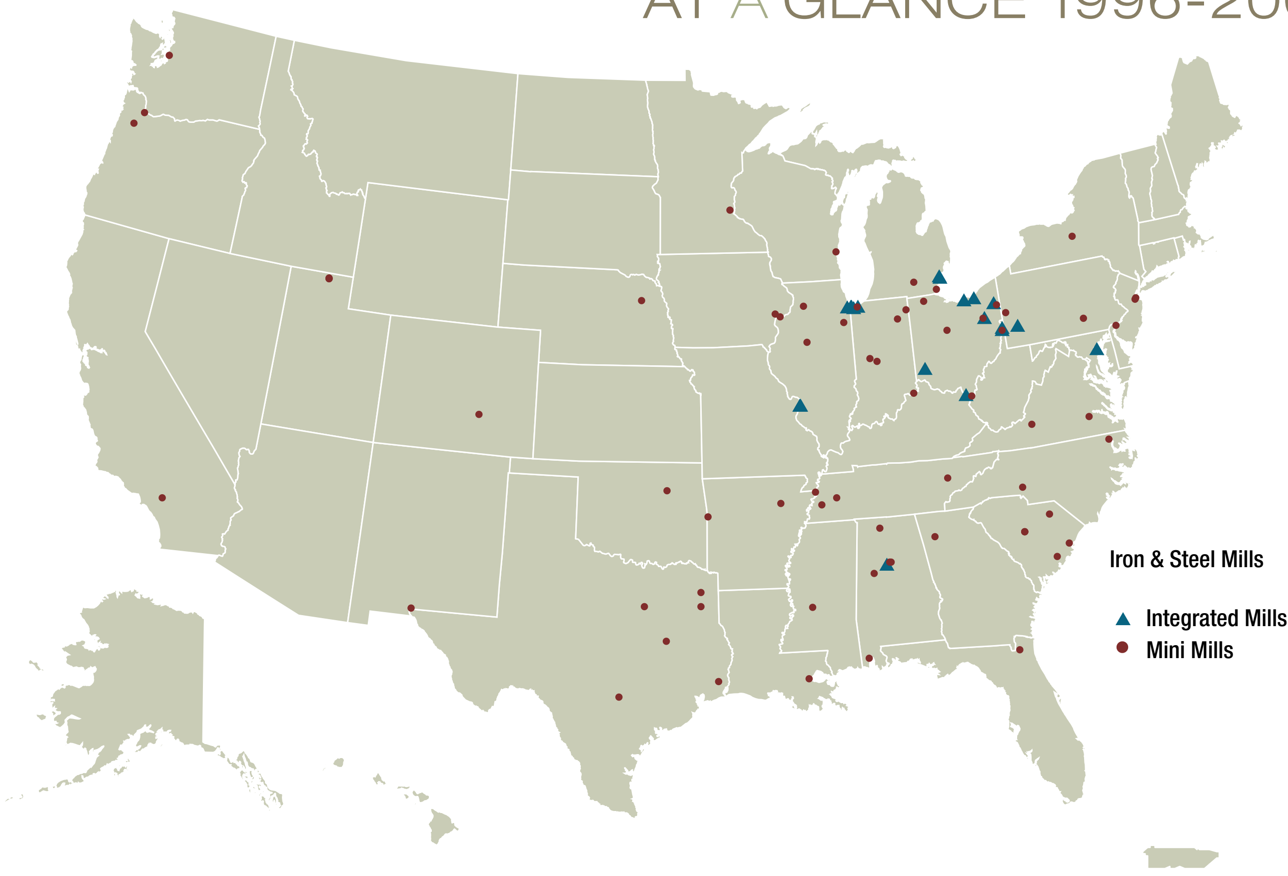
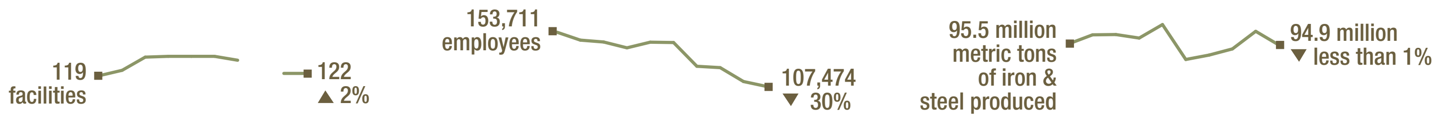
IRON & STEEL

AT A GLANCE 1996-2005[1]





Latest Environmental Statistics[2]

Energy Use: 1.5 quadrillion Btu

Emissions of Criteria Air Pollutants: 755,000 tons

Releases of Chemicals Reported to TRI: 263.9 million lbs.

