Industrial Demand Module

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 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 fewer data are available. The petroleum refining industry is not included in the IDM, because it is simulated separately in the Liquid Fuels Market Module (LFMM) of NEMS. The IDM calculates energy consumption for the four Census Regions (Table 2) and disaggregates regional energy consumption to the nine Census Divisions based on fixed shares from the U.S. Energy Information Administration's (EIA) *State Energy Data System* [1].

Table 1. Industry categories and NAICS codes

Energy-Intensive Manufacturing		**Non-Energy-Intensive Manufacturing**		**Non-Manufacturing**	
Food products	311	*Metal-based durables industries*		Agriculture: Crop production	111
Paper and allied products	322	Fabricated metal products	332	Other agricultural production	112, 113, 115
Bulk chemicals group[2]		Machinery	333	Coal mining	2121
Inorganic	325120-325180	Computer and electronic products	334	Oil and natural gas extraction	211
Organic	325110, 32519	Electrical equipment and appliances	335	Metal and other non-metallic mining	2122-2123
Resins	3252	Transportation equipment	336	Construction	23
Agricultural Chemicals	3253	Wood Products	321		
Glass and glass products	3272, 327993	Plastic and rubber products	326		
Cement and Lime	327310, 327410	Balance of manufacturing	312-316, 323, 3254-3256, 3259, 3271, 327320, 327330, 327390, 327420, 3279, 3314, 3315, 337, 339		
Iron and Steel	331110, 3312, 324199[1]				
Aluminum	3313				

NAICS = North American Industry Classification System (2012).

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

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

Source: Department of Commerce, Census Bureau, North American Industry Classification system 2012 (NAICS) - United States (Washington, DC: August 2011)). https://www.census.gov/cgi-bin/sssd/naics/naicsrch?chart=2012.

Table 2. Census regions, Census divisions, and states

Census Region	Census Divisions	States
1 (East)	1,2	CT, ME, MA, NH, NJ, NY, PA, RI, VT
2 (Midwest)	3, 4	IL, IN, IA, KS, MI, MN, MO, ND, NE, OH, SD, WI
3 (South)	5, 6, 7	AL, AR, DE, DC, FL, GA, KY, LA, MD, MS, NC, OK, SC, TN, TX, VA, WV
4 (West)	8, 9	AZ, AK, CA, CO, HI, ID, MT, NV, NM, OR, UT, WA, WY

Source: U.S. Energy Information Administration Annual Energy Outlook 2016 (Washington, DC: September 15, 2016), Appendix F. http://www.eia.gov/outlooks/archive/aeo16/pdf/f1.pdf

Most industries are 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 PA Component is calculated by production process (process flow) for five industries—paper, glass, cement & lime, iron & steel, and aluminum—and by end use for all other manufacturing industries. The BSC Component satisfies the steam demand from the PA and BLD Components. In some industries, the PA Component produces byproducts that are consumed in the BSC Component. The iron and steel, paper, and aluminum industries determine boiler and CHP use within the PA step.

Petroleum refining (NAICS 32411) is not modeled in the IDM. Refining energy consumption is modeled in detail in the LFMM module of NEMS, and the projected energy consumption is reported in the manufacturing total. In addition, projections of lease and plant fuel, energy used for liquefaction of natural gas, and fuels consumed in cogeneration in the oil and natural gas extraction industry (NAICS 211) are not calculated within the IDM. They are calculated in other modules.

Key assumptions - Manufacturing

The IDM 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 2014 baseline Unit Energy Consumption (UEC) estimates based on analysis and interpretations of the 2014 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.

The IDM depicts the manufacturing industries, except for petroleum refining, with either a detailed process flow or end use approach. Generally, industries with homogeneous products use a process flow approach, and those with heterogeneous products use an end use approach. 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 UEC estimates and Technology Possibility Curves (TPC). The TPC represents the annual rate of change from the base year to the end year of the projection. For end use industries, 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.

Process and/assembly component for end use models

For industries modeled using an end use approach, the process and assembly 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 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 2014 and surviving after adjusting for assumed retirements each year (Table 3). 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 2014 up through the year prior to the current projection year.

Table 3. Annual Retirement rates

Industry	Retirement Rate (percent)	Industry	Retirement Rate (percent)
Food Products	1.7	Wood Products	1.3
Bulk Chemicals	1.7	Plastics and Rubber Products	1.3
Metal-based Durables	1.3	Balance of Manufacturing	1.3

Source: SAIC, IDM Base Year Update with MECS 2006 Data, unpublished data prepared for the Office of Integrated Analysis and Forecasting, U.S. Energy Information Administration, Washington, DC, August 2010.

To simulate technological progress and adoption of more energy-efficient 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 2050 relative to the 2014 stock). Over time, the UECs for new capacity change, and the rate of change is given by the TPC. The UECs of the surviving 2014 capital stock are also assumed to change over time, but not as rapidly as for new capital stock because of retrofitting.

The concepts of REIs and TPCs are a means of embodying assumptions regarding new technology adoption in the manufacturing industry and the associated change in energy consumption without characterizing individual technologies in detail. This approach reflects the assumption that industrial plants will change energy consumption 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 end-use industries. The values for REI and TPC are listed in the Appendix, which starts on page 19.

Electric Motor Stock Model

For calculating energy consumed in the machine drive end use, an end use electric motor stock technology model is used instead of UECs and TPCs. Machine drive electricity consumption in the bulk chemicals industry, the food industry, the five metal-based durables industries; wood, plastics and rubber products industries, and balance of manufacturing is calculated using a motor stock model [3]. The beginning stock of motors is modified over the projection horizon. Motors are added to accommodate growth in shipments for each industry or industry group, as motors are retired and replaced, and as failed motors are rewound. When an old motor fails, 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. Table 4 provides the beginning stock efficiency for seven motor size groups in each of the three industry groups, as well as efficiencies for replacement motors. All replacement motors are assumed to be premium high-efficiency motors because of current efficiency regulations.

Table 4. Cost and performance parameters for industrial motor choice model

Industry/Horsepower Range	Average Efficiency	Replacement Motor Efficiency	Rewind Cost (2002$)	Replacement Cost (2002$)
Food				
1-5 hp	81.3	89.5	230	442
6 - 20 hp	87.1	93.0	427	1047
21 - 50 hp	90.1	94.5	665	1889
51 - 100 hp	92.7	95.4	1258	5398
101 - 200 hp	93.5	96.2	2231	10,400
201 - 500 hp	93.8	96.2	4363	20,942
> 500 hp	93.0	96.2	5726	28,115
Bulk Chemicals				
1-5 hp	82.0	89.5	230	442
6 - 20 hp	87.4	93.0	427	1047
21 - 50 hp	90.4	94.5	665	1889
51 - 100 hp	92.4	95.4	1258	5398
101 - 200 hp	93.5	96.2	2231	10,400
201 - 500 hp	93.3	96.2	4363	20,942
> 500 hp	93.2	96.2	5726	28,115
Metal-Based Durables[a]				
1-5 hp	82.2	89.5	230	442
6-20 hp	87.3	93.0	427	1047
21-50 hp	90.1	94.5	665	1889
51-100 hp	92.4	95.4	1258	5398

Industry/Horsepower Range	Average Efficiency	Replacement Motor Efficiency	Rewind Cost (2002$)	Replacement Cost (2002$)
101-200 hp	93.5	96.2	2231	10,400
201-500 hp	94.5	96.2	4363	20,942
>500 hp	94.4	96.2	5726	28,115
Wood, Plastic & Balance of Manufacturing				
1-5 hp	81.8	89.5	230	442
6-20 hp	86.6	93.0	427	1047
21-50 hp	89.9	94.5	665	1889
51-100 hp	92.1	95.4	1258	5398
101-200 hp	93.2	96.2	2231	10,400
201-500 hp	93.1	96.2	4363	20,942
>500 hp	93.1	96.2	5726	28,115

[a]The metal-based durables group includes five industries that are modeled separately: Fabricated Metals; Machinery; Computers and Electronics; Electrical Equipment; and Transportation Equipment.
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.
Source: U.S. Energy Information Administration, Model Documentation Report, Industrial Sector Demand Module of the National Energy Modeling System (Washington, DC, September 2013).

Petrochemical feedstock requirement

The IDM 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) (e.g., ethane, propane, butane) and petrochemical feedstocks (e.g., gas oil, naphtha) [4]. 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 petroleum-based) baseline intensities, feedstock consumption intensities are derived from the 2014 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: 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 that 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.

Process/assembly component for process flow models

Five energy-intensive manufacturing industries are modeled using a process flow approach instead of an end use approach. Those industries are the paper, glass, cement and lime, iron & steel, and aluminum industries. These modules, completed in AEO2016, use a suite of detailed technology choices for each process flow. Instead of the aggregate energy intensity evolving according to TPCs, the process flow models use technology choice for each process flow. Energy requirements for each technology are obtained from technology estimates (e.g., expenditures, energy coefficients, and utility needs) from the Consolidated Impacts Modeling System (CIMS) database, which is prepared by the Pacific Northwest National Laboratory [5]. Depending on the industry, these data are calibrated using inputs from the U.S. Geological Survey (USGS) of the U.S. Department of the Interior, the Portland Cement Association, and the latest MECS released by EIA [6, 7, and 8].

The process flow models calculate surviving capacity based retirement and needed capacity based on shipments and surviving capacity. The baseline capacity (as of 2014) 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, with a potential maximal life of 30 years. The exact shape of the “S” curve can be obtained by parameters adjusted by the analyst. New capital equipment information (capital and operating costs, energy use, and emissions) was obtained from the CIMS database. Each step of the process flow allows for several technology choices whose fuel type and efficiency are known at the national level, because regional fuel breakouts are fixed using available EIA data.

Pulp and Paper industry

The pulp and paper industry's principal processes involve the conversion of wood fiber to pulp, and then paper and board to consumer products that are generally targeted at the domestic marketplace. The industry produces a full line of paper and board products, as well as dried pulp, which is sold as a commodity product to domestic and international paper and board manufacturers. Below is a summary list of steps and technologies:

1. Wood preparation involves removing the bark and chipping the whole tree into small pieces
2. Pulping is the process by which fibrous cellulose in the wood is removed from the surrounding lignin. Pulping can be conducted with a chemical process or a mechanical process
3. Pulp washing is the process of washing the pulp with water to remove the cooking chemicals and lignin from the fiber
4. Drying, liquor evaporation, effluent treatment, and other miscellaneous steps are part of the pulping process. Prior to heat drying, pulp is sent to a pressing section to squeeze out as much water as possible though mechanical means. The pulp is compressed between two rotating rolls where the extent of water removal is dependent on the design of the machine and its running speed. When the pressed pulp leaves the pressing section, it has about 65% moisture content. There are various techniques for drying, each with a different energy footprint
5. Bleaching is required to produce white paper stock
6. Paperboard, newsprint, coated paper, uncoated paper, and tissue paper are final products. Production of final products requires drying, finishing, and stock prep.

Combined cement and lime industry

For the cement process flow, each step (raw material grinding, kiln, finish grinding) allows for several technology choices whose fuel type and efficiency are known at the national level, because regional fuel breakouts are fixed using available EIA data.

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. Finish grinding: 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 process step evolves over time and depends on the relative cost of equipment, cost of fuel, and fuel efficiency. 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 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 2014 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, affecting energy use.

Lime energy consumption is estimated separately from cement but presented together as the consolidated cement and lime energy consumption. Energy consumption and technology evolution in the lime industry are driven by the same methods implemented for cement, with different, industry-specific equipment choices. Lime shipments are now explicitly provided by the Macroeconomic Activity Module (MAM), rather than estimated as a percentage of the non-metallic minerals industry.

