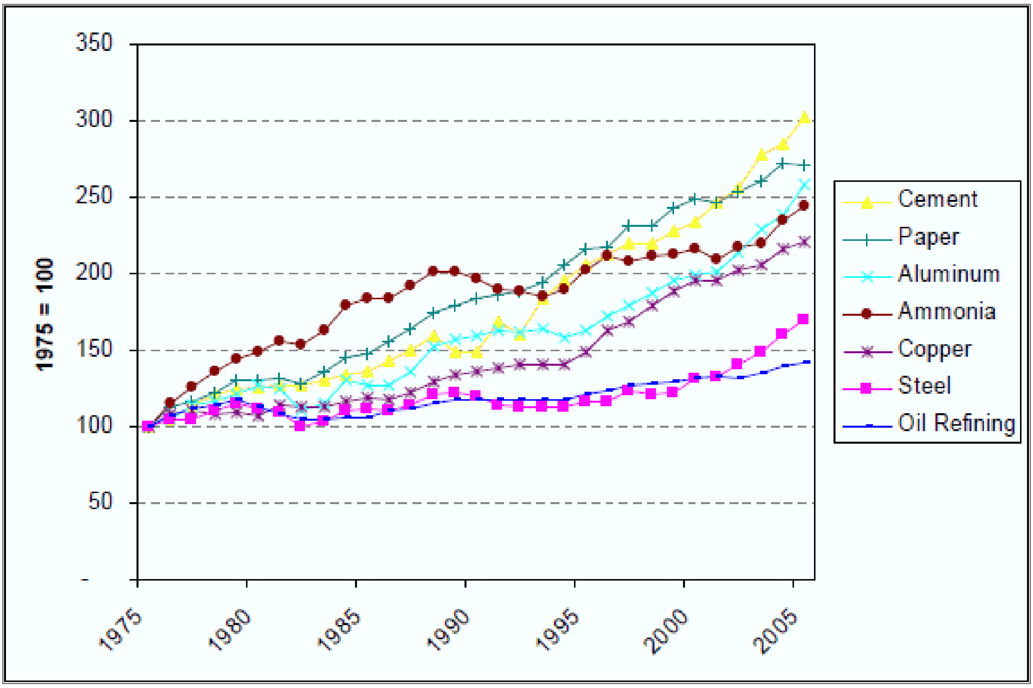
© Joerg Boethling / Still Pictures

Irrigating Caribbean Pine saplings at sawmill for pencil production from FSC wood. Brazil.

4. Basic Industry

The industrial sector of the global economy uses some 160 exajoules (EJ) of global primary energy, equivalent to 37 percent of total energy use worldwide.[506] Industries producing basic materials—iron and steel, chemicals, cement, aluminum, and pulp and paper—are among the most energy-intensive industries. North America, Europe, and Japan (as well as South Korea more recently) have long been dominant in these sectors. But during the past decade or so, major changes have occurred. In particular, China has dramatically increased its output, serving not only a fast-growing domestic market but also export markets, and pushing global production up considerably.[507] (See Figure II.4-1.)

Figure II.4-1. Global Production of Seven Energy-Intensive Industrial Commodties, 1975–2005



Source: See Endnote 507 for this section.

It may be difficult to regard these heavy industries as "green." However, reducing their environmental impact, and especially their carbon footprint, is a critical task. We can think of such efforts in terms of the shades-of-green approach. (Another aspect not discussed here is that polluting factories are often located near poor communities that have little influence over such matters, and thus often suffer the deleterious health effects. The so-called "cancer alley"—a concentration of chemical factories in the U.S. state of Louisiana—comes to mind. Greening these industries needs to embrace not only questions of decent employment, but also environmental justice.)

Energy-intensive products like steel, aluminum, cement, and paper are the lifeblood of modern societies. Short of foregoing some of the services and conveniences that these items offer, boosting energy and materials efficiency, curtailing pollution, and enhancing use of scrap for recycling are key to bringing these industries' environmental footprints more into balance with environmental needs.

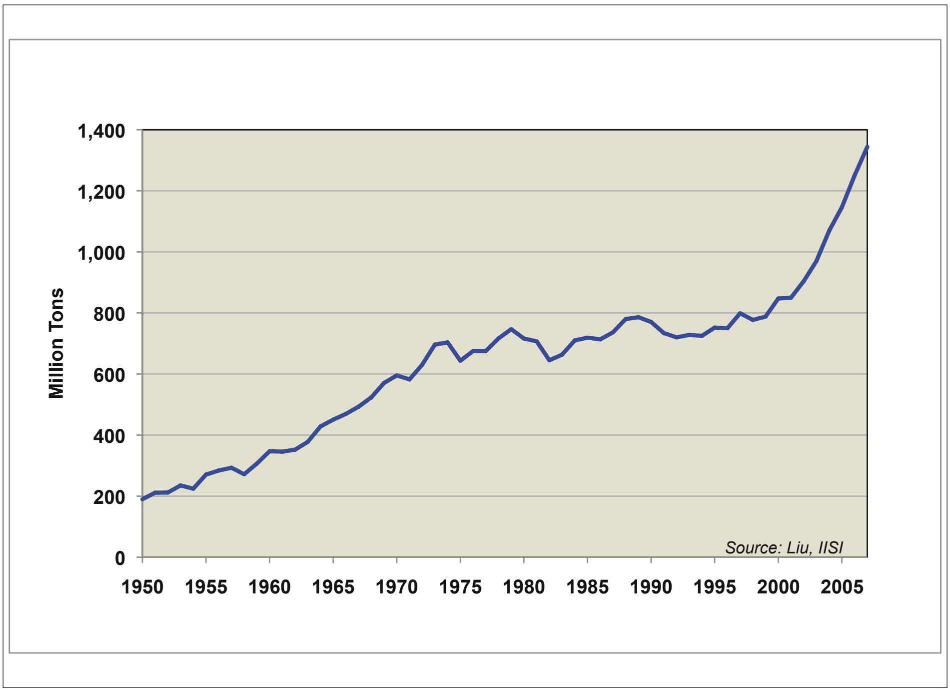
Using secondary materials offers substantial energy savings relative to producing them from scratch. The energy savings for different materials are as follows: aluminum (95 percent), copper (85 percent), plastics (80 percent), steel (74 percent), lead (65 percent), and paper (64 percent). Producing steel from recycled scrap reduced air pollution by 86 percent. Producing paper from recycled stock instead of virgin pulp reduces water pollution by 35 percent and air pollution by 74 percent.[508]

The following analysis of selected industries offers a sketch of efforts to green these industries, and the implications for green employment.

Iron and Steel

World steel production is rising steeply, reaching more than 1.3 billion tons in 2007. This is 71 percent higher than in 1999, when the current expansion started. Following a long post-World War II expansion, output had leveled off at a range of 650 to 750 million tons between the early 1970s and late 1990s.[509] (See Figure II.4-2.)

Figure II.4-2. World Steel Production, 1950–2007

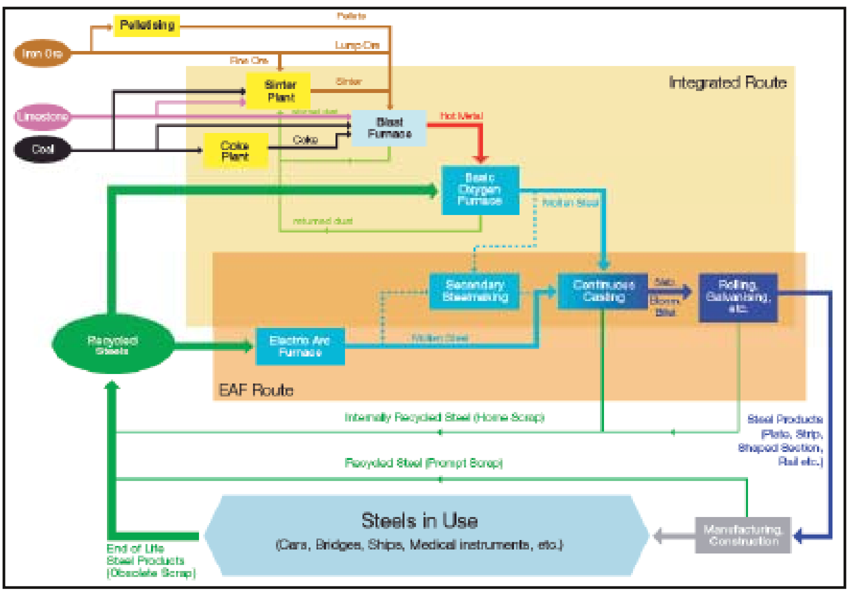


China's steamroller economy is the major engine behind soaring global production, but Asia in general has been the most dynamic steel-producing region during the past decade. Boosting its production from 66 million tons in 1990 to 489 million tons in 2007, China became the leading producer in 1996. It is followed at a considerable distance by Japan (120 million tons), the United States (98 million), Russia (72 million), India (53 million), South Korea (51 million), and Germany (49 million). The 27 member states of the European Union combined produced 210 million tons in 2007.[510] In 2006, China overtook Japan, Russia, and the European Union to become the largest steel exporter.[511]

Steelmaking is a highly energy-intensive process. Because the industry consumes large volumes of coal, it emits a significant amount of carbon dioxide (CO_2). According to statistics compiled by the International Energy Agency (IEA), total final energy use by the iron and steel industry was 21.4 EJ in 2004, or about 20.2 gigajoules per ton (GJ/t) of steel.[512] On average, producing one ton of primary steel results in emissions of about two tons of CO_2. Altogether, steelmaking accounts for 5–6 percent of anthropogenic CO_2 emissions, and 27 percent of the total emissions of the world's manufacturing sector.[513] (The International Iron and Steel Institute, IISI, reports slightly different figures—average energy intensity of 19.1 GJ per ton of crude steel produced, and 1.7 tons of CO_2 emitted per ton produced.[514])

Steel is produced by two main methods.[515] (See Figure II.4-3.) Blast furnaces and basic oxygen furnaces use iron ore, coal, and limestone, as well as recycled steel. Electric arc furnaces use primarily recycled scrap iron and steel, and electricity. Blast furnaces account for about two-thirds of world steel production (but about 90 percent of CO_2 emissions), and electric arc furnaces for about one-third. Outdated and highly polluting open-hearth furnaces contribute a diminishing share. They accounted for about 2–3 percent in recent years.[516]

Figure II.4-3. Primary Steel Production and Recycling



Source: See Endnote 515 for this section.

Reducing Energy Use and Environmental Impacts

Technological advances over the past two to three decades have led to improved energy efficiency, greater use of byproduct gases and materials, enhanced steel recycling, and substantial reductions in CO_2 emissions per ton produced.[517] Among European firms, for instance, carbon emissions per ton were cut more than 50 percent in 1975–2000.[518] Yet these per-unit gains are offset by surging production.

A 2007 International Energy Agency (IEA) report discusses a variety of processes and factors that have a key bearing on energy use and carbon emissions.[519] (See Table II.4-1.) The IEA concludes that if the best technologies currently in use were applied worldwide, the steel industry's annual energy consumption of 21.4 EJ (in 2004) could be reduced by 2.3–2.9 EJ, or 11–14 percent. CO_2 emissions could thus be reduced by 220–270 million tons per year. This figure does not include effects of closing outdated plants, more efficient operation of coke ovens, or recovery of waste heat from sintering plants. These measures, along with boosted steel recycling, could raise the total of avoided primary energy use to some 5 EJ. (And using steelmaking slag as a substitute for clinker in cement production could avoid another 140–185 million tons of CO_2 emissions in that industry.)[520]

Table II.4-1. Energy and Carbon-Emission Implications of Steelmaking Processes

Process	Observations
Iron Ore Agglomeration	• About a quarter of all iron ore is of sufficient quality to be used directly without agglomeration. Another quarter is pelletized (especially suitable for low-quality ores, such as those in the United States). Sintering is used for more than 50 percent of all iron ore, and is the most efficient process. • The energy needs of a blast furnace depend to some extent on the quality of the ore. The higher the metal content, the lower the energy needs. China's iron ore has very low metal content, whereas that in Brazil, India, and Australia has high metal content.
Coal and Coke Quality/ Charcoal	• China accounts for more than half of global coke production; its coal is of mixed quality. Australian coal is of much higher quality than Russian and U.S. coal (resulting in higher usage). • Coal injection reduces the need for coke and reduces CO_2 emissions. • Brazil makes heavy use of charcoal in iron production. While this does not result in energy efficiency gains, it can reduce CO_2 emissions substantially—if the charcoal is produced in a sustainable manner (more than half was produced from tree plantations, the rest from native forests). The efficiency of charcoal making in Brazil is far below that for coke production from coal.
Coke Oven	• About 90 percent are so-called slot ovens. Old beehive ovens (important in China, where they account for one fifth of coke production, and in Brazil) are less efficient, but modern variants are also being introduced. • For slot ovens, Japan and Germany have the most efficient plants, but China is introducing installations that are close to OECD levels of energy consumption. • Overall efficiency can be improved if a coke oven is fired with blast furnace gas, and coke oven gas (COG) is put to higher-quality use, such as power generation. In China, under half of coke producing plants recovered COG in 2005, still leaving considerable room for improvement.

Table II.4-1. Energy and Carbon-Emission Implications of Steelmaking Processes (...cont'd)

Process	Observations
Blast Furnace	• There are considerable differences in energy efficiency among different types of furnaces. Larger ones have lower heat losses than smaller ones, and the installation of heat recovery equipment is more cost effective. In China, smaller furnaces emit up to 25 percent more CO_2 than large ones. The government aims to close all furnaces with capacities of less than 300 cubic meters (with 7–8 percent of total capacity and CO_2 emissions) by 2010. • Top-Pressure Turbines (TRT) offer reduced CO_2 emissions. They are widely used in Japan, for instance; half of China's production capacity was equipped with TRT in 2004. • Combined gas turbines and steam cycles offer important efficiency gains. • Water-cooled blast furnace slag (ash residues from coal, coke, and ore) can be used as clinker substitute in cement making, resulting in significant CO_2 emission reductions (used predominantly in Europe, Japan, and China). Air-cooled slag (used mostly in the United States) offers limited CO_2 benefits.
Electric Arc Furnace (EAF)	• Scrap steel accounts for about 80 percent of feedstock. Most EAF installations use a three-electrode design, but the lower energy requirements of two-electrode designs have sparked renewed interest in many countries. • A range of factors, such as raw material composition, power input rates, and operating procedures, affect energy consumption. The average electricity use of EAFs decreased by about 10 percent between 1990 and 1999.
Direct Reduced Iron (DRI) Production	• DRI accounts for about 5 percent of global steel production (used principally in the Middle East, Latin America, and India). Most countries use natural gas as a feedstock. • India—the leading DRI producer and fast expanding—relies on coal (implying higher CO_2 emissions). India's DRI plants exhibit a wide range of energy efficiency (most plants are small, limiting economic viability of efficiency equipment).
Steel Finishing	• The amount of finishing energy depends on the product (with steel for cars and white goods requiring both hot and cold rolling, and thus more energy). • Thin slab or strip casting processes reduce steel rolling energy needs significantly. Less than 10 percent of world production is currently based on this technology, though some companies achieve much higher rates. • Germany has raised its steel yield (reducing manufacturing waste and thus less energy) from 65 percent in 1960 to almost 88 percent in 2005. The yield in other countries is often considerably lower.