Air Emissions: 3.7 million lbs.

Water Discharges: 2.9 million lbs.

Waste Disposals: 257.0 million lbs.

Recycling, Energy Recovery, or Treatment: 462 million lbs.

Hazardous Waste Generated: 1.4 million tons

Hazardous Waste Managed: 1.3 million tons

The data discussed in this report are drawn from multiple public and private sources. See the Data Guide *and the* Data Sources, Methodologies, and Considerations *chapter for important information and qualifications about how data are generated, synthesized, and presented.*

Profile

The Iron & Steel sector manufactures steel used in products such as vehicles, appliances, machinery, and equipment, and in other sectors. The Construction sector uses more than 22% of steel shipments.[3]

The sector includes facilities that produce carbon steel. As noted in the chapter, some data sets define the sector more broadly, to include facilities producing stainless and specialty steels, facilities producing coke for steel production and other uses, and facilities using steel to make new products. NAICS code 331111, for example, also includes facilities making primary metal products, in addition to steel.[4] Data from the U.S. Geological Survey, used to portray the trend in total number of facilities, also include facilities making stainless and specialty steels.

Integrated mills produce steel from iron ore using a blast furnace, which consumes carbon, primarily in the form of coke, to convert iron ore to molten iron, known as "pig iron." A basic oxygen furnace (BOF) then converts the pig iron, along with up to 30% steel scrap, into refined steel. Steelmakers also rely on coal, natural gas, and other fuels and raw materials, in combination with iron, to produce steel.

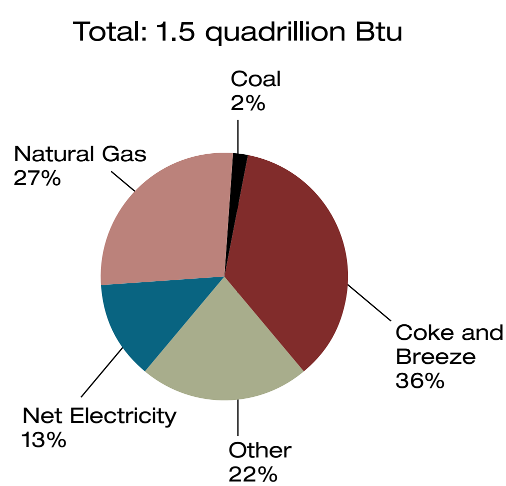
Electric arc furnaces (EAFs) melt steel scrap, along with limited amounts of other iron-bearing materials, to produce new steel. Because scrap can contain a wider range and higher percentage of contaminants, EAF steel requires additional refining to produce some grades of steel that are still made almost exclusively by integrated mills. Steelmakers continue to build new mills using EAFs (also known as mini-mills) and to modernize existing mills, increasing capacity and efficiency while reducing man-hours and energy needed per ton of steel produced.

Energy Use

Significant amounts of energy are required to convert iron ore and scrap to steel. Still, the sector's energy use per

FIGURE 1

Fuel Use for Energy 2002



Note:
1. Other is net steam (the sum of purchases, generation from renewables, and net transfers), and other energy that respondents indicated was used to produce heat and power.
2. Net electricity is an estimation of purchased power and power generation onsite.

Source: U.S. Department of Energy

ton of steel shipped improved over the last decade, with corresponding reductions in actual energy used. In 1998, for example, total energy consumption was approximately 1.7 quadrillion Btus,[5] while in 2002 the sector consumed 1.5 quadrillion Btu.[6]

Though both integrated and EAF processes are energy-intensive, integrated steelmaking requires more energy per ton of shipped product.[7] The rising percentage of steel made by EAFs has contributed to the sector's energy efficiency improvements. EAFs consume mostly recycled steel, although integrated mills also rely on steel scrap for a percentage of their raw materials.

Altogether, when recycling steel, rather than making it all from virgin raw materials, the steel industry saves enough energy each year to electrically power 18 million homes.[8] However, further EAF growth may face constraints in the limited supply of scrap or the inability of EAFs to produce many grades of steel that are in high demand.[9]

Integrated steelmaking accounts for roughly 75% of the sector's fuel consumption, relying heavily on coal and coke (which is made from coal), while EAFs account for 64% of the sector's electricity consumption.[10] The sector uses natural gas for about one-quarter of its energy, primarily in heating and annealing furnaces, but also in blast furnaces, boilers, and for EAF injection and cogeneration. Cogeneration, or combined heat and power (CHP), increases energy efficiency through onsite production of thermal energy and electricity from a single fuel source.