Glass industry

For the glass industry model, each step of the three glass product processes modeled in the IDM (flat glass, pressed and blown glass, and glass containers) allows for several technology choices 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 and finish, and tempering. For pressed and blown glass (NAICS 327212), the process steps include preparation, furnace, form and finish, and fire polish. For glass containers (NAICS 327213), the process steps include preparation, furnaces, and form and finish. For fiberglass (*mineral wool*–NAICS 327993), the process steps include preparation, furnaces, and form and finish. The final category (*glass from glass products*–

NAICS 327215) was not modeled as a process flow with technology choice but instead endowed with fuel-specific UECs, which evolved over time via TPC. 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 that use natural gas. Electric boosting furnace technology is also available. Direct electric (or Joule) heating is available for fiberglass production.

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

Iron and Steel industry

The iron and steel industry includes the following major process steps: coke making, iron making, steel making, steel casting, and steel forming. Steel manufacturing plants can be classified as integrated or non-integrated. The classification is dependent upon the number of the major process steps that are performed in the facility. Integrated plants perform all the process steps, whereas non-integrated plants, in general, perform only the last three steps.

For the IDM, a process flow was developed to separate the process into five steps around which unit energy consumption values were estimated. Below is a summary list of steps and technologies for steel made primarily from raw materials (i.e., primary steel):

1. Coke ovens convert metallurgical coal into coke.

2. Iron is produced in the blast furnace (BF), which is then charged into a basic oxygen furnace (BOF) to produce raw steel.

3. The electric arc furnace (EAF) is used to produce raw steel from an all-scrap (recycled materials) charge, sometimes supplemented with direct-reduced iron or hot-briquetted iron.

4. The raw steel is cast into blooms, billets, or slabs using continuous casting, or more rarely, ingots. Some ingot or cast steel is sold directly (e.g., forging-grade billets).

5. Steel is then hot-rolled into various mill products. Some of these are sold as hot-rolled mill products, while others are further cold rolled to impart surface finish or other desirable properties.

The technology slate in each of these process steps evolves over time and depends on the relative cost of equipment, cost of fuel, and fuel efficiency. The base year technology slate is determined from the latest CIMS database and calibrated for the base year 2014 MECS and USGS physical output for 2014 through 2016.

Aluminum industry

For the aluminum industry model, each step—alumina production, anode production, and electrolysis for primary aluminum production, and melting for secondary production—allows for several technology choices for new capacity 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 widely in their energy demands. Recently, the share of secondary aluminum has increased significantly above its historical share. A number of primary smelters have closed over the past few years and are not expected to reopen. Therefore, based on expert judgment, the share of secondary aluminum is expected to constitute at least 75% of total aluminum output through 2050. Consistent with assumptions in previous years, no new primary aluminum plants are assumed to be built in the United States before 2050, although very limited capacity expansion of existing primary smelters may occur.

Some technologies are available to both processes, 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: a standard melter 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, subject to the constraint that secondary production represents at least 75% of all aluminum production. The base year technology slate is determined from the latest CIMS database and calibrated for the base year 2014 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.

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 the amount provided by steam (Table 5). Energy consumption in the BLD Component for an industry is estimated based on regional employment and output growth for that industry using the 2014 MECS as a basis.

Table 5. Buildings component energy consumption inputs (trillion Btu)

Industry	Census Region	Lighting - Electricity	HVAC - Electricity	HVAC - Natural Gas	HVAC - Steam	Facilities Support total	Onsite transportation total
Food Products							
	1	2	2	3	2	2	1
	2	9	10	15	5	9	2
	3	6	7	9	5	6	3
	4	3	4	9	5	5	3
Paper Products							
	1	1	2	2	0	1	0
	2	3	4	3	0	1	1
	3	7	8	9	0	3	2
	4	2	3	2	0	1	1
Bulk Chemicals							
	1	1	1	1	0	1	1
	2	5	5	8	0	3	2
	3	10	11	23	0	7	4
	4	1	2	1	0	1	1
Glass							
	1	0	1	2	0	0	0
	2	1	1	2	0	0	0
	3	1	1	3	0	0	0
	4	0	0	1	0	0	0

Industry	Census Region	Lighting - Electricity	HVAC - Electricity	HVAC - Natural Gas	HVAC - Steam	Facilities Support total	Onsite transportation total
Cement & Lime							
	1	0	0	0	0	0	0
	2	0	0	0	0	0	1
	3	0	0	0	0	0	1
	4	0	0	0	0	0	1
Iron & Steel							
	1	1	1	2	0	1	0
	2	3	2	9	0	4	2
	3	3	2	3	0	2	1
	4	1	0	0	0	0	0
Aluminum							
	1	1	1	1	0	0	0
	2	2	5	2	0	1	1
	3	3	6	4	0	2	1
	4	1	3	0	0	0	0
Metal-based durables: Fabricated Metals							
	1	2	2	5	1	1	1
	2	7	11	29	7	4	3
	3	4	7	8	2	2	1
	4	2	3	4	1	1	1
Metal-based durables: Machinery							
	1	1	2	4	1	1	0
	2	5	7	20	8	2	1
	3	4	5	7	3	1	1
	4	1	1	1	0	0	0
Metal-based durables: Computers							
	1	2	5	3	2	1	0
	2	1	4	4	3	1	0
	3	2	6	3	2	2	0
	4	5	13	6	5	3	1
Metal-based durables: Transportation Equipment							
	1	1	2	4	0	1	0
	2	9	13	25	2	4	3
	3	7	11	15	1	3	3
	4	2	3	6	0	1	1

Industry	Census Region	Lighting - Electricity	HVAC - Electricity	HVAC - Natural Gas	HVAC - Steam	Facilities Support total	Onsite transportation total
Metal-based durables: Electrical Equipment							
	1	1	1	1	1	0	0
	2	1	2	1	1	1	0
	3	2	3	3	2	1	0
	4	0	1	1	1	0	0
Wood Products							
	1	0	1	1	1	0	2
	2	1	1	1	3	0	2
	3	2	4	3	6	1	5
	4	1	1	1	3	0	2
Plastic Products							
	1	2	2	3	0	0	1
	2	5	6	9	0	2	1
	3	7	8	9	0	2	2
	4	3	3	1	0	1	0
Balance of Manufacturing							
	1	5	9	14	0	2	1
	2	12	19	29	0	5	1
	3	18	30	41	0	8	8
	4	5	8	11	0	2	1

HVAC = Heating, Ventilation, Air Conditioning.

Source: Leidos, IDM Base Year Update with MECS 2014 Data, unpublished data prepared for the Industrial Team, Office of Energy Consumption and Efficiency Analysis, U.S. Energy Information Administration, (Washington, DC, September 2017)

Boiler, steam, and cogeneration component

With the exception of the iron and steel and the pulp and paper industries, 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) to the boiler steam requirements to compute the required energy consumption. The iron and steel and pulp and paper industries have independent BSC and cogeneration-related modeling that is calculated as part of the PA step.

The boiler fuel shares apply only to the fuels that are used in boilers for steam-only applications. 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 fuel shares are a function of fuel prices; the logit parameter is assumed to be -2 for all regions and industries. The equation is calibrated to 2014 so that the 2014 fuel shares are produced for the relative prices that prevailed in 2014.

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 2014 MECS and information from the Council of Industrial Boiler Owners. [8]

Table 6. Boiler steam cogeneration component energy inputs, 2014 (trillion Btu)

Industry	Region	Natural Gas	Coal	Renewables	Petroleum
Food Products					
	1	25	0	0	2
	2	145	69	21	2
	3	87	5	95	3
	4	79	15	8	3
Bulk Chemicals					
	1	19	0	0	8
	2	227	91	0	53
	3	689	61	0	382
	4	24	38	0	11
Glass					
	1	1	0	10	0
	2	1	0	1	0
	3	2	0	1	1
	4	1	0	1	0
Cement & Lime					
	1	0	0	1	0
	2	0	0	2	0
	3	0	0	4	0
	4	0	0	3	0
Metal-based durables: Fabricated Metals					
	1	2	0	0	0
	2	13	0	0	0
	3	3	0	0	0
	4	2	0	0	0
Metal-based durables: Machinery					
	1	2	0	0	0
	2	9	1	1	0
	3	3	0	0	0
	4	0	0	0	0

Industry	Region	Natural Gas	Coal	Renewables	Petroleum
Metal-based durables: Computers					
	1	3	0	0	0
	2	4	0	0	0
	3	3	0	0	0
	4	7	0	0	0
Metal-based durables: Transportation Equipment					
	1	2	0	1	0
	2	13	1	4	1
	3	8	0	3	1
	4	3	0	2	0
Metal-based durables: Electrical Equipment					
	1	1	0	0	0
	2	1	0	0	0
	3	1	0	0	0
	4	0	0	0	0
Wood Products					
	1	1	0	47	0
	2	2	1	16	0
	3	5	0	132	0
	4	3	0	48	0
Plastic Products					
	1	4	1	0	0
	2	18	0	0	0
	3	18	0	0	1
	4	3	0	0	0
Balance of Manufacturing					
	1	34	3	3	11
	2	70	20	3	30
	3	96	15	17	128
	4	25	10	3	5

Source: Leidos, IDM Base Year Update with MECS 2014 Data, unpublished data prepared for the Industrial Team, Office of Energy Consumption and Efficiency Analysis, U.S. Energy Information Administration, (Washington, DC, September 2017)

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 7. Assumed installed costs for the CHP systems are given in Table 8.

Table 7. Regional collaboration coefficients for CHP deployment

Census Region	Collaboration Coefficient
1 (Northeast)	0.48
2 (Midwest)	0.44
3 (South)	0.51
4 (West)	0.57

Source: Calculated from American Council for an Energy-Efficient Economy, "The 2016 State Energy Efficiency Scorecard," (Washington, DC: September 2016) http://aceee.org/research-report/u1606 and Annual Electric Generator report (Form 860) (Washington, DC: October 2016) Energy Information Administration, Office of Energy Statistics, https://www.eia.gov/electricity/data/eia860/.

Table 8. Cost characteristics of industrial CHP systems

System	Capacity Megawatts (MW)	2014 Overall Heat Rate (btu/kWh)	2014 Installed Cost (2015$/kW)	2050 Overall Heat Rate (btu/kWh)	2050 Installed Cost (2015$/kW)
Reciprocating Engine	1	9,509	$1,884	9,447	$1,285
	3	8,126	$1,716	7,675	$1,178
Gas turbine	5	12,929	$1,611	11,834	$1,006
	10	12,082	$1,308	11,225	$852
	25	10,341	$1,038	9,503	$662
	40	9,433	$887	8,678	$545
Combined cycle	103	8,528	$1,515	7,789	$1,032

Source: Leidos, *Review of Distributed Generation and Combined Heat and Power Technology Performance and Cost Estimates and Analytic Assumptions for the National Energy Modeling System* (Washington, DC: May 2016)

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 natural gas extraction, almost all of the energy use in the non-manufacturing sector takes place in the process and assembly step. Oil and natural gas extraction uses a significant amount of residual fuel oil in the BSC component.

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.

Non-manufacturing data were revised using EIA and Census Bureau sources to provide more realistic projections of diesel and gasoline for off-road vehicle use, allocate natural gas, HGL use, and electricity. Sources used are EIA's Fuel Oil and Kerosene Sales (FOKS) [9], Agricultural Resource Management Survey (ARMS) [10], and the Census Bureau's Census of Mining [11] and Census of Construction. [12] Non-manufacturing consumption is no longer dictated solely by the difference between the State Energy Data System (SEDS) and MECS difference as it had been in years prior to AEO2014.

Agriculture Sector

U.S. agriculture consists of three major subsectors:

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

These sub-industries have historically been tightly coupled owing 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. Forestry and logging are not modeled within NEMS.

