292	-1.343	-2.753
Process Cooling-Electricity	0.825	0.762	-0.714	-0.902	0.638	0.514	0.473	-0.714	-0.992
Process Cooling-Natural Gas	0.844	0.804	-0.563	-0.726	0.675	0.551	0.508	-0.672	-0.943
Electro-Chemical Process	0.968	0.984	-0.108	-0.053	0.713	0.589	0.684	-0.634	-0.137
Other Natural Gas	0.844	0.826	-0.563	-0.636	0.675	0.551	0.517	-0.672	-0.883

[1]REI 2040 Existing Facilities = Ratio of 2040 energy intensity to average 2010 energy intensity for existing facilities.
[2]TPC = annual rate of change between 2010 and 2040.
[3]REI 2010 New Facilities = For new facilities, the ratio of state-of-the-art energy intensity to average 2010 energy intensity for existing facilities.
[4]REI 2040 New Facilities = Ratio of 2040 energy intensity for a new state-of-the-art facility to the average 2010 intensity for existing facilities.
[5]REI's and TPCs apply to virgin and recycled materials.
[6]No new plants are likely to be built with these technologies.
[7]Net shape casting is projected to reduce the energy requirements for hot and cold rolling rather than for the continuous casting step.
NA = Not applicable.
BF = Blast furnace.
BOF = Basic oxygen furnace.
EAF = Electric arc furnace.
Source: SAIC, IDM Base Year Update with MECS 2010 Data, unpublished data prepared for the Industrial Team, Office of Energy Consumption and Efficiency Analysis, Energy Information Administration, Washington, DC, July 2013.

Table 6.4. Cost and performance parameters for industrial motor choice model

Industrial Sector Horsepower Range	2002 Stock Efficiency (%)	Premium Efficiency (%)	Premium Cost (2002$)
Food			
1-5 hp	81.3	89.2	601
6 - 20 hp	87.1	92.5	1,338
21 - 50 hp	90.1	93.8	2,585
51 - 100 hp	92.7	95.3	6,290
101 - 200 hp	93.5	95.2	11,430
201 - 500 hp	93.8	95.4	29,991
> 500 hp	93.0	96.2	36,176
Bulk Chemicals			
1-5 hp	82.0	89.4	601
6 - 20 hp	87.4	92.6	1,338
21 - 50 hp	90.4	93.9	2,585
51 - 100 hp	92.4	95.4	6,290
101 - 200 hp	93.5	95.3	11,430
201 - 500 hp	93.3	95.5	29,991
> 500 hp	93.2	96.2	36,176
Metal-Based Durables[a]			
1-5 hp	81.9	89.2	601
6-20 hp	87.0	92.5	1,338
21-50 hp	89.9	93.9	2,585
51-100 hp	92.0	95.3	6,290
101-200 hp	93.5	95.2	11,430
201-500 hp	93.7	95.4	29,991
>500 hp	93.0	96.2	36,176
Balance of Manufacturing[b]			
1-5 hp	83.0	89.2	601
6-20 hp	88.3	92.5	1,338
21-50 hp	90.3	93.9	2,585
51-100 hp	92.7	95.3	6,290
101-200 hp	94.3	95.2	11,430
201-500 hp	94.2	95.4	29,991
>500 hp	92.9	96.2	36,176

[a]The metal-based durables group includes five sectors that are modeled separately: Fabricated Metals; Machinery; Computers and Electronics; Electrical Equipment; and Transportation Equipment.
[b]The balance of manufacturing group includes three sectors that are modeled separately: Wood Products; Plastic and Rubber Products; and All Other Manufacturing.
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.

Below is a summary list of technologies used in the glass sub-module. Not all of the technologies below are available to all processes.

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

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

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

4. There is no known technology choice for the tempering step (flat glass) or the polish (blown glass). Placeholders for more efficient future technology choices were implemented, but their introduction into these processes was rather limited.

As with the other sub-modules, 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 vs. electricity.

Petrochemical feedstock requirement

This subroutine estimates feedstock requirements for the major petrochemical intermediates such as ethylene, propylene, and butadiene. The primary feedstocks used to produce these chemicals are natural gas liquids (NGL) (ethane, propane, butane) and petrochemical (oil-based) feedstocks (gas oil, naphtha) [6]. Biomass is a potential raw material source, but it is assumed that there will be no biomass-based capacity over the projection period because of economic barriers. The type of feedstock not only determines the source of feedstock but also the energy for heat and power requirements to produce the chemicals.

