Chapter 7
Industrial sector energy consumption

Overview

The industrial sector uses more delivered energy[294] than any other end-use sector, consuming about 54% of the world's total delivered energy. The industrial sector can be categorized by three distinct industry types: energy-intensive manufacturing, nonenergy-intensive manufacturing, and nonmanufacturing (Table 7-1). The mix and intensity of fuels consumed in the industrial sector vary across regions and countries, depending on the level and mix of economic activity and on technological development. Energy is used in the industrial sector for a wide range of purposes, such as process and assembly, steam and cogeneration, process heating and cooling, and lighting, heating, and air conditioning for buildings. Industrial sector energy consumption also includes basic chemical feedstocks. Natural gas feedstocks are used to produce agricultural chemicals. Natural gas liquids (NGL) and petroleum products (such as naphtha) are both used for the manufacture of organic chemicals and plastics, among other uses.

In the *International Energy Outlook 2016* (IEO2016) Reference case, worldwide industrial sector energy consumption is projected to increase by an average of 1.2%/year, from 222 quadrillion British thermal units (Btu) in 2012 to 309 quadrillion Btu in 2040 (Table 7-2). Most of the long-term growth in industrial sector delivered energy consumption occurs in countries outside of the Organization for Economic Cooperation and Development (OECD). From 2012 to 2040, industrial energy consumption in non-OECD countries grows by an average of 1.5%/year, compared with 0.5%/year in OECD countries. Non-OECD industrial energy consumption, which accounted for 67% of world industrial sector delivered energy in 2012, accounts for 73% of world industrial sector delivered energy consumption in 2040.

Overall, total industrial sector energy use increases from 73 quadrillion Btu in 2012 to 85 quadrillion Btu in 2040 in the OECD countries, and from 149 quadrillion Btu in 2012 to 225 quadrillion Btu in 2040 in the non-OECD countries. OECD industrial sector energy use grows slowly in the IEO2016 Reference case, averaging 0.5%/year from 2012 to 2040. The industrial sector accounts for approximately 40% of total OECD delivered energy use from 2012 to 2040. In the non-OECD industrial sector, the share of delivered energy use declines from 64% in 2012 to 59% in 2040, as many emerging non-OECD economies move away from energy-intensive manufacturing, while energy use grows more rapidly in all other end-use sectors.

Table 7-1. World industrial sector: major groupings and representative industries

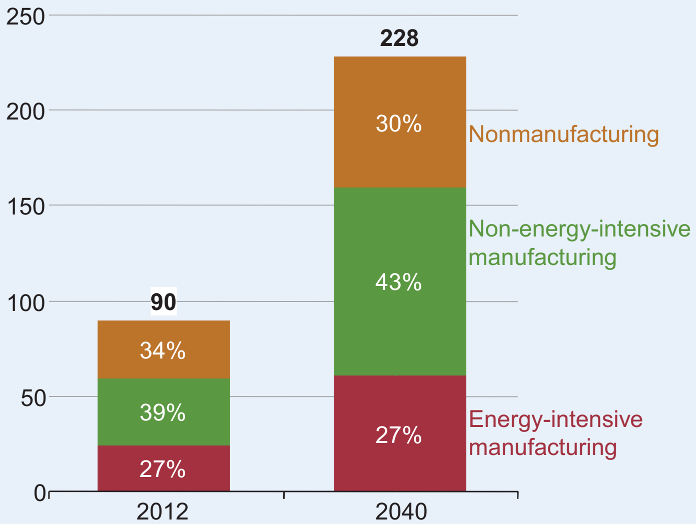
Industry grouping	Representative industries
Energy-intensive manufacturing	
Food	Food, beverage, and tobacco product manufacturing
Pulp and paper	Paper manufacturing, printing and related support activities
Basic chemicals	Inorganic chemicals, organic chemicals (e.g., ethylene propylene), resins, and agricultural chemicals; includes chemical feedstocks
Refining	Petroleum refineries and coal products manufacturing, including coal and natural gas used as feedstocks
Iron and steel	Iron and steel manufacturing, including coke ovens
Nonferrous metals	Primarily aluminum and other nonferrous metals, such as copper, zinc, and tin
Nonmetallic minerals	Primarily cement and other nonmetallic minerals, such as glass, lime, gypsum, and clay products
Nonenergy-intensive manufacturing	
Other chemicals	Pharmaceuticals (medicinal and botanical), paint and coatings, adhesives, detergents, and other miscellaneous chemical products, including chemical feedstocks
Other industrials	All other industrial manufacturing, including metal-based durables (fabricated metal products, machinery, computer and electronic products, transportation equipment, and electrical equipment)
Nonmanufacturing	
Agriculture, forestry, fishing	Agriculture, forestry, and fishing
Mining	Coal mining, oil and natural gas extraction, and mining of metallic and nonmetallic minerals
Construction	Construction of buildings (residential and commercial), heavy and civil engineering construction, industrial construction, and specialty trade contractors

[294] Delivered energy is measured as the heat content of energy at the site of use. It includes the heat content of electricity (3,412 Btu/kWh) but does not include conversion losses at generation plants in the electricity sector. Delivered energy also includes fuels (natural gas, coal, liquids, and renewables) used for combined heat and power facilities (cogeneration) in the industrial sector.

Regional gross output and industrial energy consumption

In the IEO2016 Reference case, real inflation-adjusted gross output is used to estimate industrial sector energy consumption by disaggregating economic activity into sectors and industries. Gross output includes intermediate inputs such as energy, materials, and purchased services used in production processes, providing data on all industry links that make up economic activity. In contrast, gross domestic product (GDP) and its components—which are value-added concepts—do not include intermediate inputs to industrial processes. In the IEO2016 projections, analysis of the key components of industrial gross output and how they change over time helps to explain regional changes in industrial sector energy consumption.

Figure 7-1. Global gross output by industrial subsector, 2012 and 2040 (trillion 2010 dollars)



Total gross output includes all economic activity, while industrial energy use includes three subsectors: nonmanufacturing, energy-intensive manufacturing, and nonenergy-intensive manufacturing (Table 7-3).[295] The shares of the gross output sectors vary by region and over time. Worldwide, gross output from the services sector increases by 3.5%/year from 2012 to 2040 in the IEO2016 Reference case, and energy-intensive manufacturing increases at a similar rate of 3.4%/year. In contrast, gross output from the nonmanufacturing sector grows at a slower rate of 2.9%/year. The fastest growth is projected for the nonenergy-intensive manufacturing sector, at 3.9%/year. This results in a long-term shift in the composition of gross output in the IEO2016 Reference case (Figure 7-1), showing a general long-term trend toward a worldwide economy that is slightly less dependent on agricultural and mined natural resources—two of the three nonmanufacturing industries. A move away from resource-based or agriculture-based national output, which has long been observed in the developed economies, is anticipated in the long-term outlook for the world's emerging economies.

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Table 7-2. World industrial sector delivered energy consumption by region and energy source, 2012–40 (quadrillion Btu)

Energy source by region	2012	2020	2025	2030	2035	2040	Average annual percent change, 2012–40
OECD	**73.3**	**77.6**	**80.0**	**81.7**	**83.0**	**84.6**	**0.5**
Liquid fuels	27.2	28.9	29.8	30.3	30.4	30.6	0.4
Natural gas	21.0	22.7	23.4	24.2	24.9	25.7	0.7
Coal	8.5	8.7	8.8	8.9	9.0	9.0	0.2
Electricity	10.9	11.6	12.1	12.5	12.8	13.2	0.7
Renewables	5.7	5.7	5.8	5.9	5.9	6.1	0.3
Non-OECD	**149.0**	**168.3**	**182.6**	**196.3**	**211.0**	**224.5**	**1.5**
Liquid fuels	39.3	43.3	46.7	50.3	54.2	57.9	1.4
Natural gas	29.7	33.6	38.6	43.8	49.6	54.7	2.2
Coal	47.3	53.4	55.5	57.1	58.6	59.7	0.8
Electricity	21.0	25.5	27.9	29.7	31.5	33.1	1.6
Renewables	11.8	12.5	13.9	15.4	17.1	19.0	1.7
Total World	**222.3**	**245.8**	**262.6**	**278.0**	**294.0**	**309.1**	**1.2**
Liquid fuels	66.5	72.2	76.5	80.6	84.6	88.6	1.0
Natural gas	50.7	56.2	62.0	68.0	74.5	80.4	1.7
Coal	55.7	62.0	64.3	66.0	67.2	68.7	0.8
Electricity	31.9	37.2	40.0	42.2	44.3	46.3	1.3
Renewables	17.4	18.2	19.7	21.3	23.0	25.1	1.3

Note: Data on delivered industrial sector energy consumption do not include conversion losses at electricity sector generation plants. Delivered energy includes fuels (natural gas, coal, liquids, and renewables) used for combined heat and power facilities (cogeneration) in the industrial sector.