Energy consumption in the agricultural sectors modeled in NEMS—crops and other—are disaggregated into three activities: irrigation, buildings, and vehicles. TPCs for these activities are derived from the Commercial Demand Module and the Transportation Demand Module. TPCs for irrigation depends upon the relative change in energy intensity for ventilation from the CDM. Similarly, TPCs for buildings depend upon a weighted average of the change in intensity for heating, lighting, and building shells from the CDM. TPCs for vehicles change over time depending on the relative intensity change of trucks from the TDM.

Baseline energy consumption data for the two agriculture sectors (crops and other agriculture) are 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 ARMS. These data are converted from dollar expenditures to energy quantities using fuel prices from NASS and EIA.

Mining Sector

The mining sector comprises three industries: coal mining, metal and nonmetal mining, and oil and natural gas extraction. Energy use is based on what equipment and onsite vehicles are used at the mine. 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 the Coal Market Module (CMM). Currently, 70% of the coal is assumed to be mined at the surface, and the rest is mined underground. As these shares evolve, however, so does the energy consumed, because surface mines use less energy overall than underground mines. Moreover, the energy consumed for coal mining depends on coal mine productivity, which is also obtained from the CMM. Diesel fuel and electricity are the predominant fuels used in coal mining. Electricity used for coal grinding is calculated using the raw grinding process step from the cement 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 MAM's variable for *other* mining that also provides the shares of each type of mining.

For oil and natural gas extraction, production is derived from the Oil and Gas Supply Module (OGSM). 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. Oil and natural gas extraction also includes fuel consumed for liquefied natural gas liquefaction.

Construction Sector

The construction sector uses diesel fuel, gasoline, electricity, and HGL as energy sources. Construction also uses asphalt and road oil as a nonfuel energy source. Asphalt and road oil use is tied to state and local government real investment in highways and streets. This investment is derived from the MAM. TPCs for diesel and gasoline fuels are directly tied to the Transportation Demand 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 (EIEA 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% of the installed cost. For systems between 15 and 50 megawatts, the percentage tax credit declines linearly with the capacity, from 10% to 3%. To qualify, systems must exceed 60% fuel efficiency, with a minimum of 20% total energy produced each for useful thermal and electrical energy. The provision was modeled in AEO2018 by adjusting the assumed capital cost of industrial CHP systems to reflect the applicable credit.

The Energy Independence and Security Act of 2007 (EISA2007)

Under EISA2007, the motor efficiency standards established under the Energy Policy Act of 1992 (EPACT1992) 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 National Electrical Manufacturers Association (NEMA) design "B" motors (201-500 horsepower) that were not previously covered by EPACT standards. In 2013, the Energy Policy and Conservation Act was amended (Public Law 113-67), and efficiency standards were revised in a subsequent DOE rulemaking (10 CFR 431.25). For motors manufactured after June 1, 2016, efficiency standards for current regulated motor types [13] were expanded to include 201500 hp motors. Also, special- and definite-purpose motors of from 1–500 hp and NEMA design "A" motors from 201–500 hp became subject to efficiency standards. The 2014 regulations had been modeled in the

AEO2017 by modifying the specifications for new motors in electric motor technology choice module and were unchanged in AEO2018.

Energy Policy Act of 1992 (EPACT1992)

EPACT1992 contains several implications for the industrial module. These implications concern efficiency standards for boilers, furnaces, and electric motors. The industrial module assumes efficiency of 80% and 82% for natural gas and oil burners, respectively. These efficiencies meet the EPACT1992 standards. EPACT1992 mandates minimum efficiencies for all motors up to 200 hp purchased after 1998. The choices offered in the motor efficiency assumptions are all at least as efficient as the EPACT minimums.

Clean Air Act Amendments of 1990 (CAAA1990)

CAAA1990 contains numerous provisions that affect industrial facilities. Three major categories of such provisions are as follows: process emissions, emissions related to hazardous or toxic substances, and sulfur dioxide (SO2) emissions. Process emissions requirements were specified for several industries and activities (40 CFR 60). Similarly, 40 CFR 63 requires limitations on emissions of almost 200 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 CAAA1990 requires the U.S. 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). Because industrial coal use, the main source of SO2 emissions, has been declining, EPA does not anticipate that specific industrial SO2 regulations will be required (Environmental Protection Agency, National Air Pollutant Emission Trends: 19901998, 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 from 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 AEO2018. Pollutants covered by Boiler MACT include the hazardous air pollutants (HAP): hydrogen chloride (HCl), 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 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 IDM.

California Assembly Bill 32: Emissions cap-and-trade as part of the Global Warming Solutions Act of 2006 (AB32) as amended by California Senate Bill 32, 2016 (SB32)

AB32 established a comprehensive, multi-year program to reduce greenhouse gas (GHG) emissions in California, including a cap-and-trade program [14]. 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, industry; combined heat and power goals; and renewable portfolio standards.

For AEO2018, the cap-and-trade provisions were modeled for industrial facilities, refineries, and fuel providers. GHG emissions include both non-CO2 and specific non-CO2 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 of allowances, as well as a price containment reserve and offsets, have been modeled in NEMS. AB32 is not modeled explicitly in the IDM, but enters the module implicitly through higher effective fuel prices and macroeconomic effects of higher prices, all of which affect energy demand and emissions primarily in Region 9, the Pacific Census region.

In September 2016, SB32 was enacted requiring California regulators to plan for a 40% reduction in GHG below 1990 levels by 2030 [15]. Emissions goals in the cap-and-trade program for AEO2018 are modeled assuming a ceiling on CO2 allowance prices to prevent infeasible solutions or extremely high allowance prices. The AEO2018 projections generally have a shortfall in SB32 compliance starting around 2030 where emissions exceed the declining cap. Further cost-effective emissions reductions are not available and, consequently, the allowance price is at the price ceiling. This price ceiling is set by assumption at just above the price of the Tier 3 Allowance Price Containment Reserve.

The cap-and-trade program is only one part of California’s GHG reduction strategy. According to the California Air Resources Board, the cap-and-trade program is assumed to compose less than 30% of total GHG emissions reductions targets [16]. Emissions reductions targeted by the other GHG reduction programs described above affect the industrial sector only indirectly.

Appendix Tables

The tables in this appendix are used to calculate Unit Energy Consumption (UEC) for the end use manufacturing industries: food, bulk chemicals, metal-based durables, and other manufacturing industries. There are four tables per region. The number on the table corresponds to the region. For example, Table A-1a corresponds to the food industry in Census Region 1. The small letter on the table corresponds to the industry. As another example, Table A-3c corresponds to the metal based durables industry in Census Region 3.

Below are the definitions of the items in the table:

- Existing Facility Reference REI 2050 is the ratio of 2050 energy intensity to 2014 energy intensity for existing facilities in the Reference case.
- New Facility REI 2014 is the ratio of energy intensity for new, state-of-the-art facilities to average 2014 energy intensity for existing facilities in the Reference case.

- New Facility Reference TPC is the ratio of 2050 energy intensity for a new state-of-the-art facility to the average 2014 energy intensity for existing facilities in the Reference case.
- Existing Facility Reference TPC is the annual change in energy intensity for existing facilities in the Reference case. In the table, TPCs are multiplied by 100 for easier readability. For example, a TPC of -0.500 in the table corresponds to a value of -0.005 in the IDM.
- New Facility Reference TPC is the annual change in energy intensity for new facilities in the Reference case. In the table, the values are multiplied by 100 for easier readability. For example, a TPC of -0.500 in the table corresponds to a value of -0.005 in the IDM.

Data source for all tables: Leidos, IDM Base Year Update with MECS 2014 Data, unpublished data prepared for the Industrial Team, Office of Energy Consumption and Efficiency Analysis, U.S. Energy Information Administration, (Washington, DC, September 2017).

Table A-1a. Relative Energy Intensities (REI) and Technology Possibility Curves (TPC) for Food Industry—Region 1

Industry, End Use & Fuel	Existing Facility Reference REI 2050	Existing Facility Reference TPC (x100)	New Facility REI 2014	New Facility Reference REI 2050	New Facility Reference TPC (x100)
Milling					
Process Heating-Electricity	0.882	-0.351	0.901	0.782	-0.392
Process Heating-Natural Gas	0.881	-0.351	0.900	0.781	-0.392
Process Heating-Steam	0.776	-0.701	0.900	0.678	-0.784
Process Cooling-Electricity	0.881	-0.351	0.900	0.781	-0.392
Process Cooling-Natural Gas	0.881	-0.351	0.900	0.781	-0.392
Machine Drive-Electricity	0.881	-0.351	0.900	0.781	-0.392
Machine Drive-Natural Gas	0.881	-0.351	0.900	0.781	-0.392
Other-Electricity	0.882	-0.351	0.901	0.782	-0.392
Other-Natural Gas	0.940	-0.171	0.950	0.831	-0.370
Dairy					
Process Heating-Electricity	0.977	-0.067	0.970	0.946	-0.069
Process Heating-Natural Gas	0.940	-0.171	0.950	0.890	-0.180
Process Heating-Steam	0.917	-0.242	0.950	0.831	-0.370
Process Cooling-Electricity	0.881	-0.351	0.900	0.781	-0.392
Process Cooling-Natural Gas	0.976	-0.067	0.970	0.946	-0.069
Machine Drive-Electricity	0.905	-0.278	0.960	0.818	-0.444
Machine Drive-Natural Gas	0.976	-0.067	0.970	0.946	-0.069
Other-Electricity	0.916	-0.242	0.960	0.829	-0.405
Other-Natural Gas	0.976	-0.067	0.970	0.946	-0.069

Industry, End Use & Fuel	Existing Facility Reference REI 2050	Existing Facility Reference TPC (x100)	New Facility REI 2014	New Facility Reference REI 2050	New Facility Reference TPC (x100)
Animal Processing					
Process Heating-Electricity	0.976	-0.067	0.970	0.946	-0.069
Process Heating-Natural Gas	0.940	-0.171	0.950	0.890	-0.180
Process Heating-Steam	0.940	-0.171	0.950	0.890	-0.180
Process Cooling-Electricity	0.917	-0.242	0.950	0.831	-0.370
Process Cooling-Natural Gas	0.977	-0.067	0.971	0.947	-0.069
Machine Drive-Electricity	0.940	-0.171	0.980	0.885	-0.283
Machine Drive-Natural Gas	0.977	-0.067	0.971	0.948	-0.069
Other-Electricity	0.940	-0.171	0.980	0.885	-0.283
Other-Natural Gas	0.976	-0.067	0.970	0.946	-0.069

Industry, End Use & Fuel	Existing Facility Reference REI 2050	Existing Facility Reference TPC (x100)	New Facility REI 2014	New Facility Reference REI 2050	New Facility Reference TPC (x100)
Other Food					
Process Heating-Electricity	0.976	-0.067	0.970	0.946	-0.069
Process Heating-Natural Gas	0.940	-0.171	0.950	0.890	-0.180
Process Heating-Coal	0.939	-0.171	0.946	0.892	-0.180
Process Heating-Steam	0.917	-0.242	0.950	0.831	-0.370
Process Cooling-Electricity	0.917	-0.242	0.950	0.831	-0.370
Machine Drive-Electricity	0.940	-0.171	0.960	0.888	-0.215
Machine Drive-Natural Gas	0.975	-0.067	0.970	0.945	-0.069
Other-Electricity	0.940	-0.171	0.959	0.887	-0.215
Other-Natural Gas	0.975	-0.067	0.970	0.945	-0.069

Table A-1b. Relative Energy Intensities (REI) and Technology Possibility Curves (TPC) for the Bulk Chemicals Industry—Region 1