Source: See Endnote 519 for this section.

The most efficient or otherwise waste- and pollution-minimizing practices described in Table II.4-1 can arguably be seen as representing at least a shade of green. Japan and Europe appear to be performing well in this regard. China is lagging behind in many ways, but is trying to improve its record. Yet sufficiently detailed employment data do not seem to exist to permit a quantification of green jobs.

One instance where job figures are available is ferrous slags that are valuable byproducts of iron and steel making (see last item in the "blast furnace" category in the table).[521] In the United States, 21 million tons of iron and steel slag were recovered from iron and steel mills or reprocessed from old slag piles in 2005, up from 17 million tons in 2001. These activities provided employment for about 2,600 to 2,700 people in recent years.[522] Under the assumption that labor productivities elsewhere are comparable, extrapolating U.S. data to other countries suggests that slag recycling worldwide might employ some 25,000 people. Particularly in China, however, labor productivities are much lower, making this a very conservative job estimate.

Energy intensity and carbon emissions vary greatly from country to country, and from one company to another. By late 2004, at least five of the largest 10 steel producers had developed annual environment/sustainability reports, with four of the five adhering to, or drawing on, sustainability reporting standards developed under the Global Reporting Initiative.[523] Three companies— European-based ArcelorMittal, Dofasco (a Canadian subsidiary of ArcelorMittal), and Posco (South Korea)—have been listed on the Dow Jones Sustainability Index. ArcelorMittal says it has reduced the CO_2 footprint of its European operations by more than 20 percent since 1990.[524] Through energy-savings projects and closely monitored energy management, Turkish steel maker Erdemir (one of the 60 largest steel companies worldwide) has improved its energy consumption by 38 percent since 1982.[525] In South Korea, POSCO has developed a simplified, cheaper, and more efficient steelmaking process.[526] (See Box II.4-1.)

Box II.4-1. Simplifying Blast Furnaces at POSCO

South Korea's POSCO, the fourth-largest steelmaker in the world, has developed a process called FINEX that eliminates the need for sintering and coking processes in steelmaking. This results not only in lower capital investment and production costs, but also improved energy efficiency and fewer pollutants. Tests at a demonstration plant in 2003 indicated reductions of sulfur oxides (SOx), nitrogen oxides (NOx), and dust emissions by 92, 96, and 79 percent, respectively—compared with traditional blast furnace methods. Carbon dioxide emissions are almost 20 percent lower. POSCO initiated construction of a 1.5 million ton/year plant in 2004, which was to come online in 2007.

Plant capacity is equivalent to about 5 percent of the company's total production. The company also expects to break ground in 2008 for a full-scale commercial facility at its Indian subsidiary. It is not clear how many jobs the FINEX plant will create, but based on information about the company's existing capacity and workforce, the number might be in the range of 700–800.

Since 1990, the company has reduced its overall CO2 emissions per ton of crude steel produced by 6.8 percent. Between 1997 and 2006, POSCO cut SOx emissions by one-third and NOx emissions by about one-fifth per ton of steel produced. The company is also recycling 98.8 percent of the slag and other by-products it generates, making them available as valuable raw materials for other industries. This record suggests that a considerable portion of the company's 13,400-strong workforce can be considered a shade of green.

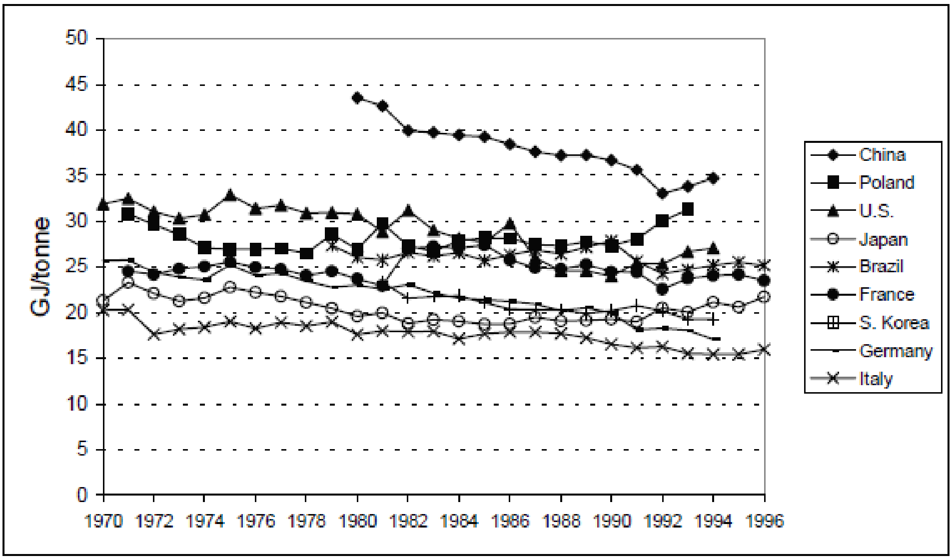
Source: See Endnote 526 for this section.

It is difficult to quantify the number of jobs at these companies and facilities that might be considered a shade of green. While particular aspects of a steel plant may be most critical to reducing its environmental footprint, there may not be an easy way to separate out the number of employees associated with that part of the overall operation. Thus, in place of a perhaps vain quest for a precise tally of green job numbers, it is important to establish clear categories and benchmarks for what can reasonably be considered green enterprises and green workplaces. This is true not just in the steel industry but other sectors as well.

A Wide Range of Efficiency

An analysis published in 2000 suggests that in the period 1970–1996, steel mills in Italy, Germany, South Korea, and Japan were the most energy efficient worldwide.[527] (See Figure II.4-4.) France, Brazil, and the United States were less efficient. China consumed far more energy than any of the other countries, though it also made major strides forward, which continue today.

Figure II.4-4. Energy Consumption per Unit of Steel, Selected Countries, 1970–1996



Source: See Endnote 527 for this section.

China, India, Russia, and Ukraine together account for about half of global steel production, but a much larger share of CO2 emissions. On average, their efficiency is notably lower than that achieved in OECD countries. Russia and Ukraine are still relying strongly on outdated open-hearth furnaces (which contribute 20 and 34 percent, respectively, of their total output).[528] Steelmaking in India carries a heavy environmental burden due to the use of low-quality coal resources. And China still contends with old blast furnaces, inefficient coking plants, as well as low-quality ore.[529] It is unlikely that many steel industry jobs in these countries can be considered green.

On the whole, steel industry efficiencies among OECD countries are fairly similar. In fact, the IEA argues in a 2007 report that "data are not sufficiently detailed to allow a ranking."[530]

Data by the Japan Iron and Steel Federation, however, suggest that: "Japan's steelmakers are already widely recognized by many multinational organizations as the world's most energy efficient. Japan ranked first in the 'Asia Pacific Partnership (APP) Concerning Clean Development and Climate,' an organization made up of public and private-sector individuals from seven countries, including the U.S., China, India and Japan. Japan also received high marks from the International Iron and Steel Institute (IISI).... Moreover, Japan's leadership in energy efficiency is backed up by quantitative data in a thesis by the Research Institute of Innovative Technology for the Earth (RITE)."[531]

Comparing steel industry energy consumption internationally (in terms of tons of oil equivalent per ton of crude steel produced), a January 2008 report by RITE concluded that Japan is 15–20 percent more efficient than its competitors in Europe.[532] (See Table II.4-2.) Japan's lead is due to the extensive use of exhaust heat recovery equipment and a high rate of utilizing byproduct gases. Furthermore, a 2007 survey found that Japanese steel companies use energy conservation equipment at a higher rate than their competitors.[533]

Table II.4-2. Energy Efficiency in the Steel Industry, Selected Countries

	Tons of Oil Equivalent per Ton of Crude Steel
Japan	0.59
South Korea	0.63
Germany	0.69
France	0.71
United Kingdom	0.72
United States	0.74
Canada	0.75
China	0.76
India	0.78
Australia	0.79
Russia	0.80

Source: See Endnote 532 for this section.

China

China accounts for approximately 50 percent of the world's steelmaking-related CO_2 emissions.[534] This is substantially higher than the country's share of world steel production (26 percent in 2004, 34 percent in 2007). Chinese steel makers on average still use one-fifth more energy per ton than the international average. Data compiled by the IEA show that on average, China used more energy use per ton of steel in 2004 than the international average in 1994.[535]

© Sinopictures / Viewchina / Still Pictures
Labourers work at a steel and iron factory. Wuhan, Hubei province, China.

Since the late 1990s, China has bought dozens of steel factories from Western countries like Germany, France, and Luxembourg, dismantling and shipping them piece by piece. But much of it is outmoded equipment. In effect, Western countries outsourced their polluting industries.[536] The New York Times described the four-square-mile (10 square kilometer) area occupied by Hangang, a steel company in southern Hebei Province, as: "a working museum of the industrial age. Its oldest coal-powered furnace, with its corroded, protruding shoots and shafts, might have belonged to Andrew Carnegie. The newest, part of a big expansion, uses waste heat to generate power, a technology that saves energy. The European castoffs fell somewhere in between."[537]

But China has also made considerable strides to improving its environmental record. A September 2000 Internatinal Labour Organization (ILO) report noted that open-hearth furnaces were being taken out of service, along with smaller, inefficient blast furnaces. As part of a modernization effort, new electric arc furnaces have been installed and more stringent regulations introduced.[538] There is thus a wide range of performance among Chinese plants. Some facilities are efficient in international comparison, and are working to reduce environmental impacts.[539] (See Box II.4-2.)

Box II.4-2. China Steel Corporation's Zero-Waste Program

China Steel Corporation (CSC), the world's 25th largest steel producer, generates more than 400,000 tons of sludge annually. Zinc-rich wastes are generated during the process of electro-galvanizing—which coats crude steel with zinc to prevent corrosion. After CSC launched a Zero-Waste Program, it succeeded in July 2001 in finding a long-term customer for its high-zinc sludge. This allowed the company to raise its sludge-recycling rate from 76 percent in 1999 to 100 percent today. Now, CSC separates the sludge based on zinc and oil content and decides on the most appropriate recycling route. High-zinc sludge is sold to zinc smelting companies. The remainder is mixed with power plant coal fly-ash and sold as inexpensive raw material to cement companies.

Source: See Endnote 539 for this section.

Steel Recycling

A considerable portion of global steel production is now based on recycled steel. Recycling saves 40 to 75 percent of the energy needed to produce virgin steel and thus helps to reduce CO2 emissions.[540] And it of course obviates the need for a share of iron mining, further reducing the industry's environmental footprint. Hence, the share of scrap steel used in different countries and by different companies can plausibly be regarded as one key indicator of greening this industry and providing jobs that are a shade of green.

There are three sources of recycled steel: "home" scrap that emanates from within the steel mill, "prompt" scrap derived from the production of finished goods, and "obsolete" scrap from products once they reach the end of their life cycle.[541] The IEA notes that "the amount of steel that is stored in capital stock is more than 10 times annual steel production and it is still increasing continuously."[542] In principle, the recycled content of steel can be close to 100 percent, as there are no technical limitations, relatively limited processing losses, and recycled steel is as strong and durable as steel newly made from iron ore. However, the time span within which old steel becomes available for recycling ranges from a few weeks to several months to many years or even decades. Relative to the rapidly rising demand for steel products, there is currently not enough steel scrap available.

In most sectors, including the automotive industry and construction, steel recycling rates are between 80 and 100 percent.[543] A typical passenger car uses approximately a ton of steel.[544] The United States has achieved a recycling rate higher than 100 percent for automotive steel (meaning more steel was recovered from old cars than used in manufacturing new ones), 98 percent for construction beams, 90 percent for appliances, and 65 percent for rebar and other construction materials.[545] Worldwide, 65 percent of steel cans are recycled, representing more than 5 million metric tons in 2005. The can-recycling rate has been rising in recent years, and some countries reach a rate of 85 percent or higher.[546]

Even though the total amount of scrap steel has increased significantly, its share in total steel production has actually fallen slightly. The IEA says this is due to rapid growth of steel demand, improved plant production yields (limiting home scrap), and the surge in steel production in China, which has very limited scrap reserves.[547] According to the International Iron and Steel Institute, 383 million metric tons of steel was recycled worldwide in 2002, equivalent to 42.3 percent of crude steel produced that year.[548] By 2004, recycling had risen to 452 million tons, or 42.7 percent of total production.[549] By 2006, even though recycling continued to rise to 496 million tons, its share declined somewhat—equivalent to 41.3 percent of 1.2 billion tons of steel produced. Nonetheless, scrap use in 2006 avoided an estimated 894 million tons of CO2 that would have been generated by producing an equivalent amount of steel from virgin ore.[550]

Table II.4-3 shows that Turkey, the United States, South Korea, the CIS countries, Germany, and Japan rely to a significant degree on scrap for their steel production.[551] According to the IEA, Spain also has a strong position in scrap-based steel production.[552] On the whole, developing countries have a lower share, because their steel recycling systems are still limited and thus less scrap steel is available. A 2007 paper prepared for United Nations Industrial Development Organization (UNIDO) puts the share of secondary steel at 4 percent in India and 10 percent in China (a lower share than what IISI statistics suggest).[553] In Brazil, the share of scrap steel is 25 percent. However, the country's largest producer, the Gerdau Group (at 16 million tons the world's 14th-largest steel company), relies mostly on scrap. Its Açominas plant in Minas Gerais recovers 98 percent of the energy contained in byproduct gases, covering 75 percent of the facility's energy needs.[554]

The U.S. iron and steel scrap recycling industry recovered 71 million tons of scrap in 2007. Taking imports and exports into account, 66 million tons were available for domestic use. This industry employs an estimated 30,000 people.[555] U.S. scrap recovery was equivalent to about 13 percent of the global total in 2006. Under the assumption that companies in other countries employ a comparable number of people for scrap recycling, this would yield a global figure of 225,000 jobs. Of course, this can be seen as no more than a back-of-the-envelope calculation, as labor productivities vary widely from country to country. Although China's recycling rate is quite low, the overall size of its steel industry and its comparatively low labor productivity suggest that it employs a rather large number of people in recycling. (In 2001, China's steel labor productivity was less than one-tenth that typical of developed countries, though this ratio may have narrowed somewhat since then.[556])

Table II.4-3. Total and Recycled Steel Production, Selected Countries, 2005

Country*	Total Steel Production	Scrap Steel Recovered Domestically	Recycled Steel Used in New Production**	Share of Recycled Steel†
	(Million metric tons)			(Percent)
China	356	50	60	17
CIS‡	113	65	50	44
Japan	112	54	47	42
United States	95	66	57	60
South Korea	48	19	25	52
Germany	45	21	20	44
Brazil	32	8	8	25
Turkey	21	4	18	86
World§	1,146	434	442	39

**India is one of the leading steel producers (46 million tons in 2005). But because IISI does not report Indian scrap consumption, it is not included in this table. **Includes domestic recovery of scrap steel plus net imports. †Recycled steel (domestic recovery and net imports) as a share of total steel production. ‡Principally, Russia and Ukraine. §For the world as a whole, domestic scrap and total scrap available should be the same, as all exports must equal all imports. However, IISI statistics show a discrepancy in these numbers, presumably due to gaps in reporting.*
Source: See Endnote 551 for this section.