[295] Details of the industries included in gross output, along with their NACE 2 codes, can be found in the IEO2016 macroeconomic documentation.

Globally, much of the slower growth in the nonmanufacturing sector is offset by increased growth in the services and nonenergy-intensive manufacturing sectors, whereas the energy-intensive manufacturing share of total gross output does not change. Many manufacturing industries are driven by trade. Some countries benefit from access to supply chains for technology goods; some benefit from competitive labor costs that lead to increases in nonenergy-intensive manufacturing production. Regional growth in the nonmanufacturing and services sectors differs according to the variety of industries that make up the sectors. In some regions, growth in the services sector is based on government spending, which is not necessarily linked to technological advances or access to markets. In other regions, growth in the nonmanufacturing sector is based on the availability of natural resources.

On a regional basis, the largest changes in industrial sector composition in the IEO2016 Reference case are projected for the Middle East and Russia (where mining/extraction is the largest component of the nonmanufacturing sector), and for India (where agriculture is currently the largest component of the nonmanufacturing sector) as a result of development and increasing standards of living, as well as changing fuel markets. In those regions, relatively rapid increases are projected for the services sector from 2012 to 2040, with all other gross output sectors, and particularly the nonmanufacturing sector, becoming smaller. For India, the shift toward services is explained by slower growth in the agriculture industry. For the Middle East and Russia, the shift is explained by slower growth in the oil and natural gas extraction industry.

For Mexico and Chile, there is a notable increase in the nonenergy-intensive manufacturing sector share of their combined economies. Although the IEO2016 projections do not include explicit calculations for the individual industries that make up the "other" industrial category, its largest component is transportation equipment. Growth in the transportation equipment industry is expected to account for much of the growth in both countries' nonenergy-intensive manufacturing sectors.

Both China and OECD Europe have declared goals to move away from heavy industry in the future. Although the IEO2016 Reference case does not show double-digit changes for its industrial sector, China remains one of the most influential economies in the world. The services sector share of China's economy increases in the Reference case, and growth in the nonmanufacturing and energy-intensive manufacturing sectors is slower than growth in the services sector. OECD Europe, which continues to account for the third-largest share of world gross output through 2040, shows a small shift away from the most energy-intensive industries over the projection period.

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Table 7-3. Average annual growth in gross output by region and sector, 2012–40 (percent per year)

	IEO2016 industrial sector activity			
Region	Energy-intensive manufacturing sector	Nonenergy-intensive manufacturing sector	Nonmanufacturing sector	Service sector/ rest of economy
OECD	**1.5**	**2.4**	**1.8**	**2.0**
OECD Americas	**2.0**	**3.5**	**2.5**	**2.5**
United States	1.1	2.4	1.5	1.9
Canada	1.8	2.2	2.1	2.1
Mexico/Chile	3.2	4.2	2.2	3.2
OECD Europe	**1.2**	**1.9**	**1.1**	**1.8**
OECD Asia	**1.2**	**1.5**	**1.4**	**1.4**
Japan	0.0	0.4	0.2	0.7
South Korea	2.2	2.2	1.9	2.0
Australia/New Zealand	2.5	1.8	2.3	2.7
Non-OECD	**4.1**	**4.6**	**3.3**	**4.9**
Non-OECD Europe and Eurasia	**2.3**	**2.2**	**0.8**	**3.4**
Russia	2.3	1.8	0.2	3.4
Other	2.3	3.0	2.0	3.3
Non-OECD Asia	**4.5**	**4.8**	**3.7**	**5.2**
China	4.3	4.8	3.2	5.6
India	5.4	5.8	4.0	6.8
Other	4.0	4.0	4.2	3.8
Middle East	**3.5**	**4.4**	**3.0**	**7.3**
Africa	**2.8**	**4.3**	**2.9**	**3.8**
Non-OECD Americas	**2.3**	**2.1**	**3.0**	**2.8**
Brazil	2.4	1.8	3.0	2.5
Other	2.3	2.3	3.0	2.9
Total World	**3.4**	**3.9**	**2.9**	**3.5**

Within gross output sectors there is a shift in regional shares of total world production for individual industries. India gains a larger share of world nonmetallic mineral production, in part because of rapid growth in its domestic construction industry. India's share of world steel production also increases from 2012 to 2040, while China's share remains relatively flat. In the paper industry, China's share of world production increases as growth is slower in other regions, including in Russia and in other non-OECD Europe and Eurasia. For basic chemicals, the Middle East, China, and India have increasing production shares throughout the projection period. Finally, most non-OECD countries increase their shares of total world agricultural sector production through 2040, and most OECD countries have decreasing shares. Within gross output sectors there is a shift in regional shares of total world production for individual industries. India gains a larger share of world nonmetallic mineral production, in part because of rapid growth in its domestic construction industry. India's share of world steel production also increases from 2012 to 2040, while China's share remains relatively flat. In the paper industry, China's share of world production increases as growth is slower in other regions, including in Russia and in other non-OECD Europe and Eurasia. For basic chemicals, the Middle East, China, and India have increasing production shares throughout the projection period. Finally, most non-OECD countries increase their shares of total world agricultural sector production through 2040, and most OECD countries have decreasing shares.

Industrial sector delivered energy consumption varies by region, according to differences in industrial gross output, energy intensity (measured as energy consumed per unit of gross output), and the composition of industries. Enterprises are able to reduce energy consumption in a number of ways, including improving industrial sector processes to reduce energy waste and recover energy lost (often process heat), increasing the use of cogeneration, and recycling materials and fuel inputs to reduce costs and improve efficiency. In terms of industrial fuel use, natural gas and electricity are the fastest-growing forms of industrial energy use in the OECD region (Figure 7-2), with each energy source increasing by about 0.7%/year from 2012 to 2040. Consumption of liquids, coal, and renewable energy in the OECD industrial sector grows more slowly, averaging 0.4%/year (liquids), 0.3%/year (renewable energy), and 0.2%/year (coal). As a result, from 2012 to 2040, the natural gas and electricity shares increase from 28.7% to 30.3% (natural gas) and from 14.9% to 15.6% (electricity). As in OECD, the fastest-growing forms of industrial sector energy consumption in the non-OECD region from 2012 to 2040 are natural gas (2.2%/year) and electricity (1.6%/year). Non-OECD consumption of renewable energy also expands rapidly, by an average of 1.7%/year from 2012 to 2040, while consumption of liquid fuels and coal increases by 1.4%/year and 0.8%/year, respectively (Figure 7-3). Most of the world growth in industrial sector energy use occurs in the emerging non-OECD economies.

The strong rates of growth in industrial sector consumption of electricity and natural gas in both the OECD and non-OECD regions are attributable to increases in the other industrials group of nonenergy-intensive manufacturing (see Table 7-1). Although the other industrials are not energy intensive, they do make up approximately 30% and 36% of total OECD and non-OECD industrial sector delivered energy consumption, respectively. Moreover, the manufacture of bulk chemicals in the non-OECD region expands rapidly in the Reference case. Because nonenergy-intensive manufacturing—including both other industrials and other chemicals—relies heavily on electricity and natural gas, consumption of both energy sources shows strong growth in the OECD and non-OECD industrial sectors, in comparison with most other energy sources.

