CHAPTER 14

The Role of Industrial Consumption

CHAPTER OBJECTIVES

A. Primary Industrial Contributors to Carbon Emissions

B. Carbon Emissions Associated with Steel Production

C. Carbon Emissions in the Nonmetallic Minerals Industry

D. Carbon Emissions Endemic to Chemical Production

E. Carbon Emissions Associated With the Paper and Pulp Industries

F. Industrial Standards that Seek to Limit Carbon Emissions

A. Primary Industrial Contributors to Carbon Emissions

AMERICAN INSTITUTE OF STEEL CONSTRUCTION—STEEL DAY

On September 18, 2009, Hillsdale Fabricators of St Louis, Missouri, held an open house to inform members of the community about its sustainable operations. Hillsdale Fabricators is a full-service steel fabricator that specializes in complex fabrication, and it is the only St. Louis-area fabricator certified in major steel bridges. The recently opened Lucas Oil Stadium that serves as the home of the Indianapolis Colts is one of this company's celebrated accomplishments.[1]

The open house at the Hillsdale facility was one of 173 events hosted by the American Institute of Steel Construction (AISC). Engineers, architects, university faculty and students, and the general public visited steel mills, fabricators, service centers, galvanizers, and other steel facilities to network and witness advanced technologies in action. Moreover, Steel Day enabled visitors to see how the structural steel industry is building high-performance and sustainable projects. More than 7,000 people throughout the United States participated in the Steel Day activities.[2]

Steel Day drew attention to the critical role of structural steel in the country's infrastructure, economy, and employment. In addition, the day enabled the U.S. steel industry to illustrate some of the tremendous strides it has made toward sustainability. Steel is the world's most recycled material, and greenhouse gas, air, and water emissions have markedly dropped in this industry over the past 20 years.

The Steel Day project underscores some of the significant changes taking place in the industrial sector. In this chapter, we provide an overview of green marketing efforts associated with this part of the economy. Given that this sector accounts for one third of all energy consumption, there are important dividends that can be realized from effective management of energy usage and carbon emissions. We therefore begin by outlining several industries in this sector that reflect the largest usage of energy as well as the highest potential to reduce carbon emissions. We subsequently describe international efforts to enhance the sustainability of industry. Consider first the leading contributors to climate change in industry.

In a recent review of energy consumption in the industrial sector, the International Energy Agency (IEA) recognized marked potential to reduce emissions.[3]

FIG. 14-1 Lucas Oil Stadium in Indianapolis, Indiana

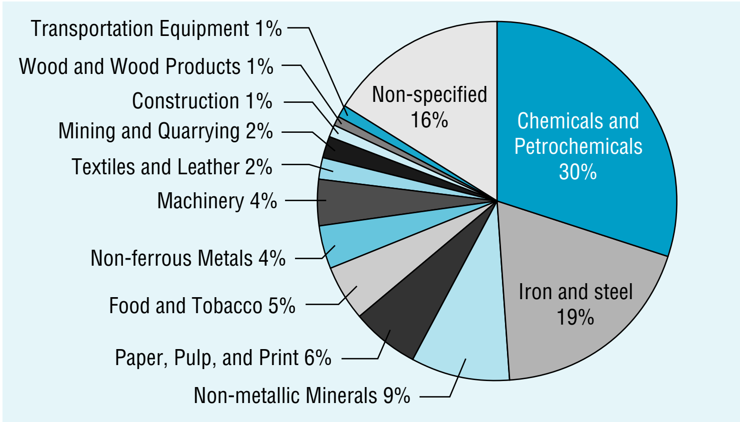
Source: © *Jeremy A. Williams*

On a worldwide basis, industry accounts for 33% of energy consumption and 36% of carbon emissions. There have been tremendous strides in the improvement of industrial efficiency, yet IEA estimates suggest that the equivalent of 600 to 900 million tons of oil equivalence could be reduced in the industrial sector. Moreover, the equivalent reduction in carbon emissions is 7 to 12% of global emissions or 1.9 to 3.2 gigatons of carbon dioxide.

The use of energy and the amount of carbon emissions varies considerably from one industry to the next. Figure 14-2 indicates that more energy is used in the chemical and petrochemical industries than in any other sector. Although chemicals are associated with the highest amount of energy use, a substantial portion of the energy is feedstock that is incorporated into chemical products. For example, much of the oil used in refining automobile fuel is incorporated into gasoline. In addition, the chemical sector, the iron and steel and the nonmetallic minerals industries are also large users of energy.

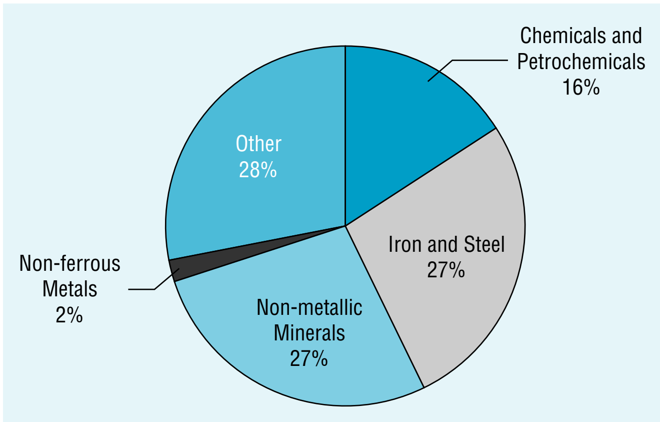
Figure 14-3 illustrates that 70% of carbon emissions for the sector are associated with iron and steel (27%), nonmetallic minerals (27%), and chemical/petrochemical industries (16%). In addition to these industries, there are substantial opportunities to reduce the amount of carbon emissions associated with the paper industry and nonferrous metal sectors. Unlike the household sector, there is not a single indicator associated with emissions across industries. Each industry has different factors that must be considered in efforts to reduce emissions. Therefore, we highlight factors associated with enhanced energy efficiency and carbon emissions in each of these industries.

FIG. 14-2 Final Energy Consumption by Industry, 2004



Source: *Based on International Energy Agency data, Tracking Industrial Energy Efficiency and CO_2 Emissions, (Paris, France: © OECD/IEA, 2007).*

FIG. 14-3 Carbon Emissions by Industry, 2004



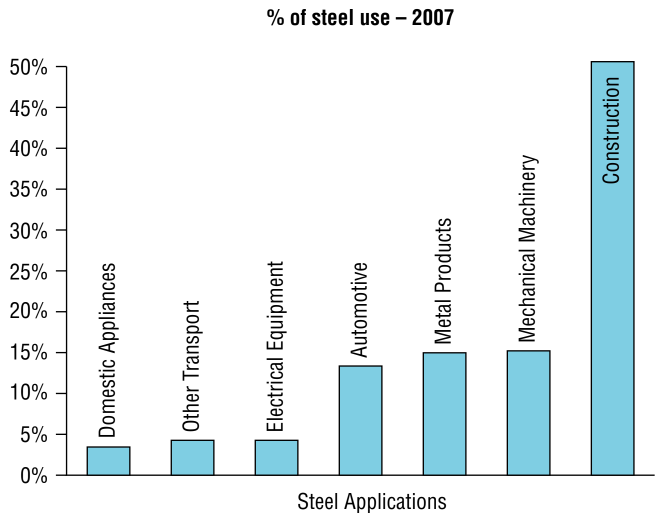
Source: *International Energy Agency, Tracking Industrial Energy Efficiency and CO_2 Emissions (Paris: France, © OECD/IEA, 2007), figure 2.3, page 44.*

B. Carbon Emissions Associated with Steel Production

In 2007, more than 1.3 billion tons of steel were produced in the world. Steel is a seemingly ubiquitous commodity that is incorporated into many final products.[4] Figure 14-4 indicates that construction is the largest user of steel, followed by machinery, metal products, and the automotive sector.

