Industrial Demand Module

The NEMS Industrial Demand Module estimates energy consumption by energy source (fuels and feedstocks) for 15 manufacturing and 6 non-manufacturing industries. The manufacturing industries are further subdivided into the energy-intensive manufacturing industries and nonenergy-intensive manufacturing industries (Table 6.1). The manufacturing industries are modeled through the use of a detailed process-flow or end-use accounting procedure, whereas the non-manufacturing industries are modeled with substantially less detail. The petroleum refining industry is not included in the Industrial Module, as it is simulated separately in the Petroleum Market Module of NEMS. The Industrial Module calculates energy consumption for the four Census Regions (see Figure 5) and disaggregates the energy consumption to the nine Census Divisions based on fixed shares from the State Energy Data System [1].

Table 6.1. Industry categories

Energy-Intensive Manufacturing		Nonenergy-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	(NAICS 3253)	**Other**		Metal and other non-metallic mining	(NAICS 2122-2123)
Glass and glass products	(NAICS 3272)	Wood products	(NAICS 321)		
Cement	(NAICS 32731)	Plastic and rubber products	(NAICS 326)	Construction	(NAICS 233-235)
Iron and steel	(NAICS 3311-3312)	Balance of manufacturing	(all remaining manufacturing NAICS)		
Aluminum	(NAICS 3313)				

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

The energy-intensive industries (food products, paper and allied products, bulk chemicals, glass and glass products, cement, 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 Petroleum Market Module of NEMS, and the projected energy consumption is included 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

The NEMS Industrial Demand Module primarily uses a bottom-up process 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 2006 baseline Unit Energy Consumption (UEC) estimates based on analysis and interpretations of the Manufacturing Energy Consumption Survey (MECS) 2006 conducted by the Energy Information Administration on a four-year survey cycle [2]. The UECs represent the energy required to produce one unit of the industry's output. The output may be defined in terms of physical units (e.g., tons of steel) or in terms of the dollar value of shipments.

The Industrial Module depicts the manufacturing industries (apart from petroleum refining) with a detailed process flow or end use approach. The dominant process technologies are characterized by a combination of unit energy consumption estimates and "technology possibility curves." The technology possibility curve is an exponential growth trend corresponding to a given average annual rate of change, or technology possibility coefficient (TPC). The TPC defines the assumed average annual rate of energy intensity change of a process step or an energy end use (e.g., generic 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 adoption of new process technologies.

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 are more energy efficient than the average efficiency of the existing capital stock. Consequently, the amount of energy required to produce a unit of output using new capital stock is less than that required by the existing capital stock. The old vintage consists of capital existing in 2006 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 2006 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 2035 relative to the 2006 stock). For example, state-of-the-art additions to steel hot rolling capacity in 2006 are assumed to require only 80 percent as much energy as does the average existing plant, so the REI for new capacity in 2006 is 0.80 (see Table 6.3). Over time, the UECs for new capacity are assumed to improve, and the rate of improvement is given by the TPC. The UECs of the surviving 2006 capital stock are also assumed to decrease over time, but not as rapidly as for new capital stock. For example, with hot rolling, the TPC for new facilities is -0.008, while the TPC for existing facilities is -0.007. Table 6.3 provides more examples, including alternative assumptions used to reflect a more optimistic, "high tech" case.

Table 6.2. Retirement rates

Industry	Retirement Rate (percent)	Industry	Retirement Rate (percent)
Food Products	1.7	Glass and Glass Products	1.3
Pulp and Paper	2.3	Cement	1.2
Iron and Steel		Aluminum	
Blast Furnace and Basic Steel Products	1.5	Metal-Based Durables	1.3
Electric Arc Furnace	1.5	Other Non-intensive Manufacturing	1.3
Coke Oven	2.5		
Other Steel	2.9		

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, DOE/EIA-M064(2010), (Washington, DC, 2010).

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 food industry, the five metal-based durables industries, and the three non-intensive manufacturing industries 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 [3]. 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 Bulk chemicals Sub-model. The methodology is described below.

Bulk chemical industry

The need to analyze the impacts of high energy prices on feedstock use and also to track some of the chemical products that are highly dependent on energy resources, such as ammonia and ethylene, requires a separate sub-model for this important energy user. It is important to note that this is only the PA Component of the bulk chemical energy consumption projections; the BSC and BLD components remain the same for this industry.

Table 6.5 shows the list of the chemical products represented in the model. There are 16 organic, 5 inorganic, 5 resins, and 2 agricultural chemicals, plus four aggregate groups (rest of organic, rest of inorganic, rest of resins, and rest of agricultural chemicals).

The choice of chemicals included in the model is driven by several factors, including relative production volumes, energy intensity, production growth, and/or energy and feedstock consumption. The bulk chemical sub-model has several components that are briefly discussed below.

