CHAPTER 13

Industry

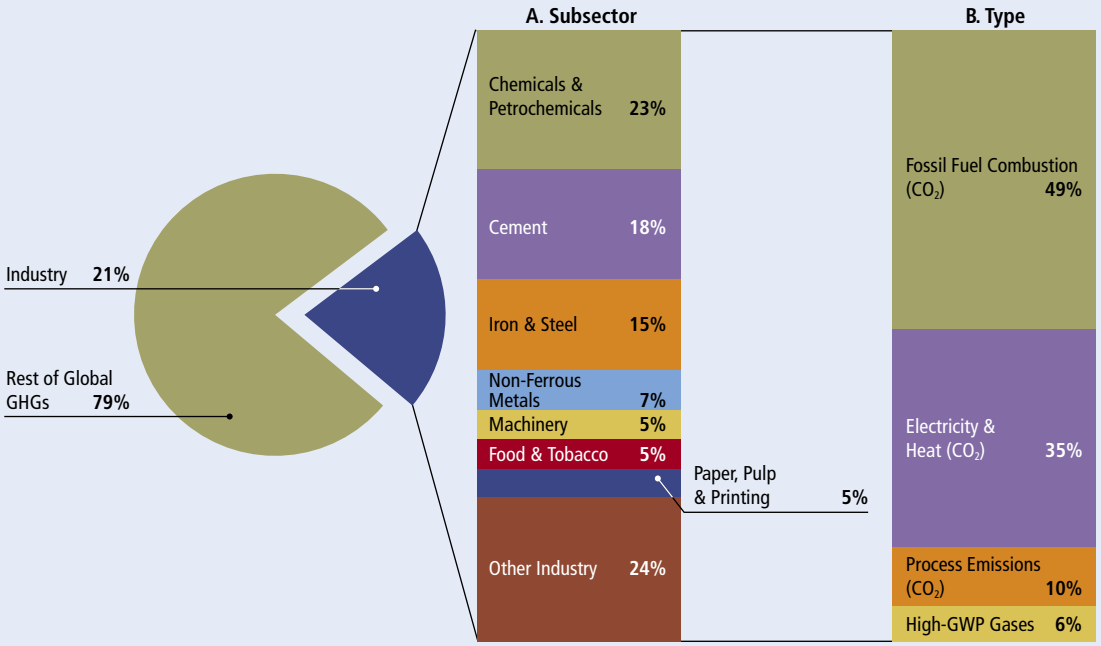
Emissions

GHG emissions associated with manufacturing and construction industries[125] represent approximately 21 percent of world GHG emissions (Figure 13.1). This figure includes direct fossil fuel combustion (49 percent), indirect CO_2 emissions from electricity and heat consumption (35 percent), and CO_2 and non-CO_2 emissions from industrial processes (16 percent). Within the industry sector, (1) chemicals and petrochemicals (23 percent), (2) cement (18 percent), and (3) iron and steel (15 percent) account for the largest shares of sector-wide emissions.

Figure 13.3 shows industry-related CO_2 emissions of the top emitting countries, in both absolute and per capita terms. Together, these countries account for 85 percent of global emissions from this sector, with the five largest emitters accounting for 62 percent of the global total. This sector is unusual in that a majority of global emissions come from developing countries, with China having the largest share (22 percent). However, in per capita terms, industrialized country emissions are still four times higher than developing countries.

