Chapter 6

Industrial Sector Energy Consumption

Worldwide industrial energy consumption increases by an average of 1.4 percent per year from 2006 to 2030 in the IEO2009 reference case. Much of the growth is expected to occur in the developing non-OECD nations.

The world's industries make up a diverse sector that includes manufacturing, agriculture, mining, and construction. Industrial energy demand varies across regions and countries, depending on the level and mix of economic activity and technological development, among other factors. Energy is consumed in the industrial sector for a wide range of activities, such as processing and assembly, space conditioning, and lighting. Industrial energy use also includes natural gas and petroleum products used as feedstocks to produce non-energy products, such as plastics. In aggregate, the industrial sector uses more energy than any other end-use sector, consuming about one-half of the world's total delivered energy.

Over the next 25 years, worldwide industrial energy consumption is projected to grow from 175.0 quadrillion Btu in 2006 to 245.6 quadrillion Btu in 2030 (Table 12). In the *IEO2009* reference case, world industrial energy demand increases at an average annual rate of 1.4 percent to 2030. National economic growth rates return to historical trends when the current economic downturn ends, with much of the subsequent growth in industrial sector energy demand expected to occur in the developing non-OECD nations.

Currently, non-OECD economies consume 58 percent of global delivered energy in the industrial sector. In the period through 2030, industrial energy use in the

Table 12. OECD and Non-OECD Industrial Energy Consumption by Source, 2006-2030
(Quadrillion Btu)

Region	2006	2010	2015	2020	2025	2030	Average Annual Percent Change, 2006-2030
OECD							
Liquids	31.3	27.8	28.2	28.2	28.2	28.4	-0.4
Natural Gas	19.1	19.5	20.5	21.0	21.7	22.4	0.7
Coal	9.2	8.6	8.5	8.4	8.4	8.5	-0.3
Electricity	11.2	11.5	12.3	12.8	13.2	13.7	0.8
Renewables	2.4	2.7	2.9	3.3	3.8	4.1	2.2
Total OECD	**73.1**	**70.0**	**72.3**	**73.7**	**75.5**	**77.1**	**0.2**
Non-OECD							
Liquids	29.2	31.4	33.6	36.7	39.4	41.8	1.5
Natural Gas	23.2	26.9	31.8	35.2	38.0	40.5	2.3
Coal	34.2	37.8	41.8	46.2	49.3	51.2	1.7
Electricity	14.9	19.6	23.4	27.4	31.3	34.6	3.6
Renewables	0.3	0.3	0.3	0.3	0.3	0.3	0.1
Total Non-OECD	**101.9**	**115.9**	**131.0**	**145.7**	**158.2**	**168.5**	**2.1**
World							
Liquids	60.5	59.2	61.8	64.9	67.6	70.3	0.6
Natural Gas	42.3	46.4	52.3	56.1	59.8	62.9	1.7
Coal	43.4	46.4	50.3	54.7	57.8	59.7	1.3
Electricity	26.2	31.0	35.7	40.1	44.5	48.4	2.6
Renewables	2.7	2.9	3.2	3.6	4.1	4.3	2.0
Total World	**175.0**	**185.9**	**203.3**	**219.4**	**233.7**	**245.6**	**1.4**

Note: Totals may not equal sum of components due to independent rounding.
Sources: **2006:** Derived from Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. **Projections:** EIA, World Energy Projections Plus (2009).

non-OECD countries is expected to grow at a rate of 2.1 percent per year, compared with 0.2 percent per year in the OECD countries (Figure 63). Thus, 94 percent of the growth in industrial energy use from 2006 to 2030 is projected to take place in non-OECD countries. In 2030, non-OECD nations are expected to consume 69 percent of total delivered energy in the world's industrial sector.

Fuel prices shape the mix of fuel consumption in the industrial sector, as industrial enterprises are assumed to choose the cheapest fuels available to them, whenever possible. Because liquids are more expensive than other fuels, world industrial sector liquids use increases at an average annual rate of only 0.6 percent in the projection (Figure 64), and the share of liquid fuels in the industrial fuel mix declines. The liquids share is displaced primarily by electricity use, which grows by an average of 2.6 percent per year from 2006 to 2030.

At present, the overall industrial fuel mixes in the OECD and non-OECD countries differ, especially for liquids and coal. In 2006, liquids made up 43 percent of industrial energy use in the OECD countries, compared with 29 percent in the non-OECD countries; however, OECD industrial liquids use declines at a rate of 0.4 percent per year between 2006 and 2030, while non-OECD liquids use increases at a rate of 1.5 percent per year. In 2030, the non-OECD industrial sector consumes 41.8 quadrillion Btu of energy from liquids, compared with 28.4 quadrillion Btu for the OECD industrial sector.

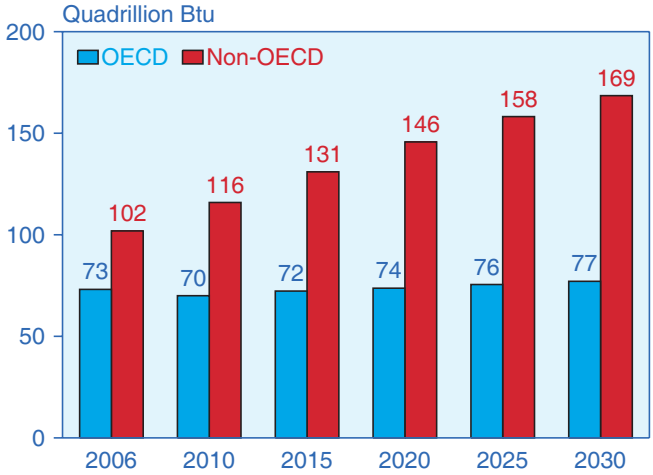
Coal use in the industrial sector also is considerably more prominent in non-OECD nations than in the OECD nations, especially in China and India, which have abundant domestic coal reserves and less stringent environmental regulations. Coal represented 13 percent of OECD industrial energy use in 2006 and is projected to decline by an average of 0.3 percent per year over the projection period. In non-OECD nations, coal represented 34 percent of industrial energy us in 2006 and increases by an average of 1.7 percent per year.

