2008 SECTOR PERFORMANCE REPORT

SectorStrategies

EPA
United States
Environmental Protection
Agency

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OFFICE OF POLICY,
ECONOMICS, AND INNOVATION

Dear Reader,

This report provides information on the environmental performance of some of America's leading manufacturing and nonmanufacturing sectors. Together, the 12 sectors profiled represent more than 856,000 entities, employ more than 12.6 million people, and contribute more than $3.5 trillion annually to the U.S. economy. This report is an important tool for measuring the performance of these sectors and for determining how we can build on that progress going forward.

Developed by EPA's Sector Strategies Division, in cooperation with sector trade associations and many other stakeholders, this report provides a comprehensive look at the environmental impacts and trends of each sector. The data, drawn primarily from government databases, show many improvements in performance, such as emissions reductions for many pollutants, both in terms of the total amounts emitted and per individual unit of production.

Thanks to the many trade associations who worked with us to make this valuable resource possible. Their willingness to share additional data, experiences, and perspectives underscores their commitment to the environment and to building a productive relationship with EPA. Thanks also to the many other contributors in governmental and non-governmental organizations who share our interest in these sectors.

As you read this report, you will learn more about these important sectors, the steps they are taking, and the results they are bringing about to protect the environment, improve economic competitiveness, and seek a sustainable future for America.

Charles Kent, Director
Office of Cross-Media Programs
Office of Policy, Economics, and Innovation
U.S. Environmental Protection Agency

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Welcome to U.S. Environmental Protection Agency's (EPA) 2008 *Sector Performance Report*, the third in a series started in 2004.[1] The report provides a comprehensive picture of the environmental performance of 12 sectors of the U.S. economy, currently and over time. The sectors have a significant collective impact environmentally and economically. They are:

- Cement Manufacturing
- Chemical Manufacturing
- Colleges & Universities
- Construction
- Food & Beverage Manufacturing
- Forest Products
- Iron & Steel
- Metal Casting
- Oil & Gas
- Paint & Coatings
- Ports
- Shipbuilding & Ship Repair

PREFACE

We provide context in the Executive Summary by, for example, comparing the sectors to the economy as a whole. In the following chapters, we provide for each sector an economic and environmental overview, detailed data on primary environmental indicators, and case studies on selected issues of interest.

Launched in 2003, and succeeding the Sustainable Industries Program launched in 1990, the Sector Strategies Program promotes sector-wide environmental gains in the 12 sectors. We work with sector trade groups and many other stakeholders to reduce pollution, conserve resources, lessen unnecessary administrative burden, measure corresponding performance results, and identify additional opportunities through quantitative metrics.

New in this Report

- Environmental data are presented in two ways—absolute and normalized:
  - Absolute emissions indicate the total amount emitted by the sector nationwide, reflecting the actual environmental impact at a given time.
  - Normalized data are adjusted by amount or value of product produced. Normalizing illuminates performance trends without highlighting changes caused by increases or decreases in production due to price or other externalities.[2]
- Economic trends over the period covered: 1996-2005
- Maps showing sector facility locations or concentrations
- New or expanded sectors:
  - Chemical Manufacturing
  - Food & Beverage Manufacturing
  - Oil & Gas
- Expanded information on indicators such as energy use and greenhouse gas (GHG) emissions

Major Sources of Data

Energy

Most of our energy use data come from the U.S. Department of Energy's (DOE) statistical agency, the Energy Information Administration (EIA). Every four years, EIA sends many manufacturers the Manufacturing Energy Consumption Survey (MECS) and extrapolates the responses to represent the full universe of manufacturers.[3]

Criteria Air Pollutants

Data on criteria air pollutants (CAPs) come from EPA's National Emissions Inventory (NEI). EPA prepares this national database every three years, based on input from state, tribal, and local air pollution control agencies; industry-submitted data; other EPA databases; and EPA emission estimates.[4]

Air, Water, and Waste in the Toxics Release Inventory

Data on other air emissions, on water discharges, and on management of chemicals in waste are from EPA's annual Toxics Release Inventory (TRI), based on reports filed by more than 23,500 facilities across the country.[5]

Toxicity of Air Emissions

EPA's Risk-Screening Environmental Indicators (RSEI) model generates the relative toxicity scores for air emissions.[6]

Hazardous Waste

Pursuant to the Resource Conservation and Recovery Act (RCRA), information on hazardous waste generation is from EPA's *National Biennial RCRA Hazardous Waste Report* (BR), based on reports from large quantity generators and treatment, storage, and disposal facilities.[7] Note that, Key to our work is collaboration with numerous stakeholders, including particular trade associations that participate in our program. They are:

Cement Manufacturing	Portland Cement Association
Chemical Manufacturing	American Chemistry Council Synthetic Organic Chemical Manufacturers Association
Colleges & Universities	American Council on Education Association for the Advancement of Sustainability in Higher Education Association of Higher Education Facilities Officers Campus Consortium for Environmental Excellence Campus Safety, Health and Environmental Management Association National Association of College and University Business Officers
Construction	Associated General Contractors of America
Food & Beverage Manufacturing	American Meat Institute Grocery Manufacturers Association
Forest Products	American Forest & Paper Association
Iron & Steel	American Iron and Steel Institute Steel Manufacturers Association
Metal Casting	American Foundry Society North American Die Casting Association
Oil & Gas	American Petroleum Institute American Exploration and Production Council Independent Petroleum Association of America
Paint & Coatings	National Paint & Coatings Association
Ports	American Association of Port Authorities
Shipbuilding & Ship Repair	American Shipbuilding Association Shipbuilders Council of America

unlike TRI, BR tracks entire waste streams, rather than only certain chemicals.

Key Data Considerations

Sector Definitions

Many data sources reflect only certain segments of a sector; others define certain sectors more broadly than we do. Most often, sectors are defined either by standard classification codes, such as the North American Industry Classification System (NAICS), or by lists of facilities based on our sector definitions. Endnotes for each chapter, and the Data Sources, Methodologies, and Considerations chapter, clarify how each sector is defined for our work and for the various databases used to generate data.

Data Completeness

Reporting thresholds and other factors influence how many facilities report to a given database and the extent to which they report on their overall footprint. The number of facilities within a sector that report to a particular database, or that report different media impacts within a database (such as air or water), can differ significantly, even within a sector. See the Data Sources, Methodologies, and Considerations chapter and sector chapter endnotes for discussion of data completeness.

Currency of Data

We use the most recent data available, but few databases are updated at the same time. See individual endnotes and the Data Sources, Methodologies, and Considerations chapter for information about the currency of the underlying data. Depending on data availability, the time period covered may vary from the years this report generally covers, which are 1996-2005.

Drivers and Barriers

The Sector Strategies Program analyzes many regulatory and nonregulatory factors that affect environmental management decisions among facilities in a given sector. These behavioral leverage points can influence the environmental performance of a facility or sector on one or more metrics. We consider these legal, technical, economic, behavioral, and other factors to be better able to develop policy and program actions that will provide strong drivers and reduce major barriers to improved environmental performance. However, the factors are beyond the scope of this report, which focuses on available quantitative data trends.

This report presents the latest environmental performance information for 12 sectors. Because every sector is unique, sector chapters provide maps, economic information, and detailed explanations, analysis, and discussions of the data presented.

To provide context for the report, this Executive Summary begins by presenting the impacts of all 12 sectors using several national and global indicators.[1]

Comparing data across sectors can illuminate broader trends and opportunities. This Executive Summary includes sector-specific data gathered side-by-side for the 9 sectors with the most environmental data.

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.*

EXECUTIVE SUMMARY

Economic Overview

Number of Facilities	856,836
Employment	12.6 million – more than 10% of U.S. workers
Economic Productivity	
Value of Shipments & Construction Put in Place	$3.2 trillion – with Revenue, below, 28% of Gross Domestic Product
Revenue	
Colleges & Universities	$341 billion
Ports	$5.5 billion

Latest Environmental Statistics

Energy Use	14.5 quadrillion Btu
Emissions of Criteria Air Pollutants	5.8 million tons
Air Emissions (TRI)	519.5 million pounds
Water Discharges (TRI)	178.2 million pounds
Land Disposals (TRI)	658.1 million pounds
Recycling, Energy Recovery, or Treatment (TRI)	14.8 billion pounds
Hazardous Waste Generated	30.6 million tons

Global Standing: Examples

Cement Manufacturing	U.S. is third, behind China and India
Chemical Manufacturing	U.S. is world's largest producer, generating more than $635 billion a year
Construction	U.S. is first, with spending of $873.1 billion in 2003 – out of $3.98 trillion spent by the 55 largest nations
Food & Beverage Manufacturing	U.S. is second, behind the European Union, and followed by Japan and China
Forest Products	U.S. is world's largest producer and consumer
Iron & Steel	U.S. is third behind China, which makes nearly four times more, and Japan

General Comparisons

Mostly Small Businesses	Construction, Metal Casting, Shipbuilding & Ship Repair
Most Widespread	Construction, Colleges & Universities, Food & Beverage Manufacturing
Most Concentrated	Iron & Steel, Ports, Shipbuilding & Ship Repair
Include Government Facilities	Colleges & Universities, Ports, Shipbuilding & Ship Repair

Economic Trends 1996-2005

Facilities	Three sectors ended the period having added facilities, led by Construction. At least half of the sectors ended with fewer facilities.
Employees	The 12 sectors were split in terms of whether they added or lost employees.
Value of Shipments, Value of Construction Put in Place, or Revenue	At least 9 sectors showed increases that were, in many cases, significant.

Energy Use

The eight sectors for which we have calculations used an estimated 14.5 quadrillion British Thermal Units (Btu) in 2002, which was nearly 15% of total domestic energy consumption of 97.9 quadrillion Btu.[2] World energy consumption in 2002 was 409.7 quadrillion Btu. The U.S. consumed more energy than any other country, followed by China, Russia, and Japan, although long-term trends appear likely to change the rankings.[3] From 1996 to 2005, the U.S. industrial sector gradually consumed less energy, while residential, commercial, and especially transportation energy consumption rose.[4] See individual sector chapters for discussions of energy use, trends, and opportunities.[5]

Energy Use and Air Emissions

Energy use causes impacts such as direct air emissions, which are reflected in this report. Other impacts, such as offsite (indirect) emissions, are generally beyond the scope of this report, as are energy-related mobile source emissions, such as from freight shipping.

Primary among on-site energy use-related air emissions are criteria air pollutants (CAPs) from combustion. The largest components of such CAP emissions are sulfur dioxide (SO_2), nitrogen oxides (NO_X), and larger particulates from coal combustion. Most SO_2 results from combusting sulfur-containing fuels, especially coal. Combustion also generates NO_X, although emissions vary less by fuel type than for SO_2. Particulate matter (PM) can be ash and dust from combustion of coal or heavy oil, or very fine particulates ($PM_{2.5}$) largely composed of aerosols formed by NO_X and SO_2 emissions.

Excepting emissions from off-road vehicles, volatile organic compound (VOC) and carbon monoxide (CO) combustion emissions are a much smaller fraction of total energy-related emissions. CO is a product of incomplete combustion, but the largest source is vehicles. VOCs can also result from incomplete combustion, but the largest energy-related sources are fugitive emissions from fuel storage tanks and pipelines and combustion-related vehicle emissions. Fossil fuel combustion also generates carbon dioxide (CO_2), which is a greenhouse gas (GHG). Other energy-related GHG emissions, such as methane (CH_4), are far less substantial.

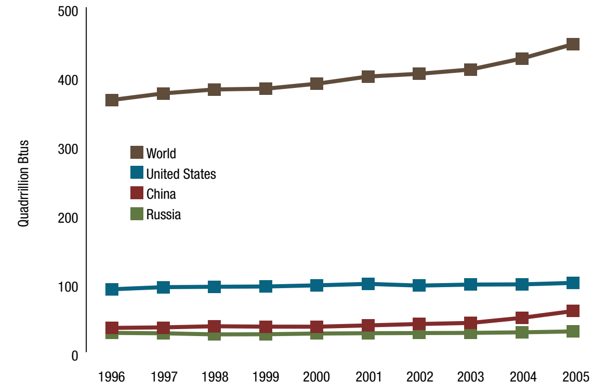
Greenhouse Gases

A sector's GHG footprint includes direct and indirect emission sources. Direct emission sources are those for which there is direct control, such as fossil fuel combustion and process emissions. Indirect emission sources are mainly those attributed to the generation of purchased electricity. Both EPA and the U.S. Department of Energy (DOE) estimate economy-wide GHG emissions, but neither provides sector-specific footprints that include direct and indirect emissions; data to generate such estimates are not readily available.