Employment Trends

World steel industry employment data are limited, and somewhat contradictory. According to the ILO, the iron and steel sector accounts for about three-quarters of the 6–7 million jobs worldwide in basic metal production.[557] That would mean a workforce of roughly 5 million. But since employment is falling in most countries, the total must be lower today. Figures for China, meanwhile, are unclear. A 2000 ILO study mentions a 1.2 million workforce.[558] But a 2001 article in the China Business Review put the number at 3 million.[559]

After World War II, steel production and employment expanded massively. But by the mid-1970s, production reached a plateau, and rising productivity translated into fewer jobs. During the last quarter of the 20th century, the global steel industry underwent significant restructuring and shed more than 1.5 million jobs.[560] (See Table II.4-4.)

Table II.4-4. Employment in the Steel Industry, Selected Countries and Years

	1974	1990	2000
	(thousands)		
Japan	459	305	197
United States	521	204	151
Taiwan	n.a.	73	83
Brazil	118	115	63
South Korea	n.a.	67	57
South Africa	100	112	56
European Union, of which:	996	434	278
Germany	232	125	77
France	158	46	39
Italy	96	56	39
United Kingdom	197	51	29
Spain	89	36	22
Total*	2,335	1,388	885

**In addition to the countries listed above, the total includes Canada, Australia, and Yugoslavia. Eastern Europe's steel industry employed about 120,000 people in 2004.*
Source: See Endnote 560 for this section.

Today, steel is no longer a labor-intensive industry. It is marked by rising globalization, ongoing consolidation, substantial gains in labor productivity through automation and computerization, and strong competition, particularly from Asian producers.[561] Among producers in North America, Europe, and Japan, there is concern about cheap wages in competitors like China.[562] (See Table II.4-5.) However, labor tends to be a minor cost factor, accounting for about 3–5 percent of cost among Western European companies, which pay the highest wages worldwide.[563] The outlook for Europe and North America is for further employment retrenchment. In Europe, a business-as-usual strategy will likely lead to the further loss of 80,000 to 120,000 jobs (out of some 370,000 currently) over the next 20 years or so.[564] U.S. steel employment, at about 154,000 jobs—is expected to decline 25 percent during 2006–2016. Generally speaking, low-skilled jobs are far more liable to be lost to automation, while remaining jobs require more education and training.[565]

Concerns about climate change could lead to further changes with negative employment effects. In fact, steel companies and unions in Western countries are concerned that the Kyoto Protocol or a successor agreement may function as a job killer if developing countries like China and India are not mandated to make their own carbon emission reductions. The industry temptation is to move carbon-intensive operations to parts of the world not subject to Kyoto rules. Outsourcing is driven by a number of factors, including weak environmental and labor standards and enforcement, but also the fact that governments—often desperate to attract foreign investment—are willing to offer generous tax terms or other inducements.

Table II.4-5. Steel Industry Wages, Selected Countries, 2000 and 2005

	2000	2005		2000	2005
	(hourly compensation in U.S. dollars)			(hourly compensation in U.S. dollars)	
Germany	22.70	34.10	Spain	10.70	17.60
Sweden	20.20	29.70	South Korea	8.20	14.10
United Kingdom	16.70	26.00	Taiwan	6.20	6.40
France	15.50	25.30	Czech Republic	2.80	6.10
Australia	14.40	24.60	Brazil	3.50	3.20
United States	19.70	23.80	Mexico	2.20	2.50
Canada	16.50	23.70	China	0.60	1.10
Italy	13.80	21.70	India	0.60	0.90
Japan	22.00	21.40	Ukraine	0.30	0.80

Source: See Endnote 562 for this section.

At the same time, however, a proactive policy to bring about a low-carbon future can help retain jobs. A 2007 European study argues that further reductions in carbon emissions (from about 2 tons CO2 per ton of steel to 1.2 tons) are achievable; East European producers in particular have ample room for such reductions. A low-carbon steel strategy would link allocation of carbon emission rights to industry R&D efforts, set standards for CO2 emissions for production processes and products, transform the reduction of greenhouse gas emissions into a conditional profit opportunity for manufacturers, introduce regulations that ensure that imported steel has the same carbon cost as European steel, and reinvigorate the social partnership in the steel industry. The study estimates that such a strategy could save 50,000 jobs.[566] The European Commission is currently supporting a long-term initiative to commercialize breakthrough steelmaking processes.[567] (See Box II.4-3.)

Making steel mills greener and more competitive is a must for job retention. At the same time, it must also be acknowledged that more energy efficient mills do not necessarily employ many people. In the United States, electric arc furnaces (which require far less energy than blast furnaces) are characterized by a lean workforce. They now produce more than 50 percent of the country's steel, up from 25 percent two decades ago, and are expected to continue to gain market share.[568]

Box II.4-3. ULCOS: Europe's Ultra-Low CO2 Steelmaking Initiative

The European Steel Technology Platform, inaugurated in March 2004 with the support of the European Commission, has initiated a cooperative project to develop technologies to make the steel industry sustainable in the face of the climate crisis. ULCOS (Ultra-Low CO2 Steelmaking) is intended to develop breakthrough steelmaking technologies with the potential to reduce CO2 emissions by at least 50 percent. ULCOS aims to develop and commercialize these technologies over the next 20 to 50 years.

A large consortium of 48 partners from 13 European Union countries has been brought together, led by Arcelor-Mittal and a core group of EU steel producers. The consortium includes steelmakers, suppliers, universities, as well as research laboratories specializing in biomass, carbon capture and storage (CCS), alternative energy sources, and energy economics.

ULCOS-I (2004–09) has a budget of $74 million (€54 million), funded by industry and the European Commission (through its 6th Framework Programme and the Research Fund for Coal and Steel). From 2004 to 2006, it undertook a detailed screening of technologies and energy sources, from improved blast furnace to plasma ore melting and from fossil fuels to biomass or green electricity. From a list of 80 technologies, four were selected for closer investigation (the top-gas recycling blast furnace, incorporating CCS in its core; smelting reduction of iron ore with CCS; natural gas pre-reduction and electrical melting with CCS; and direct electrolysis of iron ore). By 2009, these technologies will be put to the test in ULCOS-II—a five-year industrial-scale demonstration program. A final selection will then take place on the basis of technological, process, economic, and environmental criteria. The world's most ambitious R&D effort to reduce steel-related CO2 emissions, ULCOS-II will likely have a budget of more than $400 million (€300 million).

It remains to be seen what the employment implications of this initiative will be. On one hand, successful development of low-carbon steel is likely to help in the retention of steel industry jobs in Europe. On the other hand, the march of labor productivity growth will hardly be halted, so that a gradual reduction in employment numbers is still possible. ULCOS is not a job generation or retention program as such.

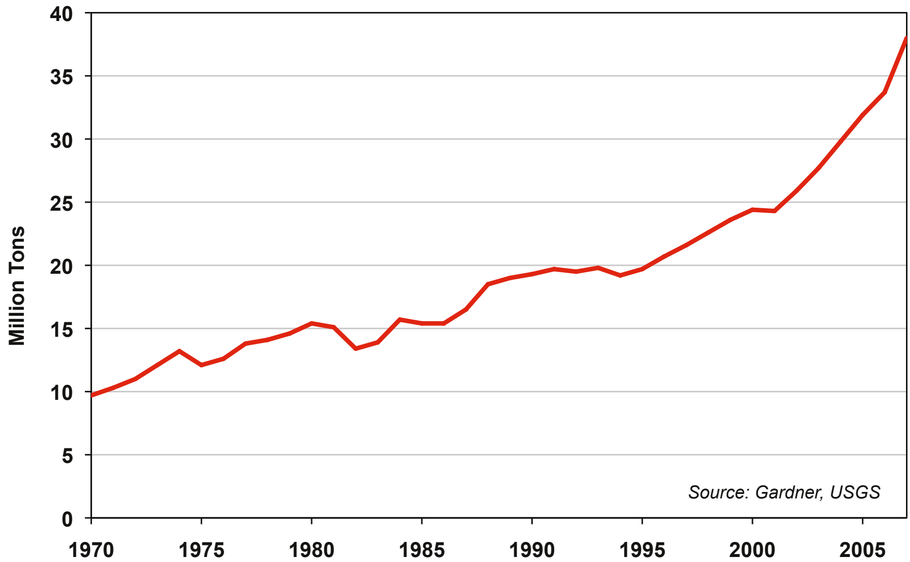
Source: See Endnote 567 for this section.

Steel industry employment data are incomplete, and data collection for many aspects of this industry is still in its infancy in many developing countries. This limits the extent to which even rough green job calculations can be undertaken beyond the numbers suggested here.

Aluminum

World primary aluminum production has grown from about 2 million tons in 1950 to an estimated 38 million tons in 2007 (see Figure II.4-5), plus at least another 10 million tons from secondary production based on scrap recycling.[569] Aluminum output has been surging in the last few years, and primary production is projected to reach around 60 million tons by 2020.[570] This lightweight yet strong metal is primarily used in the aerospace industry, automotive industry, buildings/construction, and in packaging.

Figure II.4-5. World Primary Aluminum Production, 1970–2007



Source: See Endnote 569 for this section.

Even as output grew, dramatic changes occurred in the lineup of major producing countries, along with a substantial consolidation of companies. Whereas in 1960, the United States accounted for slightly more than 40 percent of primary aluminum produced worldwide, its share is now down to 7 percent.[571] U.S. primary production peaked in 1980, and secondary output in 1999.[572] Employment is now at 60,000, down from a peak of 77,800 in 1998.[573] China, on the other hand, has surged to take a commanding 32 percent share in 2007. Russia, the second largest producer, accounts for 11 percent, and Canada for 8 percent. Other leading producers are Australia, Brazil, Norway, and India.[574]

Energy Use and Intensity

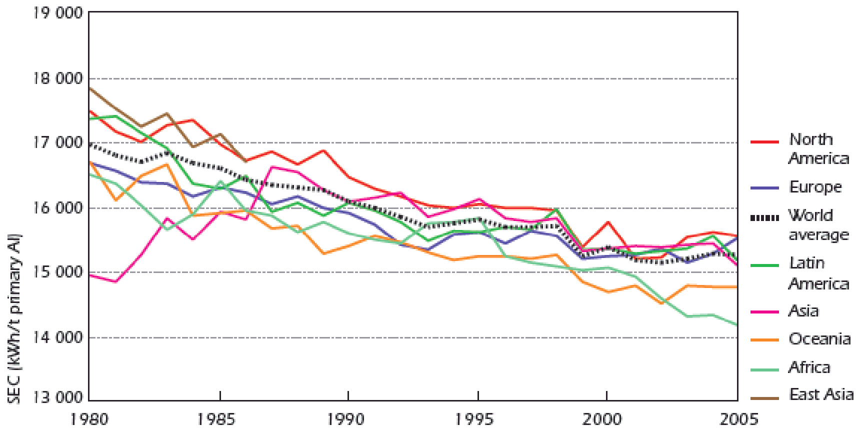
Accounting for roughly 3 percent of global electricity use, the aluminum industry is among the most energy-intensive sectors of the world economy.[575] Smelting (electrolysis) takes the biggest chunk of energy, followed by process heating.[576]

The industry is a large emitter not only of carbon dioxide (in 2005, producing 1 ton of aluminum generated 10.5 tons of CO2 equivalent, including emissions from transportation and ancillary processes), but also a major source of perfluorocarbons (PFCs)—greenhouse gases far more potent than CO2.[577] Aluminum smelting and bauxite mining also contribute a range of other wastes and air and water pollutants.[578]

According to the International Energy Agency, more than 60 percent of the electricity consumed by aluminum smelters worldwide in 2005 was produced from hydropower plants.[579] Large-scale hydro imposes substantial costs on surrounding ecosystems and communities. Coal-generated electricity accounts for roughly one-third of the industry's total energy consumption.[580] Natural gas and nuclear power contribute most of the remainder. But the precise breakdown, and thus the environmental footprint, varies by region.[581]

The industry has become steadily more energy-efficient. Worldwide average energy use in smelting was more than 50,000 kilowatt hours (kWh) per ton in 1900, about 25,000 kWh in 1950, and about 16,000 kWh in 2000.[582] An international comparison shows that improvements have been made in all regions of the world.[583] (See Figure II.4-6.) However, substantial further improvements are both needed and possible.[584] (See Box II.4-4.)

Figure II.4-6. Electricity Consumption in Aluminum Smelting, by Reion, 1980–2006



Note: In this graph, Europe includes EU25 plus Iceland, Norway, Switzerland, Bosnia and Herzegovina, Croatia, Romania, Russian Federation, Ukraine, Serbia and Montenegro.

Source: See Endnote 583 for this section.

Box II.4-4. Energy and Greenhouse Gas Emissions Initiatives at Alcoa

Alcoa is the world's leading aluminum producer, accounting for 11 percent of global primary output with operations in 43 countries that employ some 129,000 people. The company generates approximately 25 percent of its own electricity needs. It emits about 34 million tons of CO2 equivalent; another 27 million tons are associated with electricity purchased from power companies.

In 1998, Alcoa set a target to reduce its direct greenhouse gas emissions 25 percent below 1990 levels, and achieved its goal in 2001. Changes in the way the company manages the smelting process have also led to a cut in emissions of perfluorocarbons (PFCs) of more than 75 percent since 1990.