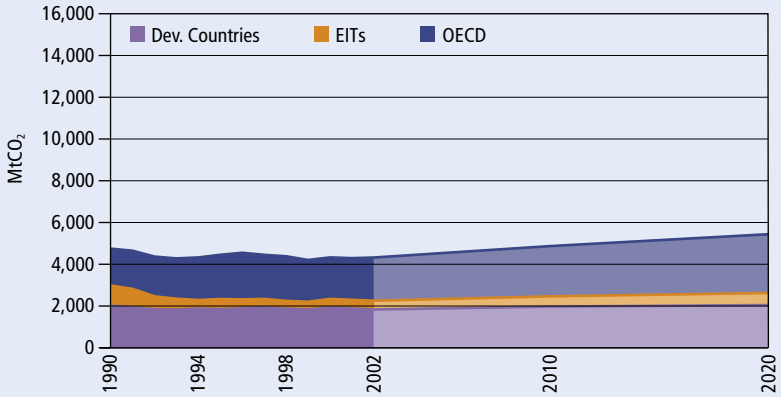
In terms of trends, this sector has declined as a relative share of many countries' national emissions totals since 1990, as evidenced by the relatively modest growth rates, some of which are negative. Industry emissions have declined since 1990 in Mexico (-26 percent), Russia (-22 percent), Australia (-18 percent), EU-25 (-15 percent), and the U.S. (-10 percent). Growth has been significant in India, China, Brazil, and South Korea, but slower than in other major sectors (Figure 13.4).

Figure 13.1. GHGs from Industry



Sources & Notes: CAIT, IEA, 2004a, Hendriks, 1999. See Appendix 2.A for sources and Appendix 2.B for sector definition. Absolute emissions in this sector, estimated here for 2000, are 8,856 $MtCO_2$.

Figure 13.2. GHGs from Industry, Trends and Projections

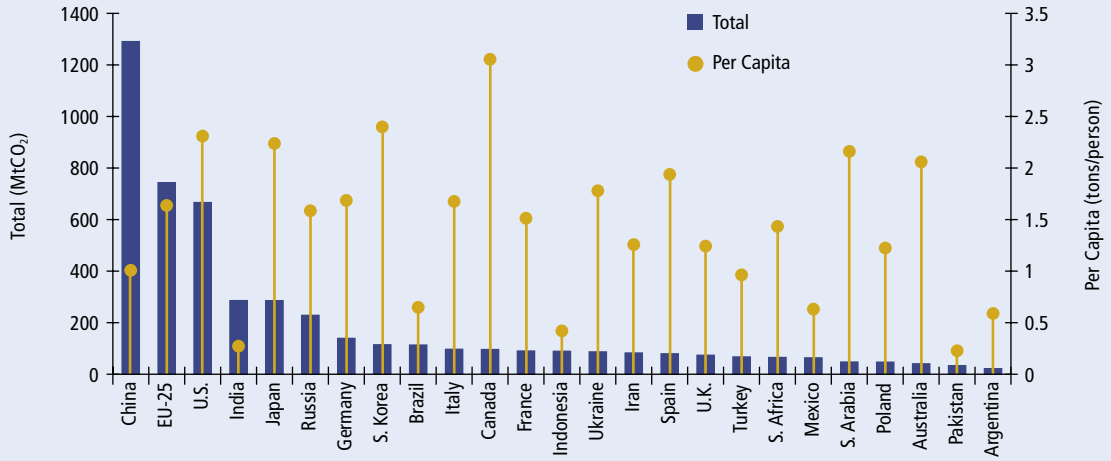


Source: IEA, 2004b,c.

Sector Context

The industry sector is notable for the sheer diversity of activities, processes, and technologies. This is a sharp contrast to electricity and heat, where the end product is homogeneous, and transport, where the technologies are relatively uniform. In addition to chemicals, cement, steel, and aluminum (which are discussed in more detail below), other significant contributors to industry emissions include food and tobacco, pulp and paper, and machinery. Naturally, given the lack of uniformity in the manufacturing and industry sector, there are a large number of diverse actors operating in a multitude of regulatory contexts.

Figure 13.3. CO_2 from Industry, Total and Per Capita, 2002
Top 25 GHG emitters



Sources & Notes: WRI, based on IEA, 2004a and CAIT. CO_2 emissions are from direct fossil fuel combustion and cement manufacture. Emissions from public electricity and heat are not included here.

The industry sector is also characterized by a high degree of trade and international competition. Manufactured goods account for 75 percent of all global trade.[126] And while developed and developing countries have large disparities in consumption patterns, described throughout this report, they often are competitive in key industrial sectors. As the emission trends suggest, the industrial sectors of many developed countries have been in decline, with gradual loss of output and employment (substituted by service sector growth). Greater detail is provided below for specific industry subsectors. Not coincidentally, manufacturing output has risen more significantly in developing countries, with particularly astonishing growth in China.