In 2005, total U.S. GHG emissions were 7,260 million metric tons of CO_2 equivalent, having risen 8.5% since 1996.[6] Including emissions from generation of purchased electricity, industry and transportation each accounted for 28% of total U.S. GHG emissions in 2005. In all sectors except agriculture, CO_2 accounted for more than 80% of GHG emissions, primarily from the combustion of fossil fuels.[7]

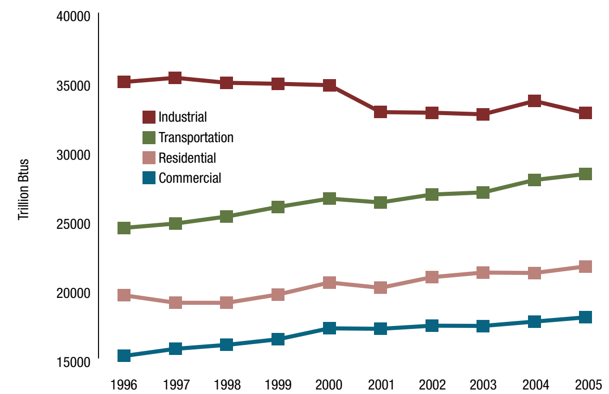
Although some gases have a higher global warming potential (GWP) per unit than CO_2, CO_2 is by far the dominant GHG emitted in terms of volume and total GWP emitted each year. EPA reports on CO_2 emissions from fossil fuel combustion for broad sectors of the U.S. economy. For CO_2 emissions other than fossil fuel use, EPA reports on particular sources, such as industrial processes in the Cement Manufacturing and Iron & Steel sectors.[8]

Top World Energy Consumption 1996–2005



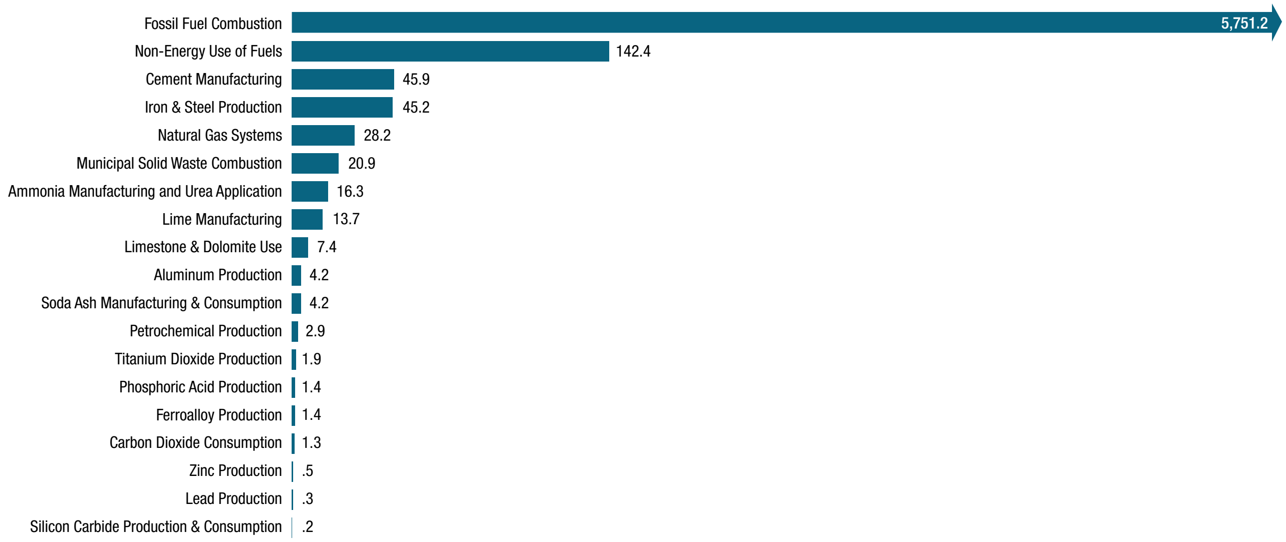
Source: U.S. Department of Energy

U.S. Energy Consumption 1996–2005



Source: U.S. Department of Energy

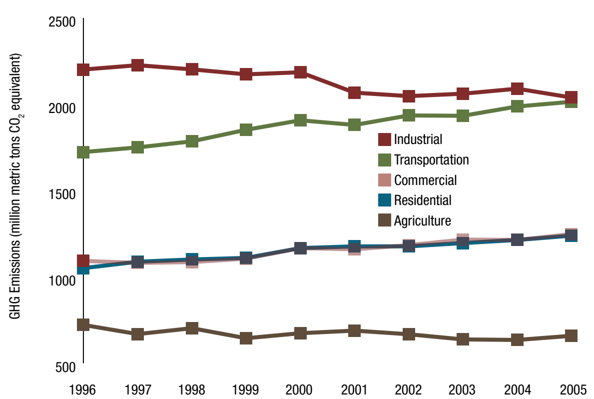
U.S. CO_2 Sources in Million Metric Tons of CO_2 Equivalent 2005



Source: U.S. Environmental Protection Agency

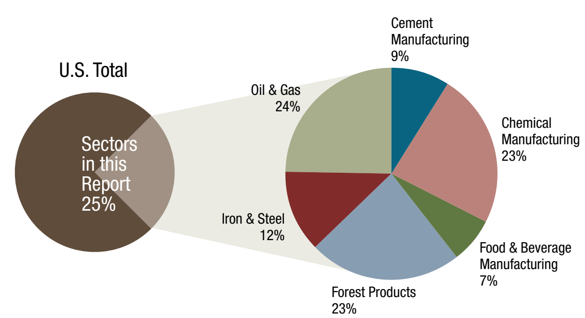
U.S. GHG Emissions 1996–2005

with Electricity-Related Emissions Distributed



Source: U.S. Environmental Protection Agency

Criteria Air Pollutant and VOC Emissions 2002



Note: Sectors at 1% or less are not represented.
Source: U.S. Environmental Protection Agency

Direct CO_2 and CH_4 combined process emissions from the Iron & Steel sector fell 33% from 1996 to 2005, although total steel produced was relatively unchanged.[9] Direct CO_2 process emissions from Cement Manufacturing in the same time period rose 24%, while the sector's cement production also rose 24%.[10] Trade associations for these two sectors, as well as for the Forest Products sector, estimate their members' total GHG footprint, including carbon "sinks" such as forests and products. See the respective chapters.

Criteria Air Pollutants and VOCs

Sectors in this report, which emit CAPs and VOCs from energy use and from other processes and activities, emitted 25% of total U.S. point source CAP and VOC emissions in 2002.[11] Sector-specific trend data are not available for CAP and VOC emissions.[12]

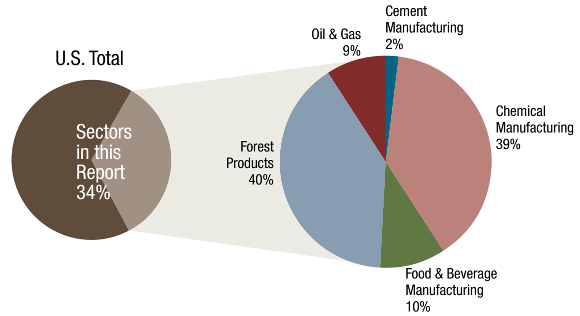
Sector Data Side by Side

The following sections present sector data for several sectors together. Because the sectors vary so substantially in size, scope, makeup, data availability, relevant drivers and barriers, and numerous other factors, a direct-one-on-one comparison of their performance would be inappropriate. To consider energy-related air emissions, for example, a sound analysis should also include sector-specific information on fuel flexibility, which is driven by percentages of fuel used for energy or for raw materials and other considerations.

TRI Air Emissions

In 2005, the 9 of our 12 sectors that report to EPA's Toxics Release Inventory (TRI) reported emitting 520 million lbs. of TRI chemicals, out of 1.5 billion lbs. emitted by all TRI reporters nationwide. Of the nine sectors, absolute total air emissions fell from 1996-2005 for all but one, while absolute emissions of hazardous air pollutants (HAPs) fell for all nine. To understand the sector-specific data, including apparent spikes, dips, and other trends, see individual sector chapters.

TRI Air Emissions 2005



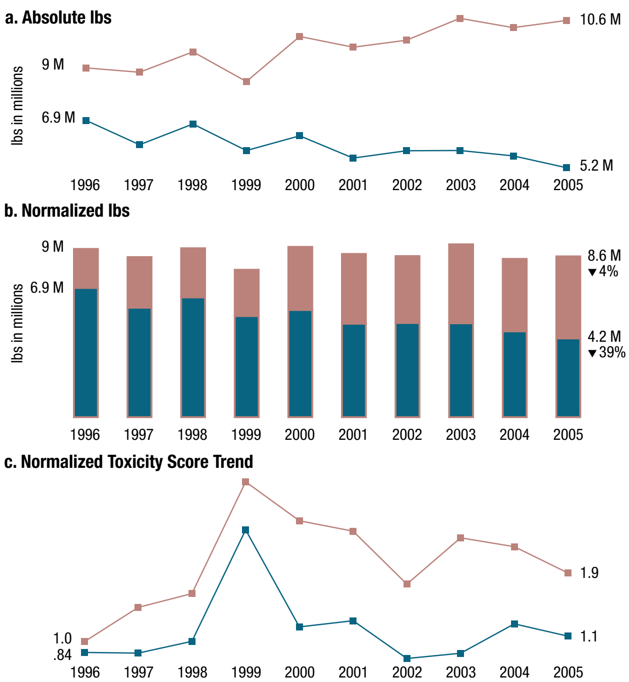
Source: U.S. Environmental Protection Agency

RSEI

To consider toxicity, EPA's Risk-Screening Environmental Indicators (RSEI) model assigns TRI chemicals a relative toxicity weight, then multiplies the pounds of media-specific releases (e.g., lbs. of mercury released to air) by it to calculate a relative Toxicity Score. RSEI methodological considerations are discussed in 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 released. For chemical categories such as chromium, RSEI 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 a sector's air emissions reveals a Normalized Toxicity Score Trend; these fell from 1996-2005 for most sectors, but rose for several. To better understand apparent spikes and trends, see individual sector chapters. The figures below show TRI air emission trends by corresponding bar and data points for each year between 1996 and 2005.

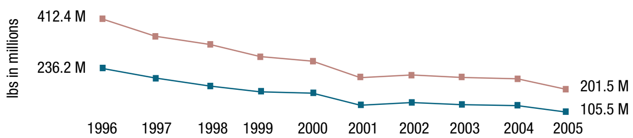
TRI Air Emissions Across Sectors 1996–2005

CEMENT MANUFACTURING

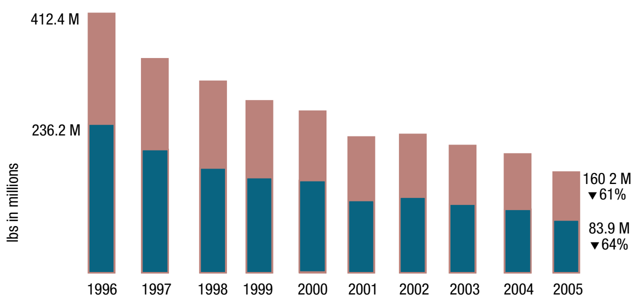


CHEMICAL MANUFACTURING

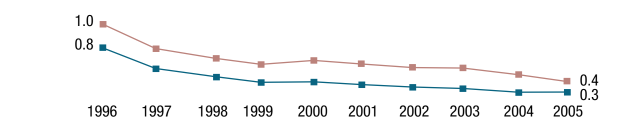
a Absolute lbs



b. Normalized lbs

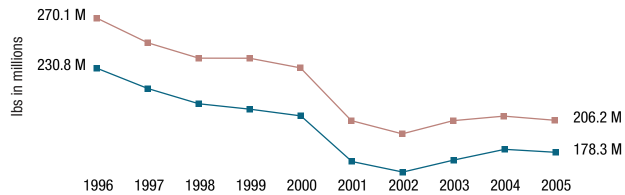


c. Normalized Toxicity Score Trend

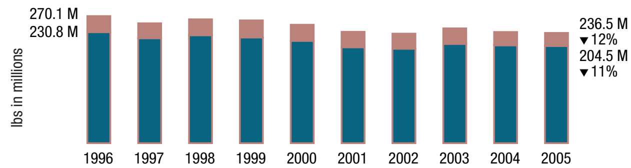


FOREST PRODUCTS

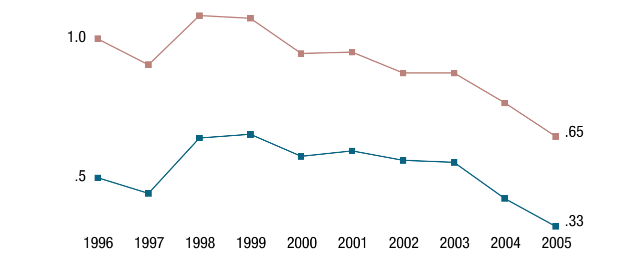
a Absolute lbs



b. Normalized lbs

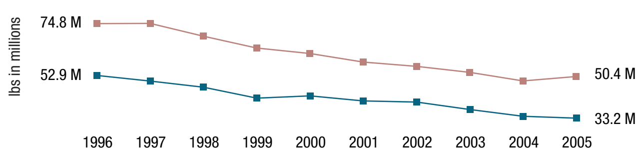


c. Normalized Toxicity Score Trend

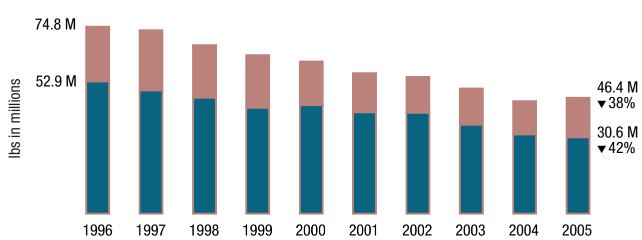


FOOD & BEVERAGE

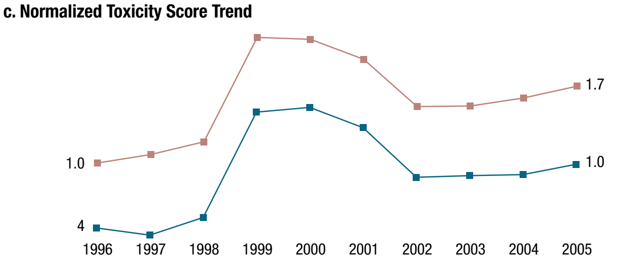
a Ab o ute lbs



b. Normalized lbs

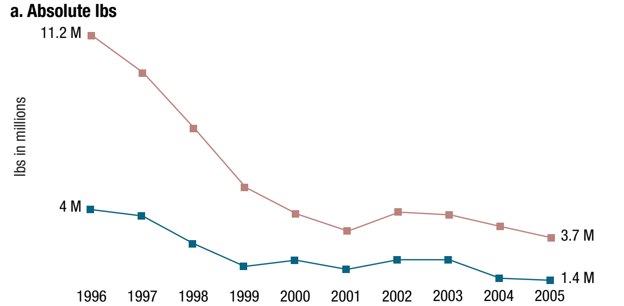


c. Normalized Toxicity Score Trend

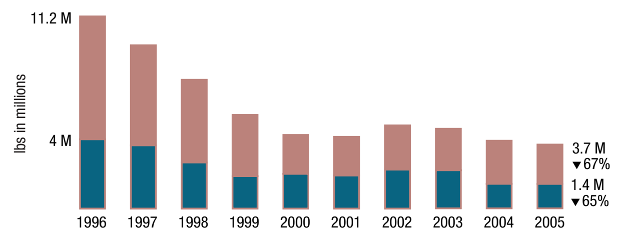


IRON & STEEL

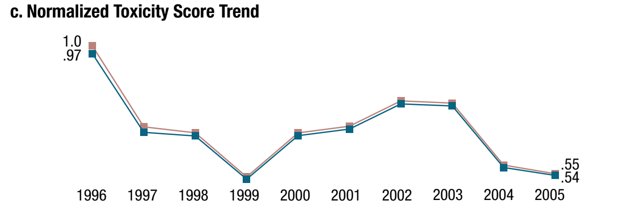
a. Absolute lbs



b. Normalized lbs



c. Normalized Toxicity Score Trend



FOR SECTOR-SPECIFIC AIR CHARTS

■ All TRI Chemicals, including HAPs ■ All TRI HAPs

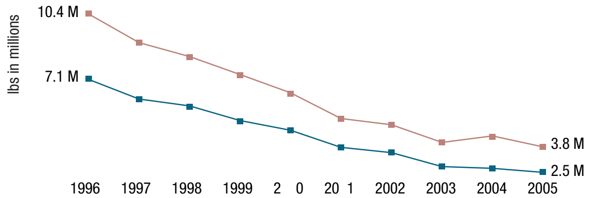
Note: Normalized by annual value of shipments or production.