Total industrial energy consumption in each region is a product of the energy intensity of industrial output—as measured by the energy consumed per unit of output—and the level of industrial output. To capture the dynamics of industrial energy consumption, those two elements must be examined in concert. This chapter focuses on the policy and economic trends that drive both the changes in the energy intensity of production in key industries and the trade and development patterns that affect the levels of industrial output in different areas.

Energy-intensive industries, which consume most of the energy in the industrial sector, have focused on reducing their energy consumption for years, because energy represents a large portion of their costs [*1*]. Enterprises can reduce energy use in numerous ways. Industrial processes can be improved to reduce energy waste and recover energy, often process heat, which would otherwise be lost. Recycling material and fuel inputs also improves efficiency. Public policies aimed at reducing greenhouse gas emissions often include mandates for heavy industry to lower the energy intensity of production, especially in OECD countries.

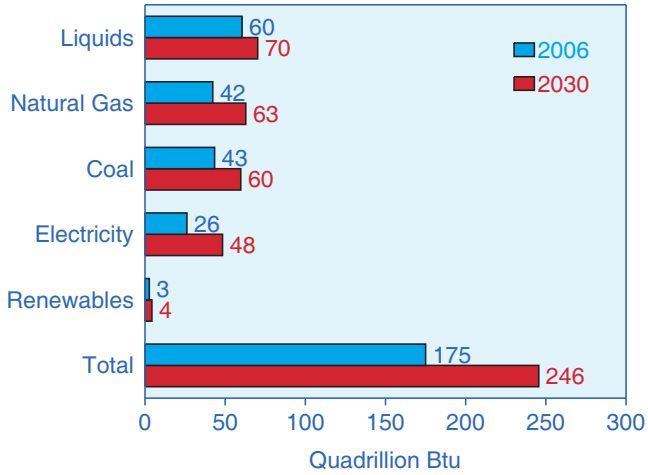
Policies governing greenhouse gas emissions also can influence the location of new energy-intensive industrial enterprises. The phenomenon of industries relocating

Figure 63. OECD and Non-OECD Industrial Sector Energy Consumption, 2006-2030



Sources: **2006:** Derived from Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. **Projections:** EIA, World Energy Projections Plus (2009).

Figure 64. World Industrial Sector Energy Consumption by Fuel, 2006 and 2030



Sources: **2006:** Derived from Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. **2030:** EIA, World Energy Projections Plus (2009).

their emissions-intensive facilities to less restrictive operating environments, know as "carbon leakage," is only one of many factors influencing global patterns of industrial output [**2**]. Countries' development trajectories also play a major role. When economies initially begin to develop, industrial energy use rises as manufacturing output begins to take up a larger portion of GDP, as has taken place already in many non-OECD economies (most clearly in China). When the developing economies attain higher levels of economic development, they begin to transition to service-oriented economies, and their industrial energy use begins to level off as can be seen currently in OECD countries.

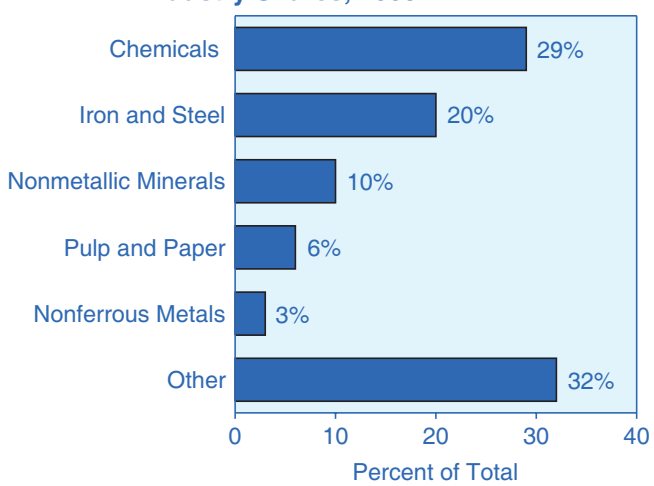
The following section describes patterns of energy use in the world's most energy-intensive industries. Subsequent sections examine specific patterns of industrial energy use in the major OECD and non-OECD regions.

Energy-Intensive Industries

Five industries account for 68 percent of all energy used in the industrial sector (Figure 65): chemicals (29 percent), iron and steel (20 percent), nonmetallic minerals (10 percent), pulp and paper (6 percent), and nonferrous metals (3 percent) [**3**]. The quantity and fuel mix of future industrial energy consumption will be determined largely by energy use in those five industries. In addition, the same industries emit large quantities of carbon dioxide, related to both their energy use and their production processes (see box on page 88).