Chemical production component

This component forecasts chemical production for each chemical in Table 6.5. In the bulk chemical industry, there is significant interplay among basic chemicals, intermediate chemicals, and final chemical products. Experts on the relationships among these chemicals helped develop the methodology used to forecast the production levels of each chemical. The equations that forecast chemical production reflect the relationships between the chemicals. In addition, the relationships between the production levels of the chemicals and the dollar values of output (or shipments) from the chemical industry and other industries that use the chemicals, and other drivers such as gross domestic product (GDP), energy prices, and U.S. population were also considered.

Chemical process component

This component forecasts processes for each chemical in Table 6.5. Besides the level of chemical production, a major driver of energy consumption in the bulk chemical industry is the process used to produce a chemical product. Table 6.6 shows the industrial processes used to produce each chemical represented in the model.

The unit energy requirements of steam, electricity, and fuel for each process listed in Table 6.6 are provided for 14 categories of energy services: process water cooling, pumping, compression, motive force, direct clean heat, indirect heat, indirect drying, concentration, distillation, electrolysis, feedstocks, reforming, fuel from feed [4], and byproduct adjustment [5].

Because the choice of processes is not generally driven just by energy prices, the shares of processes used to produce a chemical are usually estimated outside the model. The exceptions are those chemicals and their processes that use significant amounts of energy feedstocks, such as ethylene, propylene and butadiene. These three basic chemicals are sensitive to energy prices, the model captures the feedstock switching response to changing energy prices. There are other chemicals in which only one production process is used (at an industrial-scale). For these chemicals, the process is assigned a 100 percent share.

As indicated above, three chemicals, ethylene, propylene, and butadiene are modeled with more detail than the other chemicals in the model. More detailed descriptions of the representations of process or feedstock requirement choices for these chemicals are discussed below.

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

	Existing Facilities					New Facillities			
Industry/Process Unit	Reference REI2035[1]	High Tech REI 2035[1]	Reference TPC%[2]	High Tech TPC%[2]	REI 2006[3]	Reference REI2035[4]	High Tech REI 2035[4]	Reference TPC%[2]	High Tech TPC%[2]
Food Products									
Process Heating	0.883	0.987	-0.426	-0.045	0.900	0.784	0.876	-0.477	-0.094
Process Heating-Steam	0.780	0.974	-0.853	-0.091	0.900	0.682	0.852	-0.953	-0.188
Process Cooling-Electricity	0.855	0.983	-0.540	-0.057	0.850	0.734	0.826	-0.506	-0.100
Process Cooling-Natural Gas	0.883	0.987	-0.426	-0.045	0.900	0.784	0.876	-0.477	-0.094
Other-Electricity	0.900	0.989	-0.364	-0.039	0.915	0.793	0.890	-0.493	-0.097
Other-Natural Gas	0.883	0.987	-0.426	-0.045	0.900	0.784	0.876	-0.477	-0.094
Paper & Alllied Products									
Wood Preparation	0.792	0.990	-0.802	-0.033	0.882	0.701	0.987	-0.790	-0.386
Waste Pulping-Electricity	0.936	0.954	-0.228	-0.161	0.936	0.936	0.876	0.000	-0.228
Waste Pulping-Steam	0.876	0.954	-0.456	-0.161	0.936	0.936	0.876	0.000	-0.228
Mechanical Pulping-Electricity	0.800	1.006	-0.767	0.021	0.931	0.622	1.205	-1.380	0.893
Mechanical Pulping-Steam	0.639	1.006	-1.533	0.021	0.931	0.413	1.205	-2.760	0.893
Semi-Chemical-Electricity	0.951	0.993	-0.173	-0.025	0.971	0.930	0.956	-0.149	-0.952
Semi-Chemical-Steam	0.904	0.933	-0.346	-0.025	0.971	0.891	0.956	-0.297	-0.052
Kraft, Sulfite, Misc. Chemicals	0.860	0.930	-0.519	-0.249	0.914	0.810	0.790	-0.415	-0.502
Kraft, Sulfite, Misc Chemicals-Steam	0.739	0.930	-1.037	-0.249	0.914	0.718	0.790	-0.830	-0.502
Bleaching-Electricity	0.780	0.929	-0.853	-0.252	0.878	0.680	0.912	-0.878	0.129
Bleaching-Steam	0.607	0.929	-1.706	-0.252	0.878	0.525	0.912	-1.756	0.129
Paper Making	0.869	0.835	-0.485	-0.621	0.885	0.852	0.592	-0.132	-1.376
Paper Making-Steam	0.976	0.835	-0.969	-0.621	0.885	0.820	0.592	-0.264	-1.376
Glass and Glass Products[5]									
Batch Preparation-Electricity	0.941	1.000	-0.209	0.000	0.882	0.882	0.882	0.000	0.000
Melting/Refining	0.934	0.846	-0.235	-0.576	0.900	0.858	0.601	-0.125	-1.381
Melting/Refining-Steam	0.872	0.846	-0.470	-0.576	0.900	0.837	0.601	-0.250	-1.381
Forming	0.984	0.976	-0.056	-0.085	0.982	0.968	0.933	-0.048	-0.175
Forming-Steam	0.968	0.976	-0.111	-0.085	0.982	0.955	0.933	-0.096	-0.175
Post-Forming	0.978	0.990	-0.078	-0.034	0.968	0.955	0.948	-0.045	-0.069
Post-Forming-Steam	0.955	0.990	-0.157	-0.034	0.968	0.943	0.948	-0.090	-0.069
Cement									
Dry Process	0.885	0.870	-0.420	-0.479	0.885	0.770	0.621	-0.479	-1.216
Wet Process[6]	0.944	0.931	-0.197	-0.245	NA	NA	NA	NA	NA
Wet Process-Steam	0.892	0.851	-0.395	-0.554	NA	NA	NA	NA	NA
Finish Griding-Electricity	0.975	0.851	-0.087	-0.554	0.950	0.950	0.660	0.000	-1.248
Iron and Steel									
Coke Oven[6]	0.935	0.883	-0.233	-0.429	0.902	0.869	0.659	-0.128	-1.076
Coke Oven-Steam	0.873	0.883	-0.467	-0.429	0.902	0.837	0.659	-0.257	-1.076
BF/BOF	0.994	0.951	-0.022	-0.172	0.987	0.987	0.885	0.000	-0.375
BF/BOF-Steam	0.987	0.951	-0.045	-0.172	0.987	0.987	0.865	0.000	-0.375
EAF	0.915	0.904	-0.308	-0.346	0.990	0.830	0.781	-0.606	-0.813
Ingot Casting/Primary Rolling[6]	1.000	1.000	0.000	0.000	NA	NA	NA	NA	NA