Sources: U.S. Environmental Protection Agency, U.S. Geological Survey, U.S. Department of Commerce, American Foundry Society, U.S. Department of Energy

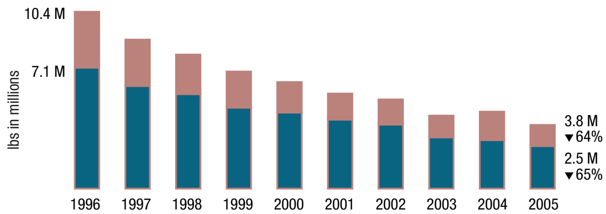
TRI Air Emissions Across Sectors 1996–2005 (continued)

METAL CASTING

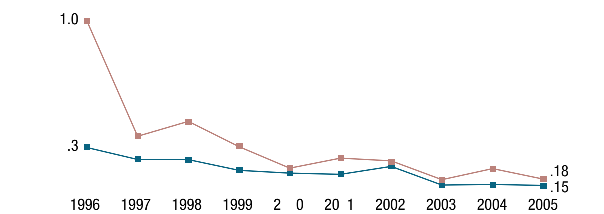
a. Absolute lbs



b. Normalized lbs

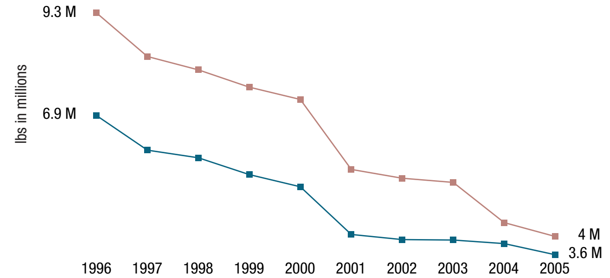


c Normalized Toxicity Score Trend

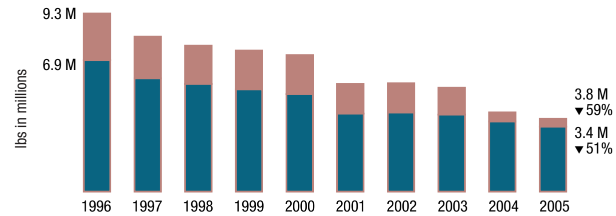


PAINT & COATINGS

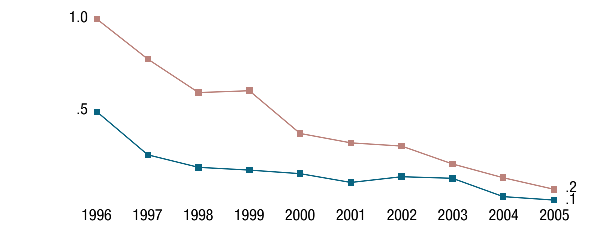
a. Absolute lbs



b. Normalized lbs

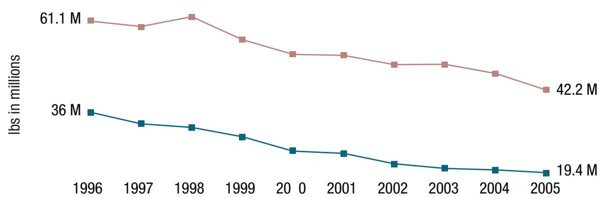


c. Normalized Toxicity Score Trend

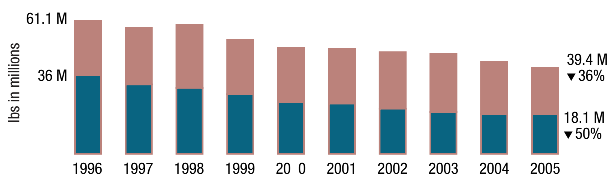


OIL & GAS (PETROLEUM REFINING)

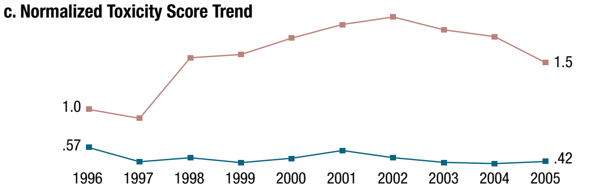
a. Absolute lbs



b. Normalized lbs

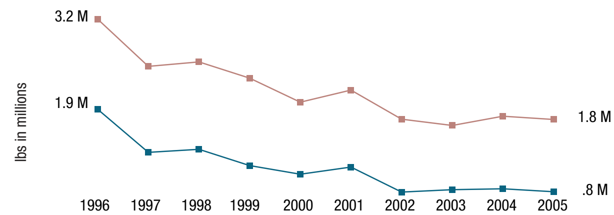


c. Normalized Toxicity Score Trend

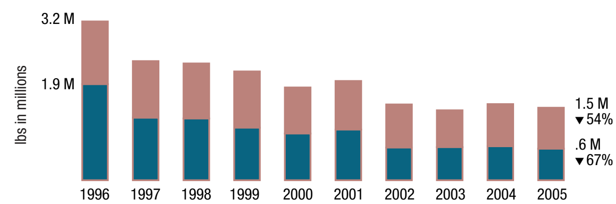


SHIPBUILDING & SHIP REPAIR

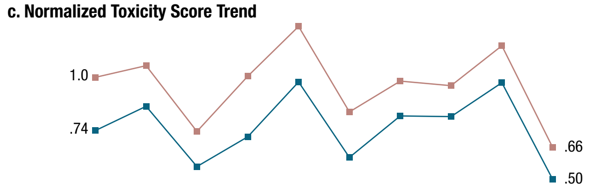
a. Absolute lbs



b. Normalized lbs



c. Normalized Toxicity Score Trend



Waste Management

This section includes information on hazardous wastes and on TRI chemicals managed as waste.[13] EPA emphasizes reducing waste generation whenever possible and, if waste is generated, minimizing the quantity that is released or disposed by instead increasing recycling, energy recovery, or treatment. TRI includes the volume of the toxic chemicals within a waste stream, while Resource Conservation and Recovery Act (RCRA) reporting on hazardous wastes encompasses the volume of the entire waste or waste stream that meets the definition of RCRA hazardous waste. See individual sector chapters for explanations of apparent spikes and trends.

Hazardous Waste Generated and Managed 2005

	Hazardous Waste Generated (Tons)	Hazardous Waste Managed (Tons)
Sectors in this Report	30,557,598	32,993,131
U.S. Total	38,350,145	42,825,913
Sectors in this Report as a Percentage of the U.S. Total	**80%**	**77%**
Sector		
Cement Manufacturing	17,195	30,641
Chemical Manufacturing	23,861,975	26,138,338
Colleges & Universities	26,158	23,544
Construction	17,058	16,437
Food & Beverage Manufacturing	3,071	2,367
Forest Products	135,541	396,336
Iron & Steel	1,395,650	1,269,594
Metal Casting	30,274	28,210
Oil & Gas (Petroleum Refining)	5,063,461	5,081,593
Paint & Coatings	145,832	147,595
Shipbuilding & Ship Repair	7,214	6,071

Source: U.S. Environmental Protection Agency

Filling in the Picture

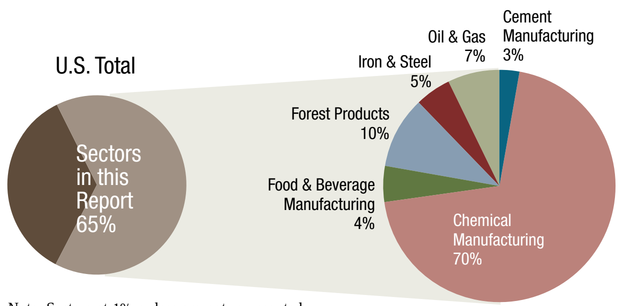
For waste and other indicators, we use available data to understand and improve sectors' environmental performance. Where data are incomplete, inadequate, or unavailable, we try to fill the gaps to provide a more complete picture. We determine what needs to be measured, what is already measured, and how to find—or create appropriate surrogates for—remaining needed information. See, for example, the discussion of GHG emissions in the Construction chapter, which draws upon DOE fuel sales data.

States also may provide useful information. See information from several states about recycling construction and demolition debris, in the Construction chapter.

When government data are unavailable, information from private organizations may be useful, such as the American Association of Port Authorities' survey cited in the Ports chapter.

When no data are available, we sometimes assist in preparing tools for generating future data. As discussed in the Shipbuilding & Ship Repair chapter, we are working with the American Shipbuilding Association and the Shipbuilders Council of America to develop a tool for individual facilities to measure their GHG emissions, which could enable those groups to provide better data on the sector's overall GHG emissions in the future.

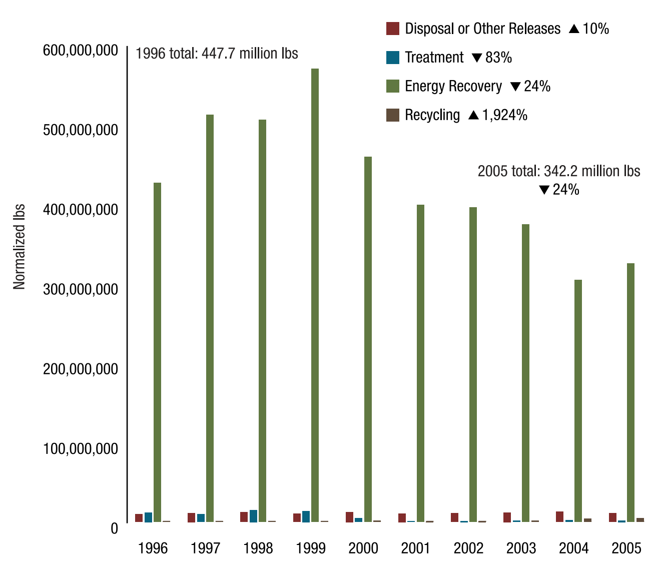
TRI Waste Management 2005



Note: Sectors at 1% or less are not represented.
Source: U.S. Environmental Protection Agency

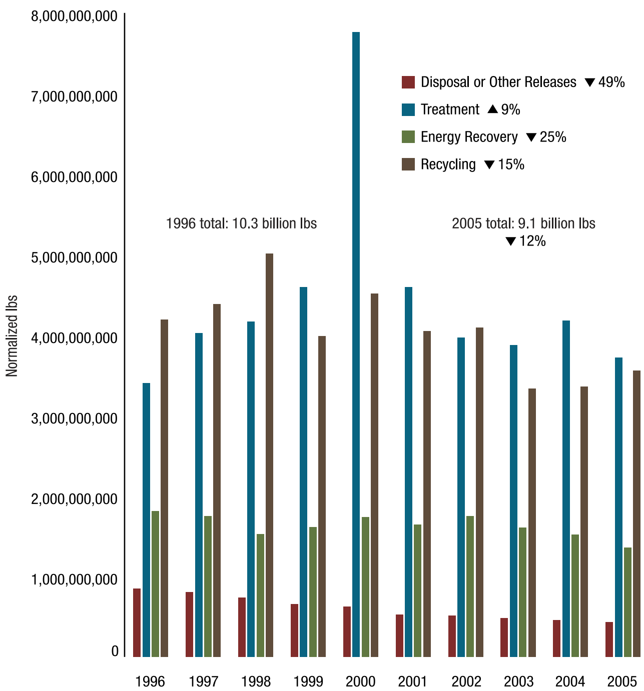
TRI Waste Management Across Sectors 1996-2005

CEMENT MANUFACTURING

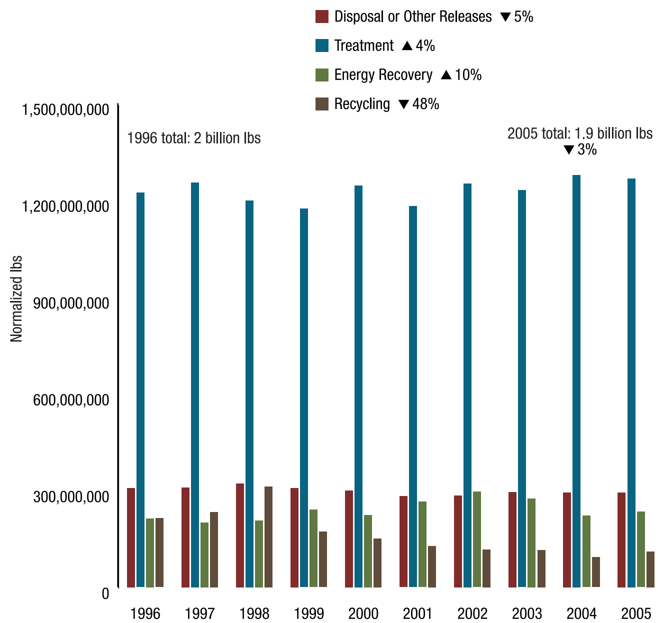


TRI Waste Management Across Sectors 1996-2005 (continued)