The largest industrial consumer of energy is the chemical sector, which made up 29 percent of total world industrial energy consumption in 2006. Energy represents 60 percent of the industry's cost structure and an even higher percentage in the petrochemical subsector, which uses energy products as feedstocks. Petrochemical feedstocks account for 60 percent of the energy used in the chemicals sector. Intermediate petrochemical products, or "building blocks," which go into products such as plastics, require a fixed amount of hydrocarbon feedstock input. In other words, for any given amount of chemical output a fixed amount of feedstock is required, depending on the fundamental chemical process of production, which greatly reduces opportunities for reducing fuel use [**4**].

Figure 65. World Industrial Sector Energy Consumption by Major Energy-Intensive Industry Shares, 2005



Source: International Energy Agency Data Services, *World Energy Balances* (2007), web site http://data.iea.org (subscription site).

By volume, the largest "building block" in the petrochemical sector is ethylene, which can be produced by various chemical processes. In Europe and Asia, ethylene is produced primarily from naphtha, which is refined from crude oil. In North America and the Middle East, where domestic supplies of natural gas are more abundant, ethylene is produced from ethane, which typically is obtained from natural gas. Because petrochemical feedstocks represent such a large share of industrial energy use, patterns of feedstock use play a substantial role in determining each region's fuel mix.

In recent years, most of the expansion of petrochemical production and consumption has taken place in non-OECD Asia. Although the global recession will slow demand growth for a time, continued aggressive expansion of petrochemical manufacturing capacity in Asia and the Middle East points toward further growth of the petrochemical industry over the projection period. Since 2004, capital expenditures in the chemical sector of the Asia-Pacific region have outpaced those in North America and Europe combined. That trend is likely to continue through 2013 [**5**]. The chemical sector also is likely to continue using hydrocarbon feedstocks throughout the projection period, although the high oil prices of recent years have sparked interest in the use of alternative renewable feedstocks, such as agricultural ("chemurgy") products, which could gain some market share[33] during the forecast period [**6**].

The next-largest industrial user of energy is iron and steel, which accounts for about 20 percent of industrial energy consumption. Across the iron and steel sector as a whole, energy represents roughly 15 percent of production costs [**7**]. The amount of energy used in the production of steel varies greatly, however, depending on the process used. In the blast furnace process, superheated oxygen is blown into a furnace containing iron ore and coke. The iron ore is reduced (meaning that oxygen molecules in the ore bond with the carbon), leaving molten iron and carbon dioxide [**8**]. Coal use and heat

[33] Analysts estimate that world oil prices must be sustained at $50 to $60 per barrel in order for this technology to be economically feasible.

generation make this process tremendously energy-intensive, and in addition it requires metallurgical coal, or coking coal, which is more costly than steam coal because of its lower ash and sulfur content.

Electric arc furnaces, the other major type of steel production facility, produce steel by using an electric current to melt scrap metal. The process is more energy-efficient and produces less carbon dioxide than the blast

Process-Related Emissions in the Industrial Sector

Carbon dioxide emissions in the industrial sector result from both energy use and production processes. Together, energy- and process-related emissions in the industrial sector account for about one-fourth of global carbon dioxide emissions.[a] Process-related emissions are a direct byproduct of production. Because releases of carbon dioxide are inherent in the production of iron and steel, cement, and aluminum, the potential for reducing process-related emissions is limited. As a result, carbon abatement will face significant technological challenges in the industrial sector. In addition, there are no economical substitutes for these materials or their production processes, and none is likely be available in the near term.

The largest carbon dioxide emitter in the industrial sector is the iron and steel industry. In addition to being tremendously energy-intensive, the blast furnace process for steel production generates carbon dioxide directly. When super-heated oxygen (O) is blown into a blast furnace containing coal coke and iron oxide (FE_2O_3), the oxygen fuses with carbon in the coke to produce carbon monoxide (CO) which, at high temperatures, reduces iron oxide by removing the oxygen to produce pure molten iron (Fe) and carbon dioxide. The primary chemical reaction involved in the process is:

$$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2 \quad .$$

Two-thirds of the world's steel production uses blast furnaces, including 90 percent of the steel made in China, which is the world's fastest-growing steel producer.[b]

The situation is similar in the cement industry. The primary ingredient in marketed cement is cement clinker, composed largely of calcium oxide (CaO). Clinker is produced by superheating quarried and ground raw materials in a massive kiln. The most abundant material in the process is limestone ($CaCO_3$). The chemical reaction involved in heating limestone is:

$$CaCO_3 \rightarrow CaO + CO_2 \quad .$$

Although there are many possible ways to improve energy efficiency in the cement production process, the fundamental chemistry of producing cement clinker will always result in direct emissions of carbon dioxide. Cement industry groups point out that cement and concrete are important components of environmentally friendly development because of their durability and energy performance.[c] To the extent that that is true, demand for cement is likely to remain strong even in the most carbon-constrained future scenario, and direct emissions from cement production will remain an issue.

The basic process involved in producing aluminum also emits carbon dioxide directly. Aluminum is produced by running an electrical current through a molten mixture of electrolyte and refined alumina (Al_2O_3). In the process, carbon (C) from a graphite anode fuses with and removes oxygen from the alumina to produce molten aluminum metal. A simplified version of the reaction is:

$$2Al_2O_3 + 3C \rightarrow 4Al + 3CO_2 \quad .$$

Just as cement will continue to be a component of energy efficiency improvements in the buildings sector, aluminum will play a role in reducing fuel use in the transportation sector. Specifically, fuel economy is substantially improved when aluminum is used to reduce the weight of vehicles. Although aluminum production from recycled scrap metal would avoid most of the process-related emissions, most of the aluminum sold in world markets probably will come from primary production for the foreseeable future.