To determine the relative amounts of feedstock (NGL or oil-based) baseline intensities, feedstock consumption intensities are derived from the 2010 MECS. Feedstock consumption of both types grows or declines with organic chemicals shipment value. It should be noted that there is no change in the feedstock intensity over time, i.e., all feedstock TPCs are assumed to be zero. Unlike most other processes represented in manufacturing PA components, chemical yields are governed by basic chemical stoichiometry which allows for specific yields under set conditions of pressure and temperature. For the projected LPG feedstock quantities, a further subdivision is made into refinery-produced propylene and ethane. All ethane produced by the NEMS Oil and Gas Supply Module is absorbed by the chemical model. The remaining balance of LPG feedstock requirement is a mixture of pentanes plus, butane, and propane.

Buildings component

The total buildings energy demand by industry for each region is a function of regional industrial employment and output. Building energy consumption was estimated for building lighting, HVAC (heating, ventilation, and air conditioning), facility support, and on-site transportation. Space heating was further divided to estimate the amount provided by direct combustion of fossil fuels and that provided by steam (Table 6.5). Energy consumption in the BLD Component for an industry is estimated based on regional employment and output growth for that industry using the 2010 MECS as a basis.

Boiler, steam, and cogeneration component

The steam demand and byproducts from the PA and BLD Components are passed to the BSC Component, which applies a heat rate and a fuel share equation (Table 6.6) to the boiler steam requirements to compute the required energy consumption.

The boiler fuel shares apply only to the fuels that are used in boilers for steam-only applications. Fuel use for the portion of the steam demand associated with combined heat and power (CHP) is described in the next section. Some fuel switching for the remainder of the boiler fuel use is assumed and is calculated with a logit-sharing equation where fuels shares are a function of fuel prices. The equation is calibrated to 2010 so that the 2010 fuel shares are produced for the relative prices that prevailed in 2010.

The byproduct fuels, production of which is estimated in the PA Component, are assumed to be consumed without regard to price, independent of purchased fuels. The boiler fuel share equations and calculations are based on the 2010 MECS and information from the Council of Industrial Boiler Owners. [8]

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 are based on the assumption that the historical relationship between industrial steam demand and CHP will continue in the future, and that 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 primarily based on supplying thermal requirements (i.e., matching thermal loads). 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, and regional deployment for these systems as characterized by the "collaboration coefficients" in Table 6.8. Assumed installed costs for the CHP systems are given in Table 6.7.