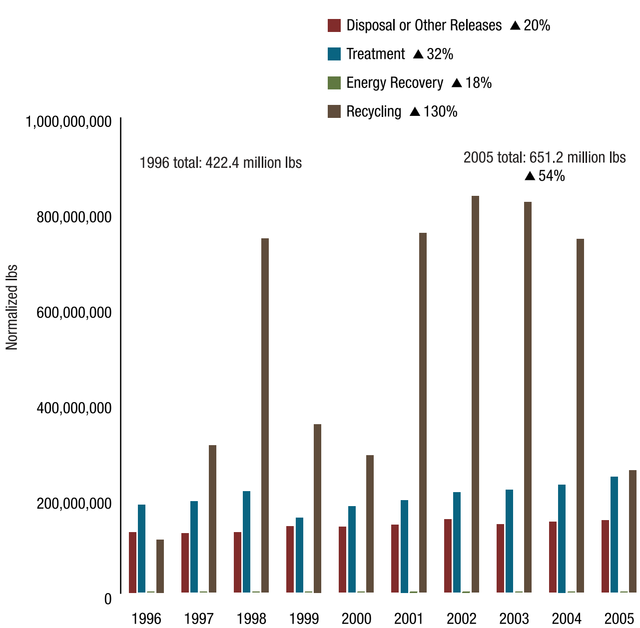
CHEMICAL MANUFACTURING



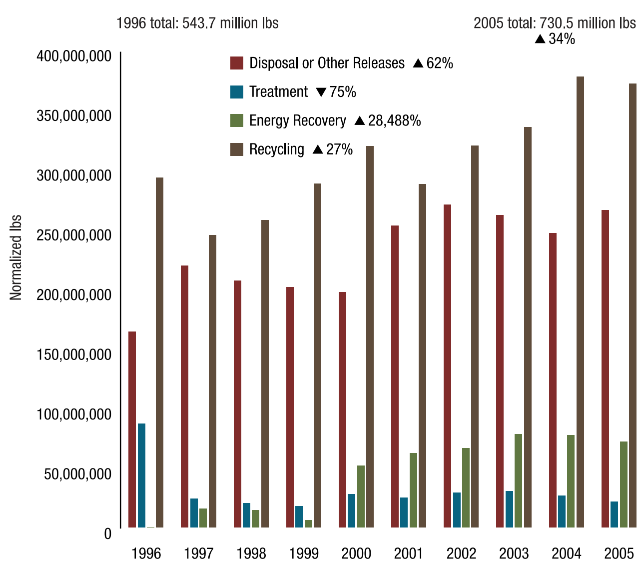
FOREST PRODUCTS



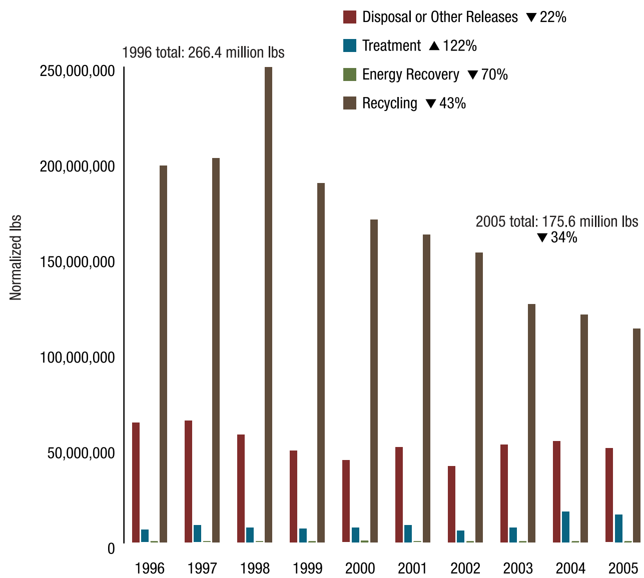
FOOD & BEVERAGE



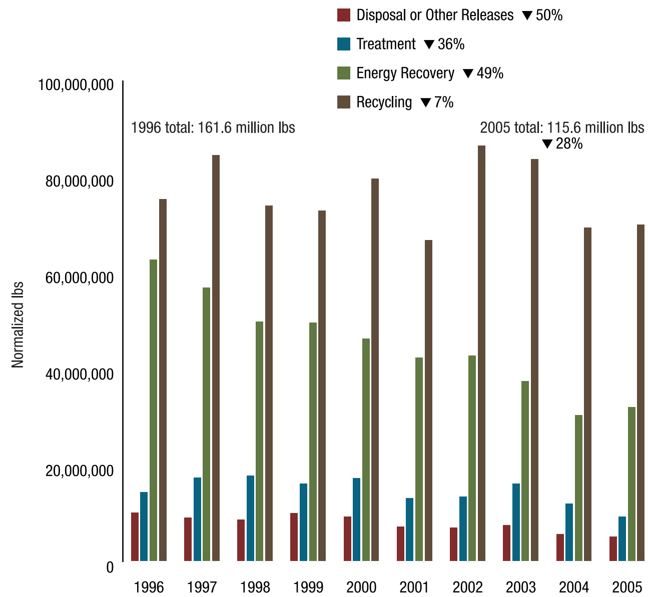
IRON & STEEL



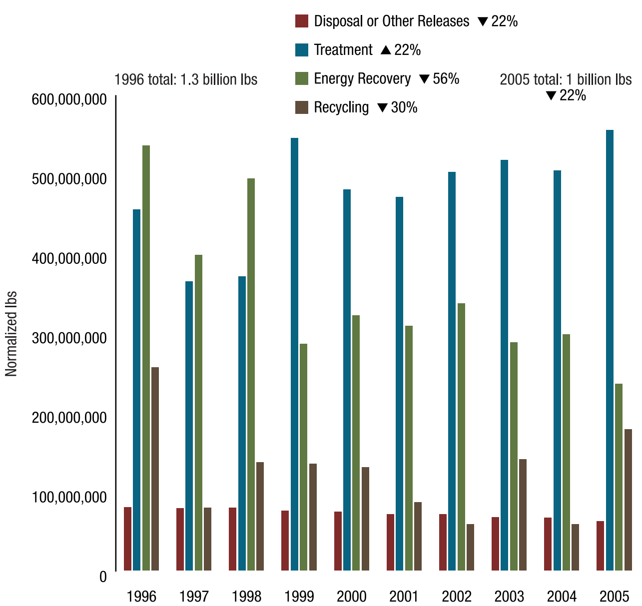
METAL CASTING



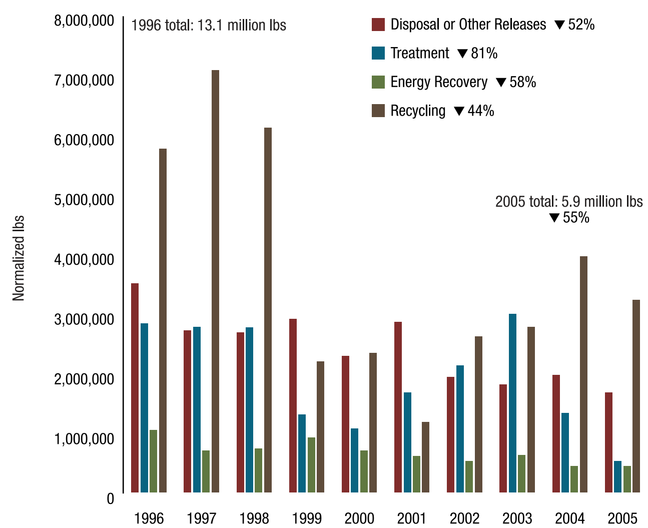
PAINT & COATINGS



OIL & GAS (PETROLEUM REFINING)



SHIPBUILDING & REPAIR



FOR SECTOR-SPECIFIC WASTE MANAGEMENT CHARTS

Notes:

1. Normalized by annual value of shipments or production. Oil & gas lbs. normalized by annual crude oil input into refineries.
2. Disposal and Other Releases includes air emissions, water discharges, and land disposals.
3. The apparent spike in treatment for Chemical Manufacturing in 2000 was due to the report filed by a single facility.

Sources: U.S. Environmental Protection Agency, U.S. Department of Commerce, U.S. Geological Survey, American Foundry Society, and U.S. Department of Energy

This report relies upon a variety of public and private data sources to provide a comprehensive account of the sectors' environmental performance between 1996 and 2005. This chapter presents an overview and basic discussion of these data sources and explains figures used in the sector chapters. The Data Sources, Methodologies, and Considerations chapter at the end of this report provides a comprehensive discussion of the sources, methodologies, and considerations concerning the data.

Sector Profile

For generating most of the data used in this report, each sector is defined by a North American Industry Classification System (NAICS) code or group of codes.[1] NAICS replaced the U.S. Standard Industrial Classification (SIC) system in 1997. Because some of the data sources used in this report use SIC codes, at least for historical data, Table 1 below shows both the NAICS and SIC definitions for each sector. Note that some sectors are defined by a specific list of facilities, rather than by these classification codes, because the codes encompass a broader range of operations.

DATA GUIDE

TABLE 1
Definition of Sectors

Sector	NAICS Code or Alternative	SIC Code
Cement	List of facilities from Portland Cement Association's Plant Information Summary directory	
Chemical Manufacturing	325	28
Specialty-Batch Chemicals	*List of facilities from the Synthetic Organic Chemical Manufacturers Association*	
Colleges & Universities	61131	8221
Construction	236, 237, 238	15, 16, 17
Food & Beverage Manufacturing	311, 3121	20, 5461
Forest Products		
Wood Products	*3211, 3212, 32191, 32192, 321999*	*242, 243, 244, 249*
Paper Products	*3221, 32221, 322221-322224, 322226, 32223, 32229*	*26*
Iron & Steel	List of integrated and mini mills from EPA's Sector Strategies Division	
Metal Casting	33151, 33152	332, 336
Oil & Gas		
Extraction	*211, 213111, 213112*	*13*
Petroleum Refining	*32411*	*2911*
Paint & Coatings	32551	2851
Ports	48831, 48832	4491
Shipbuilding & Ship Repair	336611	3731

Normalization of Absolute Releases

Where the report presents data showing trends over time, data are often adjusted to account for changes in sector production or output over the same period, also referred to in this report as "normalizing."

Normalizing means adjusting the absolute annual emissions values to account for changes in sector production or output over the same period. Normalizing removes the impact of growing or shrinking economic trends in industry, so that environmental changes occurring for other reasons can be seen more clearly. For example, if absolute emissions steadily decline over time, this could be caused by declining production in the sector, rather than any real improvement in day-to-day environmental performance.

TABLE 2

Economic Activity and Normalization Factors for TRI Data

Sector	Normalizing and Sector Output Metric	Normalizing and Sector Output Data Source
Chemical Manufacturing Food & Beverage Manufacturing Forest Products Paint & Coatings Shipbuilding & Ship Repair	Value of shipments ($, adjusted for inflation)	U.S. Department of Commerce (DOC), Bureau of Economic Analysis (BEA): Industry Economic Accounts, 2005, http://www.bea.gov/industry/xls/GDPbyInd_SHIP_NAICS_1998-2005.xls
	Inflation adjustment for value of shipments	U.S. Department of Commerce (DOC), Bureau of Economic Analysis (BEA), National Economic Accounts, Current-Dollar and "Real" Gross Domestic Product, http://bea.gov/national/xls/gdplev.xls
Cement Manufacturing	Production of Clinker (millions of metric tons)	U.S. Geological Survey's (USGS) Cement Statistics and Information: Mineral Commodity Summaries 1997-2007, http://minerals.usgs.gov/minerals/pubs/commodity/cement/index.html
Iron & Steel	Steel Production, basic oxygen and electric arc furnaces (thousands of metric tons)	U.S. Geological Survey's (USGS) Iron and Steel Statistics and Information: Mineral Commodity Summaries 1997-2007, http://minerals.usgs.gov/minerals/pubs/commodity//iron_&_steel/index.html
Metal Casting	Ferrous & Non-Ferrous Shipments (millions of tons)	American Foundry Society (AFS)
Oil & Gas (Petroleum Refining)	Crude Oil Inputs into Refineries (thousand barrels/year)	U.S. Department of Energy (DOE), Energy Information Administration (EIA), Petroleum Refining & Processing, Weekly Inputs, Utilization & Production, http://tonto.eia.doe.gov/dnav/pet/pet_pnp_wiup_dcu_nus_w.htm

The metrics used to normalize data vary across the sectors but are identified for each graphic or chart. When available, production data (e.g., tons of product produced annually by the sector) was the preferred metric for normalizing. When production data were not available for the full time frame required, value of shipments was used instead.

Economic and Geographic Information

Name: County Business Patterns

Source: U.S. Census Bureau

Metrics: Number of employees and number of establishments

Frequency: Annual

Period Analyzed: 2005

Next Data Release: 2006 data expected mid-year 2008

Website: http://www.census.gov/epcd/cbp

The employment and number of establishments data presented in the "At-a-Glance" section of each sector chapter are from the U.S. Census Bureau, County Business Patterns (CBP). CBP is an annual series published by the U.S. Census Bureau that provides economic data by industry and covers most of the country's economic activity.

When production data are not available, this report shows output using value of shipments (VOS). For some sectors, we include information more suitable than VOS to convey economic activity, as shown in Tables 2 and 3. Sector "At-a-Glance" sections showing VOS trends present current dollars for each of the years represented. In constant dollars (with a 1996 baseline), the 2005 figures would be approximately 17% lower than they appear when using current dollars.

A U.S. map is presented for each sector showing the locations of facilities within that sector. The portrayals of Alaska, Hawaii, and Puerto Rico are not drawn to scale and do not represent their respective locations relative to the contiguous states.