Biomass currently provides most of the renewable energy (excluding hydroelectricity) consumed in the industrial sector and continues to do so throughout the projection, largely because of its role in providing byproduct energy to the pulp and paper industry. OECD countries typically have either flat or declining growth in the pulp and paper industry, resulting in the slower growth

Figure 7-2. OECD industrial sector delivered energy consumption by energy source, 2012–40 (quadrillion Btu)

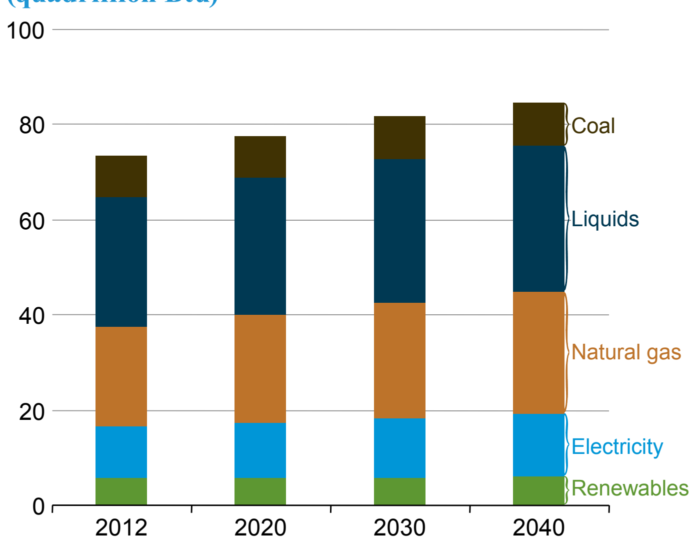
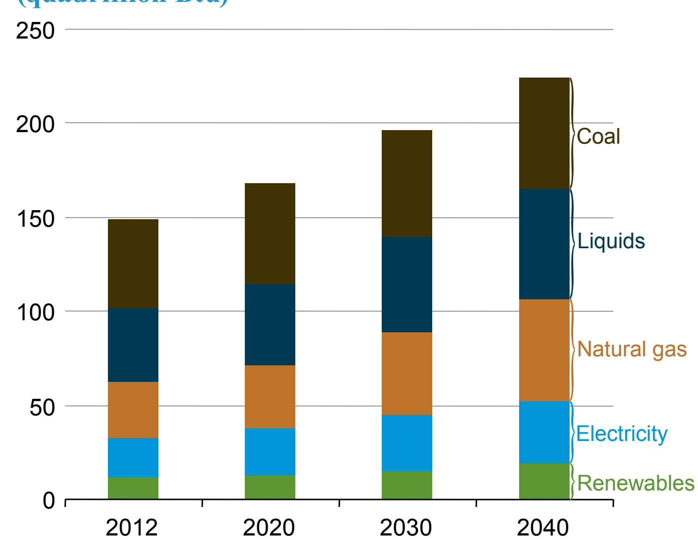


Figure 7-3. Non-OECD industrial sector delivered energy consumption by energy source, 2012–40 (quadrillion Btu)



of renewables compared with total industrial sector energy consumption. In most of the non-OECD countries, the pulp and paper industry grows significantly, with corresponding growth in industrial sector renewable energy use.

Coal becomes a less important source for industrial energy consumption in both the OECD and non-OECD regions in the IEO2016 Reference case. In the OECD industrial sector, coal use increases by 0.2%/year from 2012 to 2040, and its share of total delivered industrial energy consumption declines slightly, from 12% in 2012 to 11% in 2040. Similarly, in the non-OECD industrial sector, the coal share of total industrial delivered energy falls from 32% in 2012 to 27% in 2040. The iron and steel industry is the largest consumer of coal in the industrial sector, and as regions shift from coal-fired furnaces to electric arc furnaces, coal use for iron and steel production declines. In addition, several significant industrial manufacturing countries, including the United States and China, are initiating policies to reduce greenhouse gas (GHG) emissions from their industrial sectors by switching to electricity and natural gas and by improving energy efficiency in industries that produce large amounts of GHG emissions.

Energy-intensive industries

The following industries are considered to be energy-intensive: food, pulp and paper, basic chemicals, refining, iron and steel, nonferrous metals (primarily aluminum), and nonmetallic minerals (primarily cement). Together, they account for about half of all industrial sector delivered energy use. In 2012, OECD energy-intensive industries accounted for about 54% of the region's total industrial sector energy consumption, and non-OECD energy-intensive industries accounted for about 51% of the industrial sector total. Consequently, the quantity and fuel mix of future industrial sector delivered energy consumption will be determined largely by the overall levels of energy consumption in those seven industries. In addition, the same industries emit large quantities of carbon dioxide (CO2), related to both their energy consumption (combustion emissions) and their production processes (process emissions). Figure 7-4 and Figure 7-5 show energy consumption shares of the energy-intensive industries compared with all industrial sector energy consumption (including feedstock consumption) in 2012 and 2040 for the OECD and non-OECD, respectively. The energy consumption shares of the energy-intensive industries are shown as percentages of total delivered energy consumption in the OECD and non-OECD industrial sectors.

Increases in energy efficiency and changes in industrial gross output affect the growth of industrial sector energy consumption. Anticipated energy efficiency improvements in the industrial sector temper the growth of industrial energy demand, particularly for the energy-intensive industries. Recycling is a key contributor to industrial energy efficiency improvements, especially in the pulp and paper, iron and steel, and nonferrous metals industries *(see box on page 120)*.

Among the energy-intensive industries, the largest consumer of delivered energy is the basic chemicals industry, which in 2012 accounted for about 19% of total delivered energy consumption in the OECD industrial sector and about 14% in the non-OECD industrial sector. In both regions, the basic chemicals share of industrial energy use in the IEO2016 Reference case rises to about 20% in 2040 (Figure 7-4 and Figure 7-5). The chemicals industry in general uses petrochemical feedstocks, which are included in its energy use. In 2012, petrochemical feedstocks accounted for roughly 60% of the energy consumed in the chemicals sector (which includes both energy-intensive basic chemicals and nonenergy-intensive other chemicals). Intermediate petrochemical products (or building blocks), which go into products such as plastics, require a fixed amount of hydrocarbon feedstock as input. For any given amount of chemical output, depending on the fundamental chemical process of production, a fixed amount of feedstock is required, which greatly reduces opportunities for decreasing fuel consumption in the absence of any major shifts toward recycling and bio-based chemicals.

Figure 7-4. Energy-intensive industry shares of total OECD industrial sector energy consumption, 2012 and 2040 (percent of total)

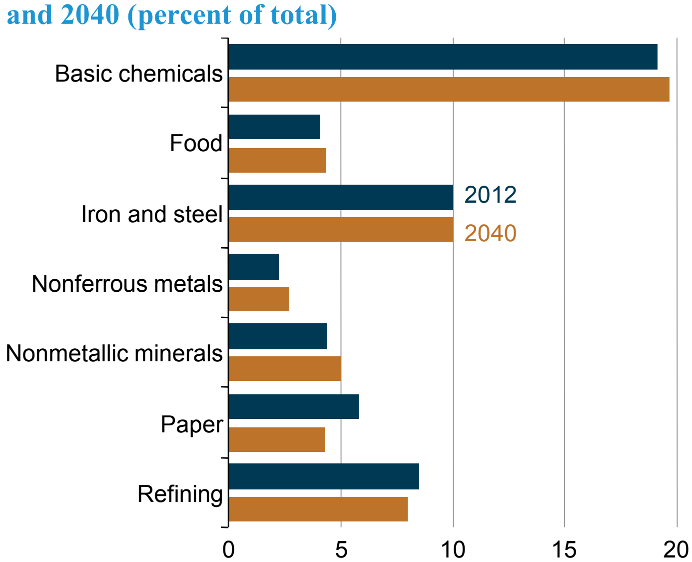
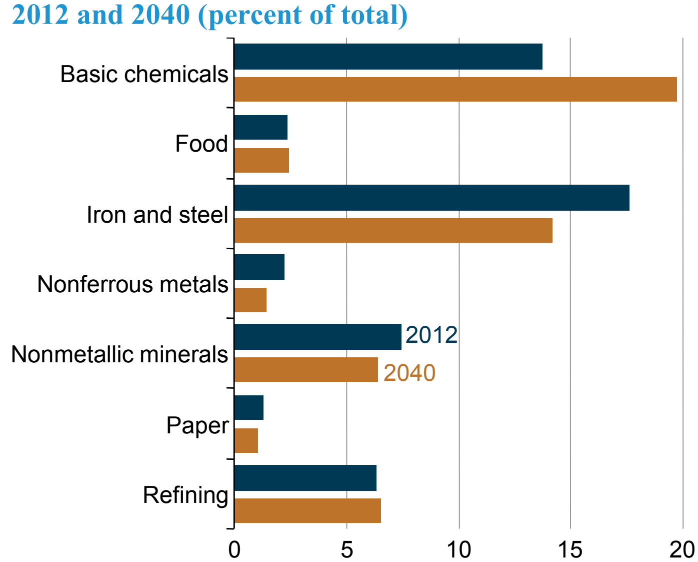


Figure 7-5. Energy-intensive industry shares of total non-OECD industrial sector energy consumption, 2012 and 2040 (percent of total)



The iron and steel industry accounted for about 10% of industrial sector delivered energy consumption in OECD countries in 2012, and its 2040 share remains the same in the IEO2016 Reference case. In the non-OECD countries, the iron and steel industry accounted for 18% of delivered industrial sector energy use in 2012, and its share declines to about 14% in 2040. The amount of energy consumed in the production of steel depends on the process used. In the blast furnace process, iron ore is reduced (meaning that oxygen molecules in the ore bond with the carbon molecules), leaving pure molten iron and carbon dioxide. The molten iron is transferred to a basic oxygen furnace, where super-heated oxygen is used to remove any remaining impurities. Coal consumption and heat generation make the process highly energy intensive. In addition, the process requires metallurgical coal (coking coal), which is more costly than steam coal because of its lower ash and sulfur content.[296]

The other major steel production process uses electric arc furnaces to melt scrap metal. The process is more energy efficient and produces less carbon dioxide than the blast furnace process but depends on a reliable supply of scrap steel. As a supplement to scrap steel, direct reduced iron (DRI) can be used in electric arc furnaces. DRI is much less energy-intensive than the blast furnace process, requiring only natural gas or steam coal, rather than coking coal.