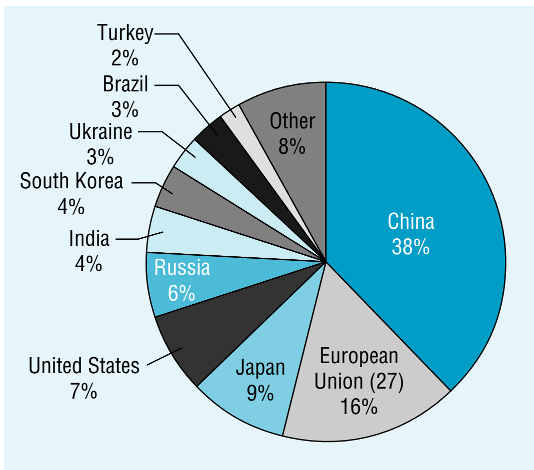
The steel industry and the nonmetallic minerals industry are the largest producers of carbon emissions in this economic sector. Figure 14-5 indicates that more than 90% of worldwide production of steel is concentrated in 10 markets. The industry has realized important efficiency gains over the past 20 years, but the worldwide average has not increased. Over this two-decade era, most growth has been in China, and the steel production in this country is relatively inefficient. In addition,

FIG. 14-4 2007 Worldwide Steel Usage



Source: *Based on World Steel Association, 2008 Sustainability Report (Brussels, Belgium: World Steel Association, 2008), p. 7.*

FIG. 14-5 Worldwide Steel Production, 2007

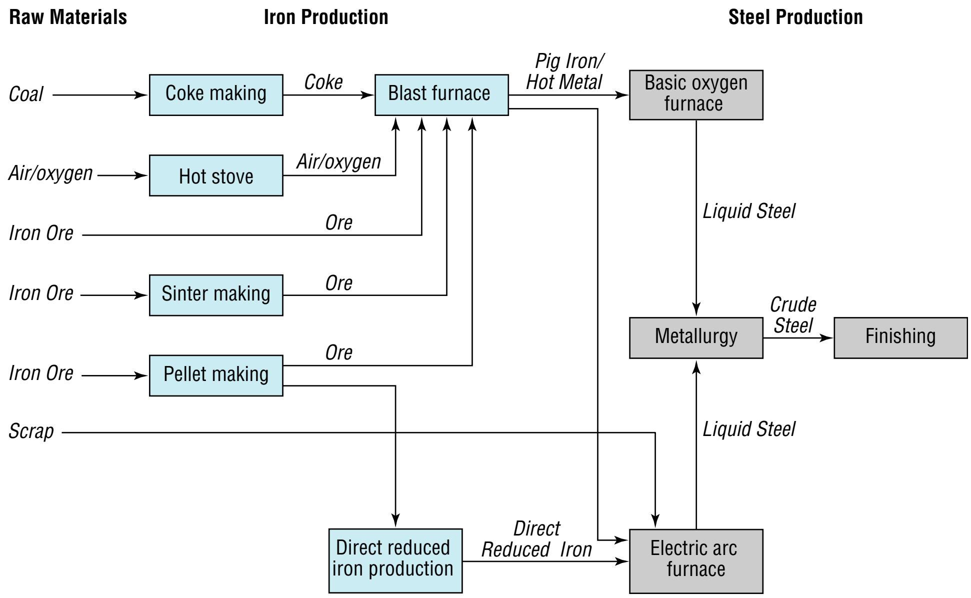


Source: *Based on World Steel Association, 2008 Sustainability Report (Brussels, Belgium: World Steel Association, 2008), p. 7.*

the Chinese market does not have substantial amounts of scrap available for steel recycling. China, Russia, India, and Ukraine account for almost half of all steel production and more than half of all carbon dioxide emissions associated with iron and steel.[5]

The production of iron and steel is complex and varies from one country to the next, yet there are similarities in the processes employed across geographic regions. In order to gain an understanding of energy consumption, it is necessary to outline the processes endemic to steel production. Figure 14-6 provides an overview of the

FIG. 14-6 Steel Production Processes[a]



[a]Processes are shaded; Inputs and outputs are in italicized text.
Source: *Based on International Energy Agency, Tracking Industrial Energy Efficiency and CO_2 Emissions, (Paris, France: © OECD/IEA, 2008).*

essential processes associated with most steel production. Two methods, **basic oxygen** and **electric arc furnaces**, account for approximately 97% of all steel production. Basic oxygen is ordinarily used for high-tonnage production of carbon steels, and electric arc furnaces are to produce low-tonnage specialty steels.[6] More than 66% of production occurs through basic oxygen processes, and 31% occurs via electric arc procedures. After one of these processing methods has been employed, the metal is ready for metallurgy and finishing.

Basic Oxygen Furnaces

The production process for steel involves converting raw materials (i.e., iron ore, coal) into iron followed by converting iron into steel. Steel is then transformed via metallurgy and finishing that make the product useful to the construction, automotive, and other industries.

The *basic oxygen furnace* process produces products such as automotive fenders, encasements of refrigerators, and packaging.[7] The production of iron via basic oxygen furnaces involves the introduction of coke, iron ore, and oxygen into a furnace. In order to make coke, bituminous coal is fed into a series of ovens in which it is heated at high temperature for 14 to 36 hours in the absence of oxygen.[8] During this process, compounds are driven off and collected. Ammonia liquor is a by-product taken to wastewater facilities, and tar removed during this process is also stored. Light oil taken from the coke ovens becomes benzene, toluene, and xylene that are useful in chemical production (see petrochemicals below). Naphthalene is also derived as a by-product, and the remaining carbon is coke. The coke is then transferred to a quenching tower, where it is cooled either by a water spray or circulating an inert gas (nitrogen) in a process referred to as **dry quenching**. Coke making requires 0.75 to 2.0 GJ per ton of crude steel and sintering requires 2 to 3 GJ per ton.

The production of coke results in several forms of waste. Coke ovens produce air emission in the forms of particulate matter, volatile organic compounds, methane, sulfur oxides, and other pollutants. Wastewater is generated from the cooling of the coke oven gas and the processing of by-products (e.g., ammonia, tar). Coke production generates coke breeze during the quenching process. This compound is used to make sinter or is sold as a by-product. In addition to breeze, coke produces solid waste containing hazardous components such as benzene.[9]

Iron is produced when coke is combined with oxygen, flux, and iron ore in a blast furnace. In hot stoves, compressed air is blended with additional oxygen and heated to 1100°C. Oxygen is then injected at the bottom of the blast furnace. Because hot stoves account for 10 to 20% of the total energy requirement in an integrated steel mill, efficient hot stoves can yield substantial energy savings.[10]

Iron ore is ordinarily introduced into the blast furnace in the form of sinter or pellets. Sintering is the more efficient process for making direct feed for blast furnaces, and more than 50% of all iron ore is converted into sinter. Sintering involves heating fine ore and causing it to agglomerate into larger granules.[11] The heat consumed for the sintering reaction is about 33% of the total heat input into a steel plant. Since almost half of this energy is released into the atmosphere, waste heat recovery is a key strategy for improved efficiency. Although sintering is more efficient than pellet production, it results in greater amounts of dust levels per ton of steel produced.