Steelmakers can continue to improve energy efficiency with existing options. The U.S. Department of Energy (DOE) estimates that integrated mills could increase use of cogeneration and process improvements—such as using technologies that save energy by improving furnace operations—to achieve savings of up to one million Btu per ton of steel produced, and that EAFs implementing best practices and using commercially available technology could save nearly 2 million Btu per ton.[11] The industry as a whole reported using 12.6 million BTUs (MMBtu) per ton of steel shipped in 2003: 19.55 MMBtu/ton for integrated mills, and 5.25 MMbtu/ton for EAFs.[12]

Research and development, often in partnership with DOE, has led to widespread innovation and process improvements in the sector—such as increasing use of thin slab casting, in which molten steel from steelmaking is cast directly into semi-finished shapes, saving time, labor, energy, and capital by eliminating numerous interim steps.[13] Although opportunities remain, energy efficiency improvements will be incremental without new, transformational technologies and processes for steel production, which the sector is pursuing.[14]

Air Emissions

Air emissions from the sector include criteria air pollutants (CAPs), greenhouse gases (GHGs), and a number of chemicals reported to EPA's Toxics Release Inventory (TRI). In general, the "toxic chemicals" tracked by TRI are found in the raw materials and fuels used in the steelmaking process, and can be generated in byproducts or end products. CAPs and GHGs are also generated as combustion byproducts from onsite combustion of fuels and the integrated steelmaking process.

Using Coke Oven Gas as a Resource

U.S. Steel and Primary Energy installed a 161-million-watt steam turbine that uses as a fuel 95% of the blast furnace gas generated at Gary Works in Gary, IN. The gas had been flared, but now produces process steam and 40% of the electricity needed for the mill, reducing emissions and fuel use and saving U.S. Steel more than $6 million each year.[15]

Air Emissions Reported to TRI

In 2005, 85 facilities[16] in the sector reported 3.7 million absolute pounds of air emissions to TRI. Between 1996 and 2005, TRI-reported absolute and normalized air emissions declined by 67%, as shown in Figures 2a and 2b, even though production levels for the sector remained relatively steady.[17]

To consider toxicity of air emissions, EPA's Risk-Screening Environmental Indicators (RSEI) model assigns every TRI chemical a relative toxicity weight, then multiplies the pounds of media-specific releases (e.g., pounds of mercury released to air) by a chemical-specific toxicity weight to calculate a relative Toxicity Score. RSEI methodological considerations are discussed in greater detail in the Data Guide, which explains the underlying assumptions and important limitations of RSEI.