In 2004, Alcoa launched the Greenhouse Gas Network in 2004 to further reduce emissions. Via a Web-based information system, the network establishes benchmarks, challenges each to become a leader in emissions reductions, and helps stimulate sharing of best practices among the company's smelters and refineries. At some facilities, a portion of each employee's annual incentive payment is tied to environmental performance.

In 2002, Alcoa launched an Energy Efficiency Network (EEN), involving more than 450 employees worldwide. EEN teams conduct energy efficiency assessments at individual facilities; identify, document any strong energy practices they observe, and alert other Alcoa plants to the associated benefits; and provide technical support. By mid-2005, assessments had been completed at more than 50 plants, confirming nearly $80 million in annual savings potential and capturing annual savings exceeding $20 million. Alcoa did not initially pursue projects with a payback period of more than one year, but is now beginning to invest in such longer-term projects.

Source: See Endnote 584 for this section.

Secondary Production: Proxy for a Greener Industry

As is the case with steel, a major way in which the aluminum industry can be greened is through boosting secondary production. Recycling aluminum is cheaper and far more energy efficient than manufacturing the metal from bauxite ore. Recycling aluminum scrap (by remelting it) uses only 5–10 percent the amount of energy it takes to make aluminum from scratch.[585] And by reducing the need for mining bauxite, scrap recycling has inherent additional environmental benefits.

Aluminum scrap is derived from two different sources. So-called "new" scrap emerges directly from the manufacturing process (process scrap, defective products, etc.); "old" scrap is derived from post-consumer or obsolete products.[586] Scrap separated by alloy (or even better, scrap from specific products used for manufacturing the same products) is preferable, as it requires less processing, avoids impurities, and thus can be used more reliably and efficiently.[587]

© Renner
Recycling aluminum.

According to a 2003 International Aluminum Institute analysis, since 1888 a total of 660 million tons of aluminum have been produced worldwide. Of that total, some 460 million tons, or two-thirds, is still in productive use—and thus potentially available for recycling.[588] Another assessment puts the amount of material in use worldwide that will eventually become available for recycling at 400 million tons.[589] This is equivalent to more than 10 times current primary production per year.

Secondary production depends not just on installing appropriate processing equipment, but also on the flow of recovered materials. Different aluminum products have vastly different life spans and recycling rates, affecting availability and price of scrap supplies.[590] (See Table II.4-6.) There are considerable differences from region to region and from country to country. In Europe, for instance, Norway and Sweden boast the highest recycling rates while Portugal's is very low.[591] In North America, only 52 percent of recovered beverage cans were recycled in 2005, down from a peak of 67 percent in 1992. By comparison, the global recycling rate averages 63 percent.[592] Brazil has the highest recovery rate in the world for aluminum cans. As in India, recycling is driven by endemic poverty.[593]

Table II.4-6. Estimated Global Aluminum Product Life and Recycling Rates, by Major End Market

	Average Product Life	Average Recycling Rate
	(years)	(percent)
Building and Construction	25–50	80–95
Transportation (Cars)	10–15	90–95
Transportation (Aerospace)	15–25	90–95
Transportation (Marine)	15–40	40–90
Transportation (Trucks, Buses, Rails)	15–30	50–90
Engineering (Machinery)	10–30	30–90
Engineering (Electrical)	10–50	40–90
Packaging (Beverage Cans)	0.1–1	30–90
Packaging (Foil)	0.1–1	20–90

Source: See Endnote 590 for this section.

Government regulations are critical. Where they are weak or absent (such as in Greece, Britain, Ireland, Eastern Europe, and Russia) recycling ratios tend to be low, while they are very high in Switzerland, Scandinavia, and Germany. In the European Union, a packaging waste directive mandates overall recycling rates of 50 percent for aluminum and steel by the end of 2008; an end-of-life vehicles directive requires a material recovery rate of more than 85 percent from old cars by 2006 and a recycling rate of more than 80 percent.[594]

International trade is an increasingly important factor in scrap markets as well. The European Union has moved from being a net scrap importer in the 1990s to a net exporter. Large quantities are being shipped from Europe and North America to China and India, causing shortages in the exporting countries and threatening disruptions in their supply chain.[595]

World secondary production of aluminum has grown steadily from very modest beginnings. It was about 2 million tons in 1970 and 4 million tons in 1980. It is now at least 10 million tons, although some sources estimate the global total to be as high as 12 to 14 million tons.[596] The portion of secondary production relative to the industry's overall output is roughly a quarter.[597] (See Table II.4-7.)

Employment statistics for this industry are surprisingly sparse. According to one estimate, it directly employs more than 1 million people worldwide.[598] It is unclear, however, how inclusive this figure is and how the boundaries are drawn. Other estimates say that China alone employed as many as 1 million people in its aluminum fabrication industry in 2002.[599] Secondary production is likely to employ considerably fewer people per unit of output than primary production does.

Table II.4-7. Primary and Secondary Aluminum Production, Selected Countries, 2007 and Earlier Years

	2007 Production			Share of Secondary Production (percent)				
	Primary	Secondary	Total					
	(million tons)			2007	1994	1990	1980	1970
China	12.0	2.4	14.4	17	7*	1	1	1
Russia	4.2	n.a.	n.a.	n.a.	n.a.	17†	9	n.a.
Canada	3.1	0.19	3.29	6	4	4	6	0
United States	2.6	3.11	5.71	54	48**	37	25	20
Australia	1.9	0.13	2.03	6	4	3	12	10
Brazil	1.7	0.25	1.95	13	7	5	15	n.a.
India	1.4	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Norway	1.1	0.35	1.48	23	5	1	2	3
Japan	‡	1.15	1.16	99	97	96	42	31
Venezuela	0.6	0.02	0.65	2	5	2	n.a.	n.a.
Germany	0.5	0.84	1.36	62	44**	43	36	8
World	**38.0**	**10.47**	**48.47**	**22**	**n.a.**	**n.a.**	**n.a.**	**n.a.**

**1996 data. **1995 data. †1989 data. ‡Japan produces only a few thousand tons of primary aluminum.*

Source: See Endnote 597 for this section.

Table II.4-7 shows that different aluminum-producing countries have a wide range of secondary production capacities. The United States, Germany, and Japan have boosted the share of secondary production. China is rapidly increasing not only its primary output, but also its secondary production. Producers like Russia, Australia, Canada, Brazil, and Venezuela have not invested much in secondary facilities, largely explained by their access to abundant domestic energy (hydropower and coal) resources.

Country Experiences

Japan's experience is unique in that it has almost completely abandoned domestic primary production, switching instead to secondary production and imports.[600] Driven by rising demand in the automobile sector, domestic shipments of secondary aluminum alloy rose from 0.9 million tons in 2001 to 1.1 million tons in 2007. Japan also imported a roughly equal quantity of secondary aluminum, as well as primary aluminum.[601] According to the Japan Aluminum Association, as of December 2004, the country's aluminum industry employed 12,739 workers at 78 plants.[602] These jobs can plausibly be considered green jobs.

In the United States, secondary production expanded 55 percent between 1990 and 1999, but subsequently declined by 16 percent.[603] (See Table II.4-8.) Primary production is stagnant, and imports are skyrocketing.[604] During the past 40 years, the U.S. aluminum industry has cut its energy intensity by nearly 58 percent. However, a 2003 study for the U.S. Department of Energy found that even after this reduction, "the industry consumes nearly three times the theoretical energy required. Significant opportunities for further energy improvements still remain."[605] The potential gross energy savings (with reference to year 2000 data) amount to a stunning 141 billion kWh, out of 185 billion kWh/year used.[606] U.S. aluminum industry employment has hovered around 60,000 people in recent years.[607] Roughly 10 percent (6,071 people) were employed in secondary aluminum production at 127 companies in 2002, most of them small and medium-sized firms employing between 20 and 250 people.[608]

Table II.4-8. Primary and Secondary Aluminum Production in the United States, Selected Years

	Primary Production	Secondary Production	Total Aluminum Industry Employment
	(million tons)		(thousands)
1980	4.7	1.6	27.2
1990	4.0	2.4	77.9
1999	3.8	3.7	76.3
2004	2.5	3.0	57.5
2007	2.6	n.a.*	60.0

**Secondary production from old scrap only was 1.3 million tons in 2007.*
Sources: See Endnote 603 for this section.

In the European Union, secondary aluminum production tripled from 1.2 million tons in 1980 to 3.6 million tons in 2003. It surpassed primary production—which increased by 12 percent during the same period of time—in the mid-1990s.[609] By 2006, the more than 5 million tons of secondary production provided about 40 percent of total output.[610] In 2003, EU aluminum recycling conserved 16.4 million tons of bauxite, and avoided 1.5 million cubic meters of waste products in landfills. One ton of recycled aluminum saves 1.3 tons of bauxite residues, 15,000 liters of cooling water, 860 liters of processing water, and 2 tons of CO2 and 11 kilograms of sulfur dioxide emissions.[611] Unlike the EU, Central European countries are still producing a larger quantity of aluminum from scratch than from scrap.[612] (See Table II.4-9.) In 2003, the European aluminum recycling industry provided more than 10,000 direct and indirect jobs, according to its own estimates. Most companies in this sector are medium size.[613] The industry's estimate for the total workforce in Western Europe is about 255,000 persons.[614]

Table II.4-9. Primary and Secondary Aluminum Production in Europe, 2003

	EU-15	Western and Central Europe*
	(million tons)	
Primary Production	2.6	4.9
Secondary Production	3.6	4.0
Total Production	6.2	8.9
Net Imports	3.6	2.7
Total Supply	9.8	11.6
	(percent)	
Share of secondary production relative to total production	58	45
Share of secondary production relative to total supply	37	34
	(number of plants)	
Primary Production	21	38
Secondary Production	235	276

**Europe excluding former CIS except Baltic states.*
Source: See Endnote 612 for this section.

China has massively increased its primary aluminum production—expanding output from 2.6 million tons in 1999 to 12.6 million tons in 2007—and thus becoming the dominant producer worldwide.[615] Reports indicate that a considerable share of its facilities were outdated before this period of rapid growth.[616] However, the industry is undergoing massive investment to add even more capacity and to update old technology and equipment.[617] The government adopted a policy to shut down small-scale, high-cost, and polluting (Søderberg) smelters by 2007.[618]

Meanwhile, China's secondary aluminum production is also increasing, to more than 2.4 million tons in 2007, according to the China Nonferrous Metals Industry Association (CNMIA). It had reached 2.35 million tons in 2006 and more than 1.9 million tons in 2005.[619] Compared to the environmental and resource impact of primary production, China's secondary aluminum industry saved an estimated 25.7 million tons of coal equivalents, 1.5 billion tons of water, and avoided the discharge of 1.2 billion tons of solid wastes as well as 413,000 tons of sulfur dioxides.[620]

Wang Gongmin, a leading CNMIA official, has expressed confidence that domestic supplies of scrap will increase further as the country develops a domestic recycling industry, including collection, recovery, and distribution facilities. The Chinese government is encouraging development in the aluminum recycling sector. It intends to increase consumption of secondary aluminum to 25 percent of total consumption by 2010 from 17 percent at present. The cancellation of export tax rebates for primary aluminum and other measures may eventually make secondary production key to exports as well.[621]

China relies heavily on fast-rising scrap imports, running to 1.77 million tons in 2006 and even higher in 2007.[622] Between China's domestic scrap supplies (mostly manufacturing scrap rather than post-consumer) and imported scrap, it is possible that as much as 40 percent of the country's total output of aluminum is based on scrap recycling.[623] However, this is a somewhat speculative figure.

If we apply the current 17 percent share of secondary production to China's estimated aluminum workforce of 1 million, this would yield a figure of 170,000—assuming secondary production takes as many workers as primary production. But even though China's labor productivity is far lower than that prevalent in Western countries (in 2003, it was estimated that the production value per aluminum worker in China was about 25 times lower than elsewhere), this figure is likely too high because secondary production does not require as many workers as primary production does.[624] If the U.S. experience bears any relevance (here, secondary production accounts for 54 percent of total output, but jobs in secondary production represent only 10 percent of the aluminum industry workforce), then China's secondary production workforce may be more on the order of 30,000 to 40,000.

Green Aluminum Jobs

Outside of China, green jobs in the aluminum industry appear to be fairly limited. Most of Japan's employment of about 12,000 falls in this category, a roughly equal number in Europe, and some 6,000 in the United States. Employment numbers in other countries are unknown, but so far, the quantities of secondary materials involved suggest very small numbers. Worldwide (excluding China), there may be some 30,000 secondary production jobs.

Clearly, the aluminum industry—which has always been a capital-intensive industry—cannot generally be expected to be a major source of green jobs. But as was stated at the beginning of this section, greening this sector of the economy by relying more strongly on recycled metals is imperative in light of its carbon emissions and other environmental impacts. Substantial changes have already taken place, but it is also clear that greater energy efficiency gains and additional strides in expanding aluminum recycling are both possible and necessary.

Huge amounts of aluminum are bound up in a broad range of products, and this quantity should increasingly enable the world to build an industry that is far more centered on recycling than on virgin production. For all the accomplishments to date, primary aluminum production continues to rise. To make the industry more sustainable and thus achieve a deeper "shade of green," secondary production will need to become the dominant aspect of the industry in coming years and decades.

Cement

Concrete is one of the most common and important building and construction materials utilized throughout the world at the present time, due in part to the availability of the raw materials needed to produce it and its viability as a structural element. Concrete is used in infrastructure to build roads, factories, homes, underground water pipes, bricks, blocks, and other structures.[625] Cement is the main ingredient in concrete, which "is used as a material in quantities second only to our use of water."[626]

Over the past 10 years, cement production has grown by 4 percent per year.[627] In 2000, cement production totaled 1.5 billion tons.[628] Estimates from the World Business Council for Sustainable Development (WBCSD) put production for 2007 at approximately 2.5 billion tons.[629] Cement production is expected to double by 2050, reaching more than 5 billion tons.[630]

The Environmental Impact of Cement

Given rising production and consumption of cement, it is necessary to recognize its major environmental impact. Table II.4-10 summarizes some of the main concerns that affect the environment, society, and the economy.[631] It is important to adopt and standardize more sustainable cement and concrete production, transportation, and end-of-life uses on a global level in order to decrease these negative impacts.

Table II.4-10. Main Concerns of Cement and Concrete Production

Environmental Impact	Societal Issues	Economic Issues
• Natural resource and land use (quarrying limestone and other materials, water use) • Waste products from concrete production (water, cement slurry, discarded cement, excess production) • CO2 emissions, energy consumption, other pollutants	• Land use, utilization of scarce resources • Poor working environment (noise, dust, accidents) and health issues • Landfilling with the risk of leaching of heavy metals	• Transportation issues: Local versus imported materials • Cost of recycling cement

Source: See Endnote 631 for this section.