Figure 13.4. Direct CO_2 Emissions from Industry

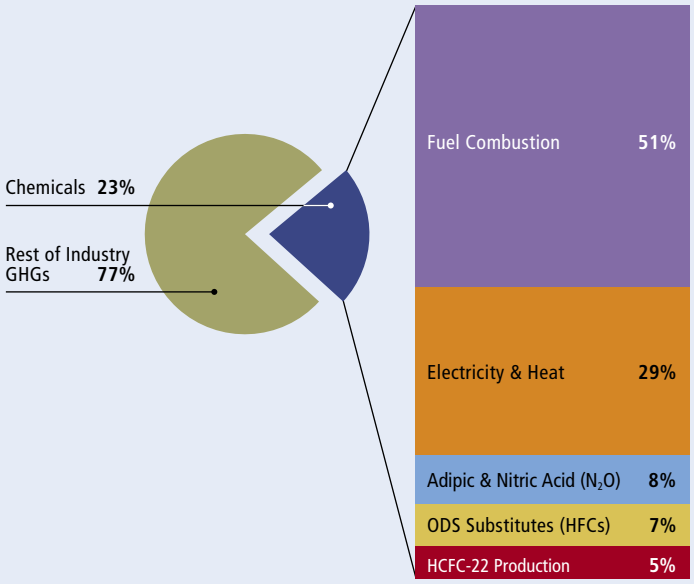
		% Change	
Country	**% of World 2002**	**1990–2002**	**Projected 2002–2020***
China	24.7	21	22
EU-25	14.2	-15	4
United States	12.8	-10	12
India	5.5	49	65
Japan	5.5	2	–
Russia	4.4	-19	44
South Korea	2.2	77	–
Brazil	2.2	61	65
Canada	1.8	3	–
Indonesia	1.7	152	54
Mexico	1.2	-26	49
Australia	0.8	-18	21
World	**100.0**	**18**	**26**

Notes: This table combines IPCC Source/Sink Categories 1A2 (manufacturing & construction) and 2 (industrial processes). Growth rates for Russia are from 1992 (not 1990). *Projections are drawn from IEA (2004c) and include only CO_2 from fossil fuels. The projected figure for U.S. includes Canada; Australia includes New Zealand. "–" signifies no data.

SECTOR SPOTLIGHT: *Chemicals and Petrochemicals*

Chemical manufacture is the second largest energy-consuming manufacturing sector in the world,[127] and accounts for almost 5 percent of global GHG emissions (Figure 13.5). The most notable attribute of the chemicals sector is the diversity of products and production processes. As defined here, this industry includes fertilizers, pesticides, pharmaceuticals, plastics, resins, synthetic rubber, refrigerants, paints, solvents, soaps, perfumes, and synthetic fibers, as well as chemicals derived from fossil fuels, such as ethylene, propylene, and butylene.[128] GHG emissions in the chemicals sector pertain to the direct production and use of chemicals, and include direct (on-site) CO_2 emissions from fossil fuel combustion, indirect emissions from electricity consumed during production, and release of non-CO_2 gases from various industrial processes. Emissions pertaining to some chemicals may derive more from use than manufacture (e.g., HFCs).

Figure 13.5. GHGs from Chemicals and Petrochemicals



Sources & Notes: CAIT, IEA, 2004a,b. See Appendix 2.A for sources and Appendix 2.B for subsector definition. Absolute emissions in this subsector, estimated here for 2000, are 2,013 $MtCO_2$.