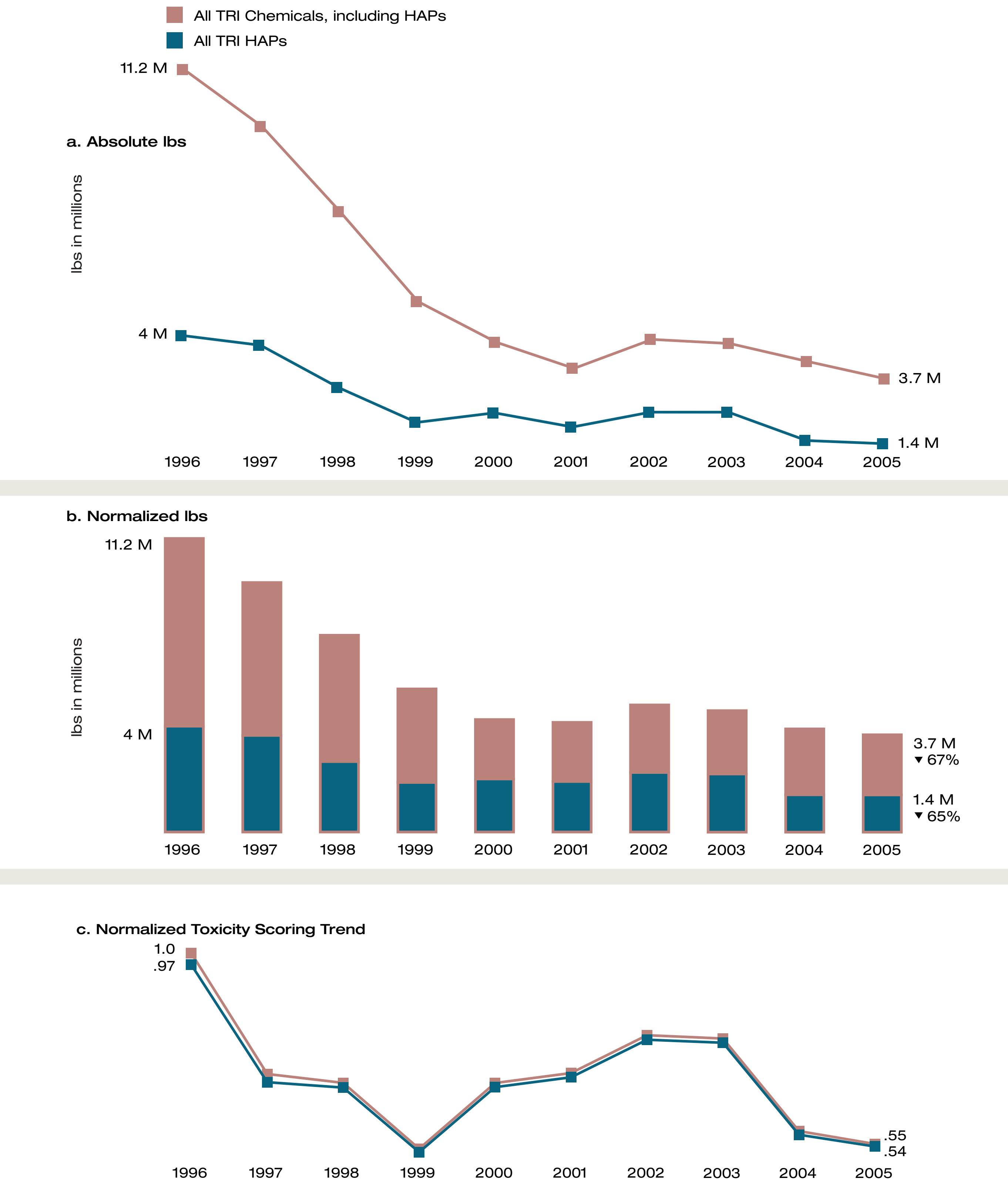
Data are not reported to TRI in sufficient detail to distinguish which forms of certain chemicals within a chemical category are being emitted. For chemical categories such as chromium, the toxicity model conservatively assumes that chemicals are emitted in the form with the highest toxicity weight (e.g., hexavalent chromium); thus, Toxicity Scores are overestimated for some chemical categories.

Summing the Toxicity Scores for all of the air emissions reported to TRI by the sector produces the trend illustrated in Figure 2c. The sector's total Toxicity Score declined by nearly half from 1996 to 2005.[18] The TRI list of toxic chemicals includes all but six of the hazardous air pollutants (HAPs) regulated under the Clean Air Act. HAPs accounted for 38% of the sector's absolute air emissions reported to TRI in 2005, and almost all the sector's toxicity-weighted results. The sector's trend for HAP emissions is similar to the trend for all TRI air emissions, as shown in Figure 2a.

The primary sources of HAP emissions are blast furnaces, co-located coke ovens, and EAFs.[19] Manganese, a HAP, accounted for three-quarters of the sector's 2005 Toxicity Score, but also declined by nearly half over the decade. Sector stakeholders have asked EPA to reassess the

FIGURE 2

Air Emissions Reported to TRI 1996–2005



Note:
Normalized by annual production of iron and steel.

Sources: U.S. Environmental Protection Agency, U.S. Geological Survey existing, high-toxicity weighting factor for inhalation for manganese. Chromium, nickel, and manganese are alloying elements used in steelmaking, and are therefore also present in steel scrap. Nickel and manganese increase steel's tensile strength; chromium increases hardness and melting temperature. Manganese and other metals are also found in iron ore. They can be emitted when they are added as alloying agents, during "tapping" of molten steel from the furnace, from casting operations, and elsewhere.

Integrated mills and mini-mills each contribute roughly half the sector's TRI-reported absolute air emissions (and the associated relative toxicity).

Table 1 presents the top TRI-reported chemicals emitted to air by the sector based on three indicators. Each indicator provides data that environmental managers, trade associations, or government agencies might use in considering sector-based environmental management strategies.