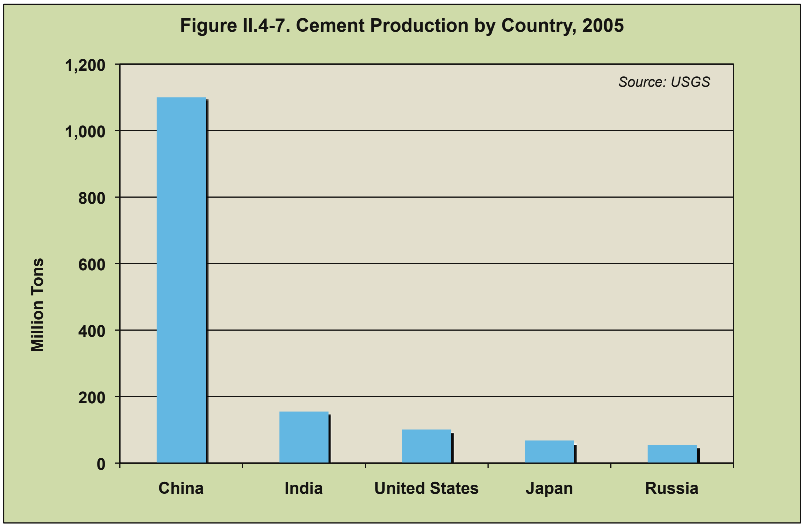
There are many concerns linked to cement production, including the production of greenhouse gases (GHGs), consumption of large amounts of energy and natural resources, dust and other pollutant emissions, disturbance of land during quarrying, and production of waste products.[632] However, this section will focus mainly on reducing GHGs by creating a more energy efficient and sustainable industry.

Cement is responsible for approximately 5 percent of all GHGs emitted worldwide.[636] These emissions come from the chemical reaction caused when converting limestone into cement (50 percent), burning fuel (40 percent), transportation (5 percent), and electricity used in manufacturing operations (5 percent).[634] For each ton of cement produced, average emissions per country range from 0.73 tons to just under 1 ton.[635] At these rates, carbon dioxide (CO2) emissions will reach nearly 4–5 billion tons per year in 2050 from the cement industry alone.

Cement Production

Cement is produced in 150 countries worldwide, and China is now the global leader.[636] Reports of its cement production and consumption vary by source, but most estimates put China at 41–47 percent of total global production.[637] Figure II.4-7 shows the four largest producers worldwide.[638]

Figure II.4-7. Cement Production by Country, 2005



Note: Production measured in billions of tons.
Source: See Endnote 638 for this section.

Many other countries are home to cement production facilities as well. South Korea, Russia, Spain, Thailand, Brazil, Italy, Turkey, Indonesia, Mexico, Germany, Iran, Egypt, Vietnam, Saudi Arabia, and France each produce between 21 and 51 million tons annually.[639] The world's remaining countries produced a combined total of 400 million tons.[640]

China has been the world's largest cement manufacturer since 1985.[641] In 2000, the country produced an estimated 576 million tons, or 36 percent of the world's total.[642] Production recently exceeded 1 billion tons, just under half of the world's total.[643] Cement consumption is also rising in China and is expected to reach 1.3 billion tons, or about half of the world's total, by 2010.[644]

The cement industry in India has grown to the second largest in the world, producing 145 million tons in 2005.[645]Fifty-nine major cement companies own 116 plants and produce the majority of cement in India.[646] Nearly 300 local "mini" cement plants are scattered through India and take advantage of limestone reserves.[647] The United States ranks third in cement production, producing 101 million tons in 2005.[648]

More Sustainable Cement Practices

According to the Battelle report, Toward a Sustainable Cement Industry, "the cement industry as a whole is not yet on a sustainable path in any of the dimensions of the 'triple bottom line'—society, economy and ecology"[649] Between 1994 and 2003, the CO2 intensity of cement production declined by 1 percent per year, but this small decrease was outweighed by increased production.[650] More sustainable production methods will need to be adopted industry-wide if the cement industry is to reduce its carbon emissions and energy use.

A 2007 International Energy Agency report observed that cement manufacturing has the greatest potential for reducing CO2 emissions compared to other industrial sectors. By adopting existing best technology industry-wide, the industry could reduce its CO2 emissions by 480–520 million tons per year and its total energy use by 28–33 percent.[651]

The raw materials required in cement production are calcium (typically limestone) and silicon (typically clay or sand). These materials are finely ground, mixed, and heated in a rotary cement kiln, which uses extremely high temperatures (about 2700° F), in order to create pellets called "clinker." Currently, half of the industry's CO2 emissions come from the chemical reaction caused by turning the limestone into clinker; the other half comes from energy used to make the cement, and to transport and quarry the materials and final product.[652] CO2 emissions can be reduced by making the cement manufacturing process more energy efficient and by using different materials to produce clinker.

Emissions vary depending on the manufacturing process used and type of production plant. The most widely used manufacturing processes for cement are called wet, semi-wet/semi-dry, and dry. The energy intensity of these processes ranges from 3.4 to 5.3 gigajoules per ton, with the wet production being the most energy intensive and the dry process being the least.[653] The dry process consumes less water and uses about half the energy of the wet production process.[654] Production plants include the vertical shaft kiln and rotary kilns. Early cement production relied on the use of vertical shaft kilns, characterized by low thermal efficiencies and high emissions levels.[655] Rotary kilns use new technology to increase the thermal efficiency and reduce the amount of energy needed for cement production.

Energy efficiency in the industry is gained as new cement plants are built. Inefficient, outdated processes are mainly found in small, regional plants.[656] Manufacturers in countries or regions with stagnant levels of demand still rely on inefficient technologies, such as small-scale vertical kilns and the wet production process. Efficiency improvements are generally being made in countries with an increasing demand for cement. More-efficient rotary kilns utilize the dry production process and are replacing inefficient vertical shaft kilns.[657] New plants built in developing countries are larger, cleaner, and more efficient than those built 10 to 30 years ago in developed countries.[658] For example, India's cement production has increased greatly in the past 20 years, and the country has some of the most efficient cement kilns.[659]

Limestone, used primarily because of its low cost and abundance, is also very energy intensive and is responsible for high levels of CO2 emissions. Replacing some of the limestone (up to 15 percent) used to make cement clinker with other materials could result in reductions of up to 240 tons of CO2 per year.[660] Ideally, materials used to substitute for limestone should have a chemical reaction that produces less CO2, and should be readily available. Selecting raw materials that are not readily available and need to travel far distances may be undesirable from both an environmental and economic perspective.[661]

Alternatives that should be considered as a partial substitute to limestone (up to 15 percent) include fly ash, furnace slag, and pozzolanas (materials containing reactive silica and/or alumina).[662] These are considered to be among the best options due to their availability, ability to create quality cement, and CO2 reduction possibilities.[663] Other possible alternatives to limestone include clay, calcium sulfates, iron oxides, silica, coal ash, sodium carbonates, and sodium chloride.[664]

Slag, a byproduct of the iron and steel industry, is recognized as a sustainable input to the cement clinker process, but remains underutilized in the industry. Currently only 60 million tons of slag is used for concrete each year; the IEA identifies an additional 120–160 million tons that could potentially be used.[665] The use of slag during the clinker process increases the production of cement by 15 percent without creating additional carbon emissions. The outcome is a reduction in CO2 emissions per ton of cement, with potential carbon savings of 90–135 million tons per year.[666]

Reliance on coal as the primary energy source is another practice that inhibits the transition to more energy-efficient practices. Coal burning as the cement fuel source is common in China and other countries. Most often, the decision to rely on coal for energy is driven by the availability of local resources or limitations in transportation of other materials.

According to an analysis in 2000, Japan had the lowest CO2 emissions per ton of cement (0.73), followed by Australia and New Zealand (0.79). Japan's top ranking was the result of energy-efficiency measures. The European Union's emissions were 0.84 tons of CO2 per ton of cement. The United States scored the worst with 0.99 tons of CO2 per ton.[667] (See Table II.4-11.)

Table II.4-11. CO_2 Emissions per Ton of Cement Produced, Selected Countries, 2000

Country or Region	CO2 Emissions per Ton Produced
Japan	0.73
Australia and New Zealand	0.79
Former Soviet Union	0.81
Western Europe	0.84
China	0.90
Korea	0.90
Canada	0.91
India	0.93
United States	0.99

Source: See Endnote 667 for this section.

Recycled Cement

The option for more sustainable cement practices carries through the entire life cycle of cement. Recent assessments of cement durability suggest that the life of cement may have been overestimated; some concrete buildings or structures may only last for 50–70 years.[668] As outdated structures face demolition, the option to recycle the remaining concrete provides a practical disposal option.[669]

Recycling cement involves crushing existing concrete from construction and demolition wastes into concrete aggregate so it can be used in place of sand or gravel. (Construction aggregates are components of concrete and include sand, gravel, recycled concrete, slag, or crushed stone.) A 2005 survey by the Construction Materials Recycling Association found that the United States recovers 140 million tons of concrete each year.[670] Re-use in the European Union varies from 10 percent in Italy and Spain to 90 percent in Belgium and Denmark.[671]

The most common application for recycled concrete is in road construction. Recycled concrete pieces are used for road sub-bases and then covered with new concrete or asphalt. Because the makeup of recycled concrete varies, this option is currently best for low-technology uses where high performance is not the goal of the material.[672] Recycled concrete can also be recycled back into new concrete as a substitute for other aggregates. However, it is not considered to be among "best available technologies" because water absorption increases and mechanical performance decreases when compared to concrete made with natural aggregates.[673] More research is needed to understand the possible uses and resource savings of recycled cement.

Employment in the Cement Industry

About 850,000 people work in the cement production industry worldwide.[674] The labor intensity of cement production is relatively low compared to other building and construction materials industries such as iron, steel, aluminum, and wood. The number of people employed in industries related to cement is much higher. Many of these jobs are in the construction industry and are discussed in the building sector.

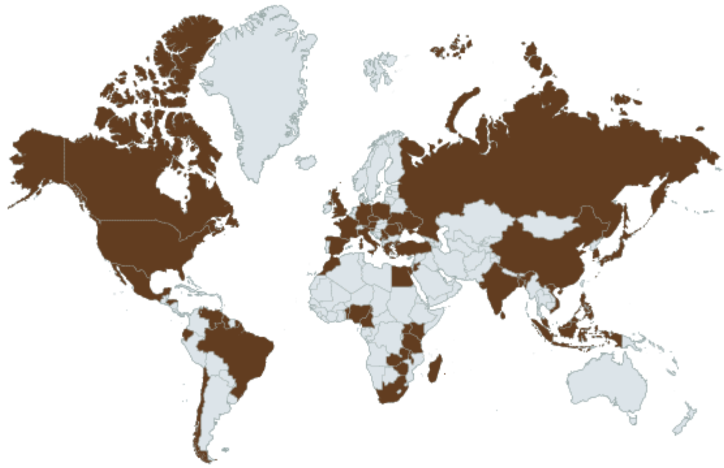
The Multinationals

Most of the large employers in the cement industry operate in multiple countries. Among the largest producers and employers are Cemex, Lafarge Corporation, and Holcim. Employment levels at each are discussed below.

Cemex operates in 50 countries located on four continents and maintains trade relationships with over 100 countries.[675] Cemex's largest industries include Mexico (15 cement plants), the United States (12 cement plants), Spain (8 plants), and Colombia (6 plants).[676] The company is the largest supplier in Venezuela and the market leader in Croatia (3 cement plants each).[677] Worldwide, Cemex employs more than 50,000 people.[678]

Lafarge is a French-based building materials company that focuses on four products: cement, aggregate, concrete, and gypsum. The cement production process employs 42,000 people at 166 production sites spread across 46 different countries.[679] In 2007, the company's sales reached $17 billion.[680] Figure II.4-8 shows countries and regions in which Lafarge owns and operates cement plants.[681] Table II.4-12 further illustrates the breakdown of employees worldwide in the company's cement production sector.[682]

Figure II.4-8. Cement Plants Owned and Operated by Lafarge



Source: See Endnote 681 for this section.

Table II.4-12. Lafarge Employees and Share of Sales, by Region, 2006

Region	Number of Employees	Share of Company Sales (percent)
Western Europe	22,330	17
North America	16,170	14
Sub-Saharan Africa	12,320	12
Asia	10,010	28
Central and Eastern Europe	6,160	16
Mediterranean Basin	5,390	7
Latin America	4,620	6

Source: See Endnote 682 for this section.

Holcim is a Swiss company that produces cement, concrete, aggregate, and other products. It has locations in more than 70 countries worldwide and a market presence on every continent.[683] The company employs approximately 90,000 people overall, with a smaller number working directly in cement production.

Other large employers in the cement industry include Heidelberg Zement (Germany), Italcementi (Italy), Cementos Portland Valderrivas (Spain), Cimpor (Portugal), Corporación Uniland (Spain), CRH plc (Ireland), Taiheiyo Cement (Japan), Titan Cement (Greece), RMC (United Kingdom), The Siam Cement Group (Thailand), Votorantim Cimentos (Brazil), Ash Grove Cement (United States), Cementos Molins (Spain), Cimentos Liz (Portugal), Grasim Industries Ltd (India), Secil Cement Company (Portugal), and Shree Cement Ltd (India). Many of these companies are involved in the WBCSD's Cement Sustainability Initiative, a global effort by 18 major cement companies to reduce the environmental impact of cement.[684]

China

On a country basis, China has the largest number of cement plants and workers. In 2000, there were between 8,000 and 9,300 cement production plants of various sizes in China.[685] Of these, 570 produced between 275,000 and 1 million tons of cement annually, and only 10 produced more than 1 million tons.[686] About 50 percent were located in rural township enterprises and produced less than 30,000 tons per year.[687]

China's largest cement company is Anhui Conch Group Co Ltd., which currently has 16,685 employees.[688] A 2005 merger between Lafarge and Shui On Construction and Materials Ltd., now Lafarge Shui On Cement, is the new cement leader in southwest China.[689] The company employs 11,000 people.[690] Other large cement companies and the number of employees are listed in Table II.4-13.[691]

Table II.4-13. Employment Levels at China's Top 10 Cement Companies

Cement Company	Number of Employees
Anhui Conch Group Co Ltd	16,685
Lafarge Shui On Cement	11,000
Jilin Yatai Cement	8,455
Hauxin Cement	7,228
Jidong Cement	6,000
Gansu QiLianShan Cement	5117
Hebei Taihang Cement	2,113
Henan Tongli Cement	1,379
Tianshan Cement	1,206
Ningxia Saima Industrial Co.	900

Source: See Endnote 186 for this section.

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A labourer walks inside a cement plant in Baokang, China.