Note that the facility counts for many sectors under "At-a-Glance" rely upon CBP data. Ideally, both the maps and facility counts would come from a single source, but CBP does not include establishment-level data or location information. Instead, facility location information is sepa-

TABLE 3

Economic Activity Data for Sectors Without TRI Data

Sector	Sector Output Value	Sector Output Data Source
Colleges & Universities	Revenue (millions of $, adjusted for inflation)	National Center for Educational Statistics: Digest of Education Statistics, http://nces.ed.gov/programs/digest/
Construction	Value of Construction Put in Place (millions of $, adjusted for inflation)	U.S. Census Bureau, Current Construction Reports, http://www.census.gov/const/www/c30index.html
Oil & Gas (Exploration & Production)	Crude Oil Field and Natural Gas Production (billion Btu)	U.S. Department of Energy (DOE), Energy Information Administration (EIA), Production in Btu derived from Crude Oil Field Production (Barrels) and Natural Gas Gross Withdrawals and Production (MMcf), http://tonto.eia.doe.gov/dnav/pet/pet_crd_crpdn_adc_mbbl_m.htm; http://tonto.eia.doe.gov/dnav/ng/ng_prod_sum_dcu_NUS_m.htm
Ports	Revenue (millions of $, adjusted for inflation)	U.S. Census Bureau, Economic Census: Transportation and Warehousing, Support Activities for Transportation, http://www.census.gov/econ/census02/

rately sourced for each sector in the individual chapters. Therefore, the number of facilities mapped will not equal the number of facilities cited as the sector universe.

Energy Use

The "Energy Use" sections in the sector chapters discuss energy consumption. A key source of information is the Manufacturing Energy Consumption Survey (MECS).

The DOE's EIA collects data on the energy consumption of U.S. manufacturers. Every four years, EIA mails a detailed questionnaire to a statistically valid sample of firms. EIA then extrapolates sample data to produce sector-level energy consumption estimates.

Name: Manufacturing Energy Consumption Survey

Source: Energy Information Administration

Metric: energy consumption by manufacturers

Frequency: quadrennial

Period Analyzed: 2002

Next Data Release: 2006 MECS expected in late 2008

Website: http://www.eia.doe.gov/emeu/mecs

Sectors Covered: Cement Manufacturing, Chemical Manufacturing, Food & Beverage Manufacturing, Forest Products, Iron & Steel, Metal Casting, and Oil & Gas

Context Beyond This Report

Where we can, we provide some perspective on the 12 sectors covered in this report by giving examples of their impact, both individually and collectively, in the national and global environment and economy. There are many different sources of data (such as federal and state governments, universities, businesses and business groups, non-governmental organizations) and many ways to analyze data. Each method can provide unique insight for understanding and influencing environmental performance. Data allowing consideration and action by sector are most readily available for industrial sectors.

This focus on a "sector" report necessarily circumscribes the types, amount, and comprehensiveness of data used. We do not, for instance, discuss releases from motor vehicles, from sources of pesticides or fertilizers, or from many other non-industrial sources. Benzene, for example, is a known human carcinogen that is reported by most of our industry sectors, yet the combined releases from these sectors is far outweighed by reported emissions from burning coal and oil, motor vehicle exhaust, and evaporation from gasoline service stations. Tobacco smoke contains benzene and accounts for nearly half of the national exposure to benzene.[2] Having said this, the value of the analysis compiled in this report, from an industrial sector perspective, is significant. It provides, for example, a multi-media look at current environmental data that both educates the sectors on specific details and trends of their environmental "footprint," and it opens the door for opportunities to reduce those footprints through source reduction or chemical substitution.

Ultimately, efforts to report, analyze, and control chemical releases stem from the recognition that they pose some degree of "risk" to human health and the environment. Determining that potential risk depends on many factors, including a determination of the toxicity of the chemical, its fate after its release to the environment, the location of the release, and the populations exposed to the chemical. There are many ongoing and complex efforts to identify this risk by this Agency and other institutions that include reviewing inventories of toxic chemical releases and the sources that emit them. That level of risk screening and analysis, even just from an industrial sector perspective, is beyond the scope of this report. What we have chosen to do, through the "Toxicity Score" table presented in most sector chapters, is not meant to be an oversimplification of risk methodologies. The Toxicity Score tables are yet another way for a sector to identify chemicals of concern and potentially prioritize opportunities for source reduction or chemical substitution. We hope that this presentation will both highlight topics to consider for action and encourage discussion of the strengths and weaknesses of this approach.

Air Emissions

The sections on "Air Emissions" include information on air emissions of chemicals reported to the Toxics Release Inventory (TRI), criteria air pollutants (CAPs), and for some sectors, greenhouse gases (GHGs). The sections rely primarily on TRI, the National Emissions Inventory (NEI), and the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2005*. An overview of these sources is given below, as well as a discussion of the model EPA uses to analyze the toxicity of air emissions, the Risk-Screening Environmental Indicators (RSEI) model.

Toxic Releases

This report presents aggregated air emissions of TRI chemicals by the reporting facilities in each sector from 1996 through 2005 (the most current data available at the time the analyses were conducted for this report). TRI is a publicly available database containing information on the release and management of more than 600 chemicals and chemical categories by facilities that use, process, or manufacture these chemicals at annual levels above reporting thresholds. TRI is based on reports filed by the facilities. TRI contains information on toxic chemicals that facilities emit or otherwise manage as waste, including hazardous air pollutants (HAPs), which are also referred to as "air toxics." HAPs are air pollutants that pose a direct threat to human health.

Name: Toxics Release Inventory

Source: EPA

Metrics: Estimated releases, transfers, and disposals

Frequency: Annual

Period Analyzed: 1996–2005

Latest Data Release: February 2008 for 2006 Public Data Release

Website: http://www.epa.gov/tri

Sectors covered: Cement Manufacturing, Chemical Manufacturing, Food & Beverage Manufacturing, Forest Products, Iron & Steel, Metal Casting, Paint & Coatings, Oil & Gas (Petroleum Refining), and Shipbuilding & Ship Repair

Considering the Toxicity of Air Emissions

This report includes discussions of the toxicity of air releases. The toxicity of TRI chemicals—meaning how harmful they can be to human health—varies greatly.

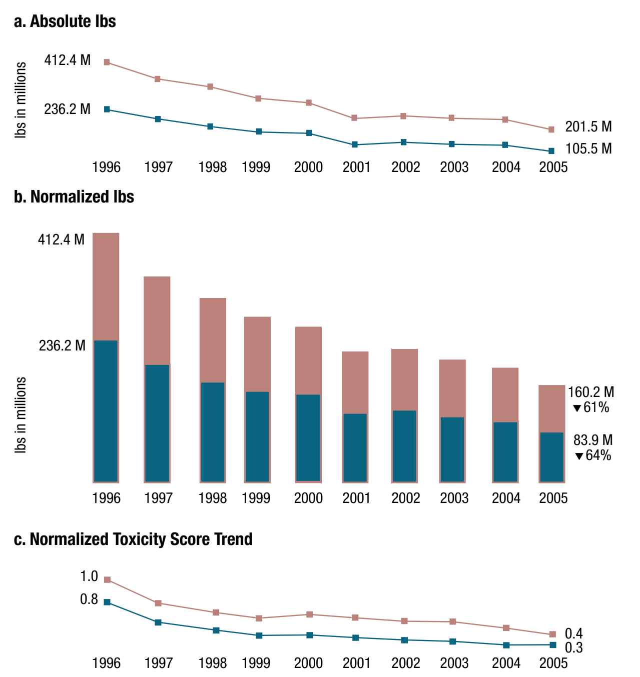
RSEI assigns each TRI chemical, to the extent data are available, two chemical-specific relative toxicity weights: one for inhalation of the chemical, and one for ingestion of the chemical. These relative toxicity weights provide a method to score the potential harm of chemicals relative to each other. Toxicity weights for chemicals increase as the toxicological potential to cause chronic human health effects increases. For example, pound for pound mercury has a higher relative toxicity weight than a pound of methanol. Risk posed by a chemical to an individual is a function of many variables such as the route and duration of exposure, the extent of the chemical's absorption into the individual, and the chemical's intrinsic toxicity. The RSEI model is not designed to address these variables. Hence, the model expresses risk in terms of relative risk or relative Toxicity Scores, not actual risk posed by releases of a specific chemical or chemicals to individuals. The results of RSEI analyses are only meaningful when compared to other results produced by the model. To consider toxicity, EPA's RSEI model multiplies the quantity of media-specific TRI releases (e.g., pounds of mercury released to air) by the chemical-specific relative toxicity weights to calculate a relative Toxicity Score. Because of data limitations, this report presents RSEI information only for air emissions reported to TRI.

Refer to the Data Sources, Methodologies, and Considerations chapter for additional information.

Presentation of TRI Air Emissions Data

As shown in the sample figure below, the TRI air emissions data discussion presents three related trends that provide a progressively focused look at the sector's toxic chemical emissions.

Air Emissions Reported to TRI 1996–2005



Section A of the figure presents the sector's TRI-reported absolute pounds of toxic chemical and HAP air emissions from 1996 to 2005. The sets of lines share the same horizontal axis, representing years, with the bars. The top, red line in the "Absolute lbs" set presents the trend for "All TRI Chemicals, including HAPs." The lower, blue line presents the trend for TRI HAP emissions only; TRI HAPs are a subset of "All TRI Chemicals." The sample graph shows that this sector released 412 million lbs. of TRI chemicals to the air in 1996, 236 million lbs. of which were HAPs. By 2005, total TRI emissions declined to 201 million lbs.

Section B of the figure presents the sector's toxic chemical and HAP emissions normalized by the sector's VOS over the same period. The overall percent changes of normalized emissions of all TRI chemicals and of just HAPs are presented beside an arrow (indicating an increase or decrease) to the right of these bars. The sample graph shows that the sector's air emissions of TRI chemicals, normalized by VOS, decreased by 61% from 1996 to 2005. Over this same period, the sector's normalized HAP emissions decreased by 64%.

Section C of the figure shows the relative Toxicity Score of the TRI chemicals and HAPs emitted to the air by the sector. The figure uses 1996 as a baseline for the relative Toxicity Score, assigned a ratio of one. Change in toxicity is calculated relative to that 1996 total value; a 60% decrease in relative Toxicity Score resulted in a 2005 relative Toxicity Score of 0.4, as seen in the example graph above. The normalized toxicity-weighted results for HAP emissions accounted for approximately 80% of the relative Toxicity Score in 1996, as indicated by the 0.8 value on the left side of the graph. The relative Toxicity Score for HAPs showed a declining trend similar to that for all TRI emissions, with a reduction from 0.8 to 0.3, a 62.5% decline

Chapters presenting TRI data include a table titled, "Top TRI Air Emissions," which identifies the top five TRI chemicals released to air in 2005 for each of three categories: the absolute quantity (in pounds) emitted, the chemicals' relative Toxicity Score, and the number of facilities reporting each chemical. The five red numbers in each category indicate the top five chemicals for that indicator. The chemicals in italics are HAPs.

In the sample table below, for example:

- Ammonia, hydrochloric acid, methanol, n-hexane, and nitrate compounds were the five chemicals reported in the largest quantity in this sector, and are shown in red in the "Absolute Pounds Reported" column. The "Percentage of Sector Total" in the "Absolute Pounds Reported" column shows that the chemicals included in this table accounted for 95% of the sector's TRI air emissions.
- Acetaldehyde, acrolein, hydrochloric acid, polycyclic aromatic compounds, and sulfuric acid were the five chemicals with the highest relative Toxicity Score reported in this sector, and are shown in red in the "Percentage of Toxicity Score" column. The "Percentage of Sector Total" in the "Percentage of Toxicity Score" column means that the chemicals included in this table accounted for 86% of the sector's relative Toxicity Score for TRI air emissions.
- Ammonia, n-hexane, lead, polycyclic aromatic compounds, and zinc were the five chemicals reported by the most facilities in this sector, and are shown in red in the "Number of Facilities Reporting" column. The "Percentage of Sector Total" in the "Number of Facilities Reporting" column means 51% of TRI reporters in the sector reported one or more of the chemicals in this table.

Top TRI Air Emissions 2005

Chemical	Absolute Pounds Reported	Percentage of Toxicity Score	Number of Facilities Reporting
Acetaldehyde	2,048,000	5%	24
Acrolein	24,000	25%	2
Ammonia	11,956,000	2%	408
Hydrochloric Acid	4,224,000	4%	34
Lead	17,000	2%	68
Methanol	3,002,000	<1%	38
N-Hexane	22,027,000	1%	86
Nitrate Compounds	2,637,000	<1%	14
Polycyclic Aromatic Compounds	59,000	10%	48
Sulfuric Acid	1,774,000	37%	22
Zinc	15,000	<1%	43
Percentage of Sector Total	95%	86%	51%

Criteria Air Pollutants

Name: National Emissions Inventory

Source: EPA

Metrics: Emission estimates for SO_X, NO_X, PM (<10 microns and <2.5 microns), CO, and VOCs

Frequency: Every 3 years

Period Analyzed: 2002

Next Data Release: 2005 NEI for point sources in Spring 2008

Website: http://www.epa.gov/ttn/chief/trends/

Sectors covered: Cement Manufacturing, Chemical Manufacturing, Colleges & Universities, Food & Beverage Manufacturing, Forest Products, Iron & Steel, Metal Casting, Paint & Coatings, Oil & Gas, and Shipbuilding & Ship Repair

NEI, a publicly available EPA database, contains information on emissions of CAPs and HAPs. The Clean Air Act regulates six CAPs, including particulate matter (both coarse, PM_{10}, and fine, $PM_{2.5}$, which is included in PM_{10}), ground-level ozone (O_3), carbon monoxide (CO), sulfur oxides (SO_X), nitrogen oxides (NO_X), and lead (Pb). Lead, also defined as a HAP, is discussed in this report as a HAP. Volatile organic compounds (VOCs) are not CAPs, but in the presence of sunlight they react with NO_X to create O_3.