Industry, End Use & Fuel	Existing Facility Reference REI 2050	Existing Facility Reference TPC (x100)	New Facility REI 2014	New Facility Reference REI 2050	New Facility Reference TPC (x100)
Inorganic Chemicals					
Process Heating-Electricity	0.873	-0.376	0.900	0.774	-0.420
Process Heating-Natural Gas	0.873	-0.376	0.900	0.774	-0.420
Process Heating-Steam	0.762	-0.751	0.900	0.664	-0.840
Process Cooling-Electricity	0.842	-0.476	0.850	0.724	-0.446
Process Cooling-Natural Gas	0.875	-0.376	0.901	0.773	-0.420
Machine Drive-Electricity	0.873	-0.376	0.960	0.809	-0.476
Machine Drive-Natural Gas	0.873	-0.376	0.900	0.774	-0.420
Electro-Chemical Process-Electricity	0.974	-0.072	0.950	0.823	-0.396
Other-Electricity	0.891	-0.321	0.915	0.782	-0.434
Other-Natural Gas	0.873	-0.376	0.899	0.773	-0.420

Industry, End Use & Fuel	Existing Facility Reference REI 2050	Existing Facility Reference TPC (x100)	New Facility REI 2014	New Facility Reference REI 2050	New Facility Reference TPC (x100)
Organic Chemicals					
Process Heating-Electricity	0.873	-0.376	0.900	0.774	-0.420
Process Heating-Natural Gas	0.762	-0.751	0.720	0.532	-0.840
Process Heating-Steam	0.580	-1.502	0.720	0.391	-1.679
Process Cooling-Electricity	0.842	-0.476	0.850	0.724	-0.446
Process Cooling-Natural Gas	0.762	-0.751	0.720	0.532	-0.840
Machine Drive-Electricity	0.873	-0.376	0.960	0.809	-0.476
Machine Drive-Natural Gas	0.873	-0.376	0.900	0.774	-0.420
Electro-Chemical Process-Electricity	0.974	-0.072	0.950	0.823	-0.396
Other-Electricity	0.891	-0.321	0.916	0.782	-0.434
Other-Natural Gas	0.762	-0.751	0.720	0.532	-0.840
Resins/Synthetic Rubber					
Process Heating-Electricity	0.873	-0.376	0.900	0.774	-0.420
Process Heating-Natural Gas	0.762	-0.751	0.720	0.532	-0.840
Process Heating-Steam	0.580	-1.502	0.720	0.391	-1.679
Process Cooling-Electricity	0.842	-0.476	0.850	0.724	-0.446
Process Cooling-Natural Gas	0.762	-0.751	0.720	0.532	-0.840
Machine Drive-Electricity	0.873	-0.376	0.960	0.809	-0.476
Machine Drive-Natural Gas	0.873	-0.376	0.900	0.773	-0.420
Electro-Chemical Process-Electricity	0.974	-0.072	0.950	0.823	-0.396
Other-Electricity	0.891	-0.321	0.915	0.783	-0.434
Other-Natural Gas	0.762	-0.751	0.720	0.532	-0.840

Industry, End Use & Fuel	Existing Facility Reference REI 2050	Existing Facility Reference TPC (x100)	New Facility REI 2014	New Facility Reference REI 2050	New Facility Reference TPC (x100)
Agricultural Chemicals					
Process Heating-Electricity	0.873	-0.376	0.900	0.774	-0.420
Process Heating-Natural Gas	0.873	-0.376	0.900	0.774	-0.420
Process Heating-Steam	0.762	-0.751	0.900	0.664	-0.840
Process Cooling-Electricity	0.842	-0.476	0.850	0.723	-0.446
Process Cooling-Natural Gas	0.872	-0.376	0.897	0.769	-0.420
Machine Drive-Electricity	0.873	-0.376	0.960	0.809	-0.476
Machine Drive-Natural Gas	0.876	-0.376	0.901	0.773	-0.420
Other-Natural Gas	0.873	-0.376	0.900	0.773	-0.420

Table A-1c. Relative Energy Intensities (REI) and Technology Possibility Curves (TPC) for Metal Based Durables Industries—Region 1

Industry, End Use & Fuel	Existing Facility Reference REI 2050	Existing Facility Reference TPC (x100)	New Facility REI 2014	New Facility Reference REI 2050	New Facility Reference TPC (x100)
Fabricated Metals					
Process Heating-Electricity	0.665	-1.127	0.675	0.367	-1.679
Process Heating-Natural Gas	0.665	-1.127	0.675	0.367	-1.679
Process Cooling-Electricity	0.595	-1.427	0.637	0.333	-1.784
Process Cooling-Natural Gas	0.664	-1.127	0.675	0.367	-1.679
Machine Drive-Electricity	0.665	-1.127	0.720	0.361	-1.903
Machine Drive-Natural Gas	0.664	-1.127	0.675	0.367	-1.679
Electro-Chemical Process-Electricity	0.925	-0.216	0.713	0.401	-1.586
Other-Electricity	0.706	-0.962	0.686	0.365	-1.737
Other-Natural Gas	0.664	-1.127	0.675	0.367	-1.679

Industry, End Use & Fuel	Existing Facility Reference REI 2050	Existing Facility Reference TPC (x100)	New Facility REI 2014	New Facility Reference REI 2050	New Facility Reference TPC (x100)
Machinery					
Process Heating-Electricity	0.665	-1.127	0.675	0.270	-2.519
Process Heating-Natural Gas	0.665	-1.127	0.675	0.269	-2.519
Process Cooling-Electricity	0.596	-1.427	0.637	0.240	-2.676
Process Cooling-Natural Gas	0.665	-1.127	0.675	0.270	-2.519
Machine Drive-Electricity	0.665	-1.127	0.720	0.254	-2.855
Machine Drive-Natural Gas	0.665	-1.127	0.675	0.270	-2.519
Electro-Chemical Process-Electricity	0.925	-0.216	0.713	0.299	-2.379
Other-Electricity	0.706	-0.962	0.685	0.264	-2.606
Other-Natural Gas	0.666	-1.127	0.676	0.269	-2.519
Computers & Electronics					
Process Heating-Electricity	0.762	-0.751	0.720	0.532	-0.840
Process Heating-Natural Gas	0.762	-0.751	0.720	0.532	-0.840
Process Cooling-Electricity	0.709	-0.952	0.680	0.492	-0.892
Machine Drive-Electricity	0.762	-0.751	0.768	0.544	-0.952
Electro-Chemical Process-Electricity	0.950	-0.144	0.761	0.571	-0.793
Other-Electricity	0.794	-0.641	0.732	0.535	-0.869
Other-Natural Gas	0.762	-0.751	0.720	0.531	-0.840
Transportation Equipment					
Process Heating-Electricity	0.827	-0.526	0.765	0.600	-0.672
Process Heating-Natural Gas	0.827	-0.526	0.765	0.600	-0.672
Process Heating-Steam	0.684	-1.052	0.765	0.470	-1.343
Process Cooling-Electricity	0.786	-0.666	0.723	0.559	-0.714
Process Cooling-Natural Gas	0.829	-0.526	0.763	0.602	-0.672
Machine Drive-Electricity	0.827	-0.526	0.816	0.620	-0.761
Machine Drive-Natural Gas	0.829	-0.526	0.765	0.599	-0.672
Electro-Chemical Process-Electricity	0.960	-0.101	0.808	0.646	-0.634
Other-Electricity	0.851	-0.449	0.779	0.606	-0.695
Other-Natural Gas	0.827	-0.526	0.765	0.600	-0.672

Industry, End Use & Fuel	Existing Facility Reference REI 2050	Existing Facility Reference TPC (x100)	New Facility REI 2014	New Facility Reference REI 2050	New Facility Reference TPC (x100)
Electrical Equipment					
Process Heating-Electricity	0.762	-0.751	0.720	0.532	-0.840
Process Heating-Natural Gas	0.762	-0.751	0.720	0.532	-0.840
Process Cooling-Electricity	0.709	-0.952	0.680	0.492	-0.892
Process Cooling-Natural Gas	0.762	-0.751	0.720	0.531	-0.840
Machine Drive-Electricity	0.762	-0.751	0.768	0.544	-0.952
Machine Drive-Natural Gas	0.762	-0.751	0.720	0.531	-0.840
Electro-Chemical Process-Electricity	0.949	-0.144	0.760	0.571	-0.793
Other-Electricity	0.793	-0.641	0.732	0.535	-0.869
Other-Natural Gas	0.762	-0.751	0.720	0.531	-0.840

Table A-1d. Relative Energy Intensities (REI) and Technology Possibility Curves (TPC) for other Manufacturing Industries—Region 1

Industry, End Use & Fuel	Existing Facility Reference REI 2050	Existing Facility Reference TPC (x100)	New Facility REI 2014	New Facility Reference REI 2050	New Facility Reference TPC (x100)
Wood Products					
Process Heating-Electricity	0.665	-1.127	0.630	0.343	-1.679
Process Heating-Natural Gas	0.665	-1.127	0.630	0.342	-1.679
Process Heating-Coal	0.665	-1.127	0.630	0.343	-1.679
Process Heating-Steam	0.440	-2.253	0.630	0.184	-3.358
Process Cooling-Electricity	0.596	-1.427	0.595	0.311	-1.784
Process Cooling-Natural Gas	0.665	-1.127	0.630	0.342	-1.679
Machine Drive-Electricity	0.665	-1.127	0.672	0.336	-1.903
Machine Drive-Natural Gas	0.665	-1.127	0.630	0.342	-1.679
Other-Electricity	0.706	-0.962	0.640	0.340	-1.737
Other-Natural Gas	0.665	-1.127	0.630	0.342	-1.679

Industry, End Use & Fuel	Existing Facility Reference REI 2050	Existing Facility Reference TPC (x100)	New Facility REI 2014	New Facility Reference REI 2050	New Facility Reference TPC (x100)
Plastic & Rubber Products					
Process Heating-Electricity	0.762	-0.751	0.675	0.498	-0.840
Process Heating-Natural Gas	0.762	-0.751	0.675	0.498	-0.840
Process Heating-Steam	0.580	-1.502	0.675	0.367	-1.679
Process Cooling-Electricity	0.709	-0.952	0.637	0.462	-0.892
Process Cooling-Natural Gas	0.766	-0.751	0.675	0.500	-0.840
Machine Drive-Electricity	0.762	-0.751	0.720	0.510	-0.952
Machine Drive-Natural Gas	0.761	-0.751	0.673	0.498	-0.840
Electro-Chemical Process-Electricity	0.950	-0.144	0.714	0.536	-0.793
Other-Electricity	0.794	-0.641	0.688	0.502	-0.869
Other-Natural Gas	0.766	-0.751	0.675	0.500	-0.840
Balance of Manufacturing					
Process Heating-Electricity	0.816	-0.563	0.675	0.530	-0.672
Process Heating-Natural Gas	0.816	-0.563	0.675	0.530	-0.672
Process Heating-Coal	0.816	-0.563	0.675	0.530	-0.672
Process Heating-Steam	0.665	-1.127	0.675	0.415	-1.343
Process Cooling-Electricity	0.773	-0.714	0.638	0.493	-0.714
Machine Drive-Electricity	0.816	-0.563	0.720	0.547	-0.761
Electro-Chemical Process-Electricity	0.963	-0.108	0.712	0.567	-0.634
Other-Electricity	0.842	-0.481	0.686	0.534	-0.695

Table A-2a. Relative Energy Intensities (REI) and Technology Possibility Curves (TPC) for the Food Industry—Region 2