TABLE 1

Top TRI Air Emissions 2005

Chemical	Absolute Pounds Reported[1]	Percentage of Toxicity Score	Number of Facilities Reporting[2]
Ammonia	355,400[3]	<1%	10
Chromium	20,300	11%[4]	75
Cobalt[5]	1,300	1%	4
Ethylene	199,100	<1%	8
Hydrochloric Acid	352,500	<1%	19
Lead	100,500	6%	83
Manganese	329,100	74%	83
Nickel	23,900	5%	69
Zinc	1,615,500	1%	80
Percentage of Sector Total	81%[6]	98%[7]	100%[8]

Notes:
1. Total sector air releases: 3.7 m llion lbs.
2. 85 total TRI reporters in the sector.
3. Red indicates that the chemical is one of the top five chemicals reported in the given category.
4. Calculation of Toxicity Score for chromium conservatively assumed that all chromium emissions were hexavalent chromium, the most toxic form, with significantly higher toxicity weights than trivalent chromium. However, hexavalent chromium may not constitute a majority of the sector's chromium releases. Thus, RSEI analyses may overestimate the relative harmfulness of chromium emissions.
5. *Italics* indicate a hazardous air pollutant under section 112 of Clean Air Act.
6. Chemicals in this list represent 81% of the sector's air emissions.
7. Chemicals in this list represent 98% of the sector's Toxicity Score.
8. 100% of facilities reported emitting one or more chemicals in this list.

Source: U.S. Environmental Protection Agency

1) Absolute Pounds Reported. Zinc, ammonia, manganese, and hydrochloric acid were the highest-ranking chemicals based on the pounds of each chemical emitted to air in 2005. Zinc emissions result from coating operations and from the recycling of galvanized steel. Ammonia is emitted primarily from coke-making operations, although it and other organics are also found in iron ore. Hydrochloric acid is emitted from "pickling" operations, where it used to remove oxides and scale from the surface of strip steel, steel wire, and some other forms of steel.[20]

2) Percentage of Toxicity Score. Manganese is the top chemical based on Toxicity Scores, as described above. Manganese is essential to iron and steel production by virtue of its sulfur-fixing, deoxidizing, and alloying properties.[21]

3) Number of Facilities Reporting. Lead, manganese, chromium, nickel, and zinc are the most frequently reported chemicals, with almost all the TRI filers in the sector reporting these chemical emissions to air. Lead emissions result from lead in scrap and other raw materials.

Another TRI-reported chemical of interest is mercury. Because methodologies to estimate mercury emissions from individual EAFs have not been formally established, however, the sector's total TRI mercury emissions estimate is conservative. In 2005, 67 iron and steel facilities reported air emissions of mercury totaling 7,200 pounds. Each year, the steel industry uses more than 14 million tons of steel from scrap vehicles, America's most recycled consumer product. Until model year 2003, several automakers installed mercury-containing switches in vehicles, predominantly for convenience lighting in the hood and trunk, and in some anti-lock braking systems. If the switches are not removed from end-of-life vehicles (ELVs), their mercury can be emitted into the environment, especially when steel from shredded vehicles is melted to make new steel. Mercury switches from vehicles are a predominant source of mercury air emissions from EAFs, which EPA estimated may emit 10 tons of mercury per year.[22]

In 2006, steelmakers, EPA, states, automakers, automobile recyclers, scrap recyclers, and environmental groups established the National Vehicle Mercury Switch Recovery Program (NVMSRP) to promote recovery of mercury switches from ELVs. The program partners have implemented the program nationwide.

As part of the NVMSRP, vehicle manufacturers established the nonprofit End of Life Vehicle Solutions Corporation (ELVS), which handles most program logistics. ELVS uses a nationwide environmental services firm to manage the transport and tracking of switches, and the recycling, retorting, or disposal of the recovered mercury. The program, which is still ramping up, has collected more than 1.3 million mercury switches, representing more than 1.4 tons of mercury, from 6,654 participating automobile recyclers who recover and submit the switches.[23]

Criteria Air Pollutants

Table 2 shows CAP and volatile organic compound (VOC) emissions from the Iron & Steel sector for 2002. In 2002, the sector emitted 755,000 tons of CAPs and VOCs. This included nearly 584,000 tons of carbon monoxide (CO), driven by emissions from 10 integrated mills.

TABLE 2

Criteria Air Pollutant and VOC Emissions 2002

	Tons
SO_2	69,000
NO_X	63,000
PM_{10}	26,000
$PM_{2.5}$	22,000
CO	584,000
VOCs	13,000

Note:
PM_{10} includes $PM_{2.5}$ emissions.