The emissions data in NEI are compiled every three years. There is no threshold amount for NEI reporting, so all point sources should be captured in the database. This report describes CAP and VOC emissions for 2002 (the most current year of data available during the analyses for this report), as shown in the sector chapters, including their latest environmental statistics.

Greenhouse Gases

Name: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2005

Source: EPA

Metrics: Emission estimates for CO_2, CH_4, N_2O, and fluorinated gases

Frequency: Annual

Period Analyzed: 2005

Most Recent Data Release: April 2008

Next Data Release: April 2009

Website: http://www.epa.gov/climatechange/emissions/usgginventory.html

GHG emissions are discussed for certain sectors, for which data were available from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* and other sources. GHGs include, but are not limited to, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated gases.

Presentation of TRI Waste Management Data

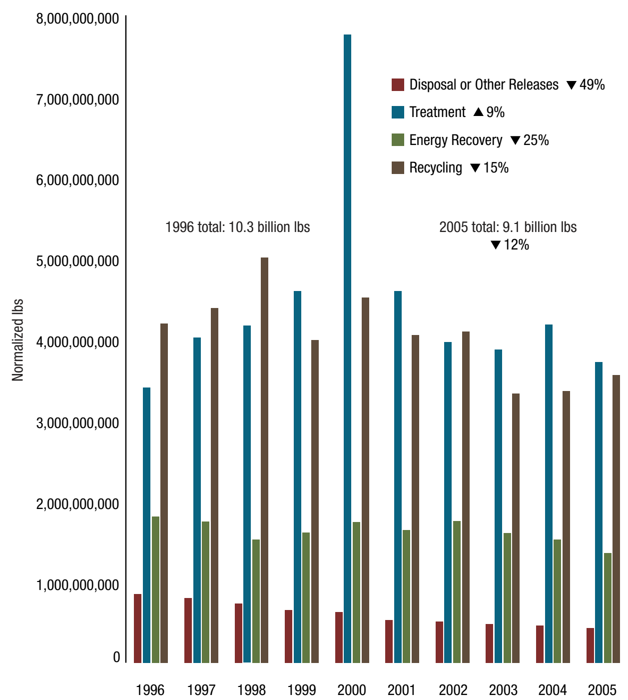
As shown in the sample figure below, the TRI data discussion in this section presents trends showing the management of toxic chemicals from 1996-2005. In this sample, the sector managed 10.3 billion lbs. of TRI chemicals in 1996. The percentages show the percent change of quantities of waste managed by each method over the 10-year period, normalized by VOS. For example, TRI chemicals recycled and used for energy recovery by the sector decreased by 15% and 25%, respectively.

The table titled "Top TRI Disposals" identifies the top TRI chemicals disposed in 2005, based on absolute pounds and the number of reporting facilities. The five red numbers in each category indicate the top five chemicals for that indicator.

In the sample table, for example:

- Nitrate compounds, barium, ammonia, zinc, and manganese were the five chemicals reported as disposed in the largest quantities, and are shown in red in the "Absolute Pounds Reported" column. The "Percentage of Sector Total" in the "Absolute Pounds Reported" column shows that the chemicals included in this table accounted for 93% of the sector's TRI disposals.
- Ammonia, lead, nitrate compounds, nitric acid, and zinc were the five chemicals disposed by the largest number of facilities reporting, and are shown in red in the "Number of Facilities Reporting" column. The "Percentage of Sector Total" in the "Number of Facilities Reporting" column shows that 26% of TRI reporters in the sector reported one or more of the chemicals in this table.

TRI Waste Management 1995–2006



Top TRI Disposals 2005

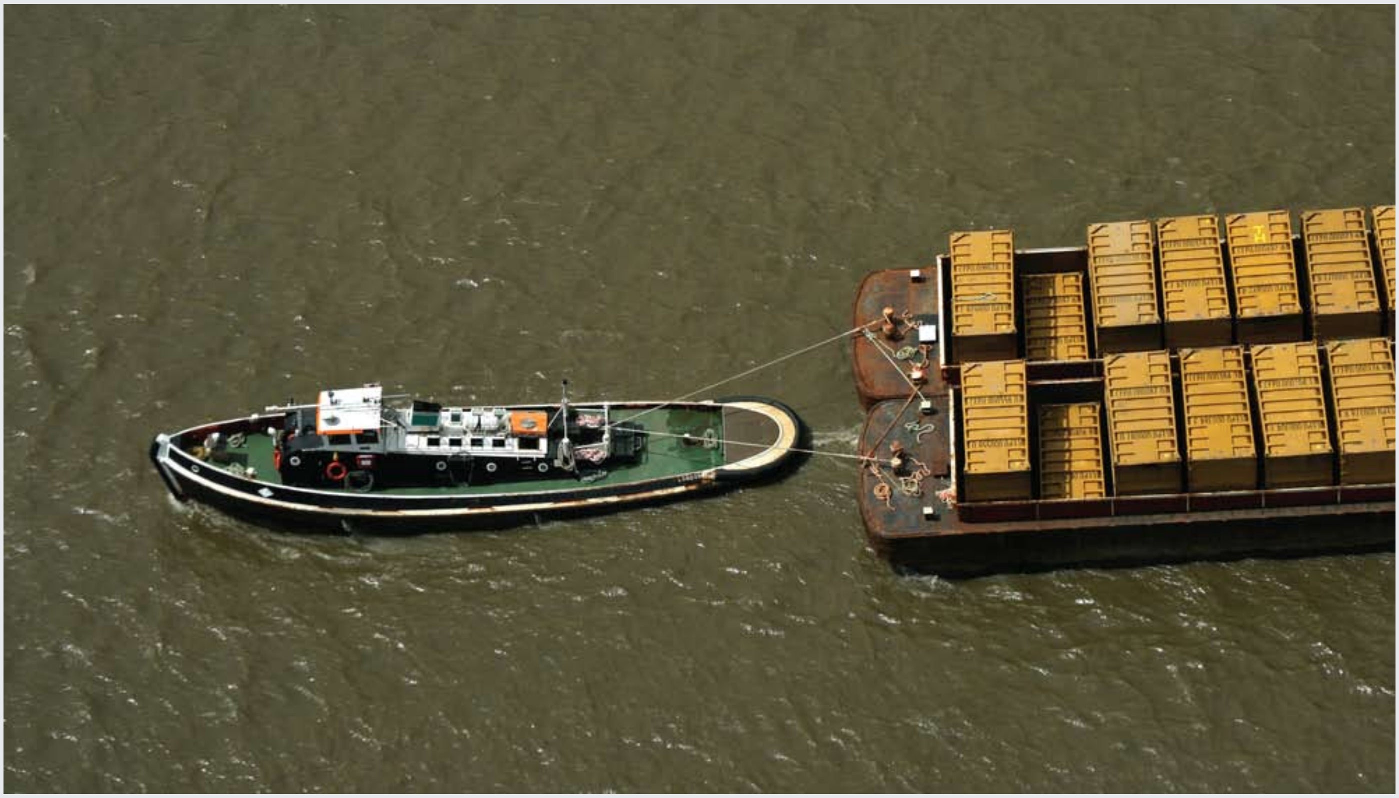
Chemical	Absolute Pounds Reported	Number of Facilities Reporting
Ammonia	1,350,000	136
Barium	1,697,000	16
Lead	92,000	37
Manganese	519,000	19
Nitrate Compounds	13,869,000	154
Nitric Acid	369,000	29
Zinc	690,000	36
Percentage of Sector Total	93%	26%

Water Use and Discharges

The "Water Use and Discharges" sections present information on TRI chemicals discharged to water and additional data from other sources for sectors where available. While TRI chemicals are not generally the most significant factors influencing water quality, data on water discharges of other pollutants are not adequately refined to allow meaningful sector-based analyses.

Waste Generation and Management

The "Waste Management" sections of this report include information on hazardous wastes and on TRI chemicals managed as waste. EPA emphasizes reducing waste generation whenever possible and, if waste is generated, minimizing the quantity that is released or disposed, by instead increasing recycling, energy recovery, or treatment. This report presents waste management information as categorized by TRI, into recycling, energy recovery, treatment, and disposal or other releases.

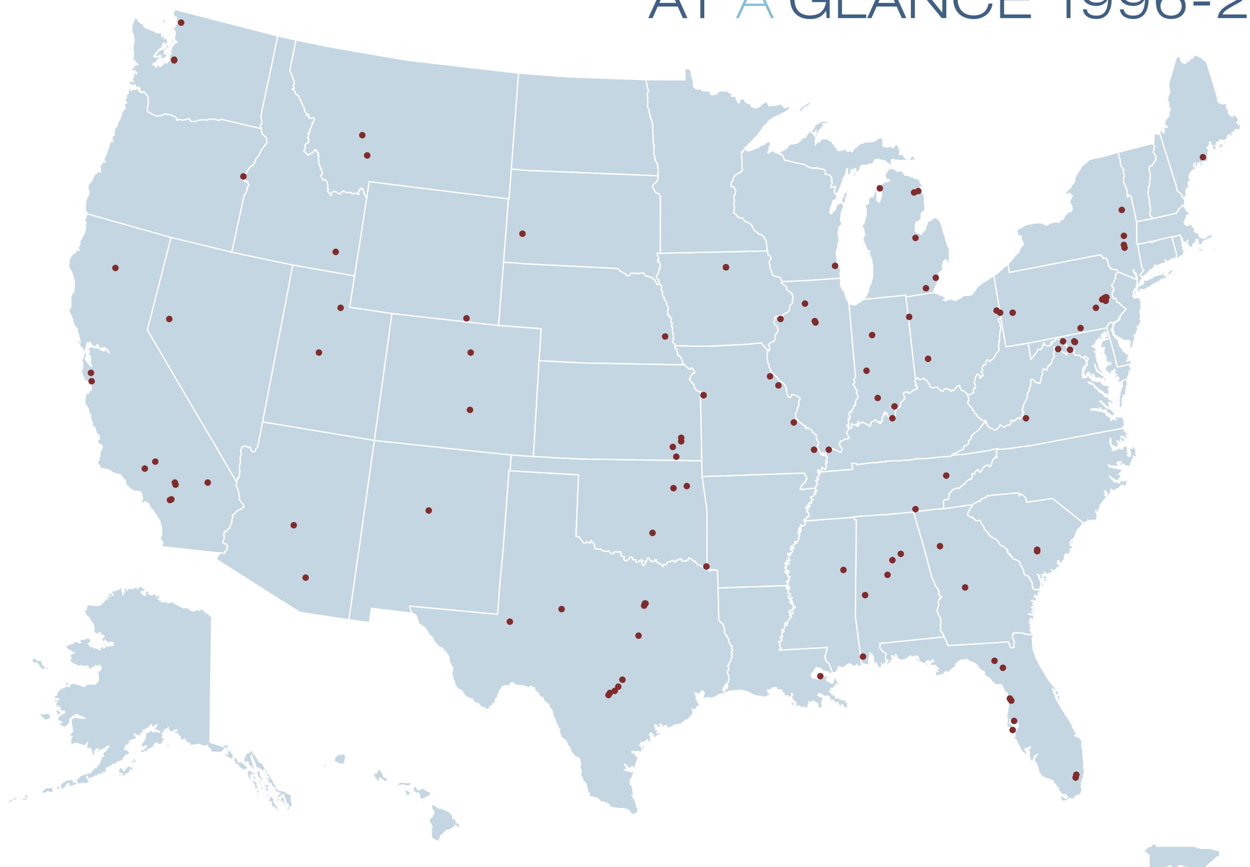


Hazardous Waste

Pursuant to the Resource Conservation and Recovery Act (RCRA), EPA biennially collects information on the generation, management, and final disposition of hazardous waste from large quantity generators (LQGs) and treatment, storage, and disposal facilities (TSDFs), and compiles a National Biennial RCRA Hazardous Waste Report (BR). Any facility that meets the criteria to be considered an LQG or TSDF is required to report. Unlike TRI, there is no restriction based on the industrial sector (e.g., no NAICS code criteria). Also, unlike TRI, BR reflects the weight of entire waste streams, rather than just the weight of particular toxic chemicals within those streams.

CEMENT MANUFACTURING

AT A GLANCE 1996-2005[1]



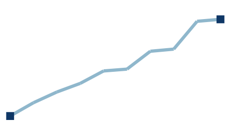
115 facilities

115 ▲ 0%

13,800 employees

13,800 ▲ 0%

70.4 million metric tons of clinker produced



87.4 million ▲ 24%

Latest Environmental Statistics[2]

Energy Use: 410.8 trillion Btu

Emissions of Criteria Air Pollutants: 576,000 tons

Releases of Chemicals Reported to TRI: 13.5 million lbs.

Air Emissions: 10.6 million lbs.

Water Discharges: 3,300 lbs.

Waste Disposals: 2.9 million lbs.

Recycling, Energy Recovery, or Treatment: 412 million lbs.

Hazardous Waste Generated: 17,000 tons

Hazardous Waste Managed: 31,000 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 Cement Manufacturing sector produces Portland cement, a binding agent that when mixed with water, sand, and gravel or crushed stone forms the rock-like mass known as concrete. Concrete, in turn, serves highway, commercial, and residential construction projects.

Limestone is the key ingredient to manufacture cement. Limestone and other ingredients, including material that is aluminous, ferrous, and siliceous, are placed into a kiln where a thermochemical process occurs to make cement clinker. The cement clinker is mixed with additives (e.g., gypsum) to make Portland cement.