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

	Existing Facilities					New Facillities			
Industry/Process Unit	Reference REI2035[1]	High Tech REI 2035[1]	Reference TPC%[2]	High Tech TPC%[2]	REI 2006[3]	Reference REI2035[4]	High Tech REI 2035[4]	Reference TPC%[2]	High Tech TPC%[2]
Continuous Casting	1.000	1.000	0.000	0.000	1.000	0.000	1.000	0.000	0.000
Hot Rolling[7]	0.816	0.905	-0.699	-0.344	0.800	0.633	0.602	-0.804	-0.978
Hot Rolling-Steam[7]	0.665	0.905	-1.397	-0.344	0.800	0.500	0.602	-1.608	-0.978
Coal Rolling[7]	0.717	0.948	-1.141	-1.183	0.924	0.433	0.854	-2.580	-0.273
Cold Rolling-Steam[7]	0.512	0.948	-2.281	-1.183	0.924	0.199	0.854	-5.160	-0.273
Aluminum									
Alumina Refining	0.927	0.982	-0.262	-0.063	0.900	0.854	0.865	-0.182	-0.138
Alumnina Refining-Steam	0.859	0.871	-0.524	-0.476	0.900	0.809	0.635	-0.365	-1.198
Primary Smelting	0.890	0.871	-0.401	-0.476	0.950	0.780	0.670	-0.678	-1.198
Primary Smelting-Steam	0.792	0.871	-0.802	-0.476	0.950	0.640	0.670	-1.355	-1.198
Secondary	0.868	0.933	-0.487	-0.238	0.850	0.736	0.716	-0.495	-0.590
Semi-fabrication, Steel	0.893	0.807	-0.389	-0.735	0.900	0.736	0.512	-0.466	-1.927
Semi-Fabrication, Other	0.918	0.874	0.295	0.465	0.950	0.836	0.688	-0.440	-1.109
Metal-Based Durables									
Fabricated Metals									
Process Heating	0.689	0.651	-1.427	-1.468	0.675	0.400	0.337	-1.784	-2.370
Process Cooling-Electricity	0.720	0.587	-1.127	-1.820	0.638	0.365	0.307	-1.903	-2.493
Process Cooling-Natural Gas	0.720	0.651	-1.127	-1.468	0.675	0.413	0.337	-1.679	-2.370
Other	0.720	0.651	-1.127	-1.468	0.675	0.413	0.337	-1.679	-2.370
Other-Electricity	0.720	0.689	-1.127	-1.274	0.686	0.401	0.335	-1.834	-2.439
Machinery									
Process Heating	0.659	0.651	-1.427	-1.468	0.675	0.307	0.236	-2.676	-3.555
Process Cooling-Electricity	0.720	0.587	-1.127	-1.820	0.638	0.275	0.211	-2.855	-3.740
Process Cooling-Natural Gas	0.720	0.651	-1.127	-1.468	0.675	0.322	0.236	-2.519	-3.555
Other	0.720	0.651	-1.127	-1.468	0.675	0.322	0.236	-2.519	-3.555
Other-Electricity	0.720	0.689	-1.127	-1.274	0.686	0.306	0.233	-2.751	-3.658
Computers and Electronics									
Process Heating	0.758	0.752	-0.952	-0.979	0.720	0.555	0.510	-0.892	-1.185
Process Cooling-Electricity	0.804	0.702	-0.751	-1.213	0.680	0.515	0.473	-0.952	-1.247
Process Cooling-Natural Gas	0.804	0.752	-0.751	-0.979	0.720	0.564	0.510	-0.840	-1.185
Other	0.804	0.752	-0.751	-0.979	0.720	0.564	0.510	-0.840	-1.185
Other-Electricity	0.804	0.781	-0.751	-0.850	0.732	0.560	0.513	-0.917	-1.219
Electrical Equipment									
Process Heating	0.758	0.752	-0.952	0.979	0.720	0.555	0.510	-0.892	-1.185
Process Heating-Steam	NA	NA	-1.502	-1.957	NA	NA	NA	-1.679	-2.370
Process Cooling-Electricity	0.804	0.7092	-0.751	-1.213	0.680	0.515	0.473	-0.892	-1.247
Process Cooling-Natural Gas	0.804	0.752	-0.751	-0.979	0.720	0.564	0.510	-0.840	-1.185
Other	0.804	0.752	-0.751	-0.979	0.720	0.564	0.510	-0.840	-1.185
Other-Electricity	0.804	0.781	-0.751	-0.850	0.732	0.560	0.513	-0.917	-1.219