Employment Trends

Over the past few decades, employment in cement production in both the European Union and the United States has decreased. From 1999 to 2005, the EU-25 lost 6,290 jobs, or approximately 13 percent of its cement workforce. In 2008, the U.S. cement industry employed 20,800 workers, a decline of 29 percent from 1982 levels.[692] This reduction is due mainly to increased efficiency achieved by automating the production process and to the closure of small cement plants.[693]

Excluding China, the average number of employees needed per million tons of cement produced declined from 555 in 1980 to 272 in 2000.[694] In the past, China has been largely excluded from this increase in productivity. Due to the abundance of cheap labor, the country did not make capital investments comparable to those undertaken in many developed countries. Chinese cement plants remain very labor intensive. A report conducted by Battelle and commissioned by the World Business Council for Sustainable Development states that in some instances, they require 10 times the amount of workers in developed countries.[695]

Yet this is beginning to change. The Chinese National Development and Reform Commission recently announced plans to consolidate cement manufacturing into 60 key cement companies, in order to meet energy-efficiency requirements and to compete with the world's largest cement producers.[696] As a result, many of the plants with outdated technology or small capacity have been, or are slated to be, closed.[697] The consolidation and energy-efficiency improvements are likely to cause significant employment problems, including unemployment and retraining costs.[698]

Green Cement Jobs

In 2007, the Chinese government released new standards in the cement industry in order to reduce energy use. These guidelines, which are a part of a joint project between the Chinese government and the United Nations Development Programme, aspire to reduce energy use in the building and industrial sectors. In the cement industry, they are expected to reduce energy use by up to 15 percent by 2010.[699] Similar energy-efficiency initiatives have been undertaken by the three largest cement companies, Cemex, LaFarge, and Holcim. Cemex plans to reduce its emissions by 25 percent by 2015; Lafarge and Holcim aim to reduce theirs by 20 percent each by 2010.[700]

Technological improvements, which include replacing vertical shaft kilns with rotary cement kilns that utilize the dry production process, are needed to make cement production plants more efficient. Using alternative or recycled materials would also lead to a greener industry. Energy-efficient plants, both newly constructed and retrofitted, require fewer workers. Often times, a large plant that is highly automated can be effectively run by 200 or fewer employees.[701] The cement industry is not expected to be a major source of new employment. More likely, it is likely to continue the existing downward trend of employment.

Although the number of jobs needed for a more energy-efficient cement industry is likely to be reduced, these jobs could be considered a pale shade of green. Using existing technology, the industry has the capacity to reduce emissions by around 20 percent. Jobs that remain in this more efficient industry will be more technological and will require higher levels of skills and enhanced training programs for workers. Some new, short-term employment would be created through construction projects, but this would not replace the number of jobs already being lost.

Despite improvements in the cement industry, the rising global demand for cement will likely outweigh any emission reductions achieved through energy efficiency. Overall, the industry is expected to increase its CO2 emissions. The 20 percent reduction is a good short-term goal, but it will likely not be enough to counteract demand. The cement industry will only become sustainable if the building industry finds completely new ways to create and use cement or eventually figures out how to replace it altogether.

Pulp and Paper

The digital revolution did not lead to the "paperless office." Instead, there has been an increase in paper production over the past several decades, and paper has become a major source of export for many countries. Half of all paper products are packaging, wrapping, and paperboard, another third are printing and writing paper, and the rest are newsprint, household, and sanitary paper.[702]

In 2004, global pulp and paper production totaled 355 million tons.[703] Paper use is rising at a rate of 3.6 percent annually.[704] The United States and European Union consume the most paper per capita, but growth in the industry is due primarily to China and India's rapidly expanding economies. This upward global trend is expected to reach 600 million tons annually by 2020.[705]

In 2006, the United States was the largest producer with 83.3 million tons, or 23.1 percent, of paper and paperboard.[706] It was followed by China (15.9 percent), Japan (8.1 percent), Germany (6.2 percent), and Canada (5 percent).[707] (See Table II.4-14.) Not surprisingly, China tripled its production between 1990 and 2004.[708] China, which is home to one-fifth of the world's population but has only 4 percent of the world's land mass, imports large amounts of pulp from the United States and other countries to keep up with its growing demand.[709]

Table II.4-14. Paper and Paperboard Production by Country, 2006

Country	Paper and Paperboard Production (million tons)	Share of Total (percent)
United States	84.32	23.1
China	57.98	15.9
Japan	29.47	8.1
Germany	22.66	6.2
Canada	18.18	5.0
Finland	14.15	3.9
Sweden	12.07	3.3
Korea	11.04	3.0
Italy	10.01	2.7
France	10.01	2.7

Source: See Endnote 707 for this section.

The pulp and paper industry comprises many large corporations that operate at the global or regional scale. In 2006, the top 100 pulp and paper companies earned a combined total of $23 billion.[710] Even with recent restructuring, International Paper remains the industry's largest company. Table II.4-15 shows net earnings and employment data for the top 10 producing companies in 2006.[711]

Table II.4-15. Top 10 Paper Product Companies: Pulp, Paper and Converting Operations, 2006

Company Rank 2006	Net Sales in Paper (billion dollars)	Total Number of Employees
1. International Paper (USA)	21.1	60,600
2. Stora Enso (Finland)	16.2	45,631
3. Procter & Gamble (USA)	12.0	125,000 (est.)*
4. Svenska Cellulosa (Sweden)	11.2	51,022
5. UPM-Kymmene (Finland)	10.8	28,704
6. Oji Paper (Japan)	9.7	19,560
7. Weyerhaeuser (USA)	9.5	46,700*
8. Smurfit Kappa Group (Ireland)	8.7	40,000
9. Kimberly-Clark (USA)	8.7	55,000*
10. Nippon Paper Group (Japan)	8.5	12,584 (est.)

** Number reflects total employees for company, many of which are not involved in paper products.*
Source: See Endnote 711 for this section.

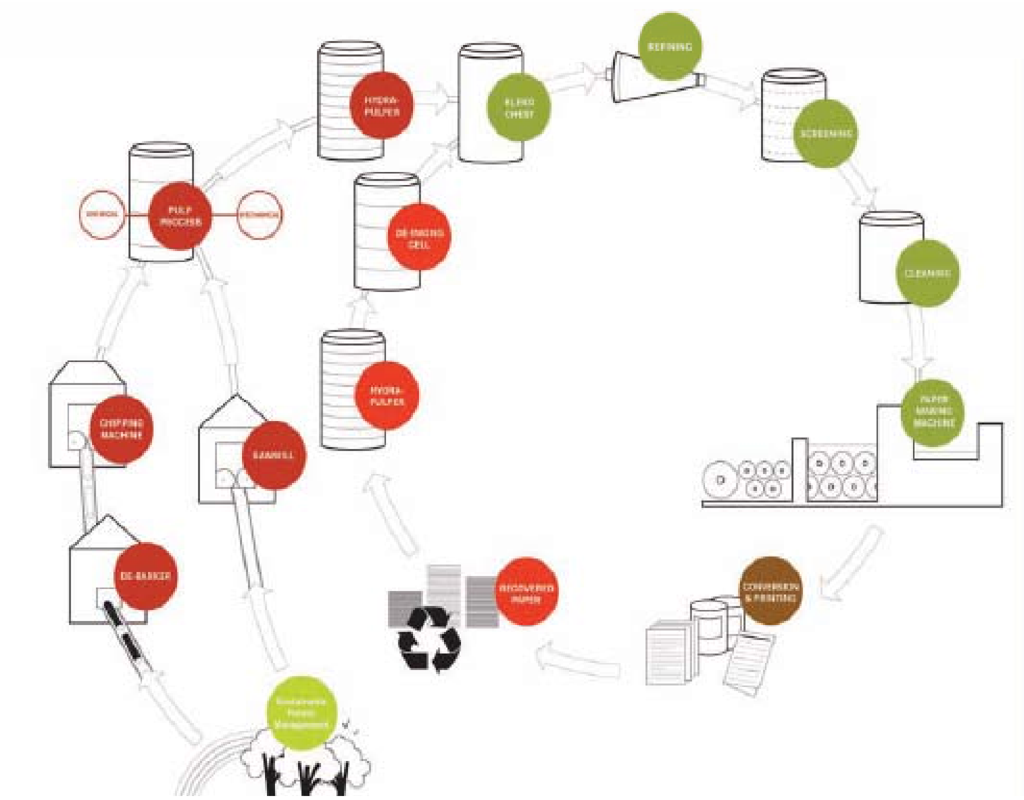
Paper's Environmental Footprint

Creating a sustainable or green paper industry is a major challenge. Over the past few decades, there have been several major attempts to make the industry more environmentally sustainable. One of the most well-known changes occurred in the 1990s as oxygen, which pollutes less, replaced chlorine in the bleaching process. The industry has also made considerable gains in using recycling content, and somewhat lesser improvements in energy efficiency.

Even with these improvements, papermaking remains one of the most resource-intensive industrial processes. Primary inputs for paper include large amounts of fiber, water, chemicals, and energy. The pulp and paper industry is the fourth largest industrial user of energy following the chemical, steel and iron, and cement industries, accounting for approximately 5.7 percent of total industrial energy use.[712] Figure II.4-9 illustrates the basic components involved in paper manufacturing, which include debarking, chipping, pulping, blending, refining, screening, cleaning, papermaking, and printing.[713] Depending on the type of paper mill, pulping and drying are often the most energy-intensive phases. Immense quantities of water are used during the pulping and the cleaning processes.

There are four major types of pulp: chemical, mechanical, recycled, and non-wood. Chemical pulp is used largely for printing and writing paper and paperboard; mechanical pulp is generally used for newsprint. Both processes are increasingly being replaced by recycled pulp. In 2004, recycled pulp had the largest share of global pulp production, with 159 million tons, compared with 128 million tons of chemical pulp, 36 million tons of mechanical pulp, and 17 million tons of non-wood pulp—for a total fiber supply of 339 million tons.[714]

Figure II.4-9 Stages of the Papermaking Process



While chemical pulping requires more energy than mechanical pulping, it is largely self-sufficient as it uses its black liquor byproduct as its main energy source. Mechanical pulping, which uses less energy overall, relies on outside electricity. In many ways, mechanical pulping is preferable to chemical pulping because it produces a higher yield and uses less water. Mechanical pulping requires only half the wood that chemical pulping does to produce the same amount of paper. The drawback to mechanical pulping is that it creates a much lower grade pulp. Recycled pulp, although it is generally dependent on fossil fuels, is more efficient in terms of overall energy use, material use, and CO2 emissions. Non-wood pulp and paper is generally less efficient and highly polluting, but helps reduce the pressure on forests.

Energy Efficiency

In 2007, the IEA reported on the state of energy efficiency and CO2 emissions in the paper industry in developed countries. According to this analysis, from 1990 to 2003, the pulp and paper industry in the OECD countries decreased its CO2 emissions and heat energy consumption by 9 percent, but reduced its electricity consumption by pnly 3 percent.[715] Several countries made considerable improvements. Korea and Japan made significant progress in heat reduction; Norway and Germany reduced electricity use, but to a lesser extent.[716] Countries with the largest decrease in CO2 emissions were the United Kingdom, Korea, and Germany, an attribute caused largely by an increase in using recycled pulp.[717] Increasing its use of biomass, Japan decreased its emissions by almost 10 percent.[718] (See Box II.4-5.) Additional efficiency gains were made in the industry during this time, but these improvements have been overshadowed by the demand for faster machines and specialty papers, both of which are more energy intensive than traditional ones.[719]

Box II.4-5. Japan Paper Association's Voluntary Action Plan

In 1997, the Japan Paper Association (JPA), an organization representing Japan's leading pulp and paper manufacturing companies and covering 88 percent of paper and paperboard production, established a Voluntary Action Plan in order to reduce the industry's environmental footprint.

The two main objectives were to reduce fossil fuel consumption per unit of production by 10 percent from 1990 levels and increase forest plantation area by 550,000 hectares by 2010. To help meet these targets, the industry started promoting energy-efficient equipment and the use of biomass, recycled waste for fuel (specifically tire waste), and the use of natural gas to power mills. In 2004, the JPA amended the plan by slightly increasing its goals and introducing a CO2 emissions reduction target. The modified plan aims to reduce fossil fuel consumption by 13 percent from 1990 levels, increase forest plantation to 600,000 hectares, and cut CO2 emissions by 10 percent from 1990 levels by 2010.

An internal analysis of the reductions showed that by 2005, fossil fuel use had decreased by 13.5 percent, total energy use by 4.7 percent, and CO2 by 9.2 percent below 1990 levels.[720] These improvements are explained mainly by the increase in biomass usage, which reduced fossil fuel consumption and associated carbon emissions.

Source: See Endnote 718 for this section.

The International Council of Forest and Paper Associations made similar findings. Between 1990 and 2000, the ICFPA reports CO2 emissions reductions in the range of 8 to 37 percent, depending on the country, as well as energy savings of 31 percent in the European Union, 36 percent in Canada, and 7 in Japan over this period (between 1990 and 1999 for Canada).[721] These gains were due to energy efficiency, use of low carbon fuels, and greater use of biomass.[722] (The ICFPA was formed in 2002 by the forestry and paper and pulp industries to discuss forest management and environmental sustainability. Areas of focus include: sustainable forest management, prevention of illegal logging, reducing CO2 emissions, and improving water quality and efficiency, among others. The Council represents 75 percent of the world's paper production.[723])

Comparing levels of efficiency between individual countries and mills is somewhat difficult due to the wide range of mills and products. Efficiency ratings sometimes tend to reflect what the country produces rather than how efficient the mills are. For example, Germany, France, and Italy have the highest efficiency for electricity use, but they also have few pulp-making facilities, which use more electricity than paper mills. Norway and Sweden's low rating for electricity use can be attributed to high levels of mechanical pulp. Similarly, Sweden, Norway, Finland, and Canada generate the lowest CO2 emissions per ton, but this is due mainly to their use of hydroelectric power and biofuels.[724]

For OECD countries, China and India's mills are among the most inefficient. These countries also tend to have small plants and depend on coal for power, although some of the most modern and most efficient mills are now being built in China.

© M. Renner, 2008
Supplies of wood chips at Hokuetsu Paper Mill in Niigata, Japan.

Non-Wood Pulp Mills

China and India also produce a large proportion of non-wood pulp, which requires two times the energy usage of wood pulp and three times that of recycled pulp.[725] Non-wood facilities are located almost exclusively in developing countries where non-wood fibers, such as wheat, hemp, rice, bamboo, and sugar cane, are readily available and paper consumption is relatively low.