The refining industry is a major energy consumer, accounting for about 8% of delivered industrial energy consumption in OECD countries and about 6% of delivered industrial energy consumption in non-OECD countries throughout the 2012–40 period. Petroleum refineries are by far the largest consumers of energy in this industry. Their energy consumption is related primarily to demand for liquid fuels (primarily in the transportation sector), with some reduction in their energy use related to increases in energy efficiency. OECD countries have a small increase in liquids demand in the projection with a small increase in refinery energy consumption. Thus, the percentage of industrial sector delivered energy consumption accounted for by refinery use falls slightly from 2012 to 2040, as a result of small increases in overall industrial sector energy consumption (about 13%) from 2012 to 2040. In contrast, demand for liquids in the non-OECD countries grows significantly. With increases in refinery energy consumption, the refinery share of total industrial sector delivered energy consumption rises slightly.

In parallel with the large growth in industrial sector energy consumption in non-OECD countries overall, energy consumption in the nonmetallic minerals industry increases significantly over the projection. In 2012, the nonmetallic minerals industry accounted for about 5% of total OECD delivered industrial energy consumption and about 7% of total non-OECD delivered industrial energy consumption. Increases in the industry's energy use result primarily from growth in the construction industry, which is accompanied by growing demand for cement.

Non-OECD countries are experiencing significant population growth, which contributes to similar growth in the food industry in the IEO2016 Reference case. In 2012, the food industry accounted for about 4% of total delivered industrial energy consumption in OECD countries and 2% in non-OECD countries. With the large growth in non-OECD industrial sector energy consumption in the Reference case, the food industry share of the sector's total energy use remains at 4% in 2040.

The pulp and paper industry accounted for about 6% of delivered industrial energy consumption in OECD countries in 2012, and its share declines to about 4% in 2040 in the IEO2016 Reference case. In the non-OECD countries, pulp and paper production accounts for about 1% of total delivered industrial energy consumption. Paper manufacturing is an energy-intensive process, but paper mills typically generate about half of the electricity they consume through cogeneration, primarily with black liquor and biomass from wood waste. In some cases, integrated paper mills generate more electricity than they need, and they are able to sell their excess power to the grid. As is the case in other industries, recycling significantly reduces the energy intensity of production in the paper industry.[297] Electronic media and digital file storage in many countries may cause global demand for paper to contract over time. For much of the rest of the world, however, output from the paper industry expands steadily in the IEO2016 Reference case, in part because of a growing need for a variety of paper products in non-OECD Asia, including paperboard for packaging and other materials. With the large increase in industrial sector energy consumption in non-OECD countries, the static percentage of the paper industry indicates a significant increase in energy consumption associated with increasing demand.

The nonferrous metals industry (primarily aluminum) accounted for about 2% of delivered industrial energy consumption in both the OECD and non-OECD regions in 2012. A small decrease in the industry's share of total non-OECD industrial energy consumption in 2040 results from the increase in total industrial sector energy use as a result of growing demand.

Regional focus: OECD Europe and non-OECD Asia

Regions around the world have different industrial sector energy profiles and may develop in different ways in the future. The OECD Europe and non-OECD Asia regions illustrate several differences. OECD Europe is a well-established industrialized region, where the major concern is implementing government policies that will improve energy efficiency and decrease GHG emissions. In contrast, much of non-OECD Asia is still developing, and although there are efforts underway to address pollution issues in the industrial sector, there is also significant government interest in increasing industrial growth that will help the non-OECD Asian economies raise incomes and standards of living. The industrial sectors of the OECD Europe and non-OECD Asia regions illustrate the range of world industrial development and future growth in the IEO2016 Reference case.

[296] D. Paul, "Modeling the U.S. Iron and Steel Industry," U.S. Energy Information Administration Task Order DE-DT0001606, Subtask 1.2 (Leidos: November 15, 2013).

[297] D. Paul, "Final Report: Modeling the U.S. Pulp and Paper Industry," U.S. Energy Information Administration Task Order 7965, Subtask 17 (Leidos: July 15, 2015).

OECD Europe

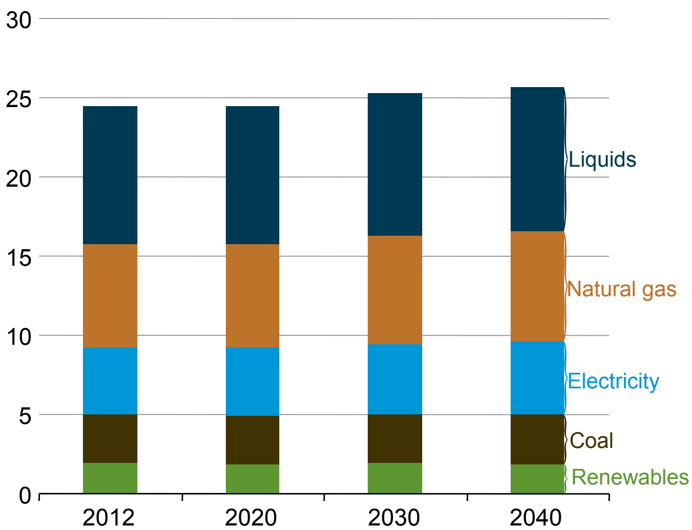
In the IEO2016 Reference case, OECD Europe's industrial sector energy consumption growth averages 0.2%/year from 2012 to 2040 (Figure 7-6), reflecting improving efficiency in the region's industrial sector and its continued transition from a manufacturing economy to a service economy. Electricity consumption has the highest rate of growth, at 0.3%/year, while the growth rates for natural gas, electricity, and liquids consumption are higher than those for other fuels. The growth rates for consumption of all fuels are positive, except for renewables with a slow decline from 1.93 quadrillion Btu in 2012 to 1.87 quadrillion Btu in 2040. The gross output of pulp and paper declines toward the end of the projection period, and improvements in energy efficiency slow the growth of renewable energy use.

Energy and environmental policies significantly influence the trends in industrial sector energy consumption in OECD Europe. European Union (EU) climate and energy policies, part of the current Europe 2020 strategy, are concerned with reducing GHG emissions. The so-called 20-20-20 plan set three separate goals to be achieved by 2020: (1) reduce GHG emissions by 20% compared with 1990; (2) increase renewable energy to 20% of final energy consumption; and (3) improve energy efficiency by 20%. To date, there has been mixed success in efforts to reach the 20-20-20 targets. From 1990 to 2012, the EU reduced GHG emissions by 18%, and it seems likely that it will achieve its 20% target for 2020. Further, 13% of EU final energy consumption in 2011 came from renewable sources—exceeding the 2011–12 interim goal of 10.7%.[298] However, only a 17% improvement in energy efficiency is expected from measures under the 2012 Energy Efficiency Directive.[299] The European Commission published the Strategy for a European Energy Union in February 2015, with a focus on energy security, completion of an internal energy market, energy efficiency, decarbonization, and research and innovation. Implementation of the strategy will require new EU legislation.[300] Because of these efforts, slow growth in energy use in industry is expected.

Non-OECD Asia

Over the past decade, much of the world's industrial sector energy growth occurred in the nations of non-OECD Asia. That trend continues in the IEO2016 Reference case with strong expansion of the region's manufacturing and nonmanufacturing industries. From 2012 to 2040, non-OECD Asia's expected total industrial sector delivered energy consumption increases by an average of 1.7%/year, as compared with the world average of 1.2%/year.

Figure 7-6. OECD Europe industrial sector delivered energy consumption by energy source, 2012–40 (quadrillion Btu)



China

Steel energy demand growth in China

Steel is a major energy-intensive industry in China, and the amount of steel being produced in China is unprecedented. China's share of world steel production has increased steadily from roughly one-quarter in 2004 to about one-half in 2013.[301] Primary steel (virgin steel from iron ore)—or, more specifically, basic oxygen furnace (BOF) steel[302]—is a major consumer of coal in China and therefore a major contributor to industrial sector GHG emissions.