Table 6.3. Coefficients for Technology Possibility Curve for all Industrial Scenarios (cont)

applies to all fuels unless specified

	Existing Facilities					New Facillities			
Industry/Process Unit	Reference REI2035[1]	High Tech REI 2035[1]	Reference TPC%[2]	High Tech TPC%[2]	REI 2006[3]	Reference REI2035[4]	High Tech REI 2035[4]	Reference TPC%[2]	High Tech TPC%[2]
Transportation Equipment									
Processing Heating	0.824	0.819	-0.666	-0.685	0.765	0.622	0.580	-0.714	-0.948
Processing Heating-Steam	0.736	0.670	-1.052	-1.370	0.765	0.517	0.439	-1.343	-1.896
Process Cooling-Electricity	0.858	0.781	-0.526	-0.849	0.723	0.579	0.540	-0.761	-0.997
Process Cooling-Natural Gas	0.858	0.819	-0.526	-0.685	0.765	0.629	0.580	-0.672	-0.948
Other	0.858	0.819	-0.526	-0.685	0.765	0.629	0.580	-0.672	-0.948
Other-Electricity	0.858	0.841	-0.526	-0.595	0.778	0.628	0.585	-0.734	-0.975
Other Non-Intensive Manufacturing									
Wood Products									
Process Heating	0.659	0.654	-1.427	-1.452	0.630	0.374	0.315	-1.784	-2.358
Process Heating-Steam	0.516	0.426	-2.253	-2.903	0.630	0.234	0.155	-3.358	-4.716
Process Cooling-Electricity	0.720	0.590	-1.127	-1.604	0.595	0.341	0.287	-1.903	-2.481
Process Cooling-Natural Gas	0.720	0.654	-1.127	-1.452	0.630	0.386	0.315	-1.679	-2.358
Other	0.720	0.690	-1.127	-1.272	0.630	0.386	0.330	-1.679	-2.209
Other-Electricity	0.722	0.879	-1.115	-0.443	0.641	0.373	0.318	-1.845	-2.388
Plastic Products									
Process Heating	0.758	0.754	-0.952	-0.968	0.675	0.521	0.479	-0.892	-1.179
Process Heating-Steam	0.645	0.567	-1.502	-1.936	0.675	0.413	0.338	-1.679	-2.358
Process Cooling-Electricity	0.804	0.704	-0.751	-1.203	0.638	0.483	0.444	-0.952	-1.241
Process Cooling-Natural Gas	0.804	0.754	-0.751	-0.968	0.675	0.529	0.479	-0.840	-1.179
Other	0.804	0.781	-0.751	-0.848	0.675	0.529	0.489	-0.840	-1.104
Other-Electricity	0.805	0.918	-0.743	-0.295	0.686	0.525	0.484	-0.922	-1.194
Balance of Manufacturing									
Process Heating	0.812	0.810	-0.714	-0.726	0.675	0.548	0.513	-0.714	-0.943
Process Heating-Steam	0.917	0.894	-0.300	-0.387	0.900	0.781	0.737	-0.490	-0.688
Process Cooling-Electricity	0.849	0.769	-0.563	-0.902	0.638	0.511	0.477	-0.761	-0.992
Process Cooling-Natural Gas	NA	NA	-0.563	-0.726	NA	NA	NA	-0.672	-0.943
Other Natural Gas	0.849	0.831	-0.563	-0.636	0.675	0.522	-0.672	-0.672	-0.883