The U.S. Cement Manufacturing sector is concentrated among a relatively small number of companies; many U.S. cement plants are owned by or are subsidiaries of foreign companies. Together, 10 companies accounted for about 80% of total U.S. cement production in 2005.[3]

California, Texas, Pennsylvania, Florida, and Alabama are the five leading cement-producing states and accounted for about 48% of recent U.S. production.[4]

Although production, imports, sales volumes, and prices of cement all reached record high levels in 2005, cement consumption is expected to decline in the near future.[5]

Energy Use

Cement Manufacturing is an energy-intensive industry. The thermochemical production process requires very high temperatures; grinding and crushing operations also use energy. On average, producing one metric ton of cement requires 4.7 million Btu.[6] Between 2000 and 2006, the sector's energy consumption, when normalized by clinker production, decreased about 7%.[7]

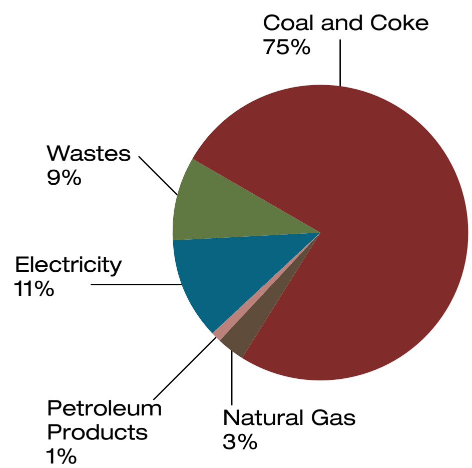
To make cement, the manufacturer places limestone and other ingredients into the upper end of a rotary kiln. At the lower end of the inclined kiln, a burner pipe emits a large flame, providing the intense heat required for the thermochemical process. The limestone and other materials go through several chemical processes that require temperatures reaching almost 1,500 degrees Centigrade (C). During the process, the raw materials, fuel molecules, and the air inside the kiln break apart. The limestone becomes calcium oxide and carbon dioxide (CO^2). Calcium oxide and silicates bond to form the principal compounds that cool into solid pellets called clinker. The manufacturer grinds clinker with gypsum and smaller amounts of other ingredients to create Portland cement.

Kilns employ either a wet or dry process. The wet process uses raw materials ground with water to create a slurry material to be fed into the kiln, while the dry process uses dry materials in a powder-like input to the kiln. The wet process was initially used to improve the chemical uniformity of raw materials being processed; however, it

FIGURE 1

Fuel Use for Energy 2006

Total: 410.8 trillion Btu



Source: Portland Cement Association

requires 32% more energy per ton of clinker production than the average for dry processes.[8] Technological improvements have allowed cement makers to utilize the dry process without quality deficiencies, and no new wet kilns have been built in the United States since 1975.[9] Some existing plants are switching from the wet to the dry process.[10] About 85% of U.S. cement production capacity now relies on the dry process technology.[11]

As shown in Figure 1, Cement makers are able to utilize a variety of fuels to maintain high temperatures within kilns, such as coal, petroleum coke, distillate and residual fuel oils, natural gas, used tires, and solid and liquid wastes. The significant quantity of fuel and raw materials needed to manufacture cement provides an opportunity for the sector to consume alternative fuels and raw materials generated as byproducts from other industries.

Many plants meet 20–70% of their energy requirements with alternative fuels.[12] These fuels include scrap tires, waste oil, refinery wastes, and other solid and liquid wastes that have fuel value. Cement kilns burn hotter, have longer gas residence times, and are much larger than most commercial thermal treatment facilities (e.g., hazardous waste incinerators), making them ideal for reclaiming such materials when properly managed.

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). CAPs and GHGs also are generated as byproducts from onsite combustion of fuels in cement kilns.

Air emissions from the kiln system are the primary environmental concern in cement manufacturing. More than 99% of the exit gases are composed of nitrogen, water vapor, and CO_2, while less than 1% is nitrogen oxide (NO_X), sulfur dioxide (SO_2), and even smaller quantities of organic compounds and heavy metals.[13]

The major processes in making Portland cement that cause air emissions are fuel combustion, the thermochemical process of making clinker, and crushing and grinding operations. The intense heat of the combustion process separates the fuel into organic and inorganic components. The organic components are consumed as fuel, while the various inorganic components become either part of the cement product or are collected in a plant's air pollution control device (e.g., electrostatic precipitator or baghouse).

Raw materials, particularly clay, may contain ammonia, which is partially roasted off during material preheating. Smaller amounts may come from loss of ammonia when used in selective non-catalytic reduction (SNCR) NO_X control devices. Benzene and ethylene are found in both conventional and alternative raw materials and are partially roasted off during material preheating.

Chlorine may be present in raw materials as well as in alternative fuels (e.g., spent solvents, plastics). Much of the chlorine becomes bound in the clinker. Emissions can result if inputs exceed the capacity of the clinker to absorb inbound chlorine, in which case the chlorine combines with hydrogen to produce hydrochloric acid.

Metals are found in all cement input materials, including limestone, clay, coal, and cement kiln dust (CKD). Semi-volatile and volatile metals evaporate and condense on the fine dust fraction of material recovered in air pollution control equipment. Reduction controls for most heavy metals include efficient dedusting equipment (baghouses and electrostatic precipitators) and limits to inputs in feed materials (currently the primary control method for mercury).

Air Emissions Reported to TRI

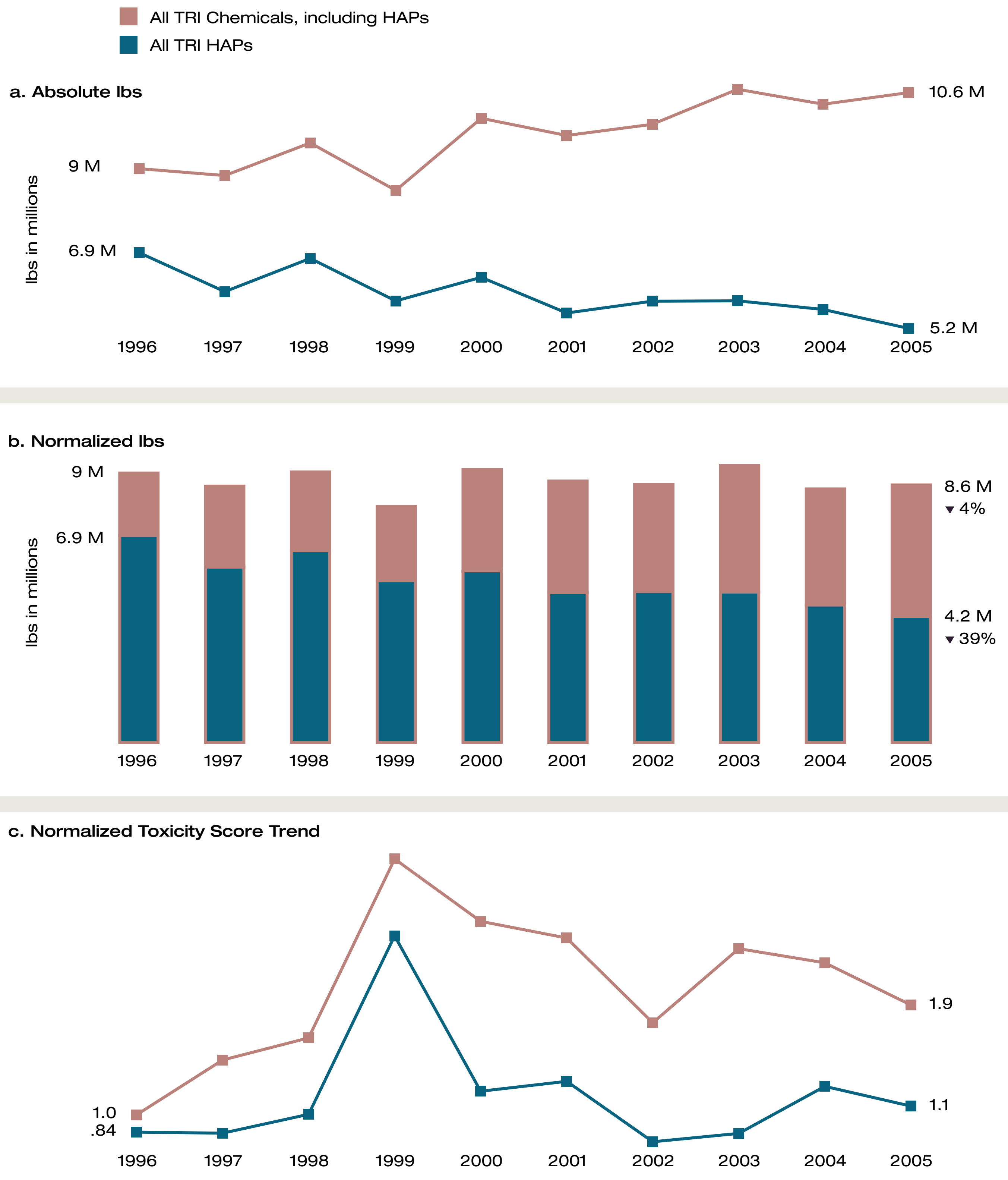
In 2005, 109 facilities in the sector reported 10.6 million absolute lbs. of air emissions to EPA's TRI.[14] The TRI list of toxic chemicals includes all but six of the hazardous air pollutants (HAPs) regulated under the Clean Air Act. The absolute pounds emitted annually increased nearly 19% from 1996 to 2005, as shown in Figure 2a, but when normalized by annual clinker production, the sector's TRI air emissions decreased by 4% over the same period, as shown in Figure 2b.[15]

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.

FIGURE 2

Air Emissions Reported to TRI 1996–2005



Note:
Normalized by annual clinker production.

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

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 Toxicity Scores fluctuated from 1996 to 2005, with an overall increase of 98%, when normalized by clinker production. Fluctuations in emissions of sulfuric acid and chromium caused reciprocal fluctuations in the sector's overall Toxicity Score. Fluctuations in sulfuric acid, which is released as a byproduct from burning coal during clinker manufacturing, were driven by changes in pounds reported by only a few cement plants. Changes in chromium results were due to naturally occurring variations in the level of chromium in limestone.[16] The apparent spike in 1999 was due, among other things, to changes in methodologies used to calculate releases, and to changes in TRI reporting requirements. In absolute pounds, HAPs accounted for 49% of the sector's air emissions reported to TRI in 2005, and 54% of the overall Toxicity Score.

Table 1 presents the sector's top TRI-reported air emissions based on three indicators.

TABLE 1

Top TRI Air Emissions 2005

Chemical	Absolute Pounds Reported[1]	Percentage of Toxicity Score	Number of Facilities Reporting[2]
Ammonia	1,469,000[3]	<1%	15
Benzene[4]	599,000	1%	14
Chlorine	50,000	7%	1
Chromium	10,000	14%[5]	63
Dioxin and Dioxin-Like Compounds	<1	<1%	74
Ethylene	1,811,000	<1%	1
Hydrochloric Acid	3,900,000	6%	35
Lead	15,000	2%	107
Manganese	34,000	19%	34
Mercury	11,000	1%	104
Sulfuric Acid	1,580,000	45%	11
Percentage of Sector Total	89%[6]	95%[7]	100%[8]

Notes:
1. Total sector air releases: 10.6 million lbs.
2. 109 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. *Italics* indicate a hazardous air pollutant under section 112 of Clean Air Act.
5. 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.
6. Chemicals in this list represent 89% of the sector's air emissions.
7. Chemicals in this list represent 95% 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. Hydrochloric acid and ethylene were the highest-ranking chemicals based on the pounds of each chemical emitted to air in 2005, although ethylene was largely reported by a single facility.
2) Percentage of Toxicity Score. Sulfuric acid and metals—manganese and chromium—dominated top chemicals based on Toxicity Score. Manganese and other metals can occur naturally in limestone.
3) Number of Facilities Reporting. Lead and mercury were the most frequently reported chemicals, with almost all of the TRI filers in the sector reporting these chemical emissions.

Criteria Air Pollutants

At 219,000 tons in 2002, NO_X were the largest CAP emissions from cement making, as shown in Table 2.[17] NO_X formation is an inevitable consequence of high temperature combustion. Called "Thermal NO_X," it is produced in the main flame of all cement kilns and is formed during combustion of air. Some NO_X may result from combustion of fuels.[18] Control strategies include low-NO_X burners and SNCR technologies.

TABLE 2

Criteria Air Pollutant and VOC Emissions 2002

	Tons
SO_2	161,000
NO_X	219,000
PM_{10}	37,000
$PM_{2.5}$	17,000
CO	150,000
VOCs	9,000

Notes:
1. PM_{10} includes $PM_{2.5}$ emissions.

Source: U.S. Environmental Protection Agency

SO_2 results from volatilization of sulfur from raw materials roasted off during material preheating. The range of emissions depends on the content of volatile sulfur compounds in the raw materials. Control strategies include the addition of hydrated lime to the kiln feed and the use of wet sulfur scrubbers. Volatile organic compounds (VOCs) result from volatilization of organics in raw materials (limestone and shale) that are roasted off at material preheating. The range of emissions depends upon the content of the raw materials mined. Carbon monoxide (CO) is formed either because of incomplete combustion or the rapid cooling of combustion products below the ignition temperature of 610°C.

At the end of the thermal treatment process, gases and pulverized materials must be separated again. Incomplete separation gives rise to dust emissions from the kiln/raw mill main stack, the clinker cooler stack, cement mill stacks, or material transfer point dedusting air outlets. Bag filters and electrostatic precipitators are emission reduction techniques typically used.

The fine dust generated from the kiln line, collectively labeled cement kiln dust, includes particulates representing the raw mix at various stages of burning, particles of clinker, and even particles from the eroded refractory brick linings of the kiln tube. Most U.S. plants have reduced CKD air emissions to small amounts by using dust scrubbers—either electrostatic precipitators or filtration baghouses.

In general, the introduction of newer kiln technology and improved process controls by the sector has led to overall reductions of CAP emissions. Process controls stabilize kiln operations by improving energy efficiency, reducing heat consumption, improving clinker quality, and reducing emissions.

Greenhouse Gases

Cement manufacturers directly emit GHGs from their consumption of raw materials and combustion of fuels. The chemical reaction creating cement emits large amounts of CO_2 as limestone breaks down into calcium oxide. Noncombustion cement production processes emitted 45.9 million metric tons of CO_2 equivalent in 2005.[19] The combustion of fuels in cement kilns and generation of electricity purchased by the sector also emit GHGs.