Industry, End Use & Fuel	Existing Facility Reference REI 2050	Existing Facility Reference TPC (x100)	New Facility REI 2014	New Facility Reference REI 2050	New Facility Reference TPC (x100)
Milling					
Process Heating-Electricity	0.881	-0.351	0.900	0.781	-0.392
Process Heating-Natural Gas	0.881	-0.351	0.900	0.781	-0.392
Process Heating-Coal	0.881	-0.351	0.900	0.781	-0.392
Process Heating-Steam	0.776	-0.701	0.900	0.678	-0.784
Process Cooling-Electricity	0.881	-0.351	0.900	0.781	-0.392
Process Cooling-Natural Gas	0.881	-0.351	0.900	0.781	-0.392
Machine Drive-Electricity	0.881	-0.351	0.900	0.781	-0.392
Machine Drive-Natural Gas	0.881	-0.351	0.900	0.781	-0.392
Other-Electricity	0.881	-0.351	0.900	0.781	-0.392
Other-Natural Gas	0.940	-0.171	0.950	0.831	-0.370
Dairy					
Process Heating-Electricity	0.976	-0.067	0.970	0.947	-0.069
Process Heating-Natural Gas	0.940	-0.171	0.950	0.890	-0.180
Process Heating-Coal	0.942	-0.171	0.951	0.890	-0.180
Process Heating-Steam	0.917	-0.242	0.950	0.831	-0.370
Process Cooling-Electricity	0.881	-0.351	0.900	0.781	-0.392
Process Cooling-Natural Gas	0.976	-0.067	0.970	0.946	-0.069
Machine Drive-Electricity	0.905	-0.278	0.960	0.818	-0.444
Machine Drive-Natural Gas	0.976	-0.067	0.970	0.947	-0.069
Other-Electricity	0.917	-0.242	0.960	0.829	-0.405
Other-Natural Gas	0.976	-0.067	0.970	0.947	-0.069
Animal Processing					
Process Heating-Electricity	0.976	-0.067	0.970	0.946	-0.069
Process Heating-Natural Gas	0.940	-0.171	0.950	0.890	-0.180
Process Heating-Steam	0.940	-0.171	0.950	0.890	-0.180
Process Cooling-Electricity	0.917	-0.242	0.950	0.831	-0.370
Process Cooling-Natural Gas	0.957	-0.067	0.957	0.957	-0.069
Machine Drive-Electricity	0.940	-0.171	0.980	0.885	-0.283
Machine Drive-Natural Gas	0.976	-0.067	0.969	0.946	-0.069
Other-Electricity	0.940	-0.171	0.980	0.884	-0.283
Other-Natural Gas	0.976	-0.067	0.970	0.946	-0.069

Industry, End Use & Fuel	Existing Facility Reference REI 2050	Existing Facility Reference TPC (x100)	New Facility REI 2014	New Facility Reference REI 2050	New Facility Reference TPC (x100)
Other Food					
Process Heating-Electricity	0.976	-0.067	0.970	0.946	-0.069
Process Heating-Natural Gas	0.940	-0.171	0.950	0.890	-0.180
Process Heating-Coal	0.940	-0.171	0.950	0.890	-0.180
Process Heating-Steam	0.917	-0.242	0.950	0.831	-0.370
Process Cooling-Electricity	0.917	-0.242	0.950	0.831	-0.370
Machine Drive-Electricity	0.940	-0.171	0.960	0.888	-0.215
Machine Drive-Natural Gas	0.975	-0.067	0.968	0.946	-0.069
Other-Electricity	0.940	-0.171	0.959	0.887	-0.215
Other-Natural Gas	0.975	-0.067	0.968	0.946	-0.069

Table A-2b. Relative Energy Intensities (REI) and Technology Possibility Curves (TPC) for the Bulk Chemicals Industry—Region 2

Industry, End Use & Fuel	Existing Facility Reference REI 2050	Existing Facility Reference TPC (x100)	New Facility REI 2014	New Facility Reference REI 2050	New Facility Reference TPC (x100)
Inorganic Chemicals					
Process Heating-Electricity	0.873	-0.376	0.900	0.774	-0.420
Process Heating-Natural Gas	0.873	-0.376	0.900	0.774	-0.420
Process Heating-Steam	0.762	-0.751	0.900	0.664	-0.840
Process Cooling-Electricity	0.842	-0.476	0.850	0.724	-0.446
Process Cooling-Natural Gas	0.873	-0.376	0.900	0.774	-0.420
Machine Drive-Electricity	0.873	-0.376	0.960	0.809	-0.476
Machine Drive-Natural Gas	0.873	-0.376	0.900	0.774	-0.420
Electro-Chemical Process-Electricity	0.974	-0.072	0.950	0.823	-0.396
Other-Electricity	0.891	-0.321	0.915	0.782	-0.434
Other-Natural Gas	0.873	-0.376	0.900	0.774	-0.420

Industry, End Use & Fuel	Existing Facility Reference REI 2050	Existing Facility Reference TPC (x100)	New Facility REI 2014	New Facility Reference REI 2050	New Facility Reference TPC (x100)
Organic Chemicals					
Process Heating-Electricity	0.873	-0.376	0.900	0.774	-0.420
Process Heating-Natural Gas	0.762	-0.751	0.720	0.532	-0.840
Process Heating-Coal	0.873	-0.376	0.900	0.774	-0.420
Process Heating-Steam	0.580	-1.502	0.720	0.391	-1.679
Process Cooling-Electricity	0.842	-0.476	0.850	0.724	-0.446
Process Cooling-Natural Gas	0.762	-0.751	0.720	0.531	-0.840
Machine Drive-Electricity	0.873	-0.376	0.960	0.809	-0.476
Machine Drive-Natural Gas	0.873	-0.376	0.900	0.774	-0.420
Electro-Chemical Process-Electricity	0.974	-0.072	0.950	0.823	-0.396
Other-Electricity	0.891	-0.321	0.915	0.782	-0.434
Other-Natural Gas	0.762	-0.751	0.720	0.532	-0.840
Resins/Synthetic Rubber					
Process Heating-Electricity	0.873	-0.376	0.900	0.773	-0.420
Process Heating-Natural Gas	0.762	-0.751	0.720	0.532	-0.840
Process Heating-Coal	0.873	-0.376	0.900	0.773	-0.420
Process Heating-Steam	0.580	-1.502	0.720	0.391	-1.679
Process Cooling-Electricity	0.842	-0.476	0.850	0.724	-0.446
Process Cooling-Natural Gas	0.762	-0.751	0.720	0.532	-0.840
Machine Drive-Electricity	0.873	-0.376	0.960	0.809	-0.476
Machine Drive-Natural Gas	0.873	-0.376	0.900	0.774	-0.420
Electro-Chemical Process-Electricity	0.974	-0.072	0.950	0.823	-0.396
Other-Electricity	0.891	-0.321	0.915	0.782	-0.434
Other-Natural Gas	0.762	-0.751	0.720	0.532	-0.840
Agricultural Chemicals					
Process Heating-Electricity	0.873	-0.376	0.900	0.773	-0.420
Process Heating-Natural Gas	0.873	-0.376	0.900	0.774	-0.420
Process Heating-Steam	0.762	-0.751	0.900	0.664	-0.840
Process Cooling-Electricity	0.842	-0.476	0.850	0.724	-0.446
Process Cooling-Natural Gas	0.873	-0.376	0.900	0.773	-0.420
Machine Drive-Electricity	0.873	-0.376	0.960	0.809	-0.476
Machine Drive-Natural Gas	0.873	-0.376	0.900	0.774	-0.420
Other-Natural Gas	0.873	-0.376	0.900	0.774	-0.420

Table A-2c. Relative Energy Intensities (REI) and Technology Possibility Curves (TPC) for Metal Based Durables Industries—Region 2

Industry, End Use & Fuel	Existing Facility Reference REI 2050	Existing Facility Reference TPC (x100)	New Facility REI 2014	New Facility Reference REI 2050	New Facility Reference TPC (x100)
Fabricated Metals					
Process Heating-Electricity	0.665	-1.127	0.675	0.367	-1.679
Process Heating-Natural Gas	0.665	-1.127	0.675	0.367	-1.679
Process Cooling-Electricity	0.596	-1.427	0.638	0.334	-1.784
Process Cooling-Natural Gas	0.665	-1.127	0.675	0.367	-1.679
Machine Drive-Electricity	0.665	-1.127	0.720	0.361	-1.903
Machine Drive-Natural Gas	0.665	-1.127	0.675	0.367	-1.679
Electro-Chemical Process-Electricity	0.925	-0.216	0.713	0.401	-1.586
Other-Electricity	0.706	-0.962	0.687	0.365	-1.737
Other-Natural Gas	0.665	-1.127	0.675	0.367	-1.679
Machinery					
Process Heating-Electricity	0.665	-1.127	0.675	0.269	-2.519
Process Heating-Natural Gas	0.665	-1.127	0.675	0.269	-2.519
Process Cooling-Electricity	0.596	-1.427	0.637	0.241	-2.676
Process Cooling-Natural Gas	0.664	-1.127	0.675	0.269	-2.519
Machine Drive-Electricity	0.665	-1.127	0.720	0.254	-2.855
Machine Drive-Natural Gas	0.665	-1.127	0.675	0.269	-2.519
Electro-Chemical Process-Electricity	0.922	-0.216	0.710	0.300	-2.379
Other-Electricity	0.706	-0.962	0.687	0.265	-2.606
Other-Natural Gas	0.665	-1.127	0.675	0.269	-2.519

Industry, End Use & Fuel	Existing Facility Reference REI 2050	Existing Facility Reference TPC (x100)	New Facility REI 2014	New Facility Reference REI 2050	New Facility Reference TPC (x100)
Computers & Electronics					
Process Heating-Electricity	0.762	-0.751	0.720	0.532	-0.840
Process Heating-Natural Gas	0.762	-0.751	0.720	0.532	-0.840
Process Cooling-Electricity	0.709	-0.952	0.680	0.493	-0.892
Machine Drive-Electricity	0.762	-0.751	0.768	0.544	-0.952
Electro-Chemical Process-Electricity	0.949	-0.144	0.760	0.570	-0.793
Other-Electricity	0.793	-0.641	0.732	0.534	-0.869
Other-Natural Gas	0.763	-0.751	0.720	0.531	-0.840
Transportation Equipment					
Process Heating-Electricity	0.827	-0.526	0.765	0.600	-0.672
Process Heating-Natural Gas	0.827	-0.526	0.765	0.600	-0.672
Process Heating-Steam	0.683	-1.052	0.765	0.470	-1.343
Process Cooling-Electricity	0.786	-0.666	0.722	0.558	-0.714
Process Cooling-Natural Gas	0.828	-0.526	0.763	0.602	-0.672
Machine Drive-Electricity	0.827	-0.526	0.816	0.620	-0.761
Machine Drive-Natural Gas	0.825	-0.526	0.766	0.602	-0.672
Electro-Chemical Process-Electricity	0.962	-0.101	0.808	0.644	-0.634
Other-Electricity	0.851	-0.449	0.777	0.605	-0.695
Other-Natural Gas	0.828	-0.526	0.766	0.601	-0.672
Electrical Equipment					
Process Heating-Electricity	0.762	-0.751	0.720	0.532	-0.840
Process Heating-Natural Gas	0.762	-0.751	0.720	0.531	-0.840
Process Cooling-Electricity	0.709	-0.952	0.680	0.492	-0.892
Process Cooling-Natural Gas	0.760	-0.751	0.721	0.531	-0.840
Machine Drive-Electricity	0.762	-0.751	0.768	0.544	-0.952
Machine Drive-Natural Gas	0.760	-0.751	0.721	0.531	-0.840
Electro-Chemical Process-Electricity	0.949	-0.144	0.760	0.571	-0.793
Other-Electricity	0.793	-0.641	0.733	0.534	-0.869
Other-Natural Gas	0.760	-0.751	0.721	0.531	-0.840

Table A-2d. Relative Energy Intensities (REI) and Technology Possibility Curves (TPC) for other Manufacturing Industries—Region 2