Table 6.5. 2010 Building component energy consumption

trillion Btu

		Building Use and Energy Source					
Industry	Region	Lighting Electricity Consumption	HVAC Electricity Consumption	HVAC Natural Gas Consumption	HVAC Steam Consumption	Facility Support Total Consumption	Onsite Transportation Total Consumption
Food Products	1	2.1	2.1	3.3	2.1	1.7	0.9
	2	9.7	9.7	14.8	4.9	7.4	0.9
	3	6.8	6.8	8.7	5.5	4.4	1.6
	4	3.5	3.5	7.4	4.7	3.8	3.0
Paper & Allied Products	1	1.2	1.3	2.8	0.0	0.3	0.9
	2	3.7	4.0	3.3	0.0	0.3	0.9
	3	6.8	7.4	7.1	0.0	0.7	2.0
	4	3.2	3.4	2.2	0.0	0.3	0.9
Bulk Chemicals	1	0.8	1.0	3.7	0.0	2.8	5.2
	2	2.9	3.5	5.8	0.0	3.9	5.6
	3	7.7	9.3	15.0	0.0	9.0	9.7
	4	0.9	1.0	3.7	0.0	2.8	5.0
Glass & Glass Products	1	0.4	0.5	3.8	0.0	3.2	3.4
	2	0.7	0.9	4.1	0.0	3.3	3.4
	3	0.9	1.2	4.5	0.0	3.4	3.5
	4	0.3	0.4	3.4	0.0	3.1	3.4
Cement	1	0.1	0.1	0.6	0.0	0.6	1.1
	2	0.3	0.3	0.6	0.0	0.6	1.1
	3	0.4	0.4	0.7	0.0	0.7	1.1
	4	0.2	0.2	0.5	0.0	0.5	0.6
Iron and Steel	1	0.8	0.8	1.9	0.0	0.7	0.6
	2	2.7	2.7	8.7	0.0	1.9	2.4
	3	3.1	3.1	3.6	0.0	1.0	1.7
	4	0.4	0.4	1.0	0.0	0.6	0.6
Aluminum	1	0.2	0.2	0.5	0.0	0.2	0.2
	2	0.8	0.8	1.0	0.0	0.3	0.3
	3	0.8	0.8	2.6	0.0	0.7	0.8
	4	0.3	0.3	0.4	0.0	0.1	0.2
Metal-Based Durables							
Fabricated Products	1	1.8	1.5	5.1	2.9	0.6	1.4
	2	6.6	5.6	16.3	9.1	1.2	1.5
	3	5.2	4.4	8.8	5.0	0.8	1.7
	4	1.4	1.2	2.6	1.5	0.2	0.3
Machinery	1	1.6	2.3	4.2	0.7	0.2	0.2
	2	4.8	6.8	20.7	3.6	0.9	0.9
	3	3.1	4.3	8.6	1.5	0.5	0.7
	4	0.6	0.8	0.5	0.1	0.1	0.2
Computers & Electronic Products	1	2.2	5.6	4.2	2.5	0.9	0.8
	2	2.0	4.0	4.4	2.7	0.9	0.8
	3	4.2	10.5	4.4	2.7	0.9	0.8
	4	4.1	10.2	9.4	5.7	1.2	0.8
Transportation Equipment	1	1.6	2.0	4.8	0.4	0.6	0.2
	2	10.5	13.1	23.1	2.1	2.0	1.2
	3	6.1	7.6	10.1	0.9	1.1	0.8
	4	2.5	3.1	3.9	0.4	0.3	0.2
Electrical Equipment	1	0.7	1.0	1.7	1.3	0.5	0.5
	2	1.1	1.6	2.6	2.1	0.4	0.4
	3	2.1	3.1	4.0	3.1	0.6	0.4
	4	0.2	0.3	0.1	0.1	0.1	0.4
Other Non-Intensive Manufacturing							
Wood Products	1	0.2	0.2	0.8	2.5	0.5	0.4
	2	0.6	0.5	1.6	4.9	0.7	1.7
	3	2.4	1.8	2.7	8.4	0.7	2.1
	4	0.8	0.6	1.3	4.0	0.3	4.2

Table 6.5. 2010 Building component energy consumption (cont.)
trillion Btu

		Building Use and Energy Source					
Industry	Region	Lighting Electricity Consumption	HVAC Electricity Consumption	HVAC Natural Gas Consumption	HVAC Steam Consumption	Facility Support Total Consumption	Onsite Transportation Total Consumption
Plastic Products	1	0.8	0.9	1.8	0.0	0.2	0.3
	2	4.5	5.6	7.7	0.0	0.5	0.7
	3	5.5	6.8	10.3	0.0	0.7	0.8
	4	2.5	3.0	2.1	0.0	0.2	0.2
Balance of Manufacturing	1	5.5	9.1	13.4	0.0	0.0	1.2
	2	10.5	17.4	20.6	0.0	0.0	2.1
	3	15.7	26.0	28.1	0.0	0.0	3.4
	4	4.5	7.5	9.5	0.0	0.0	0.8

HVAC = Heating, Ventilation, Air Conditioning.

Source: SAIC, IDM Base Year Update with MECS 2010 Data, unpublished data prepared for the Industrial Team, Office of Energy Consumption and Efficiency Analysis, Energy Information Administration, Washington, DC, July 2013.