Many of these mills rely on outdated technology and are highly polluting. They also rely on a very short growing season and have a limited, seasonal production timeframe. The production facilities are generally small, typically producing less than 100,000 tons annually. Because of these inefficiencies, many are being replaced by modern wood pulp mills. China, which traditionally used non-wood pulp for the majority of its paper production, has been closing many of these mills. In 2004, only 27 percent of China's pulp came from non-wood sources, a sharp decline from 53 percent in 1990.[726]

While modern non-wood pulp and paper production reduce pressure on forest ecosystems and could make an important contribution to green employment, they account for only 5–8 percent of the global paper market. [727] They are not expected to meet the pulp needs of the growing industry. Each year, 42 percent of all industrial wood harvested is used by the pulp and paper industry, only a small fraction which comes from certified forests.[728] By 2050, this share is expected to grow to more than half of all wood harvested.[729]

Recycling

When viewed as an entire system, including all energy, resources, and waste, recycling emerges as the most sustainable practice in the pulp and paper industry. Recycling makes an indirect contribution to mitigating climate change as forests that may have been used to produce paper are left untouched, leaving the carbon sinks intact. Moreover, recycling addresses the problem of landfills. Paper comprises approximately one-third of all municipal solid waste and creates large amounts of methane.[730] (With so much focus on CO2 emissions, the greenhouse gas methane is often overlooked or ignored. It is important to note that even though there is significantly less methane in the atmosphere; methane has 23 times the heat trapping capacity as CO2.) Using recycled pulp can significantly reduce energy consumption, greenhouse gas emissions, water use, and solid waste. Table II.4-16 illustrates the environmental benefits of using recycled paper.[731]

Table II.4-16. Benefits of 100% Recycled Content Compared with 100% Virgin Forest Fiber

Environmental Indicator	Copy Paper (percent reduced)	Newsprint (percent reduced)
Total Energy Consumption	44	39
Net Greenhouse Gas Emissions	37	51
Particulate Emissions	41	N/A
Wastewater	46	17
Solid Waste	49	55
Wood Use	100	100

Source: See Endnote 731 for this section.

In 2005, the IEA reported that 45 percent, or 159 million tons, of pulp production was recovered pulp.[732] In 2007, a report by the Environmental Paper Network reported that 37 percent of U.S. pulp and 25 percent of Canadian pulp is produced from recovered paper.[733] This is roughly one-third of the fiber content in North America. Recovered pulp includes mill broke, pre-consumer, and post-consumer fibers. Products with the high post-consumer rates are newspaper, corrugated cardboard, paperboard, and tissue. Printing and writing paper is still lagging far behind other products, although there have been some recent breakthroughs with major multinationals pledging to increase their recycled content.[734] (See Table II.4-17)

Paper recycling collection has made considerable improvements over the past several decades due to widespread adoption of recycling policies by national and local governments in most developed countries. Between 1970 and 2004, the global paper collection rate increased from 24.3 percent to 45.3 percent.[735] Germany, Japan, and South Korea, which have strong national policies on recycling, have some of the highest recycling rates. Europe remains the strongest region with a recycling rate of 63.4 percent in 2006.[736] (See Box II.4-6.) In 2007, the American Forest and Paper Association reported a 56 percent paper recycling rate for all paper—up from 51.5 percent in 2005—and set a new target of 60 percent recovery by 2012.[737] Canada also reported an all-time high of 58 percent in 2007.[738] In 2005, China imported 17 million tons of recovered paper, mainly from the United States and the European Union.[739]

Table II.4-17. Examples of Green Paper Practices by Major U.S. Multinationals

Company	Environmental Policy or Practice
Office Depot	In 2004, Office Depot's post-consumer waste content reached an average of 26.9 percent, an increase of 90 percent from 2003. Office Depot was the first office-supply company to set its own internal environmental performance standards.
Staples	In 2008, Staples, the world's largest office supply company, became the first multinational to adopt the standard practice of using Forest Stewardship Council certified recycled paper in all of its 1400 US copy and print centers.
FedEx Kinkos	FedEx Kinkos sells more than 50 kinds of post-consumer recycled paper, including 12 100 percent post-consumer paper, 2 non-wood paper, and 16 FSC certified options. FedEx Kinkos has more than 20,000 employees.

Source: See Endnote 734 for this section.

Box II.4-6. European Declaration on Paper Recycling

In 2000, the European Paper and Board Industry and Recovered Paper Collectors and Merchants signed the European Declaration on Paper Recycling, which set a target of 56 percent paper recycling by 2005. The Declaration was designed to improve the entire recycling process from paper recovery and sorting to manufacturing, converting, and printing. Initial targets have been met, and in 2006, the European Declaration increased its target to a 66 percent recycling rate by 2010. This declaration covers the EU-25 plus Bulgaria, Norway, Romania, and Switzerland. This voluntary commitment is supported by both the European Commission and the business community.

Source: See Endnote 736 for this section.

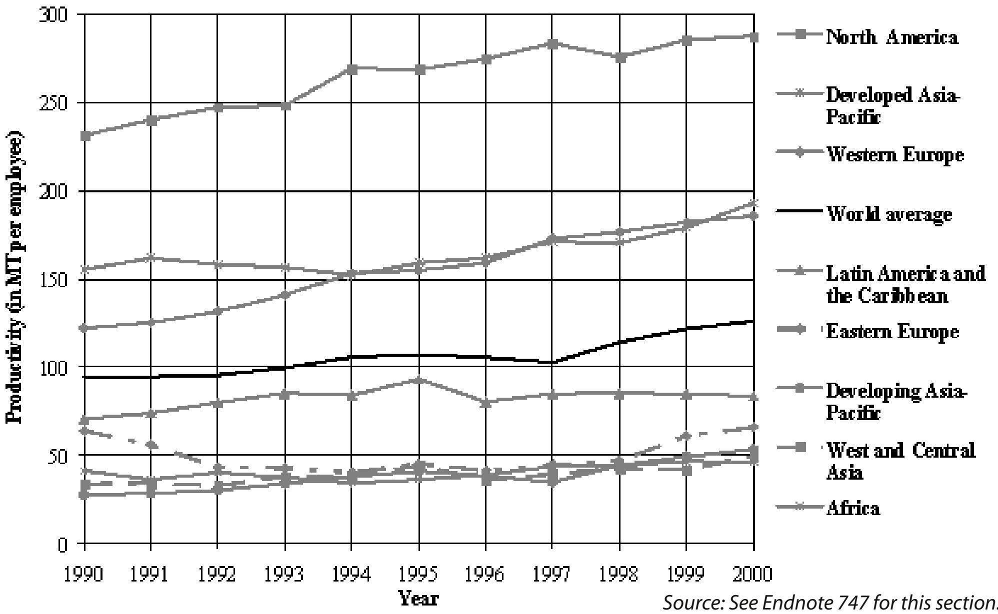
Recovery rates are highest for newspaper and corrugated cardboard, but there is still tremendous potential to recycle office paper. "If we take into account paper that cannot be recycled such as cigarette papers, archives, or papers used in construction materials, then the maximum theoretical recycling rate for paper would be 81% instead of 100%."[740] Given the global paper collection rate of 45.3 percent in 2004, an additional 35 percent of paper could be collected and recycled.[741]

Green Jobs in the Pulp and Paper Industry

Despite rapid growth in the industry, employment levels have remained relatively flat with a slight decrease in employment. In 2000, the pulp and paper industry provided jobs to 4.1 million people worldwide, down from 4.3 million in 1990.[742]From 1970 through the mid-1990s, employment in the U.S. pulp and paper industry was relatively stable, at between 650,000 and 700,000 people, even though production nearly doubled.[743] Since the mid-1990s, the industry has experienced a slight decrease in employment. In 2001, employment was 612,650, with 177,450 working in pulp, paper, and paperboard mills.[744] In 2006, according to the U.S. Department of Labor, there were 473,330 employed in the industry, with 137,960 people working in pulp, paper, and paperboard mills.[745]

Similarly to industries previously discussed, industrialized countries have developed new technologies to increase productivity and reduce labor costs. Labor productivity in North America, Western Europe, and Japan is three times higher than in developing countries.[746] Between 1990 and 2000, labor productivity increased not only in developed countries, but in all regions.[747] (See Figure II.4-10.)

Figure II.4-10. Labor Productivity in the Pulp and Paper Industry, by Region, 1990–2000



Source: See Endnote 747 for this section.

The IEA further identifies an additional energy reduction of 1.3–1.5 exajoules (15–18 percent) per year and 52–105 million tons of potential CO2 savings through advanced technology, more integrated mills, recycling, and combined use of heat and power.[748] As countries, particularly developing and emerging countries, make technological and efficiency improvements, the number of people working in the industry is likely to decline—even with the increased demand for paper. The jobs that remain in this more efficient sector could be considered a shade of green, and in many cases these efficiency improvements will be necessary in order to retain jobs.

Non-wood pulp and paper production remains a major source of income and employment. Farmers in Asia and Africa sell their agricultural waste to mills to help subsidize their income. The shift away from non-wood pulp and paper manufacturing will result in the loss of income for farmers as well as actual job losses. Estimates for the number of jobs lost in China are as high as 1 million.[749] Some of these losses could be replaced by new employment, but the number of jobs in modern chemical mills is unlikely to counteract job losses from non-wood pulp closures.

If these non-wood pulp and paper mills were upgraded and made more efficient, they would be a major source of green employment. A 2006 study by the International Finance Corporation, funded by the Finnish Ministry of Trade, and Industry, analyzed the potential for a more sustainable non-wood pulp and paper industry in China. The study concluded that by modernizing pulping and chemical recovery processes, China could significantly reduce pollution, energy consumption, and water consumption, while maintaining employment for 8 million people in the industry.[750]

Recycling is the fastest growing source of new green employment for the pulp and paper industry. Recycling is an important source of employment because it is labor intensive and creates more jobs than incineration and landfilling.

Although employment data for paper recycling are generally lumped in with recycling employment in general (including glass, steel, aluminum, plastic, etc), there are some data specifically concerning paper. In 2000, 9,765 jobs in paper reprocessing (along with an additional 5,450 in general recycling collection and 1,624 in general sorting) were reported in the United Kingdom.[751] The World Bank estimates that in 2002, Brazil collected 3 million tons of paper and had 28, 347 jobs specifically in paper recycling.[752] The U.S. EPA estimates that 150,000 people are employed in the paper recycling manufacturing.[753]

The EPA identified another 192,875 people employed in general recycling collection and processing, with a large percentage of these in paper recycling. An extremely rough estimate of those jobs attributed to paper could be calculated by weight. In 2006, paper comprised 44 million out of 81.8 million tons, or 53.7 percent of all recycled materials. Using this figure, a rough estimate for the number of paper collectors and processors would add another 103,500 people for a total of 253,500.[754] (This is approximately one-quarter to one-fifth of the entire U.S. recycling industry. Depending on the source, total employment estimates of this entire industry are between 1.1 million and 1.3 million.)[755] Similar or slightly higher employment figures would be expected for the European Union, which recycles more paper than the United States: 52.5 million tons in 2004 and 58.2 tons in 2006.[756]

With increased population growth, urbanization, and consumption, waste is projected to increase drastically over the next few decades. China's waste alone will increase 150 percent by 2030, and paper waste is growing faster than any other material.[757] This presents a unique challenge and opportunity for countries to adopt strong recycling policies and promote job creation in the recycling industry. The number of paper recycling jobs is expected to increase in both the formal and informal economies. Yet the growth in the recycling industry does not come without a tradeoff. Recycled paper still requires some virgin wood inputs, although the overall amount of new raw materials should be reduced. Jobs in the forestry sector will still be necessary, but there are likely to be fewer jobs in logging. Because logging is highly mechanized and not very labor intensive, the number of gained jobs in recycling should outweigh any losses in logging jobs.

Recycling

Recycling makes an important contribution to reducing energy consumption and associated pollution of air and water. But recycling practices vary widely across the planet. Some are subject to strict laws and others are essentially unregulated; some involve manual sorting, others are highly automated; some are sophisticated in terms of materials recovery, separation, and processing, but others are not. Recycling operations—and associated reprocessing and remanufacturing activities—are run by municipal governments, private companies, neighborhood associations, and others.

This makes for a broad diversity of jobs, in terms of required skills, health and occupational conditions, and wage levels. Due to this diversity, there is no single, complete tally of the number of jobs involved worldwide. Employment may not be formal in nature, or jobs data are otherwise typically hard to come by at community-based recycling and composting programs, such as one implemented in Dhaka, Bangladesh.[758]

As noted earlier, the extent to which materials are recycled and recovered depends strongly on local and national laws. In adopting directives on packaging and electronics waste, for instance, the European Union has become a pioneering force. Particularly the concept of requiring companies to take back their products at the end of the life cycle has had significant influence in other parts of the world.

Existing estimates from a variety of sources tend to offer an incomplete picture of the number of jobs involved in recycling operations—either capturing only certain types of recycling operations or covering only some of the countries in the world. For instance, the Bureau of International Recycling (BIR) in Brussels, Belgium, reports that it has members in 60 countries worldwide, but clearly they represent only a fraction of the companies and other entities in the field. BIR estimates that its members process 500 million tons annually, including ferrous and non-ferrous metals, stainless steel and special alloys, paper, textiles, plastics, and rubber. With an annual turnover of $160 billion, federation members employ more than 1.5 million people.[759] This figure is but a fraction of worldwide recycling employment, and presumably excludes most of the developing world. As is true for so many other sets of data, there is a tremendous North-South reporting gap.