The inability of major energy users (and carbon dioxide emitters) in the industrial sector—including the iron and steel, cement, and aluminum industries—to remove carbon dioxide from their production processes limits their ability to respond to climate change initiatives. The situation is further complicated in that demand for their products is unlikely to subside in the near future. As a result, policy regimes insituted by OECD nations to address carbon dioxide emissions already have begun to afford those industries special treatment.

[a]International Energy Agency, *Energy Technology Perspectives: Scenarios and Strategies to 2050* (Paris, France, June 2008), p. 471.
[b]World Steel Association, "World Steel in Figures 2008" (2008), web site www.worldsteel.org/pictures/publicationfiles/WSIF%202008%202nd%20edition.pdf.
[c]Portland Cement Association, "Sustainable Development" (2008), web site www.cement.org/newsroom/newsroom_reference_sustain.asp.

furnace process, but it depends on a reliable supply of discarded steel. Currently, two-thirds of global steel production uses the blast furnace process. The only major steel producers that make a majority of their steel using the electric arc furnace process are the United States (59 percent) and India (58 percent) [*9*].

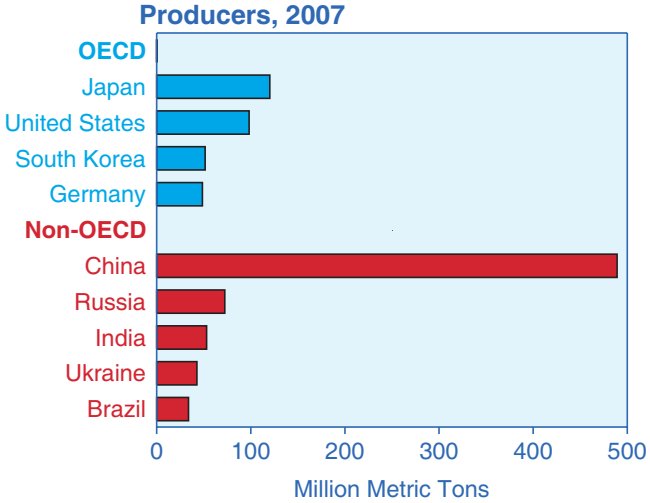
Earlier this decade, non-OECD economies witnessed a (now-subsiding) boom in steel production and consumption that drove up global production and prices. Fueled by demand from the construction and manufacturing sectors, China has become the world's largest steel manufacturer, producing more steel than the seven next-largest producers combined (Figure 66). Ninety percent of China's production employs the blast-furnace method [*10*]. A major effect of increased steel production has been a sharp rise in the price of scrap metal, which has made the blast furnace method of production more cost-effective, especially in non-OECD countries that do not have large inventories of scrap metal. When scrap steel becomes available and cheap enough to have a clear cost advantage over iron ore, use of electric arc furnaces in non-OECD countries will increase, reducing coal use and increasing electricity use.

After iron and steel, the next largest energy-consuming industry is nonmetallic minerals, which includes cement, glass, brick, and ceramics. Production of those materials requires a substantial amount of heat and accounts for 10 percent of global industrial energy use. The most significant nonmetallic minerals industry is cement production, which accounts for 83 percent of energy use in the nonmetallic minerals sector [*11*]. Although the cement industry in OECD countries has improved energy efficiency over the years by switching from the "wet kiln" production process to the "dry kiln" process, which requires less heat [*12*], energy costs still constitute 40 percent of the total cost of cement production [*13*].

Although OECD countries are beginning to add some additional cement production capacity, the primary growth in cement production over the next few years is expected to be in non-OECD countries. As is the case for steel, the growth in cement production is fueled by growing demand in the construction sector [*14*]. In the coming years, the energy efficiency of cement production is likely to increase as a result of continued improvements in kiln technology, the use of recycled material (such as used tires) as fuel, and increased use of additives to reduce the amount of clinker (the primary ingredient in marketed cement) needed to produce a given amount of cement [*15*].

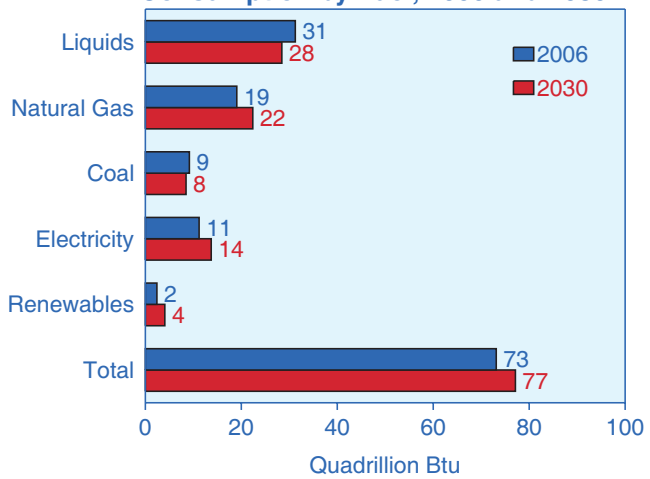
Pulp and paper production accounts for 6 percent of global industrial energy use. Paper manufacturing is an energy-intensive process, but paper mills typically generate about one-half of the energy they use through cogeneration with biomass from wood waste. In some cases, paper mills generate more electricity than they need and are able to sell their excess power back to the grid [*16*]. Because of the widespread use of biomass and the high efficiency of the cogeneration process, a dramatic reduction in the energy intensity of paper output is unlikely in the near future. In addition, total output of the paper industry has declined in recent years as technological substitutes for paper—notably, electronic record keeping and the dissemination of information via the Internet. Although the world's total paper output is unlikely to grow over the projection period, increases in non-OECD demand should slow the decline in the

Figure 66. OECD and Non-OECD Major Steel Producers, 2007



Source: World Steel Association, "World Steel in Figures 2008" (October 2008), web site www.worldsteel.org/pictures/publicationfiles/WSIF%202008%202nd%20edition.pdf.