Table 6.6. 2010 Boiler fuel component and logit parameter
trillion Btu

	Region	Alpha	Natural Gas	Coal	Oil	Renewables
Food Products	1	-2.0	33	1	3	1
	2	-2.0	147	131	3	31
	3	-2.0	85	14	6	31
	4	-2.0	74	18	3	8
Paper & Allied Products	1	-2.0	44	44	8	122
	2	-2.0	55	55	9	97
	3	-2.0	113	81	45	898
	4	-2.0	35	16	2	108
Bulk Chemicals	1	-2.0	17	0	55	0
	2	-2.0	164	43	17	0
	3	-2.0	705	18	56	0
	4	-2.0	21	44	6	0
Glass & Glass Products	1	-2.0	1	0	2	1
	2	-2.0	1	0	2	1
	3	-2.0	1	0	2	1
	4	-2.0	0	0	2	1
Cement	1	-2.0	0	0	0	1
	2	-2.0	0	0	0	5
	3	-2.0	0	0	0	3
	4	-2.0	0	0	0	1
Iron & Steel	1	-2.0	4	6	16	0
	2	-2.0	24	0	64	0
	3	-2.0	9	0	14	0
	4	-2.0	2	0	0	0
Aluminum	1	-2.0	1	0	0	0
	2	-2.0	3	0	0	1
	3	-2.0	8	0	1	1
	4	-2.0	1	0	0	0
Metal-Based Durables						
Fabricated Metal Products	1	-2.0	4	0	0	0
	2	-2.0	12	0	0	0
	3	-2.0	6	0	0	0
	4	-2.0	2	0	0	0

Table 6.6. 2010 Boiler fuel component and logit parameter (cont.)
trillion Btu

	Region	Alpha	Natural Gas	Coal	Oil	Renewables
Machinery	1	-2.0	1	0	0	1
	2	-2.0	4	0	1	1
	3	-2.0	2	0	0	0
	4	-2.0	0	0	0	0
Computers & electronic Products	1	-2.0	3	0	1	0
	2	-2.0	3	0	1	0
	3	-2.0	3	0	1	0
	4	-2.0	7	0	1	0
Electrical Equipment	1	-2.0	1	0	1	0
	2	-2.0	2	0	0	0
	3	-2.0	3	0	0	0
	4	-2.0	0	0	0	0
Transportation Equipment	1	-2.0	3	8	2	1
	2	-2.0	17	-5	1	3
	3	-2.0	7	1	2	1
	4	-2.0	3	0	0	0
Other Non-Intensive Manufacturing						
Wood Produts	1	-2.0	0	0	1	79
	2	-2.0	1	0	2	31
	3	-2.0	4	0	2	188
	4	-2.0	2	0	2	54
Plastic Products	1	-2.0	3	2	1	0
	2	-2.0	16	0	0	0
	3	-2.0	21	0	1	0
	4	-2.0	4	0	0	0
Balance of Manufacturing	1	-2.0	35	-10	3	1
	2	-2.0	54	29	37	5
	3	-2.0	74	42	118	10
	4	-2.0	25	7	0	1

Alpha: User-specified.
Source: U.S. Energy Information Administration, Model Documentation Report, Industrial Sector Demand Module of the National Energy Modeling System, (publication pending) (Washington, DC 2013).

Table 6.7. Cost characteristics of industrial CHP systems

System	Size Kilowatts (KW)	Installed Cost (2005$ per KWh)[1] Reference 2010	Reference 2040	High Tech 2040
Engine	1000	1440	576	535
	2000	1260	396	354
Gas turbine	3510	1719	1496	1450
	5670	1152	1023	1006
	14990	982	869	869
	25000	987	860	860
	40000	875	830	830
Combined cycle	100000	723	684	668

[1]Costs are given in 2005 dollars in original source document.
Source: U.S. Energy Information Administration, Model Documentation Report, Industrial Sector Demand Module of the National Energy Modeling System, (Washington, DC, September 2013).

Table 6.8. Regional collaboration coefficients for CHP deployment

Census Region	Collaboration Coefficient
Northeast	1.46
Midwest	1.34
South	0.33
West	1.06

Source: Calculated from American Council for an Energy-Efficient Economy, "Challenges Facing Combined Heat and Power Today: A State-by-State Assessment," September 2011, website: www.aceee.org/research-report/ie111 and Energy Information Administration, Office of Energy Analysis.

Key assumptions - non-manufacturing

The non-manufacturing 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, natural gas liquids (NGL), and residual fuel oil, and the construction industry also uses other petroleum in the form of asphalt and road oil. Except for oil and gas extraction, almost all of the energy use in the nonmanufacturing sector takes place in the process and assembly step. Oil and gas extraction uses a significant amount of residual fuel oil in the BSC component. Table 6.9 shows the baseline unit energy consumption values for the nonmanufacturing subsectors in 2010.