Iron is produced in the blast furnace from coke, oxygen, iron ore, and flux. Limestone in the form of flux is added to remove sulfur and other impurities.[12] Impurities in the furnace produce blast furnace slag that rises to the top of the furnace.[13]

Iron that is produced in blast furnaces is then introduced into the basic oxygen furnace. The oxygen steelmaking process converts the molten iron from the blast furnace and steel scrap into steel. High-purity oxygen is introduced that lowers carbon, silicon, manganese, and phosphorous content of the iron, and flux is added to reduce sulfur and phosphorous levels.[14] These impurities are carried off in the slag that floats on the surface of the hot metal. The basic oxygen furnace production of steel requires approximately 1 to 13 GJ per ton of crude steel, including the hot stove, blast furnace, and oxygen furnace.

Electric Arc Furnaces

The *electric arc furnace* (EAF) produces products whose primary requirement is strength. For example, structural beams, steel plates, and reinforcement bars are made via electric arc furnaces.[15] Processing of steel from ore occurs in this manner via direct reduced iron production and electric arc furnace operations. In direct reduced iron production, oxygen is removed from lump iron oxide pellets to produce direct reduced iron (DRI).[16] The electric arc furnace employs this direct reduced iron and scrap to produce steel. Scrap is the most important element because about 80% of the inputs are of this nature.[17] Consequently, it is difficult to control the purity and quality of the steel produced. Mills that focus on EAF steel production normally concentrate on market segments where steel quality is not as critical.[18] During melting and refining operations, some of the undesirable materials within the bath are oxidized and become electric arc slag.[19] The production of direct reduced iron using natural gas requires about 12 GJ per ton of crude steel. Electric arc furnaces use 1 to 1.5 GJ of electricity per ton of crude steel.

Metallurgy and Finishing

The use of a basic oxygen or electric arc furnace yields crude steel, but refinement does not end. The liquid steel output from the furnaces is further refined via a series of processes referred to as **metallurgy**. The objectives of these processes are the removal of oxygen, hydrogen, sulfur, and other impurities. After removal of these impurities, the steel is cast into either ingots or semifinished shapes (e.g., slabs). Continuous casting into semifinished shapes requires less time, labor, energy, and capital than ingot casting.[20] Additional finishing such as galvanization is also incorporated into steel during this final phase.

Sustainability

The steel industry is attempting to enhance environmental sustainability via initiatives associated with *climate change*, *environmental protection*, and *management of natural resources*.[21] One aspect of climate change efforts focuses on reductions in the amount of carbon dioxide produced for each ton of steel produced. Part of this effort includes investments in technologies that raise the eco-efficiency of production. The International Energy Agency indicates that more than 3% of total sector energy use (2.9 EJ) and 3% of CO_2 emissions can be realized through improved efficiency of production processes and better reclamation of by-products of these processes.[22] Improved production processes include application of dry coke quenching in coke making, blast furnace and electric arc furnace enhancements, and steel finishing improvements.[23] The reductions associated with changes in these processes are realized when companies upgrade to the best available technologies.

The steel industry's concerns with environmental protection focus on monitoring of production and life cycle inventory management. Because the monitoring of operations is essential to this industry, most steel producers operate facilities that are ISO 14001 certified. *ISO 14000* refers to a family of management standards established by the International Standards Organization. The ISO 14001 standard enables firms to assess the environmental impact of their activities, improve environmental performance, and implement a systematic approach to achieving environmental objectives.[24] More than 85% of all employees and contractors in the steel industry operate at ISO-registered facilities.[25]

The third facet of environmental sustainability in the steel industry concerns the management of natural resources. *Material efficiency* refers to the amount of material that is not sent to permanent disposal in a landfill or incineration. This efficiency is realized by the familiar reduce, reuse, and recycle perspective. Material *reductions* are realized by using cokeless steel production technologies that do not rely on coke production. Marketing the blast furnaces' and electric arc furnaces' slag to the road construction and cement industries reduces energy costs and overall carbon emissions for the industrial sector.

The *reuse* of material is exemplified by an industry that boasts a 97% material efficiency level. This 100% efficiency goal is approached by working together with other industries. Efforts to use by-products of steel production more efficiently include coke oven and basic oxygen furnace gas recovery, blast furnace gas use, and slag/steel usage in cement making. Notably, slag marketed to the cement industry has the potential to reduce cement-related CO_2 by 50%.

The steel industry is also very active in *recycling*. Virtually all steel is recyclable, and as one of the few magnetic metals, it can easily be separated from waste and other metals. Steel is the most widely recycled material in the world. In 2006, for example, the industry recycled 459 metric megatons (mmt), equivalent to 37% of the crude steel produced in the year.[26] This recycling reduced carbon emissions by 827 mmt and saved the equivalent of 868 mmt of iron ore.[27]

C. Carbon Emissions in the Nonmetallic Minerals Industry

Nonmetallic minerals account for 9% of industrial energy use but represent 27% of carbon emissions.[28] The largest contributor to energy usage in the nonmetallic minerals sector is concrete production, and a central process to this production is the production of **cement**. After water, concrete is the second most consumed product in the world.[29] In 2000, worldwide concrete sales exceeded $97 billion.[30] The production of cement represents about 80% of energy use for nonmetallic metals and is an important source of CO_2 emissions. There have been substantial improvements in energy use in this industry over the past 15 years, yet there is potential for additional reduction associated with adoption of best available technologies.

Concrete is a global industry operating in 150 countries with more than 850,000 employees. At 46% of global cement production in 2005, China is the largest producer of cement. The top 10 producers (China, India, United States, Japan, Korea, Spain, Russia, Thailand, Brazil, and Italy) account for more than 71% of global production. Transportation costs for cement are extensive, and concrete is rarely transported more than 300 kilometers. The United States exports concrete to Mexico and Canada, and most of the country's imports come from China, Thailand, Canada, Thailand, and Greece.[31]

Concrete production is a relatively simple four-stage process.[32] The first stage is acquisition of raw materials. These materials include limestone, sand, and clay that typically come from quarries located near the cement manufacturing plant. These components provide the four main ingredients for cement: lime, silica, alumina, and iron.[33] In the second stage, these materials are analyzed, blended, and ground for further processing. In the third stage, materials are heated in a very large kiln that is more than 200 meters long with a diameter of 3 to 7.5 meters. The kiln reaches temperatures of 1,450°C, which turn the material into a marble-sized substance called **clinker**. When the limestone is heated, it undergoes a reaction in which carbon dioxide is released and calcium oxide is formed. Importantly, about half of the carbon emissions for concrete are associated with this process, and these emissions are unaffected by fuel switching or other efforts to enhance efficiency. In the fourth stage, gypsum is added, and the mixture is ground to a fine powder called **Portland cement**. Although there are other forms of cement, Portland cement is the most common and represents over 98% of cement sales in the United States.[34] Portland cement is marketed in eight different compounds that vary based on physical and chemical requirements such as durability and strength.[35]

Cement production can occur via wet or dry processes. The wet process facilitates easier control of chemical activity, but it has higher energy requirements due to the need to evaporate water prior to making calcium dioxide. Because the dry process does not require evaporation, the energy costs associated with cement production are lower. Consequently, dry processes are replacing wet processes on a worldwide basis.