Chemical production is highly concentrated geographically, with the EU-25, United States, Japan, and China accounting for three-quarters of global chemical production (Figure 13.6). Corporate presence is also geographically concentrated (Figure 13.7). Of the 30 largest chemical companies, all but two are headquartered in the EU, United States, or Japan.[129]

However, because of the diversity of products, there is overall a low concentration of actors in this subsector. The 15 leading chemical companies worldwide shown in Figure 13.7 account for less than 20 percent of global sales, and often operate in very different markets, such as pharmaceuticals, petrochemicals, and basic and consumer chemicals. Small and medium-size enterprises, which may have a single facility producing a single product, are common. The EU, for instance, has 31,000 chemical enterprises, 96 percent of which have fewer than 250 employees.[130]

Some companies shown are amongst the largest in the world. German companies BASF and Bayer have operations in 74 and 61 countries, respectively, while U.S.-based Dow Chemical and Dupont each operate in 32 countries.[131] Accordingly, there is considerable cross-border investment in this sector, in part by large transnational corporations. Overall foreign direct investment in chemicals in 2002 reached $420 billion, more than a doubling since 1990, and a 20 percent share of FDI in manufacturing (the largest sector).[132] Almost 100 percent of this investment came from industrialized countries, which were also recipients of 80 percent of this investment.[133]

The international trade in chemicals has increased steadily over the past two decades, with double digit annual

Figure 13.6. Chemical Production, 2004

Country	% of World
EU-25	33.0
United States	23.4
Japan	10.4
Asia, excl. Japan & China	10.3
China	7.7
Brazil	2.7
Switzerland	2.1
Canada	1.6
Mexico	0.8
Rest of World	7.9

Sources & Notes: CEFIC, 2005. World market shares are based on value of sales, including domestic and exports. Data for Mexico is for 2003.

growth rates.[134] An estimated 30 percent of chemical production is traded across borders.[135] In 2003, chemicals constituted about 15 percent of all manufacturing exports, with a world trade value of about $800 billion (about 40 percent of which is intra-Europe).[136] Because of the diversity of products, many countries are both significant importers and exporters.

The largest importers are the U.S. (13 percent of world total), EU-15 (11 percent), and China (6 percent).[137] The largest exporters are the EU-15 (22 percent), U.S. (12 percent), Japan (5 percent), and Switzerland (4 percent).[138] Trade raises some challenges related to attribution of emissions, as chemicals traded may already have undergone GHG-intensive production processes prior to export.

Figure 13.7. Leading Chemical Companies, 2003

Company	Sales ($US billions)	Country of Origin
Pfizer	52.5	United States
GlaxoSmithKline	39.0	UK
BASF	37.7	Germany
Dow Chemical	32.6	United States
Bayer	32.3	Germany
Merck	30.9	U.S. / Germany
Novartis AG	28.2	Switzerland
DuPont	27.0	United States
AstraZeneca	21.4	UK
Shell	20.8	UK/Netherlands
ExxonMobil	20.2	United States
Total/Arkema	20.2	France
Mitsubishi Chemical	16.6	Japan
BP	15.5	UK
Akzo Nobel	14.7	Netherlands

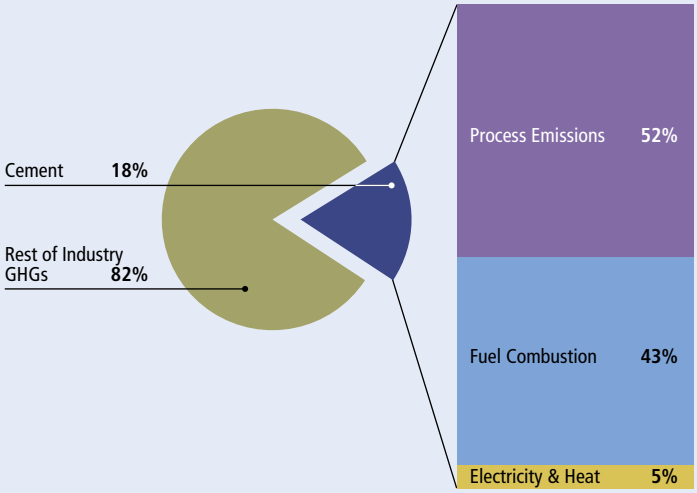
Sources & Notes: CEFIC, 2005; company reports; http://www.hoovers.com. Sales data for Pfizer, Glaxo, Merk, Novartis, and AstraZenica is from 2004.