Table 6.9 2010 UECs for nonmanufacturing

Unit Energy Consumption (UEC) in thousand Btu/2005$)

Industry/Process	UEC 2010
Agriculture	
Crop Production	
Buildings	1.82
Vehicles	2.21
Irrigation	0.70
Other Agricultural Production	
Buildings	0.64
Vehicles	1.01
Irrigation	0.27
Construction	1.65
Mining	
Coal	6.97
Oil & Gas Extraction	1.74
Metal/Non-metal	8.97

Sources: Calculations based on EIA's State Energy Data System (SEDS), EIA's Fuel Oil and Kerosene Survey (FOKS), USDA's Agriculture Research Management Survey (ARMS), and Department of Commerce's Economic Census, Construction and Mining Series. See Note and sources page notes [1], [9], [10], [11], [12] for complete citations.

Unlike the manufacturing sector, the non-manufacturing sector does not have a single source of data for energy consumption estimates. Instead, UECs for the non-manufacturing sector are derived from various sources of data collected by a number of government agencies. Furthermore, unlike the majority of manufacturing industries displayed in Table 6.3, the TPCs for non-manufacturing are not "fixed" in that they are dynamic and evolve over time. This evolution depends on output from other modules such as building and transportation equipment efficiencies which are employed in the agriculture and construction models as well as oil & gas well and coal mine productivity which is employed in the mining model.

Nonmanufacturing data was revised using EIA and Census Bureau sources to provide more realistic projections of diesel and gasoline for off road vehicle use, allocate natural gas and hydrocarbon gas liquids (HGL) use, and electricity. Sources used are EIA's Fuel Oil and Kerosene Sales (FOKS) [9] for distillate consumption, Agricultural Resource Management Survey (ARMS) [10] and the Census Bureau's Census of Mining [11] and Census of Construction. [12] Combining these sources, there is now more consumption of distillate and less consumption of motor gasoline. Also, the use of hydrocarbon gas liquids (HGL) is now accounted for in the agriculture and especially the construction industries. Nonmanufacturing consumption is no longer dictated solely by the SEDS – MECS difference as it has been in previous years.

Agriculture

U.S. agriculture consists of three major sub-sectors:

- crop production, which is dependent primarily on regional environments and crops demanded;
- animal production, which is largely dependent on food demands and feed accessibility;
- all remaining agricultural activities, which are primarily composed of forestry and logging.

These sub-industries have historically been tightly coupled due to competing use of land area. For example, crops produced for animal feed cannot be consumed by humans; forests provide the feedstock of the paper and wood industries but in turn do not allow the growth of crops or limit or prevent grazing of animals.

However, energy consumption in these industries is tied to specialized equipment, which often determines the fuel requirement with little flexibility. Within each of these sub-industries the key energy-using equipment can be broken into three major categories: off-road vehicles, buildings, and other equipment, which is primarily irrigation equipment for crop production. Agriculture TPCs are calculated within the NEMS model by further subdividing consumption in each sub-industry based on the equipment in which the energy is used: off-road vehicles, which are trucks, tractors, and other specialty vehicles; buildings, which require lighting and temperature control; and other equipment, which covers a variety of both common (e.g., pumps) and specialty (e.g. cotton gins) equipment used in all the various types of agricultural production. Thus, changes in efficiencies in heavy and medium-duty vehicles from the Transportation Sector Module and changes in lighting and heating efficiencies from the Commercial Sector Demand Module are used to dynamically modify the agriculture TPCs.

Baseline energy consumption data for the two agriculture sectors (crops and other agriculture) is based on data from the Census of Agriculture and a special tabulation from the National Agricultural Statistics Service (USDA-NASS). Expenditures for four energy sources are collected from crop farms and livestock farms as part of the Agricultural Resource Management Survey (ARMS). These data are converted from dollar expenditures to energy quantities using fuel prices from NASS and EIA.

Mining

The mining sector is comprised of three sectors: coal mining, and metal and nonmetal mining, and oil and gas extraction, Energy use is based on what equipment is used at the mine and onsite vehicles used. All mines use extraction equipment and lighting, but only coal and metal and nonmetal mines use grinding and ventilation. As with the agriculture module described above, TPCs are influenced by efficiency changes in buildings and transportation equipment.