Figure 67. OECD Industrial Sector Energy Consumption by Fuel, 2006 and 2030



Sources: **2006:** Derived from Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. **2030:** EIA, World Energy Projections Plus (2009).

global paper industry. For example, China recently made the transition from a net exporter to a net importer of paper [*17*].

Production of nonferrous metals, which include aluminum, copper, lead, and zinc, consumed 3 percent of industrial delivered energy in 2006, mostly for aluminum production. Although aluminum is one of the most widely recycled materials on the planet, 70 percent of aluminum still comes from primary production [*18*]. Energy accounts for about 30 percent of the total production cost of primary aluminum manufacturing and is the second most expensive input after alumina ore [*19*]. Lower electricity costs and increased demand have led to substantial growth in aluminum production in non-OECD countries. To guard against electricity outages and fluctuations in electric power prices, many aluminum producers have turned to hydropower, going so far as to locate plants in areas where they can operate captive hydroelectric facilities. For example, Norway, which possesses considerable hydroelectric resources, hosts seven aluminum smelters. Today, more than half of the electricity used to make primary aluminum comes from hydropower [*20*].

Aluminum production from recycled materials uses only one-twentieth of the energy of primary production [*21*]. Although both the aluminum industry and many governments encourage aluminum recycling, it is unlikely that the share of aluminum made from recycled product will increase much in the future, because most aluminum (which is consumed in the construction and manufacturing sectors) is used for long periods of time. Indeed, with three-fourths of the aluminum ever produced still in use [*22*], it is likely that the aluminum industry will continue to consume large amounts of electricity.

Regional Outlook

OECD Countries

In recent decades, OECD countries have been in transition from manufacturing economies to service economies. As a result, in the *IEO2009* reference case, industrial energy use in the OECD countries grow at an average annual rate of only 0.2 percent from 2006 to 2030, as compared with a rate of 1.0 percent per year in the commercial sector, reflecting the shift from industrial interests to service economies. In addition to the shift away from industry, slow growth in OECD industrial energy consumption can be attributed to slow growth in economic output. OECD economies are projected to grow by 2.2 percent per year in the *IEO2009* reference case, compared with 2.8 percent per year projected in the *IEO2008* reference case. Although OECD economies currently account for 59 percent of global economic output (as measured in purchasing power parity terms), their share falls to about 43 percent in 2030.

Higher oil prices in the *IEO2009* reference case lead to changes in the industrial fuel mix of OECD nations (Figure 67). OECD liquids use in the industrial sector is projected to contract by 0.4 percent per year, reducing the share of liquids in industrial energy use from 43 percent in 2006 to 37 percent in 2030. Coal use in the industrial sector also declines, and coal's share of OECD delivered industrial energy use falls from 13 percent to 11 percent, as industrial uses of natural gas, electricity, and renewables expand. Industrial consumption of renewables in the OECD countries grows faster than the use of any other fuel, nearly doubling from 2006 to 2030, but still represents just 5 percent of total OECD industrial energy use in 2030. In the coming decades, industrial fuel use patterns and energy intensity trends in the OECD countries are expected to be determined as much by policies regulating energy use as by economic and technological fundamentals.

Currently, more energy is consumed in the industrial sector in the United States than in any other OECD country, and that continues to be true throughout the *IEO2009* reference case projection. Minimal growth in U.S. industrial energy use is projected, however, averaging 0.2 percent per year and rising from 25.3 quadrillion Btu in 2006 to 26.3 quadrillion Btu in 2030,[34] with the industrial share of total U.S. energy consumption remaining at approximately one-third in 2030. In contrast, U.S. commercial energy use increases at more than five times that rate, reflecting the continued U.S. transition to a service economy. With oil prices rising steadily in the reference case, liquids consumption in the U.S. industrial sector contracts on average by 0.8 percent per year,[35] which is the steepest decline in the OECD. Increasing use of natural-gas-based feedstocks in the U.S. petrochemical sector causes demand for liquids in the industrial sector to be more elastic than it is in OECD Asia or OECD Europe.

The use of renewable fuels in the U.S. industrial sector grows faster than the use of any other energy source in the reference case, increasing its share of the fuel mix from 8 percent in 2006 to 14 percent in 2030.[36] Most of the growth can be attributed to an increase in recycling of

[34] In the *updated AEO2009* reference case (April 2009), the total contracts to 24.9 quadrillion Btu in 2030, largely as a result of slower macroeconomic growth than projected in the *published AEO2009* reference case (March 2009).

[35] In the *updated AEO2009* reference case (April 2009), the rate of contraction is 1.0 percent per year, largely as a result of slower macroeconomic growth than projected in the *published AEO2009* reference case.