SECTOR SPOTLIGHT: *Cement*

GHG emissions associated with cement manufacturing account for approximately 3.8 percent of global GHG emissions, and 5 percent of global CO_2. Cement amounts to about 18 percent of all manufacturing emissions, with CO_2 emitted at a variety of points in the production process, including (1) the chemical process of making clinker (a key component of cement); (2) the direct, on-site burning of fossil fuels; and (3) indirect emissions from electricity consumed during the cement production process (Figure 13.8). Although the energy-related emissions depend on the fuels used (both for direct energy use and electricity purchases), chemical process emissions do not. Generally about half of cement emissions come from the chemical process and 40 percent come from direct fossil fuel combustion, with the remainder coming from electricity purchases and on-site transport.[139]

Collectively, the top 12 cement-producing countries account for about 81 percent of the world total (Figure 13.9). China is by far the largest producer, accounting for 43 percent of the world total in 2004. In Europe, Japan, and Australia, cement production (and

Figure 13.8. GHGs from Cement Manufacture



Sources & Notes: CAIT, IEA, 2004a. See Appendix 2.A for sources and Appendix 2.B for subsector definition. Absolute emissions in this subsector, estimated here for 2000, are 1,588 $MtCO_2$.

Figure 13.9. Cement Manufacture, 2004

Country	Production (mil. tons)	% of World	% change since 1999
China	850	42.5	48
EU-25	214	10.7	-3
India	110	5.5	22
United States	97	4.8	10
Japan	69	3.5	-14
South Korea	60	3.0	25
Russia	46	2.3	62
Brazil	38	1.9	-6
Egypt	35	1.8	50
Mexico	35	1.8	19
Thailand	35	1.8	38
Turkey	34	1.7	-1
World	**2,000**		**25**

Sources & Notes: USGS, 2004; USGS, 2005. Individual EU member states not shown. Countries not among the top 25 absolute emitters are shown in italics.

Figure 13.10. Leading Cement Companies, 2003

Company	World Market Share (%)	Country of Origin
Lafarge	5.5	France
Holcim	5.0	Swizerland
Cemex	4.3	Mexico
HeidelbergCement	2.5	Germany
Italcementi	2.1	Italy
Taiheiyo	1.6	Japan

Source: Freedonia Group, 2004a.

related emissions) is stagnant or declining. The fastest growth is in East and South Asia. Cement emissions in the U.S. and Middle East are also rising significantly.

The cement sector employs a limited set of production processes and produces a limited range of products. Production processes range from "wet" to "dry" with intermediate variations, characterized by the amount of moisture content used during blending.[140] The main ingredient in cement is clinker—derived from limestone, iron oxide, silicon dioxide and aluminum oxide—and cement products are distinguished by the ratio of clinker to other additives.[141]

In terms of international exposure, the cement sector is mixed. Cement is not conducive to international trade, given the abundance of limestone and other primary materials, along with the high density and low value of cement. Less than 6 percent of global cement production is exported across borders;[142] accordingly, emissions attribution presents little difficulty.

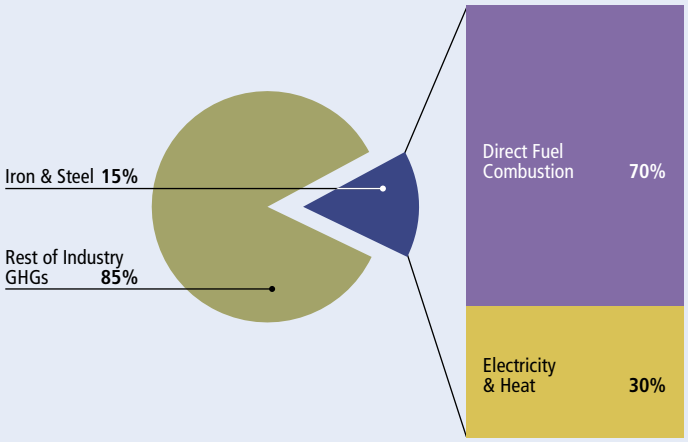
However, cross-border investment in the cement sector is significant and growing. In particular, the sector is increasingly characterized by the presence of large, multinational firms. The growth of multinationals and foreign direct investment is also leading to a gradual increase in concentration of actors in the sector. Figure 13.10 shows the leading cement manufacturing companies. The six leading multinational companies account for an estimated 21 percent of global cement production.[143] LaFarge and Holcim, the two largest, operate in 75 and 70 countries, respectively. Factoring in China (about 43 percent of global cement production) and some other developing countries, however, suggests a sector with a much lower degree of concentration of actors. China has some 5,000 cement manufacturing facilities, many of which are rural township enterprises with low production levels.[144] There are nevertheless trends toward more private ownership, foreign investment, and consolidation, including the development of large Chinese cement conglomerates.[145]