1REI 2035 Existing Facilities = Ratio of 2035 energy intensity to average 2006 energy intensity for existing facilities.
2TPC = annual rate of change between 2006 and 2035.
3REI 2006 New Facilities = For new facilities, the ratio of state-of-the-art energy intensity to average 2006 energy intensity for existing facilities.
4REI 2035 New Facilities = Ratio of 2035 energy intensity for a new state-of-the-art facility to the average 2006 intensity for existing facilities.
5REI's and TPCs apply to virgin and recycled materials.
6No new plants are likely to be built with these technologies.
7Net 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: U.S. Energy Information Administration, Model Documentation Report, Industrial Sector Demand Module of the National Energy Modeling System, DOE/EIA-M064(2010) (Washington, DC, 2010).

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

Industrial Sector Horsepower Range	Base Stock Efficiency (%)	Premium Efficiency (%)	Premium Cost (2002$)
Food			
1-5 hp	86.7	89.2	601
6 - 20 hp	91.2	92.5	1,338
21 - 50 hp	93.0	93.8	2,585
51 - 100 hp	94.0	95.3	6,290
101 - 200 hp	94.6	95.2	11,430
201 - 500 hp	93.6	95.4	29,991
> 500 hp	94.1	96.2	36,176
Metal-Based Durables[1]			
1-5 hp	86.7	89.2	601
6-20 hp	91.3	92.5	1,338
21-50 hp	93.0	93.9	2,585
51-100 hp	94.0	95.3	6,290
101-200 hp	94.6	95.2	11,430
201-500 hp	93.7	95.4	29,991
>500 hp	94.1	96.2	36,176
Other Non-Intensive Manufacturing[2]			
1-5 hp	86.7	89.2	601
6-20 hp	91.3	92.5	1,338
21-50 hp	93.0	93.9	2,585
51-100 hp	94.0	95.3	6,290
101-200 hp	94.6	95.2	11,430
201-500 hp	93.7	95.4	11,430
>500 hp	94.1	96.2	36,176

[1]The Metal-Based Durables group includes five industries that are modeled separately: Fabricated Metal Products; Machinery; Computer and Electronic Products; Electrical Equipment, Appliances, and Components; and Transportation Equipment.
[2]The Other Non-Intensive Manufacturing group includes three sectors that are modeled separately: Wood Products; Plastics and Rubber Products; and Balance of Manufacturing.
Source: U.S. Energy Information Administration, Model Documentation Report, Industrial Sector Demand Module of the National Energy Modeling System, DOE/EIA-M064(2010) (Washington, DC, 2010).
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.

Table 6.5. Chemical products in the bulk chemical industry model

Organic Chemicals	Inorganic Chemicals	Plastic Resins	Agricultural Chemicals
Ethylene	Acetylene	Polyvinyl Chloride	Ammonia
Propylene	Chlorine	Polyethylene	Phosphoric Acid
Butadiene	Oxygen	Polystyrene	Other Agricultural Chemicals
Acetic Acid	Sulfuric Acid	Styrene-Butadiene-Rubber	
Acrylonitrite	Hydrogen	Vinyl Chloride	
Ethylbenzene	Other Inorganic Chemicals	Other Resins	
Ethylene Dichloride			
Ethylene Glycol			
Ethylene Oxide			
Formaldehyde			
Styrene			
Vinyl Acetate			
Ethanol			
On-Purpose Propylene (and byproduct ethylene)			
Other Organic Chemicals			

Ethylene, propylene, and butadiene feedstock requirements component

This component forecasts feedstock requirements for ethylene, propylene, and butadiene products. The primary feedstocks used to produce these chemicals are natural gas liquids (NGLs) (ethane, propane, butane) and petrochemical 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. The main approach used to forecast the shares of ethylene, propylene, and butadiene feedstock requirements is the use of linear regression equations relating the feedstock shares with petroleum naphtha prices and NGL prices [7].

Energy consumption component

This component calculates the energy requirements (machine drive, non-machine drive electricity, direct process heat, feedstocks, steam) for each chemical/chemical group in Table 6.5. Unit energy (steam, fuel, electricity) requirements for each of the 14 energy services listed above are assumed to change as energy prices change. The calculated total steam consumption is passed to the BSC Component.

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 6.7). Energy consumption in the BLD Component for an industry is estimated based on regional employment and output growth for that industry using the 2006 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 6.8) 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 shares for the portion of the steam demand associated with combined heat and power (CHP) is assumed fixed. 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 2006 so that the 2006 fuel shares are produced for the relative prices that prevailed in 2006.