A new report analyzing the situation in the United States alone concludes that recycling generates revenues of $236 billion annually and offers employment to 1.1 million people at 56,000 public and private facilities. (A $37 billion payroll translates into average wages of about $34,000 per employee—which is below the national average wage level of about $43,000 for 2006.[760]) This is up from $4.6 billion in sales and just 79,000 jobs in 1968. Although landfilling and incineration still involves larger volumes, recycling now generates more than twice the revenue of the waste management industry since recycling recovers great economic value bound up in discarded products and equipment.[761]

Recycling rates in the United States still vary substantially. Up to two-thirds of steel and non-ferrous metals are being recycled, as is 51 percent of paper, but only 17 percent of plastics. (Plastics recycling is down from 40 percent in 1994, dragged down by the explosion of the bottled-water market, which is marked by low recycling rates.). According to the U.S. Environmental Protection Agency, the national average recycling rate of roughly 30 percent saves about 256 billion barrels of crude oil, the equivalent of fueling 22 million cars each year.[762]

Remanufacturing is the largest segment of the U.S. recycling industry, with estimated revenues of $180 billion, or about 75 percent of the total. Companies processing, sorting, and compacting recyclables generate $41 billion in sales (18 percent). Those that refurbish existing products have $16 billion in sales (6 percent). Interestingly, the aspect most visible to the public—curbside collection, along with recovery facilities and material wholesalers—has just $2 billion in revenue (1 percent).[763]

A key difficulty in accounting for recycling jobs is boundary setting. Different studies and organizations may use different criteria. In the U.S. context, for instance, the figures mentioned above appear very comprehensive. Other sources report on a narrower segment of recycling, but the precise differences are not always clear. The Institute of Scrap Recycling Industries, for instance, reports that its members process more than 145 million tons of recyclable material each year into raw material feedstock for manufacturing. This $65 billion business (2006 data) employs some 50,000 people. In terms of quantities involved, iron and steel account for the bulk, with 81 million tons. This is followed by paper (54 million tons), aluminum (5 million), copper (2 million), and stainless steel and lead (each 1.4 million). But zinc, glass, plastics, tires, and electronics are also among the valuable materials recovered. The scrap recycling industries run a lucrative export business with destinations in 143 countries; scrap is the United States' second largest export category to China, valued at $15.7 billion in 2006.[764]

The same is likely to be true in other countries. In the United Kingdom, the British Metals Recycling Association reports an annual turnover of $12 billion (£6 billion), 15 million tons of materials recovered, and some 8,000 direct employees. Like its U.S. counterpart, British recyclers sell most of their materials abroad, principally in China, India, and Turkey.[765] While international scrap trade allocates supplies where they are needed, arguably, the energy needed for long-distance shipments dims the environmental shine of the recycling industry.

A 1999 British study by Waste Watch put employment in the collection, sorting, and reprocessing of paper, glass, steel, aluminum, and plastic at slightly above 17,000, but acknowledges limits in job estimates due to poor and patchy data collection. The study projected that a 25 percent national recycling rate (up from between 10 and 20 percent in the early 1990s) could create about 25,000 jobs, and a 30 percent rate some 45,000 jobs.[766]

Different methodologies in tallying employment, plus different approaches and diverging labor intensities in materials collection and recovery, make it almost impossible to compare countries across the world or to compute a reliable global total. Figures for Brazil—the global leader in aluminum can recycling—indicate this reality vis-à-vis the U.K. figures. In 2006, the most recent year for which data are available, some 10.3 billion cans were collected in Brazil. The country achieved a recycling rate of 94 percent, climbing sharply from 46 percent in 1990. By comparison, Japan reached a rate of 91 percent, the Scandinavian countries 88 percent, and Western Europe as a whole about 58 percent. Aluminum can recycling provides employment for close to 170,000 people in Brazil. Recycling saves the country 1,976 GWh/year of electricity that would have been required to produce recycled aluminum from scratch—sufficient to supply a city with over 1 million inhabitants for one year.[767]

According to a 2005 survey, Brazil has close to 2,400 companies and cooperatives involved in recycling and scrap trading, most of them small or micro-sized. According to the non-profit associations Brazilian Micro and Small Business Support Service (SEBRAE) and the Entrepreneurial Commitment for Recycling (CEMPRE), in 2004 the country recycled 96 percent of aluminium cans, 49 percent of steel cans, 48 percent of PET plastics, 46 percent of glass packaging, 39 percent of tires, and 33 percent of paper. Sebrae and Cempre estimate that the recycling sector employs some 500,000 people in Brazil.[768]

Studies show that recycling is not only preferable to landfills and incineration on an environmental basis, but also creates more jobs. A study of the three U.S. cities of Baltimore, Washington, D.C., and Richmond found that 79 jobs were required for every 100,000 tons of materials collected and sorted, and another 162 jobs for processing, for a total of 241. This is 10 times the job potential of waste disposal.[769] Earlier studies have come to similar conclusions. Recycling 1 million tons of material in the U.S. state of Vermont generates 550 to 2,000 jobs, compared with 150 to 1,100 for incineration and 50–360 for landfills. In New York City, recycling similarly has the upper hand as a job creator.[770]

Are Recycling Jobs Decent Jobs?

While recycling is of great value in terms of resource conservation, it can entail dirty, undesirable, and even dangerous and unhealthy work, and it is often poorly paid. In many developing countries, recycling work is performed by an informal network of scrap collectors, also known as "waste pickers" or "scavengers," who collect the recycled materials for revenue. Efforts to form cooperatives have raised the pay levels and standards in many countries. In Brazil, 90 percent of recyclable material is collected by scrap collectors, who have organized themselves into a national cooperative movement with 500 cooperatives and 60,000 collectors.[771] In 2005, Brazil's Belo Horizonte state inaugurated the first recycling plant to be run by associations of independent catadores de lixo—trash scavengers. The plant is intended to end the exploitation of the trash pickers by unscrupulous middlemen and provide an increase in their income of about 30 percent.[772] Colombia has an estimated 100 scrap cooperatives which recover over 300,000 tons of material each year.[773] In Cairo, the informal garbage collectors known as Zabaleen have achieved remarkably high recycling rates.[774] (See Box II.4-7.)

Box II.4-7. Cairo's Zabaleen

In Cairo, an estimated 70,000 people work as Zabaleen, or informal garbage collectors, providing a cheap door-to-door service by hauling away household trash with the help of donkey carts or small trucks. The Zabaleen then sort out usable materials and sell them to community micro-enterprises that prepare them for reuse, or manufacture such items as bags and mats, shoe heels, coat hangers, or tourist souvenirs—creating local jobs and incomes. Organic waste is fed to pigs, and the pork meat is subsequently sold to tourist facilities. A Recycling School instructs some 100 children how to collect and reuse trash. Children can track the quantity of recyclables they collected with the help of a computer.

The Zabaleen collect about one-third of Cairo's trash. They recycle 85 percent of what they collect, leading Wael Salah Fahmi, a professor of architecture and urban design at Helwan University, to claim that the Zabaleen have created "one of the world's most efficient resource-recovery and waste-recycling systems." Their success has led Beirut, Bombay, and Manila to emulate their system.

At the same time, it is important to note that many of the Zabaleen face a difficult existence, but have few livelihood alternatives. Typically, an entire family, including small children, helps sort the materials. Sorting through the garbage entails health risks. The Zabaleen live in seven densely populated garbage-collector settlements. Fahmi notes that the settlements are characterized by "a high incidence of animal epidemics, illiteracy, poor environmental conditions, and low incomes."

In the 1980s, Muqattam (the largest Zabaleen settlement), received World Bank and international donor support through the Zabaleen Environmental Development Programme (ZEDP). Living conditions (housing, water supply, sewage disposal, electricity, and road infrastructure), along with education and health programs, improved considerably. Community-based recycling enterprises were established and a simple composting plant was set up. On the other hand, community participation was found to be lagging, and outsiders' involvement at times failed to reflect the needs of the whole community. Within the community, the gap between rich and poor has grown wider.

More recently, Cairo's municipal government has attempted to put the trash collectors out of business. It has contracted with sanitation companies from Spain and Italy, which collect another third of Cairo's trash, but requires them to recycle only 20 percent of waste collected. The bulk is dumped in desert landfills. Many residents continue to prefer the Zabaleen's door-to-door service and have successfully sued to have extra garbage collection fees charged by the companies nullified. The continuation of what Professor Fahmi describes as an "intricate relationship between community, environment and livelihood" is jeopardized by efforts to privatize waste services and by government policies to move Zabaleen activities further out of the city.

Source: See Endnote 774 for this section.

China, which surpassed the United States in 2004 with a total of 190 million tons of waste, has a mix of formal and informal collectors.[775] About 1.3 million people are employed in the formal waste collection system; there are an additional 2.5 million informal workers or scrap collectors, a large chunk of whom could be considered to be engaged directly in paper recycling.[776] By 2030, China is expected to generate 480 million tons of waste, 10 percent of which is estimated to be recoverable paper.[777]

A prominent example of dangerous recycling work is ship dismantling—a major employer mostly in South Asia. The European Commission estimates that worldwide, between 200 and 600 large ships annually are broken up after having reached the end of their useful life. Many thousands of people, often migrant workers, are employed in this sector. But this is an industry marked by great environmental and human health hazards, high accident rates, and lack of protection for workers. The ships contain valuable steel and other scrap metal, but also many hazardous materials, including asbestos and polychlorinated biphenyls (PCBs).[778]

© Rainer Kzonsek/Das Fotoarchiv / Still Pictures
The garbage people of Muqattam. In Cairo you have several garbage cities. The garbage collectors go from house to house to collect all garbage. In the garbage area it get sorted and recycled. Pigs are eating the organic garbage. Cairo, Egypt.

In consumer electronics, a proliferation of products and extremely short product life cycles make for an extremely high turnover of equipment and mountains of electronics waste. While longer product life spans and greater durability are preferable from an environmental perspective, the proliferation of gadgets allows and necessitates growing recycling. Discarded items like computers, mobile phones, and iPods are often shipped to developing countries. There, untrained workers break and burn them and sort materials, typically without proper equipment and protection against health hazards posed by various toxins.

China is a major destination for e-waste, receiving up to 70 percent of global shipments in addition to substantial amounts of domestic discards. Another 20 percent goes to India, Pakistan, Bangladesh, and Myanmar.[779] According to a 2007 study by the Öko-Institut in Freiburg, Germany, "the Chinese WEEE-recycling industry is one of the biggest of its kind worldwide," noting that it handles 1.76 million tons annually of domestic e-waste and unknown amounts of imported materials, many of them shipped illegally. (WEEE stands for Waste Electronic and Electrical Equipment Directive, adopted by the European Union).[780] Recycling Magazine puts the quantity of e-waste dismantled annually at 3.7 million tons.[781]

© Joerg Boethling / Still Pictures
Shipbreaking yard in Mumbai. India.

China's electronics recycling industry is thought to employ about 700,000 people, of whom 98 percent work in informal settings. Some 440,000 are involved in collection, 125,000 in disassembly, 140,000 in materials recovery, and about 600 in final disposal. Guiyu (Guangdong Province) and Luquiao (Zhejiang Province) are the two largest recycling centers, with about 155,000 and 13,000 jobs, respectively.[782] Employees involved in manual disassembly are most exposed to health-threatening working conditions.

The sector consists mostly of small, informal enterprises, typically family-owned workshops. The industry is fast-growing and anarchic. This makes it difficult to enforce safety, labor, and environmental rules, even though the government has adopted regulations similar to the WEEE rules in force in the European Union.[783] Studies in Guiyu have found very high levels of heavy metals and organic contaminants in samples of dust, soil, river sediment, surface water, and ground water. The proximity of many recycling centers to agricultural land means that contaminants can easily enter the food chain.[784]

The Öko-Institut report notes that, "the Chinese WEEE-recycling industry is widely associated with severe health and safety risks for workers involved in this sector. These risks mainly stem from improper techniques during the recovery of raw materials like the open burning of wires and the chemical treatment of PCBs and electronic parts. Especially in the informal structures of the Chinese WEEE-recycling industry only very few basic precautionary measures are applied to protect workers' health. As a result, occupational effects include diseases of the skin, stomach, respiratory tract and other organs."[785]

Salaries, to the extent information is available, are low, and most employees are not covered by health insurance, unemployment, or pension plans. This is a particular problem for the migrant workers who account for one-half to two-thirds of the recycling workforce. Not surprisingly, the employee turnover rate is high, and labor protection is low.[786]

Electronics recycling is but one aspect of a larger industry. Other recycling operations appear to be marked by similar conditions. In Guangdong Province, plastics recycling is mostly done by very poor people, including migrant laborers. According to Recycling Magazine, in total some 10 million people are believed to be involved in recycling in all of China. The magazine notes: "Whereas in the Western world [recycling] is linked with protecting the environment and ruled by regulations, China's recycling is about earning money: how to do this inexpensively and a source for acquiring new resources."[787]

While recycling offers the benefit of recovering resources that otherwise would have to be mined and processed at considerable environmental expense, the procedures prevalent in most of China's recycling sector themselves impose considerable human and environmental costs. Particularly the manual disassembly jobs cannot be described as green jobs.

China and the United States are among the major economies in terms of materials use and thus in terms of actual and potential recycling employment. Estimates for these two countries run to some 11 million jobs. In Europe and other OECD countries, recycling is likely to contribute substantial additional jobs, particularly given the EU's packaging and electronics directives. For many countries, employment data appear not to be available. And as mentioned earlier, many community recycling efforts are likely to be informal in nature. Increasing recycling rates beyond current rates will create substantial additional jobs worldwide, but the quality of many of these jobs is a major concern and may warrant targeted research and operational interventions in the future to promote and facilitate decent work in this rapidly growing sector.

Remanufacturing

Remanufacturing is becoming a serious business, particularly in areas like motor-vehicle components, aircraft parts, compressors, electrical and data communication equipment, office furniture, vending machines, photocopiers, and laser toner cartridges. According to the Fraunhofer Institute in Stuttgart, Germany, remanufacturing operations worldwide save about 10.7 million barrels of oil each year, or an amount of electricity equal to that generated by five nuclear power plants. They also save a volume of raw materials that would fill 155,000 railroad cars annually.[788]

According to a 2003 estimate, remanufacturing was a $40 billion business in the United States, but as indicated above it may now be considerably larger.[789] An estimated 480,000 people were employed by companies in this sector.[790] Walter Stahel of the Product-Life Institute in Geneva, Switzerland, estimated in 2000 that the remanufacturing sector in European Union member countries accounted for about 4 percent of the region's GDP.[791]

Xerox and Canon (which began remanufacturing photocopiers in 1992) are among the companies that have pushed this concept.[792] (See Box II.4-8.) A French producer of automotive drive shafts that began remanufacturing operations in 1976 has been able to reduce energy use by 24 percent and cut total costs by 50 percent for each remanufactured drive shaft compared with newly manufactured ones, even as labor costs rose. The company found that remanufacturing is twice as labor intensive and involves higher levels of job skills.[793] But clearly, there is enormous room for expansion of this activity.

Box II.4-8. Remanufacturing at Xerox

Xerox is one of the pioneers of the remanufacturing concept, having embarked on an Asset Recycle Management initiative in 1990. This program led Xerox to design its products from the very beginning with remanufacturing in mind and to make every part reusable or recyclable. As a result, 70–90 percent of the equipment (measured by weight) that is returned to Xerox at the end of its life can be rebuilt. The company developed a photocopier of which every part is reusable or recyclable; by 1997, more than a quarter of its copiers were remanufactured, and Xerox was aiming to boost this to 84 percent.

Like some of its competitors, Xerox also remanufactures spent cartridges for copy machines and printers. In 2001, it rebuilt or recycled about 90 percent of the 7 million cartridges and toner containers returned to it by consumers. All in all, the company estimates that environment friendly design has kept at least half a million tons of electronic waste out of landfills between 1991 and 2001.

Source: See Endnote 792 for this section.