Steel production in China continues to grow throughout the projection period but not as rapidly as during the past decade. From 2005 to 2012, gross output in China's iron and steel industry grew at an average annual rate of 12% (and crude steel production closely matched that growth rate at 11%). From 2012 to 2040 in the IEO2016 Reference case, the average growth rate is only 3%. Even at that rate, however, gross output shipments from the industry more than double from 2012 to 2040, while the industry's energy consumption increases by only 11% over the period. The disparity between shipments and energy consumption growth results from the

[298] European Commission, "Report from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Renewable Energy Progress Report" (Brussels: March 27, 2013), p. 3, http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52013DC0175&from=EN.

[299] European Parliamentary Research Service, "EU climate and energy policies post-2020: Energy security, competitiveness and decarbonisation" (Briefing 24/03/2014), http://www.europarl.europa.eu/RegData/bibliotheque/briefing/2014/130681/LDM_BRI(2014)130681_REV1_EN.pdf.

[300] European Parliament, "Energy Union: New impetus for coordination and integration of energy policies in the EU" (Briefing 5 March 2015: Tracking European Commission priority initiatives in 2015 – Number 1), http://www.europarl.europa.eu/RegData/etudes/BRIE/2015/551310/EPRS_BRI(2015)551310_EN.pdf.

[301] World Steel Association, *Steel Statistical Yearbook 2014* (Brussels, Belgium: worldsteel Committee on Economic Studies, October 2014), http://www.worldsteel.org/dms/internetDocumentList/statistics-archive/yearbook-archive/Steel-Statistical-Yearbook-2014/document/Steel-Statistical-Yearbook-2014.pdf.

[302] "Blast furnace steel" refers to the process of reducing iron ore in a blast furnace and processing the molten steel in a basic oxygen furnace.

Reference case assumption of energy efficiency improvements in technologies (hot and cold rolling, electric arc furnaces, blast furnaces) over time, as well as an assumed shift from BOF steel production to electric arc furnace (EAF) production, with the energy intensity of the EAF process less than one-third of that for the BOF process.[303] In aggregate, the total energy intensity of China's iron and steel industries (in units of energy per dollar value of gross output shipments) declines by 69% from 2012 to 2040.

One reason for the decline in energy intensity is the assumption that China, like most developed nations, will rely increasingly on recycled—as opposed to virgin—BOF steel. In 2013, the BOF and EAF process shares in China for crude steel production were 91% and 9%, respectively. Most of the world's major steel-producing nations currently produce far more recycled steel as a share of their total production than does China. In Japan and the United States, which are the second- and third-largest producers in the world, the EAF shares are 23% and 59%, respectively. Thus, currently, the energy intensity of China's steel industry seems very high compared with other major producers, in large measure because of its heavy reliance on BOF steel. As China's economy becomes more developed and moves toward recycling of scrap steel, its energy intensity will decrease. The gradual move toward recycling (spurred by the increasing availability of scrap steel) is expected as expansion of new buildings construction, infrastructure, and vehicle fleets begins to taper off. In the IEO2016 Reference case, the EAF share of steel production grows to 40% in 2040, which is in line with other projections for China's recycled steel production.[304]

Steel and aluminum recycling in China

Secondary production from recycled scrap metal, which uses significantly less energy than primary production from raw material inputs, can reduce the energy intensity of both steel and aluminum production.[305] The Institute of Scrap Recycling Industries estimates that recycling steel requires 60% less energy than producing steel from iron ore. According to the U.S. Department of Energy, secondary aluminum production requires as little as 6% of the energy associated with primary production, when all manufacturing energy use is considered.[306] Recyclable material includes both post-consumer scrap and pre-consumer scrap from manufacturing processes.

In China, which produces more steel and aluminum than any other country, the iron and steel industry used 16 quadrillion Btu of energy in 2012, and the nonferrous metals industry (which includes aluminum and other metals) used 2.1 quadrillion Btu.[307] In comparison with the United States, China's aluminum and steel recycling rates are low. In 2012, about 11% of China's crude steel production was secondary production (from recycling),[308] and 21% of its aluminum production was secondary production.[309] In contrast, U.S. recycling rates were 59% for steel production and 57% for aluminum production.

The two main barriers to increasing the use of scrap in secondary production of steel and aluminum are capital investment and availability of scrap. Although increasing secondary production does require additional secondary production facilities, costs for those facilities are much lower than the costs of primary production facilities. For example, the capital equipment costs for recycled aluminum production are approximately 10% of those for primary aluminum production.[310]

Steel and aluminum scrap sources include obsolete buildings and transportation equipment, as well as discarded appliances and beverage cans. Domestic scrap is usually less expensive than imported scrap, but it requires dedicated sorting, collection, and transportation, as well as access to large volumes of scrap material. Based on an analysis of China's steel industry structure in 2011,[311] recycling of scrap metal could be increased to 33% of total steel production without adding new secondary processing facilities.

(continued on page 121)

[303] E. Worrell, P. Blinde, M. Neelis, E. Blomen, and E. Masanet, *Energy Efficiency Improvement and Cost Saving Opportunities for the U.S. Iron and Steel industry: An ENERGY STAR® Guide for Energy and Plant Managers,* LBNL-4779E (Berkeley, CA: Lawrence Berkeley National Laboratory, Environmental Technologies Division, October 2010), https://www.energystar.gov/ia/business/industry/Iron_Steel_Guide.pdf.

[304] A. Hasanbeigi, Zeyi Jiang, and L. Price, "Why the energy use of Chinese steel industry may peak as early as 2015?" (Berkeley, CA: Lawrence Berkeley National Laboratory, 2014), http://proceedings.eceee.org/visabstrakt.php?event=4&doc=3-008-14.

[305] U.S. Energy Information Administration, "Recycling is the primary energy efficiency technology for aluminum and steel manufacturing" (Washington, DC: May 9, 2014), http://www.eia.gov/todayinenergy/detail.cfm?id=16211.

[306] Institute of Scrap Recycling Industries, Inc., *Recycling Industry* (undated), http://www.isri.org/recycling-industry; and U.S. Department of Energy, Energy Efficiency and Renewable Energy, *U.S. Energy Requirements for Aluminum Production: Historical Perspective, Theoretical Limits, and Current Practices* (Washington, DC: February 2007), http://www1.eere.energy.gov/manufacturing/resources/aluminum/pdfs/al_theoretical.pdf.

[307] U.S. Energy Information Administration, "Recycling is the primary energy efficiency technology for aluminum and steel manufacturing" (Washington, DC: May 9, 2014), http://www.eia.gov/todayinenergy/detail.cfm?id=16211.

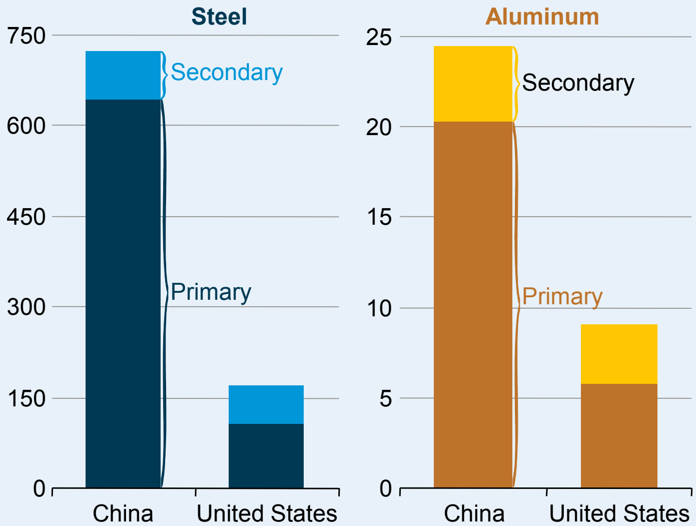
[308] Bureau of International Recycling, Ferrous Division, *World Steel Recycling in Figures 2008-2012,* http://www.bdsv.org/downloads/weltstatistik_2008_2012.pdf.

[309] United States Geological Survey, *Mineral Industry of China Data for 2012,* http://minerals.usgs.gov/minerals/pubs/country/2012/myb3-2012-ch.xls; and United States Geological Survey, *Minerals Information, Recycling Statistics and Information,* http://minerals.usgs.gov/minerals/pubs/commodity/recycle/.

[310] U.S. Department of Energy, Energy Efficiency and Renewable Energy, *U.S. Energy Requirements for Aluminum Production: Historical Perspective, Theoretical Limits, and Current Practices* (Washington, DC: February 2007), http://www1.eere.energy.gov/manufacturing/resources/aluminum/pdfs/al_theoretical.pdf.