Sustainability

Due to the amount of carbon emissions associated with the industry, concrete has been implicated as an industry that contributes to global warming.[36] Most of the carbon emissions in concrete production, however, are associated with the production of calcium oxide (a product essential to cement), and most sustainability efforts cannot address this primary source of emissions in the industry. Nevertheless, several strategies have been employed to limit the industry's impact on climate change.

Substantial efforts have been dedicated to *reducing* the amount of energy employed in the manufacturing process. The size of the kiln used to make cement influences energy costs. In China, the world's largest producer at nearly 50% of production, small kilns are being replaced by more efficient larger kilns. Concrete producers are also working with alternative fuels in order to reduce production costs, dispose of waste, reduce carbon emissions, and limit fossil fuel usage. These fuels may include tires, wood, plastics, chemicals, animal carcasses, sewage sludge, and construction waste. The use of alternative fuels varies by country. At one extreme, Germany relies on alternative fuels for about 37% of clinker production, yet South Korea, at the other extreme, incorporates less than 5% alternative fuels.

The process of grinding materials represents the largest electricity demand in the cement industry. Grinding associated with processing of raw materials and grinding of cement account for almost 100 kilowatt hours per metric ton of cement produced. Best industry practice indicates, however, that there is potential to reduce electricity usage by another 20%. Despite this potential, more than 90% of the energy associated with grinding is converted to heat that is not used in the production of cement. Clearly, there are opportunities to develop new processes that facilitate cement production at efficiency levels greater than 10%.

The concrete industry relies on *reuse* to limit carbon emissions. In many production processes, some Portland cement is replaced or supplemented with industrial by-products referred to as supplementary cementitious materials (SCMs).[37] Slag procured from the steel industry can be used as a substitute for limestone. Steel slag requires little additional fuel to convert it to cement clinker. As a result, carbon emissions are reduced due to lower energy needs. Fly ash, a by-product of coal burning, and silica fume, a by-product of silicon manufacturing, are also reused in as slag in the production of cement. The recovery of industrial by-products avoids the use of virgin materials in cement manufacturing and limits the amount of material disposed of in landfills. Moreover, greenhouse gas reductions are achievable by using SCMs to replace some Portland cement. The manufacture of Portland cement requires significant energy use, and replacement with SCMs reduces this energy burden. In addition, reuse of SCMs can improve workability of the concrete mixture, decrease concrete permeability, improve durability, and enhance strength.

Concrete is also one of the most *recycled* materials on the planet.[38] Recycling of concrete pavement involves breaking, removing, and crushing concrete from an existing pavement. Crushed concrete is then used as an aggregate in new Portland cement or other concrete processes.[39] In recent years, there have been advancements in concrete crushing technologies and methods to remove steel from concrete. This recycled concrete meets most specifications and is currently being used with other concrete and asphalt products and yielding better performance over comparable virgin concrete. The material is lighter than other concrete, which lowers the cost of material handling and transportation. Furthermore, recycling limits the amount of concrete discarded in landfills.

Analyses of the sustainability of concrete need to augment consideration of reduce–reuse–recycle logic with consideration for the long-term benefits of using concrete as a construction material.[40] The predominant raw material for the cement in concrete is limestone, the most abundant mineral on earth. Because the materials for concrete are readily available, concrete can be made from local resources and processed near a jobsite. Local shipping minimizes fuel requirements for handling and transportation. Concrete also yields durable, long-lasting structures whose life spans can be double or triple those of other common building materials. Finally, homes built with concrete (walls, foundations, and floors) are energy efficient because they take advantage of concrete's inherent ability to absorb and retain heat. Consequently, homeowners can significantly cut their heating and cooling bills and install smaller-capacity HVAC equipment.

D. Carbon Emissions Endemic to Chemical Production

The chemical industry produces plastics, synthetics, resins, detergents, fertilizers, and many other products on which we rely daily. The industry accounts for 30% of industrial energy usage, and this usage rate is growing at 2.2% annually.[41] The chemical industry also represents 16% of carbon emissions in the industrial sector.

Three types of intermediary products span raw materials (crude oil, natural gas, coal, and other minerals) and consumer goods. These intermediary products include **olefins, aromatics**, and **other intermediates**. Olefins include ethylene, propylene, and xylene. These chemicals are used to make a variety of products such as bottles and trash bags. Aromatics include benzene, toluene, and xylene used to make products such as footwear and car tires. The other intermediaries include synthetic gas used in ammonia and methanol production. The primary feedstock for olefins and aromatics is crude oil, whereas the primary feedstock for synthetic gas production is natural gas. Within the industry, 75% of feedstock is crude oil.

Nine chemical processes account for more than 65% of global energy use in the industry. These processes are associated with petrochemicals, inorganic chemicals, and fertilizers.

Petrochemicals

Steam cracking. Steam cracking is a process in which saturated hydrocarbons are broken down into smaller hydrocarbons. Steam cracking occurs in ovens in which feedstocks are broken down in the presence of steam.[42] This process also results in the removal of by-products such as hydrocarbons, water, and acid gas. Steam cracking accounts for more than 39% of final energy use in the chemical industry. It is the principal method for producing olefins (ethylene, propylene, and butadiene). This procedure has incurred a 50% reduction in energy consumption since the 1970s, yet implementation of improved technologies for the removal of by-products yields greater energy efficiency.

Aromatic extraction. Aromatic extraction includes the production of benzene, toluene, and xylene used to make products ranging from medicine to DVDs. Because the majority of energy employed in this process is feedstock, there is limited potential to reduce energy consumption.

Methanol. **Methanol** is a chemical that occurs as a result of biological processes conducted by vegetation, microorganisms, and other living species. It is produced synthetically through the catalytic steam process that typically uses natural gas as the feedstock. Methanol can be produced from natural gas, coal, municipal wastes, landfill gas, wood wastes, and seaweed, and it is used to make a variety of products such as plastics, paints, construction materials, and windshield washer fluid.[43] In 2006, 40% of methanol use was for formaldehyde and another 19% was used as a fuel additive. Seventeen countries account for more than 90% of methanol production. China is the largest producer and the only one that uses coal as a feedstock. The carbon emission cost associated with natural gas plants is lower than the emissions in coal-based facilities.[44]

Olefin and aromatic processing. Olefins are used to make plastics and synthetic rubber. The Unipol reactor process marketed by Union Carbide in 1977 was developed to manufacture polyethylene while the process for the manufacture of polypropylene was announced in 1983.[45] Polypropylene is the world's most widely used plastic, and Unipol is the most widely used process for making this plastic.[46] The Innovene process developed by BP is also widely used.[47] The rights to market Innovene are now owned by Ineos.