Industry, End Use & Fuel	Existing Facility Reference REI 2050	Existing Facility Reference TPC (x100)	New Facility REI 2014	New Facility Reference REI 2050	New Facility Reference TPC (x100)
Wood Products					
Process Heating-Electricity	0.665	-1.127	0.630	0.342	-1.679
Process Heating-Natural Gas	0.665	-1.127	0.630	0.342	-1.679
Process Heating-Coal	0.665	-1.127	0.630	0.343	-1.679
Process Heating-Steam	0.440	-2.253	0.630	0.184	-3.358
Process Cooling-Electricity	0.595	-1.427	0.595	0.311	-1.784
Process Cooling-Natural Gas	0.667	-1.127	0.632	0.344	-1.679
Machine Drive-Electricity	0.665	-1.127	0.672	0.336	-1.903
Machine Drive-Natural Gas	0.665	-1.127	0.630	0.342	-1.679
Other-Electricity	0.706	-0.962	0.640	0.341	-1.737
Other-Natural Gas	0.665	-1.127	0.630	0.342	-1.679
Plastic & Rubber Products					
Process Heating-Electricity	0.762	-0.751	0.675	0.498	-0.840
Process Heating-Natural Gas	0.762	-0.751	0.675	0.498	-0.840
Process Heating-Steam	0.580	-1.502	0.675	0.367	-1.679
Process Cooling-Electricity	0.709	-0.952	0.638	0.462	-0.892
Process Cooling-Natural Gas	0.760	-0.751	0.675	0.497	-0.840
Machine Drive-Electricity	0.762	-0.751	0.720	0.510	-0.952
Machine Drive-Natural Gas	0.763	-0.751	0.676	0.499	-0.840
Electro-Chemical Process-Electricity	0.950	-0.144	0.713	0.535	-0.793
Other-Electricity	0.794	-0.641	0.687	0.502	-0.869
Other-Natural Gas	0.760	-0.751	0.675	0.497	-0.840
Balance of Manufacturing					
Process Heating-Electricity	0.816	-0.563	0.675	0.530	-0.672
Process Heating-Natural Gas	0.816	-0.563	0.675	0.530	-0.672
Process Heating-Coal	0.816	-0.563	0.675	0.530	-0.672
Process Heating-Steam	0.665	-1.127	0.675	0.415	-1.343
Process Cooling-Electricity	0.773	-0.714	0.637	0.493	-0.714
Machine Drive-Electricity	0.816	-0.563	0.720	0.547	-0.761
Electro-Chemical Process-Electricity	0.962	-0.108	0.712	0.567	-0.634
Other-Electricity	0.841	-0.481	0.687	0.535	-0.695

Table A-3a. Relative Energy Intensities (REI) and Technology Possibility Curves (TPC) for Food Industry—Region 3

Industry, End Use & Fuel	Existing Facility Reference REI 2050	Existing Facility Reference TPC (x100)	New Facility REI 2014	New Facility Reference REI 2050	New Facility Reference TPC (x100)
Milling					
Process Heating-Electricity	0.881	-0.351	0.900	0.782	-0.392
Process Heating-Natural Gas	0.881	-0.351	0.900	0.781	-0.392
Process Heating-Coal	0.881	-0.351	0.901	0.782	-0.392
Process Heating-Steam	0.776	-0.701	0.900	0.678	-0.784
Process Cooling-Electricity	0.881	-0.351	0.900	0.781	-0.392
Process Cooling-Natural Gas	0.881	-0.351	0.900	0.781	-0.392
Machine Drive-Electricity	0.881	-0.351	0.900	0.781	-0.392
Machine Drive-Natural Gas	0.881	-0.351	0.900	0.781	-0.392
Other-Electricity	0.881	-0.351	0.900	0.782	-0.392
Other-Natural Gas	0.940	-0.171	0.950	0.831	-0.370
Dairy					
Process Heating-Electricity	0.976	-0.067	0.970	0.946	-0.069
Process Heating-Natural Gas	0.940	-0.171	0.950	0.890	-0.180
Process Heating-Steam	0.917	-0.242	0.950	0.831	-0.370
Process Cooling-Electricity	0.881	-0.351	0.900	0.781	-0.392
Process Cooling-Natural Gas	0.976	-0.067	0.971	0.947	-0.069
Machine Drive-Electricity	0.905	-0.278	0.960	0.818	-0.444
Machine Drive-Natural Gas	0.975	-0.067	0.969	0.945	-0.069
Other-Electricity	0.917	-0.242	0.960	0.830	-0.405
Other-Natural Gas	0.975	-0.067	0.969	0.945	-0.069
Animal Processing					
Process Heating-Electricity	0.976	-0.067	0.970	0.946	-0.069
Process Heating-Natural Gas	0.940	-0.171	0.950	0.890	-0.180
Process Heating-Steam	0.940	-0.171	0.950	0.890	-0.180
Process Cooling-Electricity	0.917	-0.242	0.950	0.831	-0.370
Process Cooling-Natural Gas	0.976	-0.067	0.976	0.951	-0.069
Machine Drive-Electricity	0.940	-0.171	0.980	0.885	-0.283
Machine Drive-Natural Gas	0.976	-0.067	0.970	0.945	-0.069
Other-Electricity	0.940	-0.171	0.980	0.885	-0.283
Other-Natural Gas	0.976	-0.067	0.970	0.946	-0.069

Industry, End Use & Fuel	Existing Facility Reference REI 2050	Existing Facility Reference TPC (x100)	New Facility REI 2014	New Facility Reference REI 2050	New Facility Reference TPC (x100)
Other Food					
Process Heating-Electricity	0.976	-0.067	0.970	0.946	-0.069
Process Heating-Natural Gas	0.940	-0.171	0.950	0.890	-0.180
Process Heating-Steam	0.917	-0.242	0.950	0.831	-0.370
Process Cooling-Electricity	0.917	-0.242	0.950	0.831	-0.370
Machine Drive-Electricity	0.940	-0.171	0.960	0.889	-0.215
Machine Drive-Natural Gas	0.977	-0.067	0.970	0.947	-0.069
Other-Electricity	0.941	-0.171	0.961	0.889	-0.215
Other-Natural Gas	0.977	-0.067	0.970	0.947	-0.069

Table A-3b. Relative Energy Intensities (REI) and Technology Possibility Curves (TPC) for the Bulk Chemicals Industry—Region 3

Industry, End Use & Fuel	Existing Facility Reference REI 2050	Existing Facility Reference TPC (x100)	New Facility REI 2014	New Facility Reference REI 2050	New Facility Reference TPC (x100)
Inorganic Chemicals					
Process Heating-Electricity	0.873	-0.376	0.900	0.774	-0.420
Process Heating-Natural Gas	0.873	-0.376	0.900	0.774	-0.420
Process Heating-Coal	0.873	-0.376	0.900	0.774	-0.420
Process Heating-Steam	0.762	-0.751	0.900	0.664	-0.840
Process Cooling-Electricity	0.842	-0.476	0.850	0.724	-0.446
Process Cooling-Natural Gas	0.873	-0.376	0.900	0.774	-0.420
Machine Drive-Electricity	0.873	-0.376	0.960	0.809	-0.476
Machine Drive-Natural Gas	0.873	-0.376	0.900	0.774	-0.420
Electro-Chemical Process-	0.974	-0.072	0.950	0.823	-0.396
Other-Electricity	0.891	-0.321	0.915	0.782	-0.434
Other-Natural Gas	0.873	-0.376	0.900	0.774	-0.420

Industry, End Use & Fuel	Existing Facility Reference REI 2050	Existing Facility Reference TPC (x100)	New Facility REI 2014	New Facility Reference REI 2050	New Facility Reference TPC (x100)
Organic Chemicals					
Process Heating-Electricity	0.873	-0.376	0.900	0.774	-0.420
Process Heating-Natural Gas	0.762	-0.751	0.720	0.532	-0.840
Process Heating-Coal	0.873	-0.376	0.900	0.773	-0.420
Process Heating-Steam	0.580	-1.502	0.720	0.391	-1.679
Process Cooling-Electricity	0.842	-0.476	0.850	0.724	-0.446
Process Cooling-Natural Gas	0.762	-0.751	0.720	0.532	-0.840
Machine Drive-Electricity	0.873	-0.376	0.960	0.809	-0.476
Machine Drive-Natural Gas	0.873	-0.376	0.900	0.774	-0.420
Electro-Chemical Process-	0.974	-0.072	0.950	0.823	-0.396
Other-Electricity	0.891	-0.321	0.915	0.782	-0.434
Other-Natural Gas	0.762	-0.751	0.720	0.532	-0.840
Resins/Synthetic Rubber					
Process Heating-Electricity	0.873	-0.376	0.900	0.773	-0.420
Process Heating-Natural Gas	0.762	-0.751	0.720	0.532	-0.840
Process Heating-Coal	0.874	-0.376	0.900	0.774	-0.420
Process Heating-Steam	0.580	-1.502	0.720	0.391	-1.679
Process Cooling-Electricity	0.842	-0.476	0.850	0.724	-0.446
Process Cooling-Natural Gas	0.762	-0.751	0.720	0.532	-0.840
Machine Drive-Electricity	0.873	-0.376	0.960	0.809	-0.476
Machine Drive-Natural Gas	0.873	-0.376	0.900	0.774	-0.420
Electro-Chemical Process-	0.974	-0.072	0.950	0.823	-0.396
Other-Electricity	0.891	-0.321	0.915	0.782	-0.434
Other-Natural Gas	0.762	-0.751	0.720	0.532	-0.840

Industry, End Use & Fuel	Existing Facility Reference REI 2050	Existing Facility Reference TPC (x100)	New Facility REI 2014	New Facility Reference REI 2050	New Facility Reference TPC (x100)
Agricultural Chemicals					
Process Heating-Electricity	0.873	-0.376	0.900	0.773	-0.420
Process Heating-Natural Gas	0.873	-0.376	0.900	0.774	-0.420
Process Heating-Steam	0.762	-0.751	0.900	0.664	-0.840
Process Cooling-Electricity	0.842	-0.476	0.850	0.724	-0.446
Process Cooling-Natural Gas	0.873	-0.376	0.900	0.774	-0.420
Machine Drive-Electricity	0.873	-0.376	0.960	0.809	-0.476
Machine Drive-Natural Gas	0.873	-0.376	0.900	0.774	-0.420
Other-Natural Gas	0.873	-0.376	0.900	0.774	-0.420

Table A-3c. Relative Energy Intensities (REI) and Technology Possibility Curves (TPC) for Metal Based Durables Industries—Region 3

Industry, End Use & Fuel	Existing Facility Reference REI 2050	Existing Facility Reference TPC (x100)	New Facility REI 2014	New Facility Reference REI 2050	New Facility Reference TPC (x100)
Fabricated Metals					
Process Heating-Electricity	0.665	-1.127	0.675	0.367	-1.679
Process Heating-Natural Gas	0.665	-1.127	0.675	0.367	-1.679
Process Cooling-Electricity	0.596	-1.427	0.638	0.334	-1.784
Process Cooling-Natural Gas	0.664	-1.127	0.674	0.366	-1.679
Machine Drive-Electricity	0.665	-1.127	0.720	0.361	-1.903
Machine Drive-Natural Gas	0.664	-1.127	0.674	0.366	-1.679
Electro-Chemical Process-Electricity	0.925	-0.216	0.712	0.401	-1.586
Other-Electricity	0.706	-0.962	0.687	0.365	-1.737
Other-Natural Gas	0.664	-1.127	0.674	0.366	-1.679