[311] J. Wubbeke and T. Heroth, "Challenges and political solutions for steel recycling in China," *Resources, Conservation and Recycling,* Vol. 87 (June 2014), pp. 1-7, http://www.sciencedirect.com/science/article/pii/S0921344914000627.

Figure 7-7. Steel and aluminum production from primary and secondary sources in China and the United States, 2012 (million metric tons)



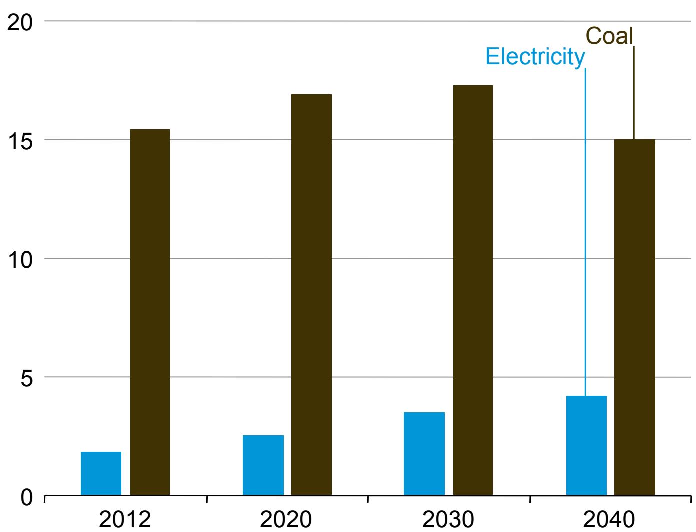
In 2012, China imported almost 5 million metric tons of steel scrap and 2.6 million metric tons of aluminum scrap[312] (Figure 7-7). Because the iron and steel industry is a much larger energy consumer than the aluminum industry, China's government aims to increase scrap input by improving recycling efficiency in the iron and steel industry. Over time, more scrap could become available in China, allowing a substantial reduction in the energy intensity of the country's steel and aluminum industries.

With the relative increase in EAF production, the electricity demand share in the steel industry rises from 10% in 2012 to 22% in 2040 (Figure 7-8). Concurrently, total energy intensity decreases by 69% due to the much lower energy intensity of the EAF process as well as ongoing energy intensity improvement, which in part follow from necessary reductions in excess steel capacity.[313] Although much of the electricity used for EAF production is expected to be generated by coal-fired power plants, the reduction in blast furnace production of steel greatly reduces the steel industry's dependence on coal (per ton of steel produced) and thus contributes to lower energy intensity and lower GHG intensity.

Chemicals industry growth and coal consumption

As with other energy-intensive industries, China's chemicals industries have experienced rapid growth. In terms of gross output shipments, bulk chemicals (which include petrochemical and commodity chemicals) grew by almost 70% from 2005 to 2012 (an average rate of 7.8%/year), while in terms of physical production, chemicals such as ethylene, propylene, and methanol had even stronger growth. China's robust growth in bulk chemicals production is projected to continue in the Reference case—in line with the growth in virtually all other industrial categories—with gross output increasing by an average of 5.0%/year.

Figure 7-8. Coal and electricity consumption in China's steel industry, 2012–40 (quadrillion Btu)



Changes in China's economy support the projected growth of its bulk chemicals industry. Olefins, including ethylene and propylene, are inputs for a wide variety of industrial and consumer chemicals, such as resins, plastics, and adhesives. Reducing dependence on imports of commodity chemicals while still satisfying industrial production growth is a major factor in China's continued expansion of its chemical industry. Methanol is another input for China's growing market for chemical derivatives, as is propylene; however, methanol also satisfies growing demand for liquid fuels in China's transportation sector.[314] Currently, China produces about one-third of the world's ammonia,[315] and although China is

[312]United States Geological Survey, *Mineral Industry of China Data for 2012,* http://minerals.usgs.gov/minerals/pubs/country/2012/myb3-2012-ch.xls.
[313]Chuin-Wei Yap, "The Fall of Steel in China: a Primer" (*The Wall Street Journal,* September 8, 2015), http://blogs.wsj.com/chinarealtime/2015/09/08/the-fall-of-steel-in-china-a-primer/.
[314]G. Dolan, "Will Politics Push the Gas or Brakes on Methanol Fuel" (Methanol Institute, 2013), http://www.methanolfuels.org/wp-content/uploads/2013/05/15-Dolan_MI.pdf.
[315]L.E. Apodaca, "2013 Minerals Yearbook: Nitrogen [Advance Release]" (Washington, DC: 2013), http://minerals.usgs.gov/minerals/pubs/commodity/nitrogen/myb1-2013-nitro.pdf.

trying to reduce its level of fertilizer use,[316] its pursuit of food security and continued modernization of farming probably will result in moderate growth of fertilizer consumption in the future.

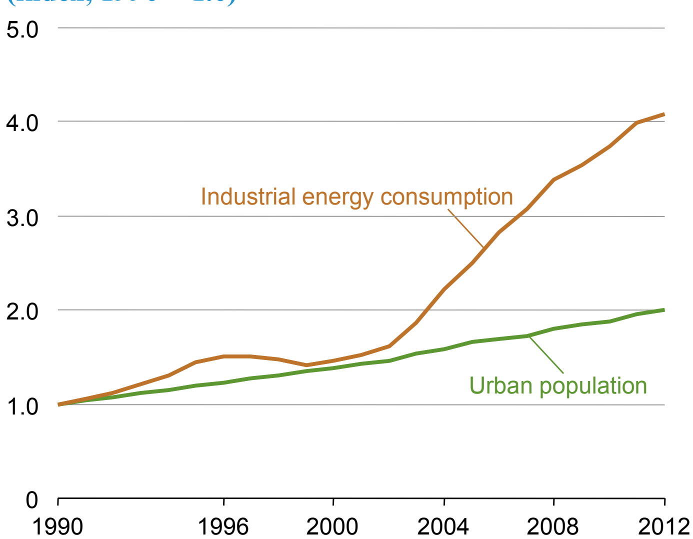
China's use of energy resources in bulk chemical production differs from use in most other large producing regions, in that it relies heavily on coal as a feedstock. Outside China, most methanol and ammonia production relies on natural gas feedstock, while ethylene production and propylene production rely largely on natural gas liquids (NGL) or on petroleum-based feedstocks. However, China continues to rely heavily (although not exclusively) on coal gasification technologies to produce many of its bulk chemicals. Currently, 70% of ammonia production[317] and more than 80% of methanol production[318] in China use coal as a feedstock, with a growing share going into the production of olefins, such as propylene and ethylene. According to its most recent Five-Year Plan, China intends to increase coal use in producing olefins.

Generally, the relative levels of use of different feedstocks depend on the delivered costs of the fuels, although other factors also matter. Coal is relatively inexpensive in China, but construction of coal-to-olefin (CTO) processing plants is not. Coal feedstock costs represent only about 25% of the total costs for CTO production because of the high capital cost of production. In contrast, for petroleum-based production of olefins, such as in a naphtha-based steam cracker, the feedstock costs for naphtha are a much higher percentage of the total production cost.[319] Thus, lower petroleum product prices will make steam crackers increasingly attractive, while lower coal prices would not have as much of an effect. In addition, the CTO process results in fewer valuable coproducts (such as butadiene and aromatics). Finally, there is a cost associated with transporting the basic olefins to China's East Coast, where most of the plastic manufacturers are located.

Environmental concerns such as CO2 emissions, water use, and waste disposal may have a larger effect on potential CTO projects. The CTO process generates more than twice as much CO2 per ton of olefin produced as a naphtha steam cracker does. The CTO process is also far more water-intensive, and most CTO projects are or will be located in water-stressed regions (such as Inner Mongolia and Western China), where water resources are well below the world average.[320] Finally, the hazardous material and waste disposal associated with CTO processes also can lead to escalating expenses for industrial-scale CTO plants.

In the IEO2016 Reference case, the coal share of China's chemical feedstock fuel use is projected to increase from 20% to 32% from 2012 to 2040, while the liquids share (mostly heavy petroleum feedstocks) declines by 6%. The difference results from the higher proportion of new ethylene crackers using coal instead of naphtha and gasoil for feedstock. The natural gas share of feedstock fuel use also increases, with some of China's projected growth in ammonia and methanol production capacity using natural gas and not exclusively coal.

Figure 7-9. Industrial energy consumption and urban population growth in China, 1990–2012 (index, 1990 = 1.0)



Urbanization and industrial energy demand in China

From 1990 to 2012, China's industrial energy consumption increased fourfold, from 14.8 quadrillion Btu to 59.0 quadrillion Btu. A review of the literature on the Chinese experience indicates that the 10th Five-Year Plan (2001–05) promoted strong growth in the manufacturing sector, resulting in 13.5% annual average growth in GDP for that period. The focus on the use of advanced technology across traditional manufacturing enterprises[321] contributed to a rapid increase in production across a wide range of industries and a corresponding increase in industrial energy consumption (Figure 7-9), with industrial sector energy use rising by 3.9%/year from 1990 and 2000, followed by 9.8%/year from 2001 to 2012.