Table 6.6. Chemical products in the bulk chemical industry model

Chemicals	Manufacturing Processes
A. Organic Chemicals	
Ethylene	Prolysis of ethane, propane, gas oil, naphtha, or butane Biomass to ethylene conversion
Propylene	Pyrolysis of ethane, propane, gas oil, naphtha, or butane
Butadiene	Pyrolysis of ethane, propane, gas oil, naphtha, or butane Catalytic dehydrogenation of butane Catalytic dehydrogenation of n-butan
Acetic Acid	N-butane oxidation Methanol carbonylation Biomass Fermentation
Acrylontrile	Ammoxidation of propylene
Ethylbenzene	Alkylation of benzene with ethylene
Ethylene Dichloride	Catalytic oxychlorination of ethylene direct Catalytic chlorination of ethylene
Ethylene Glycol	Hydration of ethylene oxide Biiomass to EG conversion
Ethylene Oxide	Catalytic oxidation of ethylene
Formaldehyde	Catalytic oxidation of methanol (silver) Catalytic oxidation of methanol (mixed) Dehydrogenation of methanol (silver)
Methanol	LP cat of reform natural gas LP synthesis from partial oxidation of resid HP cat conversion of synthesis gas Coal to methanol conversion Biomass to methanol conversion
Styrene	Catalytic dehydrogenation of ethylbenzene Ethylbenzene hydroperoxidation
Vinyl Acetate	Catalytic oxyacetylation of ethylene Acetic acid and acetylene
Ethanol (excludes wet milling)	Dry milling Ethylene hydration
On-Purpose Propylene (and byproduct ethylene)	Generic Process - On purpose Propylene
Other Organic Chemicals	Generic Process - Organic
B. Inorganic Chemicals	
Acetylene	Partial oxidation of methane Crude oil submerged flame
Chlorine	Diaphragm cell Mercury cell Membrane cell
Oxygen	Air liquefaction/Refrigeration
Sulfuric Acid	Contact process
Hydrogen	Steam methane reforming - natural gas Coal gasification Biomass gasification Electrolysis

Table 6.6. Chemical products in the bulk chemical industry model (cont.)

Chemicals	Manufacturing Processes
B. Inorganic Chemicals	
Acetylene	Partial oxidation of methane Crude oil submerged flame
Chlorine	Diaphragm cell Mercury cell Membrane cell
Oxygen	Air liquefaction/Refrigeration
Sulfuric Acid	Contact process
Hydrogen	Steam methane reforming - natural gas Coal gasification Biomass gasification Electrolysis
Other Inorganic Chemicals	Generic Process - Inorganic
C. Plastic Resins	
Polyvinyl Chloride	Suspension process
Polyethylene	Slurry process Solution process Emulsification process
Polystyrene	Mass Polymerization of Styrene
Styrene-Butadiene-Rubber	Emulsification process Solution-polymerized Solid rubber
Vinyl Chloride	Pyrolysis of Ethylene dichloride
Other Plastic Resins	Generic Process - Plastic Resins
D. Agriculture Chemicals	
Ammonia	Catalytic synthesis of methane Partial oxidation of coal Coal gasification Petroleum coke gasification
Phosphoric Acid	Wet process Electric furnace process
Other Agricultural Chemicals	Generic Process - Agricultural chemicals

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 2006 MECS.

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. Capacity additions are then determined by the interaction of CHP investment payback periods (with the time-value of money included) and market penetration rates for investments with those payback periods. Assumed installed costs for the CHP systems are given in Table 6.9.

Table 6.7. 2006 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	1.5	1.7	1.7	1.2	1.0	0.6
	2	8.3	9.1	14.9	5.3	7.0	1.2
	3	6.5	7.1	8.7	6.0	4.6	1.3
	4	3.5	3.9	7.0	4.8	3.3	1.5
Paper & Alllied Products	1	1.6	1.8	2.6	0.0	0.7	1.8
	2	3.7	4.1	2.9	0.0	1.2	1.3
	3	8.7	9.8	9.5	0.0	3.0	4.2
	4	3.9	4.4	2.9	0.0	1.3	1.8
Bulk Chemicals	1	1.0	1.3	1.6	0.0	1.1	1.9
	2	2.9	3.8	4.2	0.0	3.1	4.1
	3	11.1	14.5	11.5	0.0	10.6	6.8
	4	1.1	1.5	1.7	0.0	1.3	2.0
Glass & Glass Products	1	0.4	0.3	3.4	0.0	2.2	2.5
	2	1.2	1.0	5.8	0.0	2.7	2.8
	3	1.1	0.9	6.1	0.0	2.7	2.7
	4	0.3	0.3	3.1	0.0	2.1	2.5
Cement	1	0.2	0.4	0.7	0.0	0.6	0.7
	2	0.5	0.8	0.7	0.0	1.0	1.4
	3	0.7	1.1	0.8	0.0	1.1	2.3
	4	0.5	0.7	0.6	0.0	0.9	1.4
Iron and Steel	1	1.0	0.8	2.6	0.0	0.8	0.7
	2	2.6	2.0	8.8	0.0	1.5	1.9
	3	2.7	2.0	3.6	0.0	1.1	1.2
	4	0.4	0.3	1.3	0.0	0.6	0.7
Aluminum	1	0.4	0.2	0.6	0.0	0.4	0.2
	2	0.5	0.3	1.1	0.0	0.5	0.2
	3	1.9	1.2	2.8	0.0	1.6	0.7
	4	0.3	0.2	0.4	0.0	0.3	0.2
Metal-Based Durables							
Fabricated Metal Products	1	1.8	1.8	4.7	4.0	0.7	0.4
	2	5.9	5.9	18.7	15.9	2.5	2.0
	3	4.7	4.7	11.9	10.0	1.9	2.3
	4	1.8	1.8	2.5	2.1	0.6	0.5
Machinery	1	2.5	1.8	4.7	4.0	0.7	0.4
	2	9.5	5.9	18.7	15.9	2.5	2.0
	3	3.7	4.7	11.9	10.0	1.9	2.3
	4	0.7	1.8	2.5	2.1	0.6	0.5