Collectively, the top 12 cement-producing countries account for about 81 percent of the world total. China is by far the largest producer, accounting for 43 percent of the world total in 2004.

The iron and steel industry is the largest energy-consuming industry sector in the world.[146] CO_2 is emitted at a variety of points in the steel-making process, including the on-site combustion of fuels and indirect emissions from electricity and heat consumed during the production process. Taking all emissions into account, iron and steel accounts for an estimated 4.1 percent of total world CO_2 emissions, and about 3.2 percent of all GHGs.[147] Steel amounts to about 15 percent of all manufacturing emissions, with about 70 percent of emissions coming from direct fuel use and the remaining coming indirectly from electricity and heat (Figure 13.11).

Steel production techniques do not vary widely globally, and are now dominated by only two processes: integrated steel mills that use either a blast furnace-open hearth or blast furnace/basic oxygen furnace, and mini-mills that use scrap in electric arc furnaces.[148] However, there are a range of steel products, including ingots, semi-finished products, hot-rolled and cold-finished products, tubes, wire, and unworked castings and forgings, which have a wide variety of manufacturing and construction applications.

Figure 13.11. CO_2 from Iron and Steel



Sources & Notes: IEA, 2004a,b. See Appendix 2.A for sources and Appendix 2.B for subsector definition. Absolute emissions in this subsector, estimated here for 2000, are 1,319 $MtCO_2$.

Figure 13.12 presents steel production data for the leading countries. The 12 countries shown represent 90 percent of the worldwide totals. China, EU-25, and Japan are the three largest steel producers (55 percent of the global total). China's steel sector has grown at about 25 percent annually over the past few years[149] and, according to the Chinese Iron and Steel Association, is facing overinvestment and potential excess capacity.[150] Crude steel capacity, as well as production, has more than doubled since 2001 in China.[151]

In terms of both trade and investment, the iron and steel sector has gradually become more internationalized over the past few decades. Figure 13.13 lists the world's leading steel companies, ranked by production. Newly formed Mittal Steel, the world's most global steel producer, has steel-making capacity in 14 countries,

including South Africa, Algeria, Kazakhstan, Trinidad and Tobago, as well as North America and Europe.[152] Other companies, such as Nippon Steel, POSCO, and most Chinese companies, do not have overseas production operations, and instead rely on trade to disseminate their products. Collectively, the top 25 steel-making companies account for roughly 42 percent of global production in 2004.[153] While the sector is characterized by many large companies, there are also a large number of small steel producers.[154]

The share of steel traded across international borders has increased steadily from 22 percent in the mid-1970s to about 37 percent in 2003.[155] This amounts to a trade product value of about $180 billion, or 2.5 percent of all global trade.[156] The largest net steel importers in 2003 were China and the U.S., at about 11 and 4 percent of world steel trade, respectively.[157] The largest exporters were Japan, Russia, and Ukraine, which accounted for 8 to 9 percent each.[158] The volume of steel trade, however, is expected to decline globally in 2005 and beyond, largely due to new production capacity located near consumption centers.[159] Chinese steel imports, in particular, have declined significantly since 2003, due to expanded domestic capacity. The steel industry's trade volume raises some difficulties in attributing emissions to specific countries, since exported products embody significant amounts of CO_2 emissions.