Inorganic Chemicals

Chlorine and sodium hydroxide. Chlorine is procured when salt is electrochemically decomposed into chlorine and sodium hydroxide. Chlorine is further processed to make polyvinyl chloride (PVC), used in plumbing, whereas sodium chloride is used by the paper, textile, and other industries. At more than 25% of total output, the United States is the world leader in production. Chlorine and sodium hydroxide are produced through three processes that vary in their sodium hydroxide concentration. These methods include the mercury, diaphragm, and membrane processes. The greatest potential for energy savings lies in the conversion of mercury and diaphragm process plants to membrane technology.

Carbon black. **Carbon black** is a form of carbon that is primarily used as reinforcement in vulcanized rubber products. The tire industry uses approximately 85% of the output of this inorganic compound. In the past decade, there have been efforts to replace some portion of carbon black with silica. Silica tires wear better, offer greater fuel efficiency, and provide better traction. Nevertheless, the material costs of silica are twice the cost for carbon black.

Soda ash. **Soda ash** or sodium carbonate is primarily used to make glass, but it is also used in water softeners, detergents, brick manufacturing, and photographic processes. In the United States, the world's largest producer (31% share), soda ash is drawn from natural deposits and soda recovery from lakes. In contrast, soda ash is produced via synthetic process in every other country. This synthetic process is more costly and energy intensive than natural soda.

Industrial gases. Industrial gases are commonly found in the air and other gases. Nitrogen, the largest-selling gas, is used in the food and beverage industry and in multiple manufacturing processes. Oxygen, the second largest-selling gas, is used in manufacturing and health care. Carbon dioxide is used in the food industry but is also used in the refrigeration and health care industries. Acetylene, the fourth largest-selling gas, is used in welding.

Fertilizers

Ammonia is an essential element in fertilizer that is produced by combining hydrogen and oxygen. The nitrogen is procured from the air, whereas the hydrogen is obtained from fossil fuel. Throughout most of the world, natural gas is used to produce hydrogen. Natural gas represents 77% of ammonia production. Coal gasification is a different process for hydrogen procurement and represents 14% of the world market. Coal is primarily used to produce ammonia in China. The remaining 9% of the market relies on partial oxidation of oil to produce hydrogen. This form of production is employed in China and India, the number one and two producers, respectively, of ammonia.

Sustainability

There have been marked enhancements in technology that enable the chemical industry to *reduce* energy consumption. The specific energy consumption associated with steam cracking, for example, has been reduced by 50% since 1970.[48] These improvements have occurred via introduction of enhanced technologies such as process-to-process heat recovery systems. Similarly, application of best practice technologies in the production of olefins and aromatics has potential to improve energy efficiency by more than 30%. Best practice technologies include use of improved reactors and enhanced polymerization processes.

Among the three processes used to make chlorine, the membrane process requires the least energy. The total energy requirements include electricity used in the decomposition of salt and steam consumption. The membrane process is at least 16% more efficient than either of the other processes.[49] Conversion of chemical plants to this procedure results in reductions in the amount of energy consumed in the industrial sector.

Although many chemicals cannot be reused, there are substantial efforts to recycle by-products through the manufacturing of chemicals. In steam cracking, substantial amounts of by-products are recycled, and the form of the by-products varies with the feedstock. For example, for every metric ton of ethane that undergoes steam cracking, 803 kilograms of ethylene are produced. Ethylene is processed into a wealth of products that range from packaging to antifreeze to detergents. The by-products include propylene and butadiene used to produce plastics as well as hydrogen and methane used to fuel the steam cracking furnace.[50]

E. Carbon Emissions Associated with the Paper and Pulp Industries

At 5.7% of total industry energy consumption, the paper and pulp industry is the fourth largest user of energy in the industrial sector. The United States is the largest producer at 24% of worldwide output. The top 10 producers (United States, China, Japan, Canada, Germany, Finland, Sweden, Korea, France, and Italy) account for almost 75% of output. Since 1990, Chinese production of paper and paperboard has more than tripled.

Approximately one half of industry production is in the form of packaging, wrapping, and paperboard, and one third of production is printing and writing paper. Since 1960, the annual growth rate for printing and writing paper has exceeded increases in demand in other sectors of this industry, and the rise in computer and photocopier use is associated with this increase. The remaining output is newsprint, sanitary paper, and household paper.[51] As the popularity of the Internet and electronic media has increased, the demand for newspapers and periodicals has decreased. The demand for various forms of production is related to Organisation for Economic Cooperation and Development (OECD) membership. Within the OECD, there is a greater demand for paper used for printing and writing. By contrast, paper and paperboard used in packaging fuels demand outside of the OECD.

There are several characteristics that influence the ability to make generalizations about paper production. First, the various producers differ in their access to virgin timber and recycled materials. In addition, the energy requirements technologies and plant sizes differ considerably across markets.[52] The paper and pulp industry also differs from other industries because it is a large producer and user of biomass. Across the industry, more than one third of the energy consumed is biomass. Much of this biomass is black liquor that is produced in the making of pulp. This biomass and other forms of energy are primarily used to generate heat in the production process. Two-thirds of the energy consumed is used to produce heat, while another third is used to make electricity. The biomass use results in relatively low levels of carbon emissions in this industry and suggests that there are modest opportunities to enhance energy efficiency. Estimates from the International Energy Agency, however, indicate significant opportunities to enhance energy efficiency.

In order to understand the potential for savings, it is important to understand the flow of resources in the production process. Raw materials such as logs are cut into wood pulp, and this pulp is processed to separate wood fibers from the **lignin** that binds fibers into solid wood.[53] The processing of pulp occurs through either mechanical pulping or chemical pulping. Mechanical pulping is used for lower-grade papers and offers high yields. Chemical pulping is a thermochemical process in which a combination of solvents and heat is applied to separate lignin from wood fibers.[54] The two most common processes are sulfite and sulfate pulping. Sulfate pulping employs the Kraft process whereby sodium sulfate is used to produce a pulp of high physical strength and bulk, but relatively poor sheet formation. Sulfite pulping uses sulfurous acid and an alkali to produce pulps of lower physical strength and bulk that offer better sheet formation. These pulps are used in newsprint, printing, bond papers, and tissue.

Approximately 18% of energy use is associated with pulping, and most of this consumption (15%) is due to mechanical pulping. Chemical pulping produces large amounts of black liquor that is used to generate electricity. Thus, this pulping process produces about one third of the energy used in the industry.

Once the pulping procedure and energy recovery have occurred, the pulp is bleached and dried to prepare for papermaking. The making of paper includes the blending of pulps and additives, sheet formation, and finishing. The process of papermaking represents 47% of total energy use in the industry.