Table 6.7. 2006 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
Computers & Electronic Products	1	2.0	4.8	4.4	3.9	1.7	0.6
	2	1.7	4.0	4.6	4.0	1.5	0.6
	3	3.1	7.3	4.2	3.6	2.3	0.6
	4	4.3	10.2	7.4	6.5	3.0	0.6
Electrical Equipment	1	3.5	4.5	11.6	0.9	1.3	0.4
	2	15.2	19.9	56.2	4.2	5.8	2.1
	3	8.0	10.4	14.1	1.1	2.6	1.2
	4	2.7	3.5	6.9	0.4	0.9	0.5
Transportation Equipment	1	0.6	0.7	0.7	0.5	0.2	0.3
	2	1.7	2.1	2.4	1.9	0.8	0.5
	3	2.5	3.0	4.8	3.7	1.2	0.6
	4	0.2	0.3	0.5	0.4	0.1	0.3
Other Non-Intensive Manufacturing Wood Products	1	0.5	0.3	0.5	0.9	0.1	0.9
	2	2.1	1.5	3.0	5.8	0.6	4.2
	3	2.3	2.3	1.9	3.7	0.7	5.0
	4	1.4	1.0	1.7	3.3	0.4	4.2
Plastic Products	1	2.0	2.5	4.3	0.0	1.2	1.3
	2	7.0	8.7	9.6	0.0	3.1	1.0
	3	5.9	7.4	11.2	0.0	2.9	1.0
	4	1.1	1.4	0.8	0.0	0.5	0.3
Balance of Manufacturing	1	5.7	8.8	14.9	0.0	2.3	1.9
	2	16.7	25.8	23.1	0.0	6.1	1.3
	3	21.4	33.0	43.7	0.0	8.3	2.1
	4	4.0	6.1	11.1	0.0	1.7	0.9

HVAC = Heating, Ventilation, Air Conditioning
Source: U.S. Energy Information Administration, Model Documentation Report, Industrial Sector Demand Module of the National Energy Modeling System, DOE/EIA-M064(2010) (Washington, DC 2010).

Table 6.8. 2006 Boiler fuel component and logit parameter
trillion Btu

	Region	Alpha	Natural Gas	Coal	Oil	Renewables
Food Products	1	-2.0	19	0	4	1
	2	-2.0	168	109	12	22
	3	-2.0	96	11	12	52
	4	-2.0	76	14	4	4
Paper & Allied Products	1	-2.0	41	40	16	80
	2	-2.0	48	60	12	90
	3	-2.0	159	91	64	998
	4	-2.0	53	13	4	97
Bulk Chemicals	1	-2.0	13	0	56	0
	2	-2.0	97	37	18	0
	3	-2.0	605	31	384	0
	4	-2.0	20	21	6	0
Glass & Glass Products	1	-2.0	2	0	3	10
	2	-2.0	6	0	3	1
	3	-2.0	6	0	3	2
	4	-2.0	1	0	3	1
Cement	1	-2.0	0	0	1	1
	2	-2.0	1	0	1	5
	3	-2.0	0	0	1	3
	4	-2.0	0	0	1	3
Iron & Steel	1	-2.0	4	6	20	0
	2	-2.0	16	1	66	0
	3	-2.0	6	0	7	0
	4	-2.0	1	0	1	0
Aluminum	1	-2.0	2	0	0	0
	2	-2.0	4	0	0	0
	3	-2.0	11	0	0	0
	4	-2.0	1	0	0	0
Metal-Based Durables						
Fabricated Metal Products	1	-2.0	4	0	1	0
	2	-2.0	5	0	1	0
	3	-2.0	4	0	1	0
	4	-2.0	8	0	1	1
Machinery						
	1	-2.0	3	0	1	0
	2	-2.0	12	1	0	1
	3	-2.0	5	0	0	0
	4	-2.0	1	0	0	0
Computers & electronic Products	1	-2.0	4	0	1	0
	2	-2.0	5	0	1	0
	3	-2.0	4	0	1	0
	4	-2.0	8	0	1	1
Electrical Equipment	1	-2.0	6	8	3	7
	2	-2.0	27	-3	1	5
	3	-2.0	7	1	3	4
	4	-2.0	3	0	0	0