Figure 13.12. Steel Production, 2004

Country	Production (mil. tons)	% of World	% change since 1999
China	273	25.8	120
EU-25	193	18.3	10
Japan	113	10.7	21
United States	99	9.4	2
Russia	66	6.2	27
South Korea	48	4.5	16
Ukraine	39	3.7	41
Brazil	33	3.1	32
India	33	3.1	34
Turkey	21	1.9	43
Mexico	17	1.6	9
Canada	16	1.5	1
World	**1,057**		**34**

Sources & Notes: IISI, 2004; IISI, 2005. Individual EU member states not shown.

Figure 13.13. Leading Steel Companies, 2004

Company	Production (mil. tons)	% of World	Country of Origin
Arcelor	47	4.4	Luxembourg
Mittal	43	4.1	U.K., Netherlands
Nippon Steel	32	3.1	Japan
JFE	32	3.0	Japan
POSCO	30	2.9	South Korea
Shanghai Baosteel	21	2.0	China
US Steel	21	2.0	United States
Corus Group	19	1.8	United Kingdom
Nucor	18	1.7	United States
ThyssenKrupp	18	1.7	Italy
Riva Acciao	17	1.6	Italy
Int.'l Steel Group	16	1.5	United States
Gerdau	15	1.4	Brazil
Sumitomo	13	1.2	Japan
EvrazHolding	12	1.2	Russia

Source: IISI, 2005.

SECTOR SPOTLIGHT: *Aluminum*

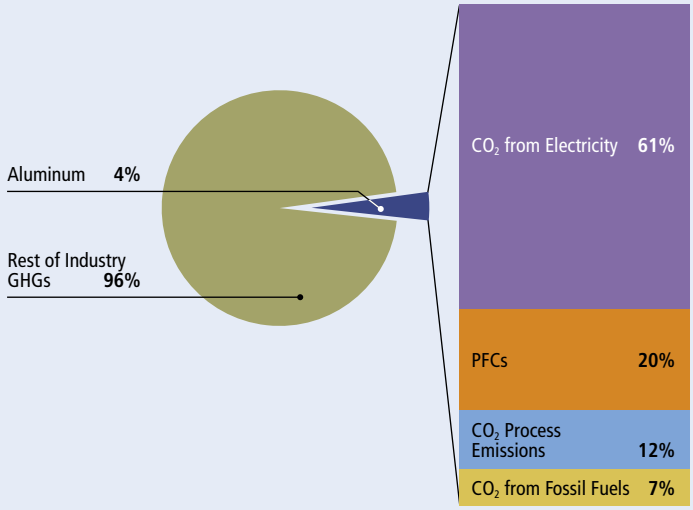
GHG emissions associated with aluminum production account for approximately 0.8 percent of global GHG emissions, which amounts to about 4 percent of all manufacturing emissions.[160] Greenhouse gases are emitted at a variety of points in the production process, including (1) fossil fuel use in the refining of bauxite (the raw material input used to produce alumina); (2) electricity consumption in the smelting process (where alumina is reduced to aluminum metal); (3) and PFC and CO_2 emissions due to chemical processes in the smelting process (Figure 13.14). Additional emissions, not factored in here, may arise from the mining of bauxite and production of a diverse array of final aluminum products, such as foils, cans, construction materials, and automotive components.[161]

Aluminum production processes and technologies do not vary widely. Most of the emissions occur in the smelting process, which requires large amounts of electricity—typically about 15,000 kilowatt hours per ton of metal produced.[162] This collectively amounts to about 2.4 percent of global electricity consumption.[163] There are only two basic smelting technologies—Söderberg and pre-bake. The phasing in of newer technologies that are variants of the pre-bake technology (Point Fed and Centre Worked Prebake plants, which now predominate) results in substantial reductions in PFC emissions.[164]

Secondary aluminum production from recycled scrap aluminum fills some 40 percent of global aluminum demand.[165] By re-melting aluminum scrap, GHG emissions are reduced more than 95 percent relative to primary aluminum production.

Like many other commodities and manufactured goods, production is dominated by a small number of countries, with 12 countries representing 82 percent of global production (Figure 13.15). China, Russia, EU-25, Canada, and the United States account

Figure 13.14. GHGs from Aluminum Manufacture



Sources & Notes: IEA, 2004a,b. See Appendix 2.A for data sources Appendix 2.B for subsector definition. Absolute emissions in this subsector, estimated here for 2000, are 324 $MtCO_2$.