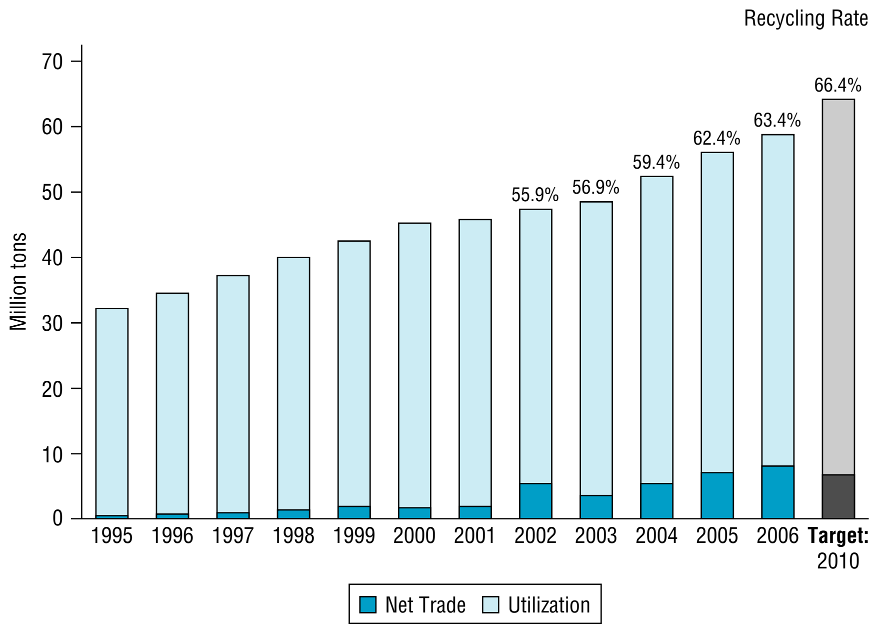
Sustainability

There have been tremendous strides toward sustainability in the industry, yet there are additional measures that would reduce the amount of energy consumption and carbon emissions. These additional measures include advanced pulp drying technologies, enhanced black liquor recovery technologies, and improved heat recovery systems. The International Energy Agency indicates that implementation of best available technologies has the potential to limit final energy consumption by 14%.

The reuse of materials in the production process has already posted strong dividends for the paper industry. The reuse of black liquor as a fuel limits reliance on fossil fuel. Moreover, use of this technology has the potential to enable chemical pulp plants to serve as net providers to the electricity grid.

Figure 14-7 outlines the value chain for the recycling of paper products. Because archival documents, construction materials, and other products cannot be recycled, the theoretical maximum for recycling of paper is 81%. At 60% recycling, Japan is the largest recycler, followed by the European Union at 52%.[55] The average global

FIG. 14-7 Paper Recycling Value Chain



Source: *Confederation of European Paper Industries,* 2007 Sustainability Report, *p. 32.*

rate of recycling is 45%, which suggests marked opportunity to recycle. The Confederation of European Paper Industries is a colloquium of EU members, Norway, and Switzerland that has set a target of 66% by 2010.[56]

The effort to promote recycling in the paper industry underscores one of the intriguing challenges of green marketing. There are situations under which one must choose among environmental goals that are somewhat incompatible. For example, the reclamation of recycled paper now accounts for 45% of inputs to global production. Note that although recycling results in use of fewer natural resources, the effort to gather and process recycled materials yields carbon emissions. By contrast, chemical pulping plants that use virgin timber may be carbon neutral. The effort to yield lower carbon emissions must be viewed simultaneously with the desire to manage natural resources such as timber.

F. Industrial Standards that Seek to Limit Carbon Emissions

The preceding review of industrial users of energy and producers of carbon dioxide illustrates the challenges associated with attempting to act in an environmentally responsible manner. The criteria for achieving sustainability vary by industry, but due to differences in environments and technologies, it is often difficult to compare levels of sustainability within or across industries. Efforts to identify standards for comparison enable firms to examine sustainability relative to produces in an industry and across industries. One organization that facilities this activity is the **International Organization for Standardization** (ISO).

ISO is a Geneva, Switzerland-based network of the national standards institutes of 157 countries. The organization was formed in 1946 to promote international standards.[57] ISO has more than 17,000 international standards focused on a broad range of industries that include agriculture, construction, mechanical engineering, manufacturing, distribution, transportation, medical devices, information and communication technologies. For example, ISO established a standard format for ATM cards that enables these cards to be used worldwide.[58] ISO has also developed standards for good management practice and for services.[59] The vast majority of standards are specific to an industry, but ISO has developed two families of generic strategies applicable to any industry.[60] In contrast to most other ISO standards, both of these families of standards focus on process rather than specific industrial measures. ISO 9000 is a generic set of requirements for implementing a quality management system. These standards codify efforts to improve quality on an ongoing basis while simultaneously managing quality requirements, regulatory requirements, and customer satisfaction.[61]

ISO 14000 is a second generic managerial system that supports organizational action designed to minimize harmful effects on the environment and achieve continual improvement of environmental performance.[62] Implementation of ISO 14000 offers many benefits to an organization.[63] First, the organization realizes cost savings due to a focus on resource consumption and waste management. Energy and material use are lowered and the overall costs to distribute products are also held in check.[64] A second benefit is associated with risk management. The organizations that establish ISO 14000 standards have fewer legal and financial liabilities because these systems help identify current and forthcoming legislation and requirements. Adherence to ISO 14000 standards lowers the risk of noncompliance.

A third facet of ISO accreditation is the marketing opportunities that it offers to the organization. Because virtually every industry today faces sustainability issues, achieving certification provides the opportunity to promote the environmental aspects of product offerings. Environmental opportunities accrue in the production process as well as the distribution and logistics functions. The development of an environmental management system that incorporates ISO 14000 certification increases the opportunities to identify customer requirements and establish ecologically based systems for projects developed with customers and suppliers.[65] Thus, the corporate image for environmental sensitivity is heightened through ISO accreditation.

Another benefit of ISO accreditation is the influence that it has on interested parties within and outside the organization. Internal stakeholders such as employees can nurture sensitivities to environmental issues that bolster their loyalty to the organization. Accreditation also assures external stakeholders such as customers, regulatory agencies, and communities that the organization is managing its relation with the environment. It supports the organization's claims about its own environmental policies, and it provides a framework for demonstrating conformity to environmental policies.[66]

Within the ISO 14000 family, ISO 14001:2004 provides the generic requirements for an environmental management system (EMS). EMS is a systematic way of managing an organization's environmental affairs that addresses the immediate and long-term influences of its products and processes on the environment.[67] It provides order for organizations to address environmental concerns through the allocation of resources, assignment of responsibilities, and ongoing evaluation of practices.

ISO 14001:2004 facilitates the establishment of an appropriate environmental policy. In addition, it incorporates a planning phase that covers the identification of the environmental aspects of the organization's activities, identification and access to legal requirements, establishment and documentation of objectives and targets consistent with the policy, and establishment of a program for achieving targets and objectives.[68] It further outlines a strategy for implementation of EMS including documentation and communication of roles and responsibilities for ecologically related activity. ISO 14001:2004 also provides procedures for monitoring key characteristics of the operations and activities, and it outlines a strategy for periodic reviews of the EMS. ISO 14001:2004 provides assurance to management and employees that they are controlling organizational processes and activities related to the environment. ISO 14001:2004 is the standard that indicates the firm's commitment to maintaining an environmental management system. This system will be established either through self-compliance efforts or via third-party registration.[69]

In contrast to ISO 14001:2004, which outlines requirements for an EMS, ISO 14004:2004 gives general EMS guidelines. ISO 14004:2004 provides guidance on the establishment, implementation, and maintenance of an EMS. ISO14004:2004 provides an overall picture of the commitment and policy of EMS, and it further provides for the creation of a plan to fulfill the policy. This standard also outlines the process for putting the plan into action by providing human, financial, and physical resources. ISO 14004:2004 also provides procedures for monitoring and improving the EMS.[70]