Table 6.8. 2006 Boiler fuel component and logit parameter (cont.)
trillion Btu

	Region	Alpha	Natural Gas	Coal	Oil	Renewables
Transportation Equipment	1	-2.0	1	0	0	0
	2	-2.0	2	0	0	0
	3	-2.0	4	0	0	0
	4	-2.0	0	0	0	0
Other Non-Intensive Manufacturing Wood Products	1	-2.0	2	0	0	11
	2	-2.0	12	1	1	40
	3	-2.0	7	0	1	123
	4	-2.0	5	0	2	48
Plastic Products	1	-2.0	10	0	2	0
	2	-2.0	23	0	0	0
	3	-2.0	25	10	6	0
	4	-2.0	2	0	0	0
Balance of Manufacturing	1	-2.0	41	-11	18	1
	2	-2.0	64	51	28	2
	3	-2.0	121	58	31	22
	4	-2.0	31	8	15	0

Alpha: User-specified.
Source: U.S. Energy Information Administration, Model Documentation Report, Industrial Sector Demand Module of the National Energy Modeling System, DOE/EIA-M064(2010) (Washington, DC 2010).

Table 6.9. Cost characteristics of industrial CHP systems

			Installed Cost ($2005 per KWh)[1]	
System	Size Kilowatts (KW)	Reference 2010	Reference 2035	High Tech 2035
Engine	100	1440	576	535
	300	1260	396	354
Gas turbine	3000	1719	1496	1450
	5000	1152	1023	1006
	10000	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, DOE/EIA-M064(2010) (Washington, DC 2010).

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 *AEO2011* 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, 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 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 SO2 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 Environmental Protection Agency (EPA) to regulate industrial SO2 emissions at such time that total industrial SO2 emissions exceed 5.6 million tons per year (42 USC 7651). Since industrial coal use, the main source of SO2 emissions, has been declining, EPA does not anticipate that specific industrial SO2 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.)

Industrial alternative cases

Technology cases

The High Technology case assumes 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 (Tables 6.3 and 6.9) [8]. The High Technology case also assumes that the rate at which biomass byproducts will be recovered from industrial processes increases from 0.4 percent per year to 0.7 percent per year. 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. Since the composition of industrial output remains the same as in the Reference case, delivered energy intensity declines by 1.1 percent annually compared with the Reference case, in which delivered energy intensity is projected to decline 1.0 percent annually.

The 2010 Technology case holds the energy efficiency of plant and equipment constant at the 2010 level over the projection period. Delivered energy intensity for this case declines by 0.7 percent annually. Both technology cases were run with only the Industrial Demand Module rather than as a fully integrated NEMS run, (i.e., the other demand models and the supply models of NEMS were not executed). Consequently, no potential feedback effects from energy market interactions were captured.

AEO2011 also includes an Integrated High Technology case, which combines the High Technology case of the four end-use demand sectors, the electricity Low Fossil Technology Cost case, the Low Nuclear Cost case, and the Low Renewable Technology Cost case.

The Low Renewable Technology Cost case assumes that the rate at which biomass byproducts will be recovered from industrial processes increases to 1.3 percent per year. The availability of additional biomass leads to an increase in biomass-based CHP.

Notes and sources

[1] U.S. Energy Information Administration, State Energy Data System, based on energy consumption by state through 2008, as downloaded in June, 2010, from www.eia.doe.gov/emeu/states/_seds.html.

[2] U. S. Energy Information Administration, Manufacturing Energy Consumption Survey, website www.eia.doe.gov/emeu/mecs/

[3] U.S., Department of Energy(2007). Motor Master+ 4.0 software database; available online: http://www1.eere.energy.gov/industry/bestpractices/software.html#mm.

[4] Fuel from Feed represents the heat (essentially fuel) from the oxidation of excess feedstocks.

[5] Byproduct adjustment represents recoverable byproduct heat.

[6] In NEMS, NGLs are reported as Liquefied Petroleum Gas (LPG).

[7] Proprietary data from Petral Consluting Company of historical feedstocks in the U.S. petrochemical industry was used; feedstock was grouped into "light" (ethane, propane originating from gas processing plants) and "heavy" (gasoil and naphtha from petroleum refineries)

[8] U.S. Energy Information Administration, Industrial Technology and Data Analysis Supporting the NEMS Industrial Model (Focis Associates, October 2005).