Coal mining production is obtained from Coal Market Module (CMM). Currently, it is assumed that 70 percent of the coal is mined at the surface and the rest is mined underground. As these shares evolve, however, so does the energy consumed since surface mines use less energy overall than underground mining. Moreover, the energy consumed for coal mining depends on coal mine productivity which is also obtained from the CMM. Diesel 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 sub-module. In metal and non-metal mining, energy use is similar to coal mining. Output used for metal and non-metal mining is derived from the Macro Analysis Module's (MAM) variable for "other" mining which also provides the shares of each.

For oil and natural gas extraction, production is derived from the OGSM module. Energy use depends upon the fuel extracted as well as whether the well is conventional, or unconventional, e.g. extraction from tight and shale formations, percentage of dry wells, and well depth.

Construction

Construction uses diesel fuel, gasoline, electricity and natural gas 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, and this investment is derived from the MAM. TPCs for diesel and gasoline fuels are directly tied to the Transportation Sector Module's heavy and medium duty vehicle efficiency projections. For non-vehicular construction equipment, TPCs are a weighted average of vehicular TPCs and highway investment.

Legislation and regulations

Energy Improvement and Extension Act of 2008

Under EIEA2008 Title I, "Energy Production Incentives," Section 103 provides an Investment Tax Credit (ITC) for qualifying Combined Heat and Power (CHP) systems placed in service before January 1, 2017. Systems with up to 15 megawatts of electrical capacity qualify for an ITC up to 10 percent of the installed cost. For systems between 15 and 50 megawatts, the percentage tax credit declines linearly with the capacity, from 10 percent to 3 percent. To qualify, systems must exceed 60-percent fuel efficiency, with a minimum of 20 percent each for useful thermal and electrical energy produced. The provision was modeled in AEO2012 by adjusting the assumed capital cost of industrial CHP systems to reflect the applicable credit.

The Energy Independence and Security Act of 2007

Under EISA2007, the motor efficiency standards established under the Energy Policy Act of 1992 (EPACT) are superseded 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 with the exception of fire pump motors. Minimum standards were created for seven types of poly-phase, integral-horsepower induction motors and NEMA design "B" motors (201-500 horsepower) that were not previously covered by EPACT standards. The industrial module's motor efficiency assumptions reflect the EISA2007 efficiency standards for new motors added after 2011.

Energy Policy Act of 1992 (EPACT)

EPACT contains several implications for the industrial module. These implications concern efficiency standards for boilers, furnaces, and electric motors. The industrial module uses heat rates of at least 1.25 (80 percent efficiency) and 1.22 (82 percent efficiency) for gas and oil burners, respectively. These efficiencies meet the EPACT standards. EPACT mandates 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 (CAAA90)

The CAAA90 contains numerous provisions that affect industrial facilities. Three major categories of such provisions are as follows: process emissions, emissions related to hazardous or toxic substances, and SO_2 emissions. Process emissions requirements were specified for numerous industries and/or activities (40 CFR 60). Similarly, 40 CFR 63 requires limitations on almost 200 specific hazardous or toxic substances. These specific requirements are not explicitly represented in the NEMS industrial model because they are not directly related to energy consumption projections.

Section 406 of the CAAA90 requires the U.S. Environmental Protection Agency (EPA) to regulate industrial SO_2 emissions at such time that total industrial SO_2 emissions exceed 5.6 million tons per year (42 USC 7651). Since industrial coal use, the main source of SO_2 emissions, has been declining, EPA does not anticipate that specific industrial SO_2 regulations will be required (Environmental Protection Agency, National Air Pollutant Emission Trends: 1990-1998, EPA-454/R-00-002, March 2000, Chapter 4). Further, since industrial coal use is not projected to increase, the industrial cap is not expected be a factor in industrial energy consumption projections. (Emissions due to coal-to-liquids CHP plants are included with the electric power sector 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 the regulation of air toxics through implementation of the National Standards for Hazardous Air Pollutants (NESHAP) for industrial, commercial, and institutional boilers. The final regulations, known as Boiler MACT, are modeled in the AEO2014. Pollutants covered by Boiler MACT include the hazardous air pollutants (HAP), hydrogen chloride (HCI), mercury (HG), dioxin/furan, carbon monoxide (CO),and particulate matter (PM). 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. Boiler MACT is modeled as an upgrade cost in the Macroeconomic Activity Module (MAM). 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 Industrial Demand Module.