Figure 13.15. Aluminum Production, 2004

Country	Production (1,000 tons)	% of World	% change since 1999
China	6,100	21.1	141
Russia	3,600	12.5	14
EU-25	2,851	9.9	4
Canada	2,640	9.1	10
United States	2,500	8.7	-34
Australia	1,880	6.5	9
Brazil	1,450	5.0	16
Norway	1,250	4.3	23
South Africa	820	2.8	19
Venezuela	600	2.1	5
World	**28,900**		**22**

Sources & Notes: USGS, 2004; USGS, 2005. EU data is based on 2003 figures. Countries not among the top 25 absolute emitters are shown in italics.

for 61 percent of total production. More than other commodities, however, aluminum production is dominated by a small number of companies, mostly multinationals. The ten leading companies produce 55 percent of the world's aluminum, with Alcan, Alcoa, and Rusal constituting one-third of global production (Figure 13.16). The 26 companies that comprise the International Aluminium Institute collectively account for 80 percent of global production.[166]

The aluminum sector is perhaps the most internationalized industry sector, in terms of both trade and investment. An estimated 45 percent of global production is exported as unwrought aluminum, with significant additional trade volumes for aluminum products.[167] The top two manufacturers, Alcan and Alcoa, each operate in more than 25 countries and have a majority of their employees working outside their home countries.[168] The international character of the aluminum sector, along with the strong concentration of multinational corporate actors, may contribute to the fact that this sector has already adopted voluntary climate change targets (Box 13.1).

Figure 13.16. Leading Aluminum Companies, 2004

Company	Primary Aluminum (1,000 tons)	% of World	Country of Origin
Alcan	3,382	11.7	Canada
Alcoa	3,376	11.7	United States
Rusal	2,671	9.2	Russia
Norsk Hydro	1,720	6.0	Norway
BHP Billiton	1,260	4.4	Netherlands
SUAL Holding	920	3.2	Russia
Comalco	837	2.9	United Kingdom
Chinalco	761	2.6	China
Dubai Alum. Co.	540	1.9	UAE
Aluminium Bahrain	525	1.8	Bahrain

Sources & Notes: Data obtained from company annual reports and websites. Alcan includes Picheney. Comalco is a division of Rio Tinto. Figures for Aluminium Bahrain are for 2003 and are derived from USGS estimates. Rusal is the Russian Aluminium Joint Stock Co. Chinalco is the Aluminum Corp. of China Ltd.

Box 13.1. The Global Aluminum Climate Change Initiative

The International Aluminium Institute (IAI) has developed a voluntary initiative on key issues related to sustainability, including climate change. The initiative is global in scope, covering IAI's 26 member companies, which collectively account for 80 percent of global primary aluminum production.

Key climate change targets include an 80 percent reduction in PFC emissions per ton of aluminum produced and a 10 percent reduction in smelting energy usage per ton of aluminum produced. Both targets apply to the industry as a whole and are to be reached by 2010 (using a 1990 base year). The IAI has a team of experts that advise and assist member companies, as well as report on the overall results.

For several reasons, this sector is unique in positioning itself at the global level to play a leadership role in climate protection. First, technological options are available to substantially reduce PFC emissions. IAI surveys show that participants have already reduced PFC emissions per unit of production in 2003 by 73 percent compared to 1990 levels. Second, aluminum is conducive to recycling, which avoids 95 percent of emissions compared to primary manufacture. Indeed, most aluminum ever produced is still in use, as the metal can be recycled and re-used continuously without deterioration in quality. Third, aluminum can replace higher density materials in transport, leading to energy efficiency improvements (and CO_2 reductions) through lighter-weight vehicles. As part of its sustainability initiative, the industry will monitor aluminum shipments for use in the transport sector. The IAI believes it is possible that aluminum will become "climate-change positive" in 20 years on a life-cycle basis.

Sources: International Aluminium Institute, 2004, 2005a,c.