The energy intensity of China's gross domestic product (GDP), or energy use per dollar of GDP, has generally improved (decreased) since 1990 from a level more than three times higher than in the OECD countries to a level two

[316] L. Jin, "China's 12th 5-Year Plan: Sustainability" (KPMG Advisory China, Ltd: April 2011), https://www.kpmg.com/CN/en/IssuesAndInsights/ArticlesPublications/Documents/China-12th-Five-Year-Plan-Sustainability-201104-v2.pdf.

[317] J. R. Bartels, "A Feasibility Study of Implementing an Ammonia Economy" (Iowa State University, 2008), http://lib.dr.iastate.edu/cgi/viewcontent.cgi?article=2119&context=etd.

[318] C. Yang, "Coal Chemicals: China's High-Carbon Clean Coal Programme?" (Taylor and Francis Group: 2016), http://people.duke.edu/~cy42/C2C.pdf.

[319] D. Hurd, S. Park, and J. Kan, *China's Coal to Olefins Industry* (Deutsche Bank AG, Hong Kong: July 2, 2014), http://www.fullertreacymoney.com/system/data/files/PDFs/2014/July/3rd/0900b8c088667819.pdf.

[320] S. Moore, "Issue Brief: Water Resources Issues, Policy and Politics in China" (Washington, DC: February 12, 2013), http://www.brookings.edu/research/papers/2013/02/water-politics-china-moore.

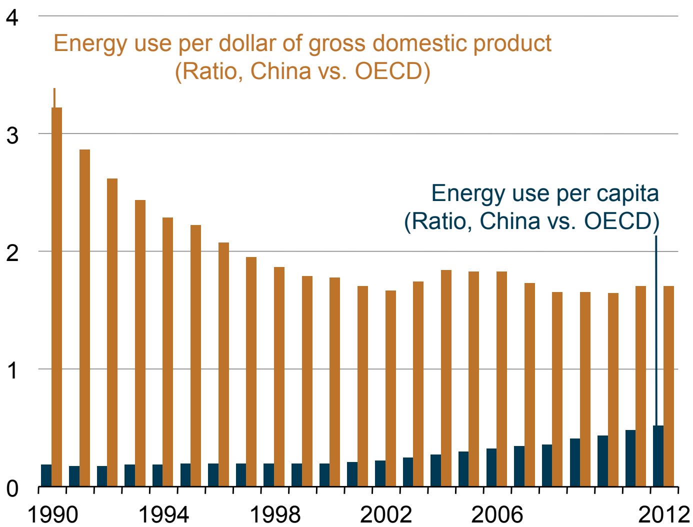
[321] Z. Ronghji, "Report on the Outline of the Tenth Five Year Plan for National Economic and Social Development (2001)," http://www.gov.cn/english/official/2005-07/29/content_18334.htm.

times higher in the mid-1990s. That progress was interrupted from 2000 to 2005, however, when aggressive manufacturing goals set in China's 10th Five-Year Plan led to increases in energy intensity as production rose across many industries. During that period, energy intensity increased to 1.8 in 2004, before settling at levels that were between 1.6 and 1.7 times the OECD level through 2012 (Figure 7-10).

Under the terms of the 12th Five-Year Plan (2011–15), China for the first time implemented specific targets aimed at reducing energy intensity (a 16% reduction in energy use per dollar of GDP, which would reduce intensity to 40% above OECD levels by 2015). Many observers expect that the 13th Five-Year Plan (2016–20) will continue to target additional energy efficiency gains,[322] along with a variety of other measures designed to reduce emissions.

Figure 7-11 shows the increase in China's energy consumption for both fuel and feedstock in the chemical industry. Feedstock plays a prominent role in the production of bulk chemicals, and there is little efficiency improvement to be gained for a given feedstock type (as opposed to heat and power uses, where incremental efficiency gains in boilers, power generation, motors, etc., have occurred in the past and are expected in the future). Consequently, the overall energy efficiency improvement in this industry from 2012 to 2040 is not expected to be significant, with overall intensity improvement at only 15%.

Figure 7-10. Comparisons of energy use per capita and per dollar of gross domestic product in China and the OECD, 1990–2012 (1990 OECD = 1)



Other non-OECD Asia

The nations of non-OECD Asia outside China and India (or other non-OECD Asia) are some of the fastest-growing industrial energy-consuming nations worldwide. Total industrial energy use in other non-OECD Asia increases from 15.7 quadrillion Btu in 2012 to 26.6 quadrillion Btu in 2040, according to the IEO2016 Reference case, an average annual increase of 1.9% (Figure 7-12). Other non-OECD Asia's industrial sector energy consumption grows at a rate higher than the combined OECD rate (0.5%/year), as well as the rate for the combined total non-OECD (1.5%/year). In general, the nations of other non-OECD Asia have among the highest projected growth in industrial sector gross output and associated delivered energy consumption. However, the focus on energy efficiency and the product mix also affects the delivered energy consumption growth rate. The fuels whose consumption grows most quickly in other non-OECD Asia are natural gas (2.2%/year between 2012 and 2040) and electricity (2.0%/year), although liquid fuels (1.8%/year), coal (1.8%/year), and renewables (1.8%/year) also grow rapidly. The fuel shares change very little over the projection period.

Figure 7-11. Fuel and feedstock consumption in China's bulk chemicals industry, 2012–40 (quadrillion Btu)

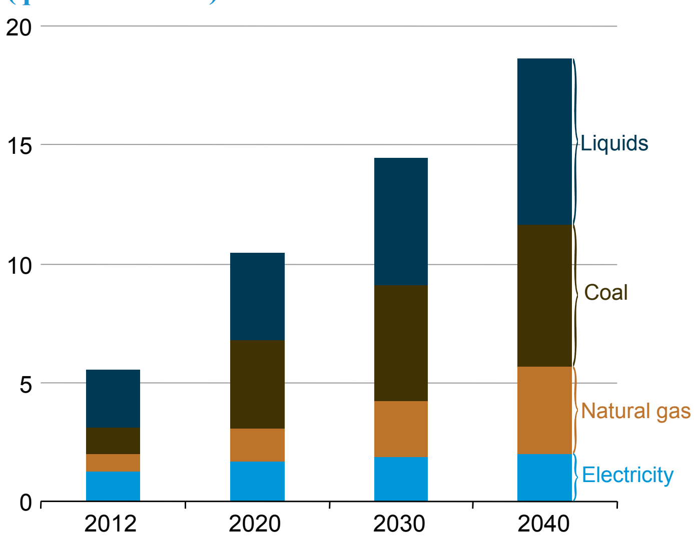
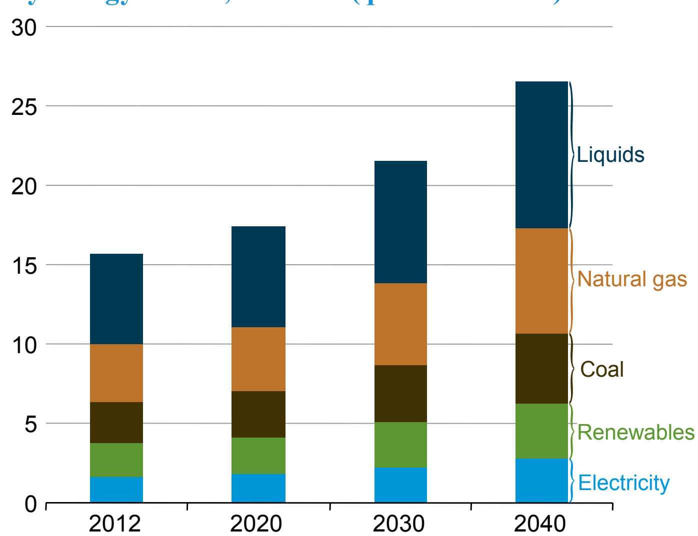


Figure 7-12. Non-OECD Asia (excluding China and India) industrial sector delivered energy consumption by energy source, 2012–40 (quadrillion Btu)



[322]For example, see Energy & Climate Intelligence Unit and China Dialogue, "China Heads to Low Carbon Future" (Davos, Switzerland: 2014), http://eciu.net/assets/ECIU_China-Doc-151015-FINAL.pdf.