California Assembly Bill 32: Emissions cap-and-trade as part of the Global Warming Solutions Act of 2006 (AB32)

AB32 established a comprehensive, multi-year program to reduce Green House Gas (GHG) emissions in California, including a cap-and-trade program. In addition to the cap-and-trade program, AB32 also 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.

For AEO2014, the cap-and-trade provisions were modeled for industrial facilities, refineries, and fuel providers. GHG emissions include both non-CO_2 and specific non-CO_2 GHG emissions. The allowance price, representing the incremental cost of complying with AB32 cap-and-trade, is modeled in the NEMS Electricity Market Module via a region specific emissions constraint. This allowance price, when added to market fuel prices, results in higher effective fuel prices in the demand sectors. Limited banking and borrowing, as well as a price containment reserve and offsets, have been modeled in the NEMS. AB32 is not modeled explicitly in the Industrial Module, but enters the module implicitly through higher effective fuel prices and macroeconomic effects of higher prices, all of which affect energy demand and emissions.

Industrial alternative cases

Technology cases

The Integrated High Demand Technology case inputs assume earlier availability, lower costs, and higher efficiency of more advanced equipment, based on engineering judgments and research compiled by Focis Associates in a 2005 study for EIA [13]. The Integrated High Demand Technology case inputs also assume that the rate at which biomass byproducts will be recovered from industrial processes 0.7 percent per year, as opposed to 0.4 percent per year in the Reference case. The availability of additional biomass leads to an increase in biomass-based cogeneration. Changes in aggregate energy intensity can result both from changing equipment and production efficiency and from changes in the composition of industrial output.

The Integrated 2013 Demand Technology case inputs hold the energy efficiency of industrial plant and equipment constant at the 2014 level over the projection period.

The IDM is used as part of the Low Renewable Technology Cost case. In this case, costs for non-hydropower renewable generating technologies are 20 percent lower than Reference case levels through 2040.

Resource Cases

Two resource cases are used in AEO2014. The Industrial High Resource Case is a combination of High Economic Growth, High Oil & Gas Resource, and Industrial High Technology cases. The Industrial Low Resource Case is a combination of Low Economic Growth and Low Oil & Gas Resource cases. The intent is to examine the impact on industrial output, the mix of production, and energy consumption of changes in the level of oil and natural gas.

In the Industrial High Resource Case, Higher oil and natural gas production drive more rapid growth in industrial output and change in mix of production by industry when compared with the Reference case. The impact of the greater oil and natural gas production are wide-spread and increase the probability of realizing the higher level of economic growth reflected in the High Economic Growth case and of achieving the technological advancements of the High Industrial Technology case.

In the Industrial Low Resource case oil and natural gas production is lower and prices higher than in the Reference Case, resulting in slower growth in industrial output. The lower oil and natural gas production levels result in a slower advance in the U.S. economy when compared with the Reference Case.

Additional Cases

The Low Electricity Demand Case

The Low Electricity Demand case uses the assumptions in the Best Available Technology case for the residential and commercial sectors and increases motor efficiency assumptions in the IDM to produce projections with zero electricity demand growth. This case assumes that all future equipment purchases in the residential and commercial sectors are made from a menu of technologies that includes only the most efficient models available in a particular year, regardless of cost. In the Low Electricity Demand case, industrial sector motor model input values were adjusted to increase the system savings values for pumps, fans and air compressors relative to the Reference case. This adjustment lowers total motor electricity consumption by slightly less than 20%. Although technically plausible, this decrease in motor adjustment is not intended to be a likely representation of motor development.

ESICA case

Senate bill S. 1392, The Energy Savings and Industrial Competitiveness Act of 2013 (ESICA) [14], was introduced in July 2013 containing provisions for building energy codes, industrial energy efficiency, federal agencies and budget offsets. EIA examined two key provisions of the proposed legislation assuming appropriation of the funding authorized in the bill: the adoption of updated building energy codes for residential and commercial buildings, and a rebate program for energy-efficient electric motors. Other provisions require further specification by federal agencies or Congress or address a level of detail beyond that modeled in NEMS. Amendments have been introduced that may have energy impacts, but they are not part of the bill as of this writing and are not considered in this analysis. Of the two analyzed provisions, the updated building codes has a small effect on energy consumption and CO_2 emissions, and the industrial motors rebate program has virtually no effect. The analysis assumes that states will take advantage of incentives offered to implement the updated codes, and that once in place the codes are persistently effective over time.

Notes and sources

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