Source: U.S. Environmental Protection Agency

Greenhouse Gases

The Iron & Steel sector directly emits GHGs mainly from integrated mills from non-combustion processes as well as consumption of fossil fuels. Non-combustion processes produce carbon dioxide (CO_2) and methane (CH_4) through metallurgical coke production, pig iron production, and raw steel production. Non-combustion processes emitted 46.2 million metric tons of CO_2 equivalent ($MMTCO_2E$) in 2005.[24] Between 1996 and 2005, the sector's process emissions of CO_2 and CH_4, combined, fell 33%. These process emissions can be broadly categorized as follows (GHGs emitted by each process are in parentheses):

- Metallurgical Coke Production (CO_2, CH_4): Whether onsite at integrated steel mills or offsite at merchant coke plants, coking coal is heated in a low-oxygen, high-temperature environment within a coke oven.[25] Some carbon contained in the coking coal is emitted during this process as CO_2 and CH_4. Coke-oven gas, a byproduct, can be used for energy purposes.
- Pig Iron Production (CO_2, CH_4): At integrated steel mills, metallurgical coke is used as a reducing agent in the blast furnace to reduce iron ore to pig iron, which is used as a raw material in producing steel. At an integrated steel mill, the coke produced is used in the blast furnace charge for iron production. The carbon contained in the coke also provides heat to the blast furnace, and produces CO_2 through both the heating and reduction process. Iron-bearing blast furnace feed is also produced through sintering, which agglomerates iron-rich small particles, such as iron ore fines and pollution control dusts and sludges, into a porous mass that can be used as blast furnace feed. This process also results in CO_2 and CH_4 emissions.[26]
- Steelmaking (CO_2): At an integrated steel mill, molten iron produced by a blast furnace enters a BOF where the iron and some scrap are combined with high-purity oxygen to produce steel. Carbon contained in both the scrap steel and molten iron is emitted as CO_2. In EAFs, some CO_2 emissions occur from use of carbon electrodes or other carbon-bearing raw materials during the melting of scrap steel.[27]

Release of CO_2 is inherent to the chemical reactions through which iron ore is chemically reduced to make iron, and from the carbon content of iron when reduced to make steel. These emissions cannot be reduced except by changing the process by which iron and steel are made or by capturing and storing the CO_2 after it is created.[28] Research into new methods of steelmaking, discussed above, is also targeting low-carbon processes.

The generation of electricity purchased by steel mills also emits GHGs. The majority of electricity purchased by the sector is for EAFs.

The American Iron and Steel Institute (AISI) participates in DOE's Climate VISION program, and has committed to the goal of achieving by 2012 a 10% reduction in sector-wide average energy consumption per ton of steel produced using a 1998 baseline of 18.1 million Btu.[29] AISI developed emission measurement and reporting protocols, is pursuing identifying and implementing opportunities to reduce GHG emission intensity, and is accelerating investment in research and commercialization of advanced technology.[30] As of 2006, sector-wide average energy efficiency had improved by 15%, compared to the 10% goal.[31] AISI estimates that steelmakers emit 1.24 tons of CO_2 per ton of steel produced, including both direct emissions from processes and fuel use and indirect emissions from generation of purchased electricity.[32] Having produced 108.2 million tons of steel in 2006, the industry's CO_2 emissions for that year would have been 134.2 million tons.[33]

Water Use and Discharges

Steelmakers use water for various processes and purposes, for example, as a coolant for equipment, furnaces, and intermediate steel shapes; a cleansing agent to remove scale from steel products; a source of steam; a medium for lubricating oils and cleaning solutions; and a wet scrubber fluid for air pollution control.[34] Indeed, AISI notes that, "[n]ext to iron and energy, water is the industry's most important commodity."[35]

The largest uses of water are to transfer heat, particularly for cooling (or "quenching") coke after it has been carbonized in coke ovens (8,000–8,500 gallons per ton of coke), in boilers for converting coke oven gas, tars, and light oils (40,000–120,000 gallons per ton of coke), and in boilers for converting blast furnace gas (20,000–60,000 gallons per ton of iron). In production and finishing processes, hot strip mills, which compress reheated steel slabs into hot-rolled sheets and coils through a series of rollers, use the most water (1,000–2,000 gallons per ton of hot rolled strip).[36]

While steelmakers require approximately 75,000 gallons of water to produce one ton of steel,[37] that number includes water that has been recycled, and process and cooling water that has been reused. Typically, more than 95% of the water used in steelmaking is recycled. Due mainly to evaporation losses, steelmakers require 13,000–23,000 gallons of additional water per ton of product through all stages of production.[38] Steelmakers obtain water from municipal sources and adjacent water bodies.