ISO 14000 also incorporates a number of other directives associated with environmental management.[71] The auditing systems (ISO 14010–14012) provide guidelines and procedures for auditing and outline the qualifications for auditors. The *environmental aspects of product standards* are a related set of guides for the inclusion of environmental aspects in product standards. Conformance to this standard increases the likelihood that product designers are familiar with the environmental consequences of their designs. Similarly, ISO 14062 enables organizations to identify the likely effects on the environment of their future products and make effective decisions during the design and development stages to improve their environmental performance. ISO 14064 directly addresses greenhouse gas (GHG) emissions. Implementation of ISO 14064 promotes transparency in GHG quantification and enables organizations to identify and manage GHG-related liabilities, assets, and risks. It also facilitates the trade of GHG credits and supports the development of systems to limit emissions.[72]

Another set of standards in the 14000 family is the set that enables a company to claim that its products are designed with consideration for the environment.[73] ISO 14020-24 seeks to achieve consistency in labeling methods and procedures by outlining criteria for self-declaration, green reporting, and labeling. Adherence to these standards provides credibility to claims about production and distribution methods employed by a firm.

The overall influence of ISO 14000 standards is the assurance that a company is attempting to address ecological concerns throughout its operations. Consumers are increasingly focused on whether a firm is environmentally responsible, and implementation of these standards enables firms to demonstrate their commitments to the environment.

Summary

A. Primary Industrial Contributors to Carbon Emissions

The purpose of this chapter has been to outline the major influences of industry on the environment. We offer evidence that the iron and steel, petrochemical and chemical, nonmetallic metals, and paper and pulp industries are the largest users of energy and largest producers of carbon dioxide.

B. Carbon Emissions Associated with Steel Production

The steel industry and the nonmetallic minerals industry are the largest producers of carbon emissions in this economic sector. The production of iron and steel is complex and varies from one country to the next, yet two methods account for nearly all steel production. Basic oxygen is ordinarily used for high-tonnage production of carbon steels, and electric arc furnaces are to produce low-tonnage specialty steels.

C. Carbon Emissions in the Nonmetallic Minerals Industry

The largest contributor to energy usage in the nonmetallic minerals sector is concrete production, and a central process to this production is the production of cement. Concrete production is a relatively simple four-stage process. The first stage is acquisition of raw materials. In the second stage, these materials are analyzed, blended, and ground for further processing. In the third stage, materials are heated in a very large kiln. In the fourth stage, gypsum is added, and the mixture is ground to a fine powder called Portland cement.

D. Carbon Emissions Endemic to Chemical Production

The chemical industry also represents 16% of carbon emissions in the industrial sector. Three types of intermediary products (olefins, aromatics, and other intermediates) span between raw materials that include crude oil, natural gas, coal, and other minerals. Nine chemical processes associated with petrochemicals, inorganic chemicals, and fertilizers account for more than 65% of global energy use in the industry.

E. Carbon Emissions Associated with the Paper and Pulp Industries

The paper and pulp industry is the fourth largest user of energy in the industrial sector. Approximately one half of industry production is in the form of packaging, wrapping, and paperboard, and one third of production is printing and writing paper. Since 1960, the annual growth rate for printing and writing paper has exceeded increases in demand in other sectors of this industry, and the rise in computer and photocopier use is associated with this increase. The demand for various forms of production is related to OECD membership.

F. Industrial Standards that Seek to Limit Carbon Emissions

ISO 14000 is a managerial system that supports organizational action designed to minimize harmful effects on the environment and achieve continual improvement of environmental performance. Implementation of ISO 14000 enables organizations to realize cost savings due to a focus on resource consumption and waste management. Adherence to ISO 14000 standards lowers the risk of noncompliance, and accreditation offers marketing opportunities to firms that pursue these standards.

Keywords

aromatics, 288
basic oxygen furnace, 283
carbon black, 289
cement, 286
clinker, 286
dry quenching, 284
electric arc furnace, 283
International Organization for Standardization (ISO), 292
ISO 14000, 285
lignin, 291
metallurgy, 285
methanol, 288
olefins, 288
other intermediates, 288
Portland cement, 286
soda ash, 289

Questions

1. What is the value that a marketing student derives from gaining an understanding of energy usage and sustainability in the industrial sector?
2. What three industries account for the most energy usage in the industrial sector, and what is their contribution to energy consumption?

3. What are the two primary forms of steel production?
4. What efforts are being made to enhance the sustainability of the steel industry? To what extent have they already been successful in enhancing sustainability?
5. What is the difference between concrete and cement?
6. To what extent have concrete producers attempted to achieve sustainability in their production processes?
7. What three products span between raw materials and consumer products, and what consumer products do they become?
8. How has the paper industry attempted to achieve sustainability? What is the role of the consumer in their efforts?
9. Contrast the influence of ISO 9000 and ISO 14000 regarding each standard's ability to help organizations achieve sustainability.
10. How does ISO 14000 accreditation enable an organization to market its products more effectively?

Endnotes

[1] American Institute of Steel Construction, "SteelDay 2009," http://www.aisc.org/WorkArea/showcontent.aspx?id=21730 (accessed May 15, 2010).

[2] American Institute of Steel Construction, "SteelDay Events Draw More than 7,000 Attendees," http://www.aisc.org/news detail.aspx?id=22246 (accessed May 15, 2010).

[3] International Energy Agency, *Tracking Industrial Energy Efficiency and CO_2 Emissions* (Paris, France: OECD/IEA, 2008), 324.

[4] World Steel Association, *2008 Sustainability Report* (Brussels, Belgium: World Steel Association, 2008), 1–35, http://www.worldsteel.org/pictures/publicationfiles/Sustainability%20Report %202008_English.pdf (accessed May 15, 2010).

[5] See Note 3 above.

[6] The World Bank Group, *Pollution and Prevention Abatement Handbook 1998: Toward Cleaner Production* (Washington, D.C.: World Bank Group, 1998) 1–472, http://www.ifc.org/ifcext/sustainability.nsf/AttachmentsByTitle/p_ppah/$FILE/PPAH.pdf (accessed May 15, 2010).

[7] Steel Recycling Institute, "2006 The Inherent Recycled Content of Today's Steel," http://www.recycle-steel.org/PDFs/Inherent 2006.pdf (accessed May 15, 2010).

[8] See Note 6 above.

[9] See Note 6 above

[10] See Note 3 above.

[11] See Note 3 above.

[12] American Iron and Steel Institute, "How a Blast Furnace Works," http://www.steel.org/AM/Template.cfm?Section=Articles3&CONTENTID=25317&TEMPLATE=/CM/ContentDisplay.cfm (accessed May 15, 2010).

[13] Energy Solution Center "Blast Furnace: Process Description," Metals Processing Advisor, http://www.energysolutionscenter.org/heattreat/MetalsAdvisor/iron_and_steel/process_descrip tions/raw_metals_preparation/ironmaking/blast_furnace/iron making_blastfurnace_processdescription.htm (accessed May 15, 2010).

[14] See Note 7 above.