Industry, End Use & Fuel	Existing Facility Reference REI 2050	Existing Facility Reference TPC (x100)	New Facility REI 2014	New Facility Reference REI 2050	New Facility Reference TPC (x100)
Machinery					
Process Heating-Electricity	0.665	-1.127	0.675	0.269	-2.519
Process Heating-Natural Gas	0.665	-1.127	0.675	0.269	-2.519
Process Cooling-Electricity	0.596	-1.427	0.638	0.241	-2.676
Process Cooling-Natural Gas	0.666	-1.127	0.674	0.270	-2.519
Machine Drive-Electricity	0.665	-1.127	0.720	0.254	-2.855
Machine Drive-Natural Gas	0.666	-1.127	0.675	0.271	-2.519
Electro-Chemical Process-Electricity	0.926	-0.216	0.710	0.297	-2.379
Other-Electricity	0.706	-0.962	0.687	0.266	-2.606
Other-Natural Gas	0.667	-1.127	0.676	0.270	-2.519
Computers & Electronics					
Process Heating-Electricity	0.762	-0.751	0.720	0.532	-0.840
Process Heating-Natural Gas	0.762	-0.751	0.720	0.532	-0.840
Process Cooling-Electricity	0.709	-0.952	0.680	0.493	-0.892
Machine Drive-Electricity	0.762	-0.751	0.768	0.544	-0.952
Electro-Chemical Process-Electricity	0.951	-0.144	0.760	0.570	-0.793
Other-Electricity	0.793	-0.641	0.732	0.535	-0.869
Other-Natural Gas	0.762	-0.751	0.720	0.532	-0.840
Transportation Equipment					
Process Heating-Electricity	0.827	-0.526	0.765	0.600	-0.672
Process Heating-Natural Gas	0.827	-0.526	0.765	0.600	-0.672
Process Heating-Steam	0.683	-1.052	0.765	0.470	-1.343
Process Cooling-Electricity	0.786	-0.666	0.723	0.559	-0.714
Process Cooling-Natural Gas	0.829	-0.526	0.763	0.601	-0.672
Machine Drive-Electricity	0.827	-0.526	0.816	0.620	-0.761
Machine Drive-Natural Gas	0.825	-0.526	0.763	0.599	-0.672
Electro-Chemical Process-Electricity	0.966	-0.101	0.804	0.642	-0.634
Other-Electricity	0.850	-0.449	0.778	0.605	-0.695
Other-Natural Gas	0.827	-0.526	0.766	0.600	-0.672

Industry, End Use & Fuel	Existing Facility Reference REI 2050	Existing Facility Reference TPC (x100)	New Facility REI 2014	New Facility Reference REI 2050	New Facility Reference TPC (x100)
Electrical Equipment					
Process Heating-Electricity	0.762	-0.751	0.720	0.532	-0.840
Process Heating-Natural Gas	0.762	-0.751	0.720	0.532	-0.840
Process Cooling-Electricity	0.709	-0.952	0.680	0.493	-0.892
Process Cooling-Natural Gas	0.761	-0.751	0.718	0.530	-0.840
Machine Drive-Electricity	0.762	-0.751	0.768	0.544	-0.952
Machine Drive-Natural Gas	0.761	-0.751	0.718	0.530	-0.840
Electro-Chemical Process-Electricity	0.950	-0.144	0.760	0.571	-0.793
Other-Electricity	0.793	-0.641	0.732	0.534	-0.869
Other-Natural Gas	0.761	-0.751	0.718	0.530	-0.840

Table A-3d. Relative Energy Intensities (REI) and Technology Possibility Curves (TPC) for other Manufacturing Industries—Region 3

Industry, End Use & Fuel	Existing Facility Reference REI 2050	Existing Facility Reference TPC (x100)	New Facility REI 2014	New Facility Reference REI 2050	New Facility Reference TPC (x100)
Wood Products					
Process Heating-Electricity	0.665	-1.127	0.630	0.342	-1.679
Process Heating-Natural Gas	0.665	-1.127	0.630	0.342	-1.679
Process Heating-Steam	0.440	-2.253	0.630	0.184	-3.358
Process Cooling-Electricity	0.596	-1.427	0.595	0.311	-1.784
Process Cooling-Natural Gas	0.665	-1.127	0.629	0.342	-1.679
Machine Drive-Electricity	0.665	-1.127	0.672	0.336	-1.903
Machine Drive-Natural Gas	0.665	-1.127	0.630	0.342	-1.679
Other-Electricity	0.706	-0.962	0.641	0.341	-1.737
Other-Natural Gas	0.665	-1.127	0.630	0.342	-1.679

Plastic & Rubber Products					
Process Heating-Electricity	0.762	-0.751	0.675	0.498	-0.840
Process Heating-Natural Gas	0.762	-0.751	0.675	0.498	-0.840
Process Heating-Steam	0.580	-1.502	0.675	0.367	-1.679
Process Cooling-Electricity	0.709	-0.952	0.637	0.462	-0.892
Process Cooling-Natural Gas	0.762	-0.751	0.675	0.498	-0.840
Machine Drive-Electricity	0.762	-0.751	0.720	0.510	-0.952
Machine Drive-Natural Gas	0.762	-0.751	0.675	0.498	-0.840
Electro-Chemical Process-Electricity	0.950	-0.144	0.713	0.535	-0.793
Other-Electricity	0.794	-0.641	0.687	0.502	-0.869
Other-Natural Gas	0.762	-0.751	0.675	0.498	-0.840
Balance of Manufacturing					
Process Heating-Electricity	0.816	-0.563	0.675	0.530	-0.672
Process Heating-Natural Gas	0.816	-0.563	0.675	0.530	-0.672
Process Heating-Coal	0.816	-0.563	0.675	0.530	-0.672
Process Heating-Steam	0.665	-1.127	0.675	0.415	-1.343
Process Cooling-Electricity	0.773	-0.714	0.638	0.492	-0.714
Machine Drive-Electricity	0.816	-0.563	0.720	0.547	-0.761
Electro-Chemical Process-Electricity	0.961	-0.108	0.712	0.566	-0.634
Other-Electricity	0.840	-0.481	0.686	0.533	-0.695

Table A-4a. Relative Energy Intensities (REI) and Technology Possibility Curves (TPC) for Food Industry—Region 4

Industry, End Use & Fuel	Existing Facility Reference REI 2050	Existing Facility Reference TPC (x100)	New Facility REI 2014	New Facility Reference REI 2050	New Facility Reference TPC (x100)
Milling					
Process Heating-Electricity	0.882	-0.351	0.900	0.782	-0.392
Process Heating-Natural Gas	0.881	-0.351	0.900	0.781	-0.392
Process Heating-Steam	0.776	-0.701	0.900	0.678	-0.784
Process Cooling-Electricity	0.881	-0.351	0.900	0.781	-0.392
Process Cooling-Natural Gas	0.881	-0.351	0.900	0.781	-0.392
Machine Drive-Electricity	0.881	-0.351	0.900	0.781	-0.392
Machine Drive-Natural Gas	0.882	-0.351	0.900	0.782	-0.392
Other-Electricity	0.882	-0.351	0.900	0.782	-0.392
Other-Natural Gas	0.940	-0.171	0.950	0.831	-0.370

Industry, End Use & Fuel	Existing Facility Reference REI 2050	Existing Facility Reference TPC (x100)	New Facility REI 2014	New Facility Reference REI 2050	New Facility Reference TPC (x100)
Dairy					
Process Heating-Electricity	0.976	-0.067	0.970	0.946	-0.069
Process Heating-Natural Gas	0.940	-0.171	0.950	0.890	-0.180
Process Heating-Steam	0.917	-0.242	0.950	0.831	-0.370
Process Cooling-Electricity	0.881	-0.351	0.900	0.781	-0.392
Process Cooling-Natural Gas	0.976	-0.067	0.970	0.946	-0.069
Machine Drive-Electricity	0.905	-0.278	0.960	0.818	-0.444
Machine Drive-Natural Gas	0.976	-0.067	0.970	0.946	-0.069
Other-Electricity	0.916	-0.242	0.960	0.830	-0.405
Other-Natural Gas	0.976	-0.067	0.970	0.946	-0.069
Animal Processing					
Process Heating-Electricity	0.976	-0.067	0.970	0.946	-0.069
Process Heating-Natural Gas	0.940	-0.171	0.950	0.890	-0.180
Process Heating-Steam	0.940	-0.171	0.950	0.890	-0.180
Process Cooling-Electricity	0.917	-0.242	0.950	0.831	-0.370
Process Cooling-Natural Gas	0.987	-0.067	0.975	0.949	-0.069
Machine Drive-Electricity	0.940	-0.171	0.980	0.885	-0.283
Machine Drive-Natural Gas	0.977	-0.067	0.970	0.946	-0.069
Other-Electricity	0.940	-0.171	0.980	0.885	-0.283
Other-Natural Gas	0.976	-0.067	0.970	0.946	-0.069
Other Food					
Process Heating-Electricity	0.976	-0.067	0.970	0.946	-0.069
Process Heating-Natural Gas	0.940	-0.171	0.950	0.890	-0.180
Process Heating-Coal	0.940	-0.171	0.950	0.890	-0.180
Process Heating-Steam	0.917	-0.242	0.950	0.831	-0.370
Process Cooling-Electricity	0.917	-0.242	0.950	0.831	-0.370
Machine Drive-Electricity	0.940	-0.171	0.960	0.888	-0.215
Machine Drive-Natural Gas	0.977	-0.067	0.970	0.947	-0.069
Other-Electricity	0.940	-0.171	0.961	0.888	-0.215
Other-Natural Gas	0.977	-0.067	0.970	0.947	-0.069

Table A-4b. Relative Energy Intensities (REI) and Technology Possibility Curves (TPC) for the Bulk Chemicals Industry—Region 4

Industry, End Use & Fuel	Existing Facility Reference REI 2050	Existing Facility Reference TPC (x100)	New Facility REI 2014	New Facility Reference REI 2050	New Facility Reference TPC (x100)
Inorganic Chemicals					
Process Heating-Electricity	0.873	-0.376	0.900	0.774	-0.420
Process Heating-Natural Gas	0.873	-0.376	0.900	0.774	-0.420
Process Heating-Coal	0.873	-0.376	0.900	0.774	-0.420
Process Heating-Steam	0.762	-0.751	0.900	0.664	-0.840
Process Cooling-Electricity	0.842	-0.476	0.850	0.724	-0.446
Process Cooling-Natural Gas	0.874	-0.376	0.900	0.774	-0.420
Machine Drive-Electricity	0.873	-0.376	0.960	0.809	-0.476
Machine Drive-Natural Gas	0.873	-0.376	0.900	0.774	-0.420
Electro-Chemical Process-Electricity	0.974	-0.072	0.950	0.823	-0.396
Other-Electricity	0.891	-0.321	0.915	0.782	-0.434
Other-Natural Gas	0.873	-0.376	0.900	0.774	-0.420
Organic Chemicals					
Process Heating-Electricity	0.873	-0.376	0.900	0.774	-0.420
Process Heating-Natural Gas	0.762	-0.751	0.720	0.532	-0.840
Process Heating-Steam	0.580	-1.502	0.720	0.391	-1.679
Process Cooling-Electricity	0.842	-0.476	0.850	0.724	-0.446
Process Cooling-Natural Gas	0.761	-0.751	0.719	0.532	-0.840
Machine Drive-Electricity	0.873	-0.376	0.960	0.825	-0.420
Machine Drive-Natural Gas	0.873	-0.376	0.900	0.773	-0.420
Electro-Chemical Process-Electricity	0.974	-0.072	0.950	0.823	-0.396
Other-Electricity	0.891	-0.321	0.915	0.782	-0.434
Other-Natural Gas	0.762	-0.751	0.720	0.532	-0.840