Integrated mills use more water per ton of steel than EAFs. With EAFs rising to represent more than half of steel production, intake water withdrawals by the sector have declined by more than 50% since peaking in 1973. Water quality discharge regulations and the cost of effluent treatment have contributed to the sector's increased reliance on recycled water.[39]

Iron and steelmakers discharge wastewater either to Publicly Owned Treatment Works or directly into waterways. Every facility discharging process wastewater directly to waterways must apply for a National Pollutant Discharge Elimination System permit. The permits set numeric limits on specific pollutants based on federal effluent limitations guidelines for each iron and steelmaking process, and include monitoring and reporting requirements. For example, mills involved in certain activities, such as acid pickling and hot coating, are limited in their discharges of metals such as chromium, lead, nickel, and zinc. Cokemaking operations have limits on their ammonia discharges. Sintering operations and blast furnace operations have limits on their discharges of phenols.

In 2005, 72 steel mills reported water discharges of TRI chemicals totaling 2.9 million pounds,[40] a 168% increase from 1996. The sector's reported discharges began to climb in 2000, when one mill began reporting nitrate compounds.[41]

Coke-making quench water becomes contaminated with coke fines and other compounds and contains carcinogenic particulates and VOCs.[42] However, most quench water is reused after removal of the coke fines and other solids. Water discharges are also associated with the treatment of scrubber water used for air pollution control equipment.[43]

Depending on the type of mill, stormwater requirements for iron and steelmakers may include effluent limits on aluminum, zinc, and total suspended solids.

Waste Generation and Management

Wastes in the Iron & Steel sector can be generated from process-related functions or other activities, such as operation of pollution control devices or remediation of contamination. Because of the sector's use of scrap steel, it is a global leader in recycling. The percentage of steel recycled in the U.S. rose to an all-time high of more than 75% in 2005, with 76 million tons consumed.[44] The rate of recycling has continued to rise, along with the production rate of mini-mills. This also raises the quantity of EAF dust from air pollution control equipment that must be disposed or recycled.

Hazardous Waste Management

EAF dust is regulated as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) because of its heavy metal components. This dust, listed as K061, can be recycled to recover zinc and other valuable metals. In the recycling process, the dust is separated into a nonhazardous iron-rich material and a small waste stream with a concentration of the heavy metals. The nonhazardous component can then be used in products, such as bricks. Of the EAF dust generated annually in the United States, however, much is shipped long distances and even exported for recycling.[45] Spent pickle liquor (SPL) from steel finishing operators is another listed hazardous waste (K062), but can also be reclaimed or recycled. In RCRA hazardous waste reporting, individually reported EAF dust and SPL accounted for 55% and 2%, respectively, of the sector's hazardous waste generation in 2005.[46] Additional quantities of these wastes were also reported as part of commingled wastes.

In 2005, 82 iron and steel mills reported to EPA's *National Biennial RCRA Hazardous Waste Report* (BR) generating 1.4 million tons of hazardous waste, with more than 60% generated by mini-mills. The sector reported managing 1.3 million tons of hazardous waste. Most of the sector's reported hazardous waste was managed through disposal (55%) and reclamation/recovery (36%).[47]