[15] See Note 7 above.

[16] Energy Solution Center, "Direct Reduction: Process Description," Metals Processing Advisor, http://www.energysolutions center.org/heattreat/MetalsAdvisor/iron_and_steel/process_de scriptions/raw_metals_preparation/ironmaking/direct_reduction/ (accessed May 15, 2010).

[17] See Note 4 above.

[18] Energy Solution Center, "Electric Arc Furnace: Process Description" Metals Processing Advisor, http://www.energysolu tionscenter.org/HeatTreat/MetalsAdvisor/iron_and_steel/process_ descriptions/raw_metals_preparation/steelmaking/electric_arc_ furnace/electric_arc_furnace_process_description.htm (accessed May 15, 2010).

[19] Jeremy A. T. Jones, "Electric Arc Furnace Steelmaking," *American Iron and Steel Institute*, http://www.steel.org/AM/Template.cfm?Section=Home&template=/CM/HTMLDisplay.cfm&ContentID=21169 (accessed May 15, 2010).

[20] Energy Solution Center, "Continuous Casting: Process Description," Metals Processing Advisor, http://www.energysolutions center.org/heattreat/MetalsAdvisor/iron_and_steel/process_descrip tions/raw_metals_preparation/steelmaking/primary_finishing/con tinuous%20casting/continuous_casting_process_description.htm (accessed May 15, 2010).

[21] See Note 4 above.

[22] See Note 3 above.

[23] See Note 6 above.

[24] International Organization for Standardization, "ISO 14000 Essentials," http://www.iso.org/iso/iso_14000_essentials.htm (accessed May 15, 2010).

[25] See Note 4 above.

[26] See Note 4 above.

[27] See Note 4 above

[28] See Note 3 above.

[29] World Business Council for Sustainable Development, *The Cement Sustainability Initiative*, *2007* (Conches-Geneva: World Business Council for Sustainable Development), http://www.wbcsd.org/DocRoot/nlYHAK4ECDi7EEcarBSH/csi-brochure.pdf (accessed May 15, 2010).

[30] World Business Council for Sustainable Development, *The Cement Sustainability Initiative*, 2002 (Conches-Geneva: World Business Council for Sustainable Development), http://www.wbcsdcement.org/pdf/agenda.pdf (accessed May 15, 2010).

[31] Portland Cement Association, "Overview of the Cement Industry," http://www.cement.org/basics/cementindustry.asp (accessed May 15, 2010).

[32] Portland Cement Association, "Four Steps to Produce Cement," http://www.cement.org/smreport08/sec_page1_3_A.htm (accessed May 15, 2010).

[33] See Note 3 above.

[34] Buckley Rumford Fireplaces, "A History of Cement," http://www.rumford.com/articlemortar.html (accessed May 15, 2010).

[35] U.S. Department of Transportation Federal Highway Administration, "Portland Cement," http://www.fhwa.dot.gov/infrastructure/materialsgrp/cement.html (accessed May 15, 2010).

[36] Elisabeth Rosenthal, "Cement Industry is at Center of Climate Change Debate," *New York Times*, October 27, 2007, 1.

[37] ConcreteNetwork.com, "Recycling Concrete," http://www.concretenetwork.com/concrete/demolition/recycling_concrete.htm (accessed May 15, 2010).

[38] American Concrete Pavement Association, "Natural Advantage," http://www.pavements4life.com/QDs/Environment_2Recycle.asp (accessed May 15, 2010).

[39] See Note 37 above.

[40] Environmental Council of Concrete Organizations, "Homepage," http://www.ecco.org/ (accessed May 15, 2010).

[41] See Note 3 above.

[42] Amos A. Avidan, Michael Edwards, and Hartley Owen, "Innovative Improvements Highlight FCC's Past and Future," *Oil & Gas Journal* 88, no. 2 (1990): 33–58.

[43] Methanol Institute, http://www.methanol.org/pdfFrame.cfm?pdf=faqs.pdf (accessed May 15, 2010).

[44] See Note 3 above.

[45] Union Carbide Corporation, "History," http://www.unioncarbide.com/history/index.htm (accessed May 15, 2010).

[46] See Note 3 above.

[47] INEOS, "Business Overview," http://www.ineos.com/abo_cha.html (accessed May 15, 2010).

[48] See Note 3 above.

[49] See Note 3 above.

[50] See Note 3 above.

[51] See Note 3 above.

[52] RISI, "World Pulp Annual Historical Data – Excerpt," http://www.risiinfo.com/Marketing/ahd/Excerpts/world_pulp.pdf (accessed May 15, 2010).

[53] University of Helsinki, "Environmental Biotechnology and Biotechnology of Renewable Natural Resources: The 'lignin group'" http://www.biocenter.helsinki.fi/groups/HATAKKA/english/background.html (accessed May 15, 2010).

[54] Oy Keskuslaboratorio - Centrallaboratorium Ab KCL Science and Consulting, "Chemical Pulping," http://www.kcl.fi/page.php?page_id=90 (accessed May 15, 2010).

[55] See Note 3 above.

[56] Confederation of European Paper Industries, "Sustainability Report 2007," http://www.twosides.info/Content/rsPDF_8.pdf (accessed May 15, 2010).

[57] Amir M. Hormozi, "ISO 14000: The Next Focus in Standardization," *SAM Advanced Management Journal* (Summer, 1997): 32–41.

[58] Jennifer Nash and John Ehrenfeld, "Code Green," *Environment* 38, no. 1 (1996): 16–30.

[59] International Organization for Standardization, "Discover ISO," http://www.iso.org/iso/about/discover-iso_the-scope-of-isos-work.htm (accessed May 15, 2010).

[60] International Organization for Standardization, "What's Different About ISO 9001 and ISO 14001," http://www.iso.org/iso/about/discover-iso_whats-different-about-iso-9001-and-iso-14001.htm (accessed May 15, 2010).

[61] International Organization for Standardization, "ISO 9000 and ISO 14000," http://www.iso.org/iso/iso_catalogue/management_standards/iso_9000_iso_14000.htm (accessed May 15, 2010).

[62] See Note 24 above.

[63] Martin Baxter, "Taking the First Steps in Environmental Management," *ISO Management Systems* (July–August, 2004): 13–18.

[64] International Organization for Standardization, "Business benefits of ISO 14000," http://www.iso.org/iso/iso_catalogue/management_standards/iso_9000_iso_14000/business_benefits_of_iso_14001.htm (accessed May 15, 2010).

[65] See Note 57 above.

[66] See Note 24 above.

[67] N.C. Division of Pollution Prevention and Environmental Assistance, "EMS & ISO 14000 FAQ," http://www.p2pays.org/iso/emsisofaq.asp#faq1 (accessed May 15, 2010).

[68] See Note 24 above.

[69] See Note 57 above.

[70] Robert Anthony Reiley, "The New Paradigm: ISO 14000 and Its Place in Regulatory Reform," *Journal of Corporation Law* 22, (1997): 535–569.

[71] See Note 57 above.

[72] International Organization for Standardization, "New ISO 14064 standards provide tools for assessing and supporting greenhouse gas reduction and emissions trading," http://www.iso.org/iso/pressrelease.htm?refid=Ref994 (accessed May 15, 2010).

[73] See Note 57 above.