[36] In the *updated AEO2009* reference case (April 2009), the share grows to 16 percent in 2030, based on renewable energy measures included in ARRA2009.

waste energy and waste products and to legislation leading to further reductions in the energy intensity of industrial processes. For example, the U.S. Department of Energy supports reductions in energy use through its Industrial Technologies Program, guided by the Energy Policy Act of 2005, which is working toward a 25-percent reduction in the energy intensity of U.S. industrial production by 2017 [*23*]. The Energy Independence and Security Act of 2007 (EISA2007) also addresses energy-intensive industries, providing incentive programs for industries to recover additional waste heat and supporting research, development, and demonstration for efficiency-increasing technologies [*24*].

Industrial energy use in Canada grows at an average rate of 1.1 percent per year in the *IEO2009* reference case, continuing to constitute just under one-half of Canada's total delivered energy use. With world oil prices projected to return to and remain at sustained high levels, liquids use in the industrial sector does not increase from current levels, while natural gas use increases by 1.8 percent per year. As a result, the share of liquids in the industrial fuel mix falls from 37 percent in 2006 to 28 percent in 2030, while the natural gas share increases from 41 percent to 48 percent. As in the United States, Canada's petrochemical sector uses a substantial amount of natural-gas-based feedstocks. In addition, increased production of unconventional liquids (oil sands) in western Canada, which requires a large amount of natural gas, contributes to the projected increase in industrial natural gas use.

Industrial energy efficiency in Canada has been increasing at an average rate of about 1.5 percent per year in recent decades, largely reflecting provisions in Canada's Energy Efficiency Act of 1992 [*25*]. The government recently increased those efforts, releasing the Regulatory Framework for Industrial Greenhouse Gas Emissions in 2007, which calls for a 20-percent reduction in greenhouse gas emissions by 2020. The plan stipulates that industrial enterprises must reduce the emissions intensity of production by 18 percent between 2006 and 2010 and by 2 percent per year thereafter. The proposal exempts "fixed process emissions," from industrial processes in which carbon dioxide is a basic chemical byproduct of production. Therefore, most of the abatement will have to come from increased energy efficiency and fuel switching [*26*].

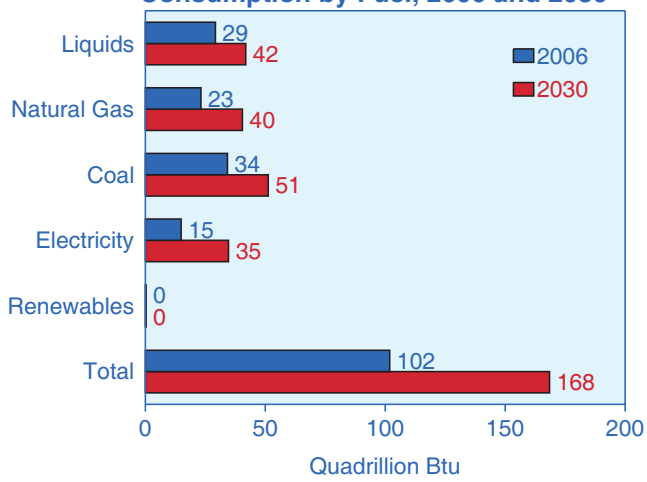
Mexico's GDP grows by 3.4 percent year from 2006 to 2030 in the reference case, which is the highest economic growth rate among all the OECD nations. Mexico also is projected to have the highest average annual rate of growth in industrial energy use, at 1.8 percent per year, with industrial energy use growing to 4.1 quadrillion Btu in 2030 from 2.7 quadrillion Btu in 2006. The country's industrial sector continues to use oil and natural gas for most of its energy needs, and the combined share of liquids and natural gas in the industrial fuel mix remains above 80 percent throughout the projection.

In OECD Europe, GDP grows by 2.0 percent per year and population by 0.2 percent per year from 2006 to 2030 in the *IEO2009* reference case, while industrial energy use increases by 0.1 percent per year. The continuing transition of Europe to a service economy is reflected in the projection for growth in commercial sector energy use, which is nine times the projected growth in industrial energy use.

Energy and environmental policies are a significant factor behind the trends in industrial energy use in OECD Europe. In December 2008, the European Parliament passed the "20-20-20" plan, which stipulated a 20-percent reduction in greenhouse gas emissions, a 20-percent improvement in energy efficiency, and a 20-percent share for renewables in the fuel mix of European Union member countries by 2020 [*27*]. In debates on the plan, representatives of energy-intensive industries voiced concern about the price of carbon allocations. They argued that fully auctioning carbon dioxide permits to heavy industrial enterprises exposed to global competition would simply drive industrial production from Europe and slow carbon abatement efforts at the global level [*28*]. The resulting compromise was an agreement that 100 percent of carbon allowances would be given to heavy industry free of charge, provided that they adhered to efficiency benchmarks [*29*].

The 20-20-20 policy also is expected to affect the mix of fuels consumed in OECD Europe's industrial sector. Industrial coal use contracts at a rate of 1.1 percent per year over the projection period, while both natural gas use and renewables use increase. Industrial sector use of

Figure 68. Non-OECD Industrial Sector Energy Consumption by Fuel, 2006 and 2030



Sources: **2006:** Derived from Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. **2030:** EIA, World Energy Projections Plus (2009).

electric power, increasingly generated from low-carbon sources in OECD Europe, also rises. Liquids use in the industrial sector decreases only slightly, by 0.2 percent per year, because the vast majority of feedstocks in OECD Europe's petrochemical sector are oil-based.