Industry, End Use & Fuel	Existing Facility Reference REI 2050	Existing Facility Reference TPC (x100)	New Facility REI 2014	New Facility Reference REI 2050	New Facility Reference TPC (x100)
Resins/Synthetic Rubber					
Process Heating-Electricity	0.873	-0.376	0.900	0.773	-0.420
Process Heating-Natural Gas	0.762	-0.751	0.720	0.532	-0.840
Process Heating-Steam	0.580	-1.502	0.720	0.391	-1.679
Process Cooling-Electricity	0.842	-0.476	0.850	0.724	-0.446
Process Cooling-Natural Gas	0.762	-0.751	0.720	0.531	-0.840
Machine Drive-Electricity	0.873	-0.376	0.960	0.809	-0.476
Machine Drive-Natural Gas	0.872	-0.376	0.900	0.774	-0.420
Electro-Chemical Process-Electricity	0.974	-0.072	0.950	0.823	-0.396
Other-Electricity	0.890	-0.321	0.915	0.783	-0.434
Other-Natural Gas	0.762	-0.751	0.721	0.532	-0.840
Agricultural Chemicals					
Process Heating-Electricity	0.873	-0.376	0.900	0.774	-0.420
Process Heating-Natural Gas	0.873	-0.376	0.900	0.774	-0.420
Process Heating-Steam	0.762	-0.751	0.900	0.664	-0.840
Process Cooling-Electricity	0.842	-0.476	0.850	0.724	-0.446
Process Cooling-Natural Gas	0.873	-0.376	0.900	0.773	-0.420
Machine Drive-Electricity	0.873	-0.376	0.960	0.809	-0.476
Machine Drive-Natural Gas	0.873	-0.376	0.900	0.774	-0.420
Other-Natural Gas	0.873	-0.376	0.900	0.774	-0.420

Table A-4c. Relative Energy Intensities (REI) and Technology Possibility Curves (TPC) for Metal Based Durables Industries—Region 4

Industry, End Use & Fuel	Existing Facility Reference REI 2050	Existing Facility Reference TPC (x100)	New Facility REI 2014	New Facility Reference REI 2050	New Facility Reference TPC (x100)
Fabricated Metals					
Process Heating-Electricity	0.665	-1.127	0.675	0.367	-1.679
Process Heating-Natural Gas	0.665	-1.127	0.675	0.367	-1.679
Process Cooling-Electricity	0.596	-1.427	0.637	0.333	-1.784
Process Cooling-Natural Gas	0.664	-1.127	0.674	0.367	-1.679
Machine Drive-Electricity	0.665	-1.127	0.720	0.361	-1.903
Machine Drive-Natural Gas	0.664	-1.127	0.674	0.367	-1.679
Electro-Chemical Process-Electricity	0.925	-0.216	0.712	0.401	-1.586
Other-Electricity	0.706	-0.962	0.687	0.365	-1.737
Other-Natural Gas	0.664	-1.127	0.674	0.367	-1.679
Machinery					
Process Heating-Electricity	0.665	-1.127	0.675	0.270	-2.519
Process Heating-Natural Gas	0.665	-1.127	0.675	0.270	-2.519
Process Cooling-Electricity	0.596	-1.427	0.637	0.240	-2.676
Process Cooling-Natural Gas	0.665	-1.127	0.674	0.268	-2.519
Machine Drive-Electricity	0.665	-1.127	0.720	0.254	-2.855
Machine Drive-Natural Gas	0.664	-1.127	0.672	0.270	-2.519
Electro-Chemical Process-Electricity	0.926	-0.216	0.714	0.300	-2.379
Other-Electricity	0.707	-0.962	0.687	0.265	-2.606
Other-Natural Gas	0.667	-1.127	0.673	0.269	-2.519
Computers & Electronics					
Process Heating-Electricity	0.762	-0.751	0.720	0.531	-0.840
Process Heating-Natural Gas	0.762	-0.751	0.720	0.532	-0.840
Process Cooling-Electricity	0.709	-0.952	0.680	0.492	-0.892
Machine Drive-Electricity	0.762	-0.751	0.768	0.544	-0.952
Electro-Chemical Process-Electricity	0.949	-0.144	0.759	0.571	-0.793
Other-Electricity	0.793	-0.641	0.732	0.534	-0.869
Other-Natural Gas	0.762	-0.751	0.720	0.532	-0.840

Transportation Equipment					
Process Heating-Electricity	0.827	-0.526	0.765	0.600	-0.672
Process Heating-Natural Gas	0.827	-0.526	0.765	0.600	-0.672
Process Heating-Steam	0.684	-1.052	0.765	0.470	-1.343
Process Cooling-Electricity	0.785	-0.666	0.722	0.558	-0.714
Process Cooling-Natural Gas	0.827	-0.526	0.770	0.604	-0.672
Machine Drive-Electricity	0.827	-0.526	0.816	0.620	-0.761
Machine Drive-Natural Gas	0.827	-0.526	0.764	0.598	-0.672
Electro-Chemical Process-Electricity	0.956	-0.101	0.802	0.637	-0.634
Other-Electricity	0.850	-0.449	0.777	0.605	-0.695
Other-Natural Gas	0.828	-0.526	0.764	0.601	-0.672
Electrical Equipment					
Process Heating-Electricity	0.762	-0.751	0.720	0.532	-0.840
Process Heating-Natural Gas	0.762	-0.751	0.720	0.532	-0.840
Process Cooling-Electricity	0.709	-0.952	0.680	0.493	-0.892
Process Cooling-Natural Gas	0.762	-0.751	0.721	0.533	-0.840
Machine Drive-Electricity	0.762	-0.751	0.768	0.544	-0.952
Machine Drive-Natural Gas	0.762	-0.751	0.721	0.533	-0.840
Electro-Chemical Process-Electricity	0.950	-0.144	0.760	0.571	-0.793
Other-Electricity	0.793	-0.641	0.733	0.535	-0.869
Other-Natural Gas	0.762	-0.751	0.721	0.533	-0.840

Table A-4d. Relative Energy Intensities (REI) and Technology Possibility Curves (TPC) for other Manufacturing Industries—Region 4

Industry, End Use & Fuel	Existing Facility Reference REI 2050	Existing Facility Reference TPC (x100)	New Facility REI 2014	New Facility Reference REI 2050	New Facility Reference TPC (x100)
Wood Products					
Process Heating-Electricity	0.665	-1.127	0.630	0.343	-1.679
Process Heating-Natural Gas	0.665	-1.127	0.630	0.342	-1.679
Process Heating-Steam	0.440	-2.253	0.630	0.184	-3.358
Process Cooling-Electricity	0.597	-1.427	0.596	0.312	-1.784
Process Cooling-Natural Gas	0.666	-1.127	0.630	0.343	-1.679
Machine Drive-Electricity	0.665	-1.127	0.672	0.336	-1.903
Machine Drive-Natural Gas	0.665	-1.127	0.630	0.343	-1.679
Other-Electricity	0.706	-0.962	0.640	0.341	-1.737
Other-Natural Gas	0.665	-1.127	0.630	0.343	-1.679
Plastic & Rubber Products					
Process Heating-Electricity	0.762	-0.751	0.675	0.498	-0.840
Process Heating-Natural Gas	0.762	-0.751	0.675	0.498	-0.840
Process Heating-Steam	0.580	-1.502	0.675	0.367	-1.679
Process Cooling-Electricity	0.709	-0.952	0.637	0.462	-0.892
Process Cooling-Natural Gas	0.764	-0.751	0.679	0.500	-0.840
Machine Drive-Electricity	0.762	-0.751	0.720	0.510	-0.952
Machine Drive-Natural Gas	0.764	-0.751	0.675	0.500	-0.840
Electro-Chemical Process-Electricity	0.949	-0.144	0.713	0.535	-0.793
Other-Electricity	0.793	-0.641	0.686	0.501	-0.869
Other-Natural Gas	0.764	-0.751	0.679	0.500	-0.840
Balance of Manufacturing					
Process Heating-Electricity	0.816	-0.563	0.675	0.530	-0.672
Process Heating-Natural Gas	0.816	-0.563	0.675	0.530	-0.672
Process Heating-Coal	0.816	-0.563	0.675	0.530	-0.672
Process Heating-Steam	0.665	-1.127	0.675	0.415	-1.343
Process Cooling-Electricity	0.773	-0.714	0.637	0.493	-0.714
Machine Drive-Electricity	0.816	-0.563	0.720	0.547	-0.761
Electro-Chemical Process-Electricity	0.961	-0.108	0.712	0.566	-0.634
Other-Electricity	0.841	-0.481	0.685	0.534	-0.695

Notes and sources

[1] U.S. Energy Information Administration, State Energy Data System, based on energy consumption by state through 2015, as downloaded in August 2017, from www.eia.gov/state/seds/.

[2] U. S. Energy Information Administration, Manufacturing Energy Consumption Survey 2014, (Washington, DC: October 2017) https://www.eia.gov/consumption/manufacturing/data/2014/ .

[3] U.S. Department of Energy (2007). Motor Master+ 4.0 software database; available at updated link http://www1.eere.energy.gov/manufacturing/downloads/MM41Setup.exe (paste into browser). User manual: https://www.energy.gov/sites/prod/files/2014/04/f15/motormaster_user_manual.pdf.

[4] In NEMS, hydrocarbon gas liquids (HGL), which comprise natural gas liquids (NGL) and olefins, are reported as "Liquefied Petroleum Gas and Other" (LPG).

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

[6] U.S. Department of the Interior, U.S. Geological Survey, Minerals Yearbook, cement data was made available under a non-disclosure agreement, http://minerals.usgs.gov/minerals/pubs/commodity/cement/myb1-2012-cemen.pdf.

[7] Portland Cement Association, U.S. and Canadian Portland Cement Industry Plant Information Summary, cement data was made available under a non-disclosure agreement, http://www.cement.org

[8] Personal correspondence with the Council of Industrial Boiler Owners.

[9] U.S. Energy Information Administration, Fuel Oil and Kerosene Survey (FOKS), http://www.eia.gov/dnav/pet/pet_cons_821usea_dcu_nus_a.htm.

[10] Agriculture Research Management Survey (ARMS), United States Dept. of Agriculture, Economic Research Service, http://ers.usda.gov/data-products/arms-farm-financial-and-crop-production-practices.aspx.

[11] U.S. Census Bureau, 2012 Economic Census Mining: Industry Series: Selected Supplies, Minerals Received for Preparation, Purchased Machinery, and Fuels Consumed by Type for the United States: 2012 (Washington, DC: February 27, 2015) available at: https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ECN_2012_US_21SM1&prodType=table

[12] U.S. Census Bureau, 2012 Economic Census; Construction: Industry Series: Detailed Statistics by Industry for the United States: 2012 (Washington, DC: January 12, 2015) available at: https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ECN_2012_US_23SG01&prodType=table

[13] Federal Register 79 FR 103 pp. 30934-31014, Washington, DC: May 29, 2014. Available at http://www.gpo.gov/fdsys/pkg/FR-2014-05-29/pdf/2014-11201.pdf

[14] California Air Resources Board "California Code of Regulations, Title 17, Division 3, Chapter 1, Subchapter 10, Article 5 §95800 - §96022" Sacramento, CA: June 14, 2014. Available at https://www.arb.ca.gov/regact/2014/capandtrade14/candtfrooal.pdf

[15] California Global Warming Solutions Act §38566 as amended (Sacramento, CA: September 8, 2016). Available at http://leginfo.legislature.ca.gov/faces/billCompareClient.xhtml?bill_id=201520160SB32

[16] Based on personal communication with CARB staff and calculations of Table II-3, page 43, of California Air Resources Board "The 2017 Climate Change Scoping Plant Update," (Sacramento, CA: January 20, 2017). Available at https://www.arb.ca.gov/cc/scopingplan/scopingplan.htm