The countries that are members of the Association of South East Asian Nations (ASEAN)[323] have the highest growth rates among the other non-OECD Asia countries. Energy efficiency is viewed as one of the most cost-effective ways of enhancing energy security and addressing climate change, as well as promoting economic competitiveness, in the ASEAN member countries. ASEAN is concerned with both energy efficiency and climate change, with the following strategic objectives[324]:

- To pursue the aspirational goal of reducing regional energy intensity by at least 8% in 2015 from the 2005 level
- To achieve higher end-use energy efficiency for all sectors through regulatory and market approaches, where appropriate
- To enhance institutional and human capacity, emphasizing the development of energy efficiency technology and service providers in the ASEAN region
- To encourage private sector participation, especially by financial institutions, in support of energy efficiency and conservation investment and implementation.

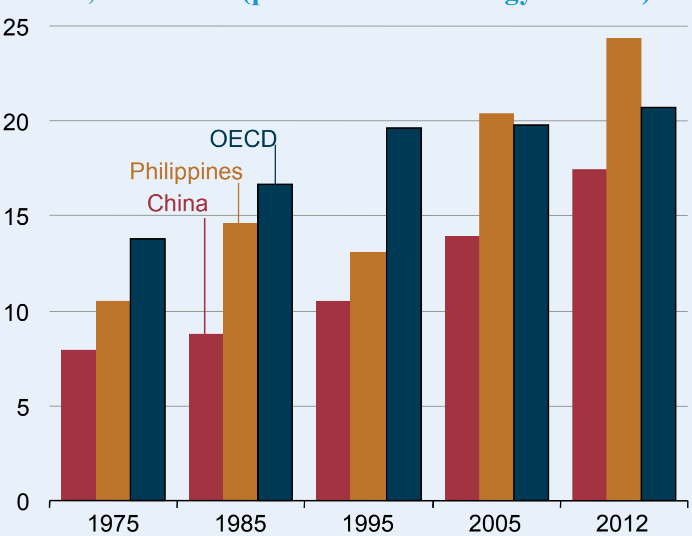
Role of electricity in changing patterns of non-OECD Asia industrial energy use

Since the 1970s, industrial sector energy demand has varied significantly among the non-OECD nations of Asia. In 2012, the electricity share of industrial energy demand ranged from 11% in Northeast Asia (Mongolia and North Korea) to nearly 25% in the Philippines (Figure 7-13). The way industrial sectors in the non-OECD Asia nations have developed over time can provide a basis for understanding the variables that may influence industrial sector electrification in the future.

In the industrialized OECD nations, electricity penetration in the industrial sector has been linked with fuel substitution in production processes (for example, replacing inefficient blast furnaces with electric arc furnaces) and the development of new uses for electricity in increasingly mechanized industries.[325] In rapidly growing Asian markets, however, industry is expanding through investment in new industrial facilities that incorporate the latest and most energy-efficient technologies.

China has experienced significant growth in industrial sector electricity demand—averaging approximately 9%/year and outpacing demand growth for all other fuels used in industrial production. The electricity share of industrial energy use in other non-OECD Asia nations also has increased rapidly. Since the early 1970s, industrial electricity use has doubled every eight years in China and in member countries of the Association of Southeast Asian Nations (ASEAN). As economic reform was unfolding in China, industrial electricity demand surged from 984 terawatthours (TWh) in 2000 to 1,802 TWh in 2005. By the end of the decade, China had recorded double-digit annual growth in total electricity demand, with a commensurate rise in the electricity share of industrial energy consumption, to 18% in 2012—close to the overall share in the OECD countries. Over the same period, industrial electricity demand in the ASEAN countries increased from 182 TWh in 2000 to 399 TWh in 2012, when it accounted for 12% of total industrial energy use.

Figure 7-13. Electricity shares of industrial sector energy demand in China, the Philippines and the OECD, 1975–2012 (percent of total energy demand)



A disaggregated view of electricity demand growth in China's industrial sector reflects the structural changes occurring as the economy grew (Figure 7-14). In the 1990s and early 2000s, the electricity share of industrial energy demand in China's energy-intensive industries (including iron and steel, pulp and paper, chemicals, and food) rose modestly, to 13%. Since 2000, nonenergy-intensive industries (including transport and electrical equipment and computers) have accounted for an increasing share of industrial electricity demand. For 2012, the electricity share of industrial energy demand was 18%.

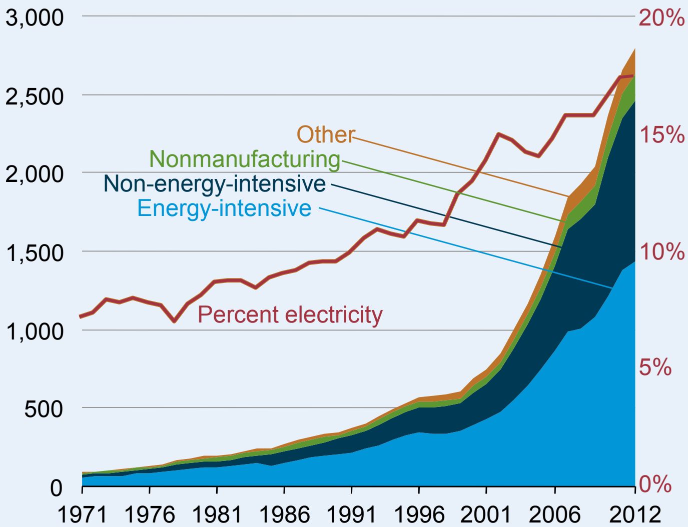
In comparison with China, the Philippines shows a more variable historical trend of electricity use in the industrial sector (Figure 7-15). The electricity share of industrial sector energy demand in the Philippines moved between 15% and 20% in the late 1990s before increasing to 24% in 2012, when it exceeded the OECD level. Most of the growth in the country's industrial sector electricity demand occurred in energy-intensive industries. Unlike China, industrial demand for electricity in the Philippines is not distributed across a wide range of sectors and corresponds more closely to changes in gross output or to changes in total value added.

(continued on page 125)

[323]ASEAN member countries include Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam.
[324]ASEAN Centre for Energy, "Energy Efficiency and Conservation" (Jakarta, Indonesia: 2015), http://www.aseanenergy.org/programme-area/eec/.
[325]N. Desbrosses, "Understanding electrification of industrial energy consumption in Europe," *Leonardo ENERGY* (February 2012), http://www.leonardo-energy.org/blog/understanding-electrification-industrial-energy-consumption-europe.

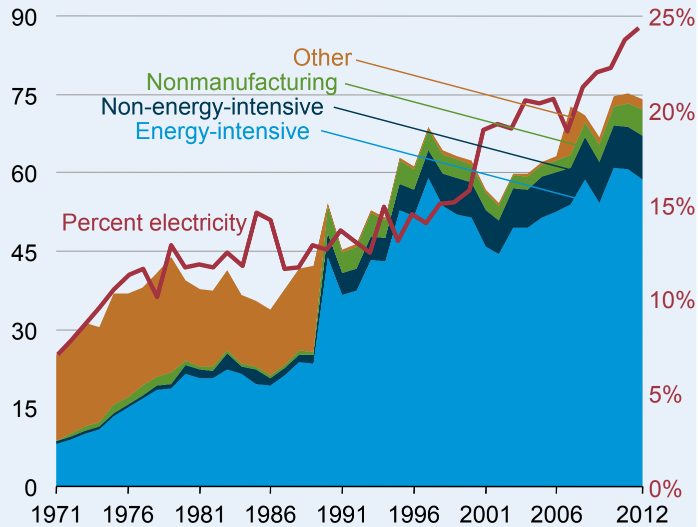
The future rate of electric demand growth in non-OECD Asia industries is more dependent on the changing composition of industry than on overall economic growth. Growth in new electricity-intensive technologies occurs largely in downstream industries—notably, nonenergy-intensive lighter manufacturing. In addition, when advanced economies reach a certain stage in their development, the growth of industrial sector electricity demand slows. As indicated by recent data, the electricity share of total industrial energy consumption in the United States and in other OECD countries has been relatively unchanged since 1990. In the United States, electricity accounted for 15% of total delivered industrial energy consumption in 2012 and is projected in the IEO2016 Reference case to account for 16% of total delivered industrial energy consumption in 2040.

Figure 7-14. Industrial sector electricity demand in China by industry type, 1971–2012 (terawatthours)



Note: *Other* industries category represents all nonspecified industrial sector electricity consumption as reported to the International Energy Agency.

Figure 7-15. Industrial sector electricity demand in the Philippines by industry type, 1971–2012 (terawatthours)



Note: *Other* industries category represents all nonspecified industrial sector electricity consumption as reported to the International Energy Agency.

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