Japan has the slowest projected GDP growth among the OECD regions, at 0.8 percent per year in the *IEO2009* reference case. Consequently, industrial consumption of delivered energy falls by 0.4 percent per year—the only projected decline among the OECD nations. Along with slow economic growth, a major factor behind Japan's slowing industrial energy use is efficiency. Because Japan possesses virtually no domestic energy supplies, it maintained a strategic focus on reducing energy use long before high prices brought energy security to the forefront of global issues. As a result, the energy intensity of Japan's industrial production is among the lowest in the world. Since 1970, Japan has reduced the energy intensity of its manufacturing sector by 50 percent, mostly through efficiency improvements, along with a structural shift toward lighter manufacturing. In 2006, Japan approved a "frontrunner" plan, aimed at improving its national energy efficiency by another 30 percent by 2030 [***30***].

South Korea, which experienced rapid industrial development during the later years of the 20th century, is beginning to make a transition to a service-oriented economy. In the *IEO2009* reference case, South Korea's GDP grows at an average annual rate of 3.3 percent from 2006 to 2030, much faster than the OECD average of 2.2 percent per year. Its industrial energy use grows by just 0.2 percent per year, however, while its commercial energy use grows by nearly 2 percent per year. Accordingly, the industrial share of delivered energy use in South Korea falls from 58 percent in 2006 to 53 percent in 2030.

South Korea currently is the sixth-largest steel producer in the world. A large portion of its steel production already is from electric arc furnaces [***31***], and that portion is projected to grow as inventories of discarded steel build up. As a result, coal consumption in South Korea's industrial sector decreases in the reference case, and electricity is the fastest-growing source of energy for industrial uses.

In Australia and New Zealand, industrial delivered energy consumption grows by 0.8 percent per year in the reference case, from 1.9 quadrillion Btu in 2006 to 2.4 quadrillion Btu in 2030. Industry's share of delivered energy consumption in the region remains steady at slightly less than 50 percent. The implementation of an Australian emissions trading scheme in 2009 is expected to reduce the region's energy use somewhat in the coming decades [***32***]. Liquids consumption in the industrial sector remains flat in the projection as a result of high world oil prices, while the share of coal in the industrial fuel mix increases from 11 percent of delivered energy use in 2006 to 17 percent in 2030, exploiting Australia's abundant coal reserves.

Non-OECD Countries

Non-OECD industrial energy consumption grow at an average annual rate of 2.1 percent in the *IEO2009* reference case—10 times the average for the OECD countries as a whole (Figure 68). The industrial sector accounted for about 60 percent of total non-OECD delivered energy use in 2006 and is expected to continue consuming approximately that share of the total through 2030. With the non-OECD economies projected to expand at an average annual rate of 4.9 percent, their share of global output increases from 41 percent in 2006 to 57 percent in 2030.

The key engines of non-OECD growth in the *IEO2009* projections are the BRIC countries (Brazil, Russia, India, and China), which are expected to account for more than two-thirds of the growth in non-OECD industrial energy use through 2030. China's growth rate in industrial energy consumption, averaging 2.7 percent per year over the period, is higher than projected for any other major economy, and its industrial energy use nearly doubles from 2006 to 2030.

The industrial sector accounted for 76 percent of China's total delivered energy consumption in 2006 and is projected to remain above 70 percent through 2030. Since the beginning of economic reform in 1979, China's GDP has grown by 9.8 percent per year through 2007 [***33***]. The *IEO2009* reference case projects a slower but substantial average growth rate of 6.4 percent per year for China's GDP through 2030, despite a reduction in the 2006-2010 growth projection relative to the *IEO2008* reference case because of the global economic slowdown. With a return to strong growth between 2011 and 2015, China still is expected to account for more than one-fourth of total global GDP growth from 2006 to 2030.

In addition to the impact of strong economic growth on industrial energy demand in China, continued rapid increases in industrial demand can be explained in part by the structure of the Chinese economy. Although the energy intensity of production in individual industries has improved over time, heavy industry accounts for more than 70 percent of China's total output [***34***]. Energy-intensive industries, including steel, cement, and chemicals, provide inputs to China's massive export and construction sectors, which continue to flourish in the *IEO2009* projection. China is expected to construct an additional 65 billion square feet of building space by 2020—equal to Europe's current total building stock [***35***]—contributing to demand for basic materials and increased energy use in the industrial sector.

Government policy contributes as much as to the energy-intensive structure of the Chinese economy as does demand growth. A considerable share of heavy industrial production in China is carried out by large State-Owned Enterprises (SOEs), which are favored by Chinese economic policy. SOEs enjoy relatively easy access to capital through state-owned banks and other forms of government support, such as subsidized energy supplies [***36***]. In some of the first policy initiatives to address the recent economic downturn, China's government extended export tax support, financing, and some direct funding to the steel industry [***37***]. Taken together, those measures and existing government policies support continued expansion of China's industrial energy use in the reference case.

China's industrial fuel mix is projected to change somewhat over the projection period. Despite its abundant coal reserves, direct use of coal in China's industrial sector is grows by an average of only 1.9 percent per year in the reference case, while industrial use of electricity (most of which is coal-fired) grows by 4.6 percent per year. As a result, coal's share in the industrial fuel mix falls from 61 percent in 2006 to 51 percent in 2030, while electricity's share increases from 18 percent to 28 percent.

The vast majority of steel production in China, which accounts for one-third of the country's industrial energy use, employs the coal-intensive blast furnace process. As China's economy matures, however, and a more reliable inventory of scrap steel is developed, much of the steel manufacturing capacity added over the projection period uses the electricity-intensive electric arc furnace process. Additionally, as China continues to expand manufacturing in areas with higher added value, such as consumer electronics and computer components, the share of industries that use electricity instead of primary fuels increases.