Waste Management Reported to TRI

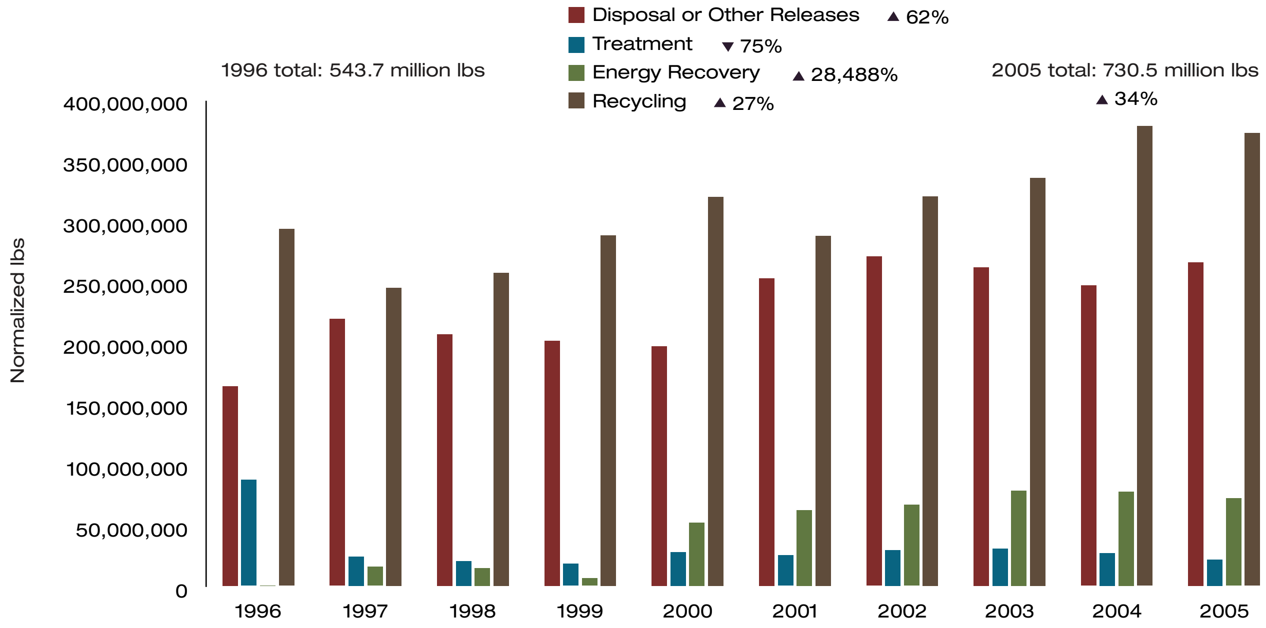
Wastes generated from this sector largely include EAF dust and SPL. The chemical components of EAF dust include zinc (averaging 20%), lead (averaging 5%), chromium (up to 15%), nickel (up to 4%), and cadmium (up to 3%).[48] These same chemicals accounted for nearly half the air emissions and nearly one-quarter of the total Toxicity Score in 2005. Between 1996 and 2005, normalized air emissions of these chemicals decreased by 44%.[49]

In 2005, the Iron & Steel sector reported managing 726 million absolute pounds of TRI chemicals. When normalized by production, this represented a 34% increase since 1996. Figure 3 shows how the sector managed these chemicals. In 2005, mini-mills accounted for a majority (86%) of the sector's recycling of waste (principally EAF dust) and 63% of the overall waste disposals or releases, while integrated mills accounted for all the sector's energy recovery and more than three-quarters of the overall treatment (principally SPL).[50]

In 2005, the sector reported disposing 257 million absolute pounds of TRI chemicals to land or transferring the chemicals to off-site locations for disposal. As shown in Table 3, zinc accounted for about three-quarters of the total pounds disposed by the sector. Lead, manganese, chromium, and zinc were the chemicals most frequently reported as disposed.

FIGURE 3

TRI Waste Management 1996–2005



Notes:
1. Normalized by annual production of iron and steel.
2. Disposal or other releases include air releases, water discharges, and land disposals.

Sources: U.S. Environmental Protection Agency, U.S. Geological Survey

TABLE 3

Top TRI Disposals 2005

Chemical	Absolute Pounds Reported[1]	Number of Facilities Reporting[2]
Chromium	4,327,000[3]	64
Copper	2,328,000	52
Lead	10,139,000	69
Manganese	40,885,000	65
Nickel	489,000	55
Zinc	195,146,000	62
Percentage of Sector Total	98%[4]	84%[5]

Notes:
1. Total sector disposals: 257 million lbs.
2. 85 total TRI reporters in the sector.
3. Red indicates that the chemical is one of the top five chemicals reported in the given category.
4. Chemicals in this list represent 98% of the sector's disposals.
5. 84% of facilities reported disposals of one or more chemicals in this list.

Source: U.S. Environmental Protection Agency

Additional Environmental Management Activities

An environmental management system (EMS) is a set of processes and practices that enable an organization to reduce its environmental impacts and increase its operating efficiency. All integrated steel mills in the United States have adopted formal EMSs based on the ISO 14001 standard (the international standard for EMSs). Approximately one-third of U.S. mini-mills have formal EMSs.[51]

The Steel Manufacturers Association (SMA) has adopted a goal that 25 or more additional EAFs (reaching a total of two-thirds of U.S. mini-mills) will implement EMSs by Earth Day 2009. SMA also has a goal of doubling the number of its members participating in EPA's Performance Track (PT) program in 2008 and 2009, so that at least eight facilities would be in PT by the end of 2009.[52] PT encourages environmental improvement through EMSs, community outreach, and measurable results. Applicants to the program must have an EMS in place.