Despite focusing primarily on economic development, the Chinese government also has introduced policy initiatives focused on improving industrial energy efficiency. In 2005, China released its 11th Five Year Economic Plan, which included the goal of reducing energy intensity by 20 percent between 2005 and 2010. In support of that goal, China introduced a "Top-1000 Energy-Consuming Enterprises" program, designed to improve the efficiency of the country's 1,000 largest energy consumers, which account one-third of China's total energy use. The program focuses on assisting major energy consumers through benchmarking, energy audits, technological assistance, and stricter reporting [***38***]. In the *IEO2009* reference case, China is projected to achieve a 16-percent reduction in the energy intensity of its GDP between 2005 and 2010, which falls short of the government's goal but still constitutes a substantial improvement. From 2006 to 2030, China's total energy intensity is projected to decline at a rate of 3 percent per year.

In the *IEO2009* reference case, India is projected to sustain the world's second-highest rate of GDP growth, averaging 5.6 percent per year from 2006 to 2030. This translates into a 2.3-percent average annual increase in delivered energy to the industrial sector. Although India is likely to achieve an economic growth rate similar to China's between 2006 and 2030, its levels of GDP and energy consumption continue to be dwarfed by those in China throughout the projection period. India's economic growth over the next 25 years is expected to derive more from light manufacturing and services than from heavy industry, so that the industrial share of total energy consumption falls from 72 percent in 2006 to 64 percent in 2030, and its commercial energy use grows nearly twice as fast as its industrial energy use. The changes are accompanied by shifts in India's industrial fuel mix, with electricity use growing more rapidly than coal use in the industrial sector.

India has been successful in reducing the energy intensity of its industrial production over the past 20 years. A majority of its steel production is from electric arc furnaces, and most of its cement production uses dry kiln technology [***39***]. A major reason is the Indian government's public policy, which provides subsidized fuel to citizens and farmers but requires industry to pay higher prices for fuel. Because the market interventions have spurred industry to reduce energy costs, India is now one of the world's lowest cost producers of both aluminum and steel [***40***]. The quality of India's indigenous coal supplies also has contributed to the steel industry's efforts to reduce its energy use. India's metallurgical coal (which is needed for steel production in blast furnaces) is low in quality, forcing steel producers to import more expensive metallurgical coal from abroad [***41***]. As a result, producers have invested heavily in improving the efficiency of their capital stock to lower the amount of relatively expensive imported coal used in the production process.

The Indian government has facilitated further reductions in industrial energy use over the past decade by mandating industrial energy audits in the Energy Conservation Act of 2001 and mandating specific consumption decreases for heavy industry as part of the 2008 National Action Plan on Climate Change. The new plan also calls for fiscal and tax incentives for efficiency, an energy-efficiency financing platform, and a trading market for energy savings certificates, wherein firms that exceed their required savings level will be able to sell the certificates to firms that have not [***42***]. Those measures contribute to a reduction in the energy intensity of India's GDP, which declines by an average of 2.9 percent per year from 2006 to 2030 in the *IEO2009* reference case.

In Russia, industrial energy consumption patterns are shaped largely by its role as a major energy producer. Russia's economy is projected to grow at a rate of 3.6 percent per year, with industrial energy demand growing by 0.9 percent per year and accounting for about 54 percent of the nation's total energy use throughout the reference case projection. The energy intensity of Russia's GDP is the highest in the world, and although its energy intensity declines in the reference case projection, Russia remains among the least energy-efficient economies in the world through 2030. The relative inefficiency of Russian industry can be attributed to Soviet-era capital stock and abundant and inexpensive domestic energy supplies. In the reference case, the share of natural gas, Russia's most abundant domestic fuel, in the country's industrial fuel mix increases, as does the share of electricity, most of which is provided by natural-gas-fired generation.

Brazil's industrial energy use grow at an average rate of 2.1 percent per year in the *IEO2009* reference case, as its GDP expands by 3.8 percent per year. Although continued growth in industrial output is expected through 2030, the Brazilian economy begins to move toward a service-based economy. The share of industry in total delivered energy use is projected to fall from 49 percent in 2006 to 45 percent in 2030, while the rate of growth for energy use in the commercial sector is projected double the rate in the industrial sector. Unlike most countries and regions, coal use in Brazil's industrial sector is projected to expand more rapidly than the use of any other fuel, primarily because of its burgeoning steel industry, which has become a significant global producer in recent years, based on plentiful domestic supplies of iron ore and increasing global demand for steel [***43***].

Industrial energy use in the Middle East grows on average by 2.1 percent per year from 2006 to 2030 in the *IEO2009* reference case. In terms of energy consumption, the largest industry in the Middle East is the chemical sector. Higher world prices for oil and natural gas have spurred new investment in the petrochemical sector, where companies can rely on low-cost feedstocks. Numerous "mega" petrochemical projects currently are under construction in Saudi Arabia, Qatar, Kuwait, the UAE, and Iran [***44***]. The Middle East is becoming a major manufacturer of the olefin building blocks that constitute a large share of global petrochemical output, and the region's ethylene production capacity is expected to double between 2008 and 2012 [***45***]. Liquids and natural gas are projected to maintain a combined 95-percent share of the Middle East's industrial fuel mix through 2030 in the reference case.

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