Figures published by major cement corporations provide some insight into the CO_2 emissions that cement companies have identified. Three reports from 2005 and 2006 from cement companies estimated CO_2 emissions in the range from 658 to 670 kilograms (kg) per metric ton of cement produced.[20]

The sector has various options for reducing GHG emissions, including using alternative sources of calcium oxide, such as steel slag, and upgrading to more efficient clinker production technologies, such as dry—rather than wet—process kilns. Under the U.S. Department of Energy's (DOE) voluntary Climate VISION program, the Portland Cement Association (PCA) adopted a voluntary goal to reduce CO_2 emissions by 10% per ton of cement product produced or sold by 2020, from a 1990 baseline.[23]

Reducing Greenhouse Gas Footprint

The California Portland Cement company signed a 25-year contract with a wind energy company that ensures a large portion of the power consumed at the plant located in Mojave, CA, will be renewable energy. This helped reduce the company's indirect GHG emissions in 2006 by 31,247 metric tons over 2005.[21]

Reducing Direct GHG Emissions

Buzzi Unicem's Signal Mountain plant in Chattanooga, TN, reduced its CO_2 emissions 51.3% after completing a $140 million upgrade to convert to a dry manufacturing process. The plant received a Green Industry Award from the Greater Chattanooga Chamber of Commerce.[22]

Water Use and Discharges

Cement plants generate little wastewater. The water used in wet process plants evaporates in the kiln. While 109 facilities reported air emissions to TRI in 2005, just 16 reported water discharges. These facilities reported 3,300 lbs. of TRI chemicals discharged to water.[24] There are currently no aggregate data available on the quantity of water used by the Cement Manufacturing sector.

Discharges to surface water also can result from stormwater runoff. Plant operators generally channel stormwater into holding ponds so the solid particles can be removed. Cement makers can discharge the water in compliance with permits or recycle the water to cool equipment.

Waste Generation and Management

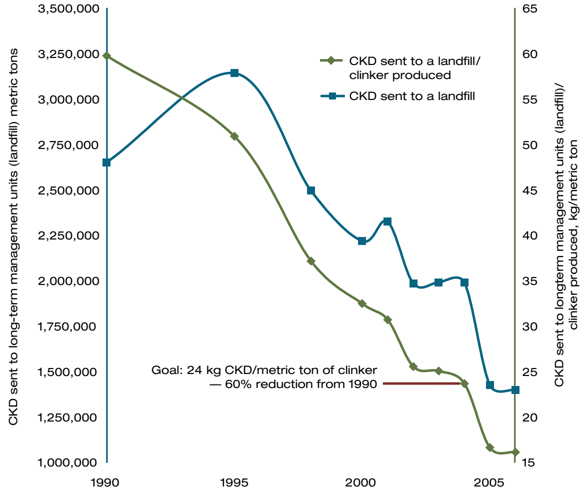
Of the solid wastes generated in a kiln, CKD is a major issue. The tumbling and grinding of materials within a kiln produce a great deal of dust. CKD consists of the ash and other tiny particles remaining from the burnt limestone and other products. It can contain metals and materials remaining from the hazardous wastes sometimes used as supplemental fuel within a kiln. CKD is removed from the kiln exhaust gases by pollution-control devices such as baghouses and electrostatic precipitators.

CKD is a valuable commodity to the industry. Recycling CKD into the cement kiln offsets the use of limestone and other raw virgin materials and reduces fuel usage. More than 75% of CKD is now fed directly back into the kiln. When not recycled to the kiln, because of contaminant build-up and quality-control concerns (e.g., alkalis), CKD can sometimes be used as a soil conditioner (liming agent), as a somewhat cementitious material for roadfill, and occasionally as a filler or cementitious extender for finished cement.

As illustrated by Figure 3, the cement industry has used process improvements to reduce the amount of CKD disposed. PCA adopted a voluntary target for its member companies of a 60% reduction (from a 1990 baseline) of

FIGURE 3

Cement Kiln Dust Disposal Rates With Reduction Goal



Source: Portland Cement Association

CKD disposed per ton of clinker produced—a goal of 24 kg CKD disposed of per metric ton of clinker produced. PCA members achieved this goal in 2004.[25]

EPA has categorized CKD as a special waste temporarily exempted from federal hazardous waste regulations under the Resource Conservation and Recovery Act (RCRA). EPA is developing standards for management of CKD and has published a set of proposed Subtitle D (concerning nonhazardous solid waste) regulations to govern CKD management.

Alternative materials from other sectors can be used to make cement. These materials include byproducts from other industrial processes, such as used foundry sand from the Metal Casting sector, mill scale from the Iron & Steel sector, or fly ash from electric utilities. These materials can replace corresponding raw materials that would have to be mined.

Burning wastes as fuel can reduce the need for virgin fuels to run the kiln, can treat hazardous waste, and can reduce the quantity of wastes buried in landfills, incinerated, or otherwise disposed. The practice can also reduce plant operating costs, improving competitiveness.

Hazardous Waste Management

In 2005, cement plants reported to EPA's *National Biennial RCRA Hazardous Waste Report* (BR) generating 17,000 tons of hazardous waste. However, only 18 of 115 facilities in the sector reported to BR, so the data may present an incomplete picture of the sector's generation of hazardous waste. For instance, 1 facility generated 32% of the sector's reported RCRA hazardous wastes, while 4 of the 18 generated almost 86% of the reported wastes.[26] Most of the generated hazardous waste reported was from pollution control and hazardous waste management activities.[27]

The sector tends to manage more wastes than it generates because some facilities receive hazardous waste from offsite for use as fuel. The sector reported managing 31,000 tons of hazardous waste in 2005. A majority of the waste was managed through reclamation and recovery activities, almost all of which was through energy recovery.

Some cement companies have subsidiaries that operate as fuel blenders that accept, store, and process (e.g., fuel blending) hazardous waste. Estimating the flow of hazardous waste into and out of these subsidiaries and into and out of individual cement facilities is difficult to do but may be examined in future reports.

Waste Management Reported to TRI

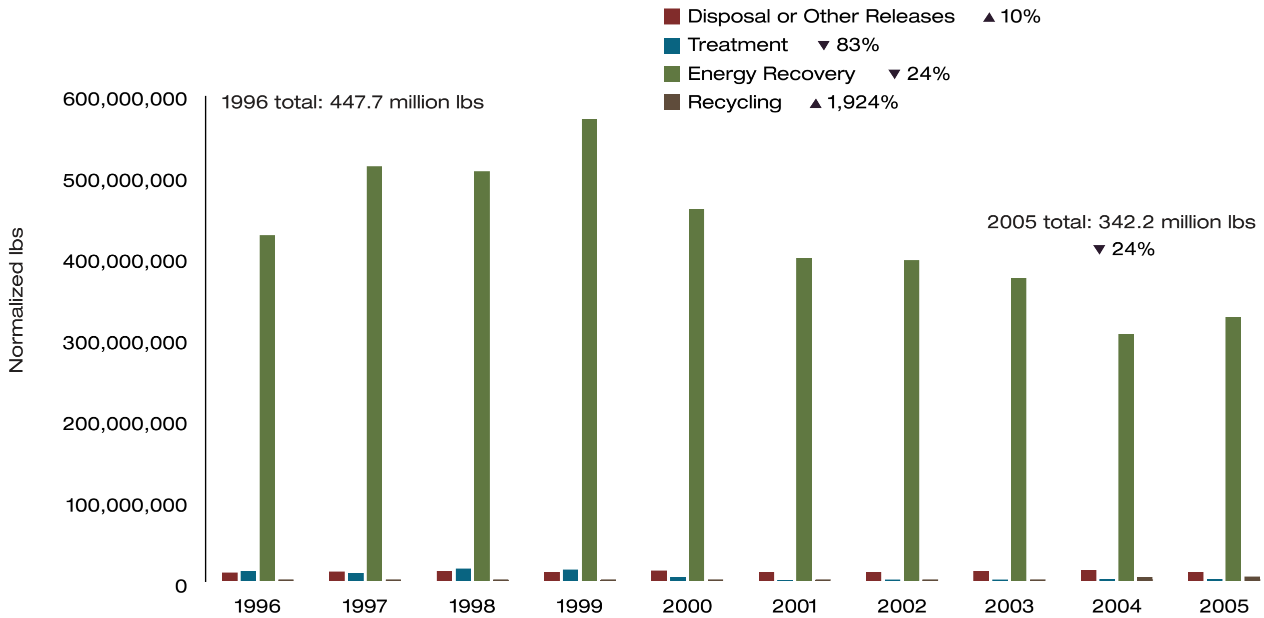
In 2005, the Cement Manufacturing sector reported managing 425 million absolute lbs. of TRI chemicals as waste. As shown in Figure 4, when normalized by annual clinker production, this quantity represented a 24% reduction since 1996. The downward trend indicates that less waste was generated per ton of clinker in the sector in 2005. In 2005, 3% of TRI-reported waste was disposed or released, while 95% was used for energy recovery. The remaining 2% was recycled or treated.[28]

In 2005, the sector reported disposing 2.9 million lbs. of TRI chemicals to land or transferring the chemicals to offsite locations for disposal. As shown in Table 3, metals dominated the sector's TRI disposals. Major sources of these disposals are metals in CKD collected in air pollution particulate control systems. Metals from raw materials or fuels are usually bound to the clinker product, except for metals that are partly or completely volatilized in the kiln system (such as mercury, thallium, or cadmium).

Additional Environmental Management Activities

PCA set four performance measure goals regarding: CO_2, CKD, environmental management systems (EMS), and energy efficiency.

FIGURE 4
TRI Waste Management 1996–2005



Notes:
1. Normalized by annual clinker production.
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]
Barium	173,500[3]	14
Chromium	97,500	32
Lead	620,200	49
Manganese	974,700	18
Mercury	1,500	39
Nickel	55,900	15
Zinc	711,700	11
Percentage of Sector Total	90%[4]	48%[5]

Notes:
1. 2.9 m llion lbs. total sector disposals.
2. 109 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 90% of the sector's disposals.
5. 48% of facilities reported disposals of one or more chemicals in this list.

Source: U.S. Environmental Protection Agency

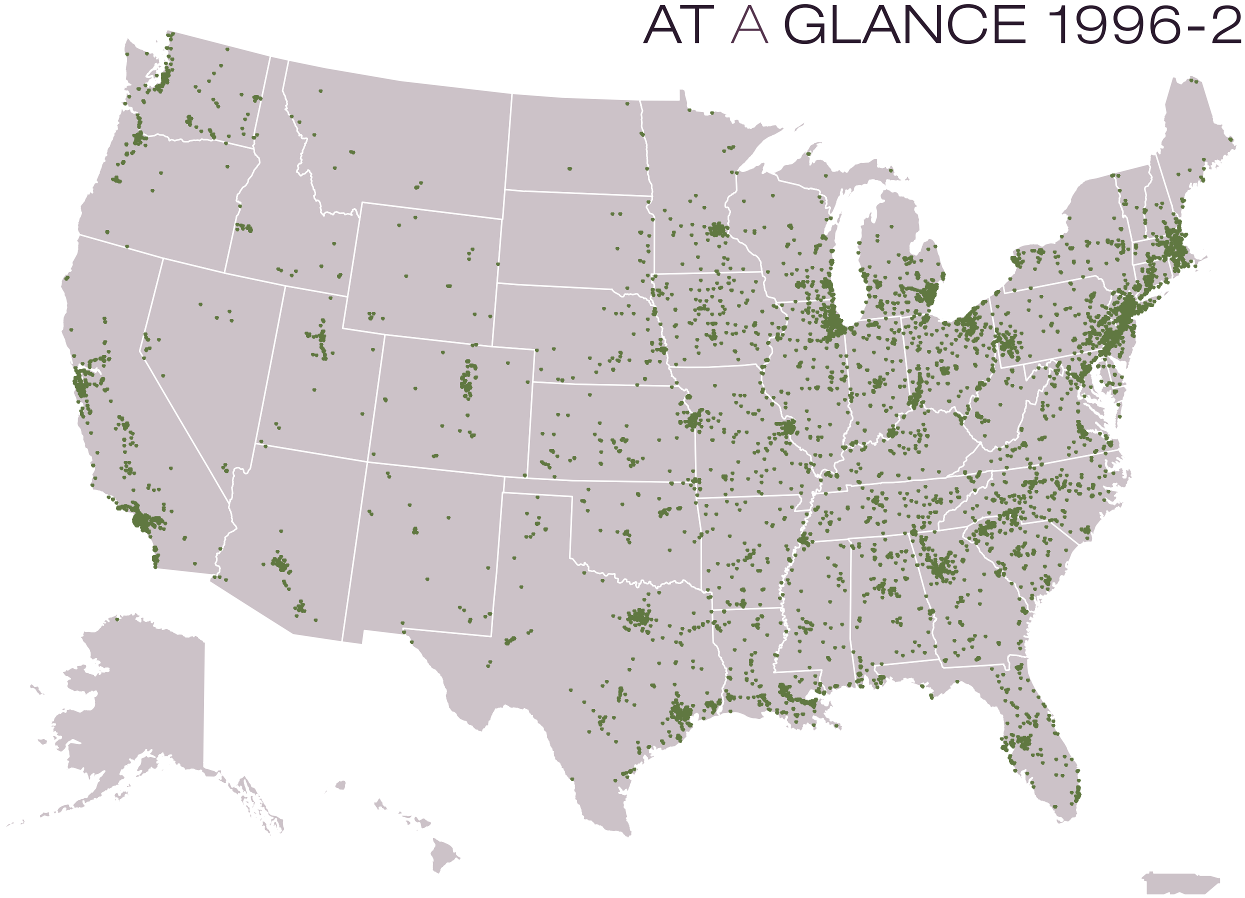
As noted above, PCA member companies achieved their CKD disposal goal in 2004. Pursuant to the goal to reduce CO_2 emissions, PCA introduced guidelines for greater use of limestone as a raw material that could reduce CO_2 generation by more than 2.5 million tons per year. The guidelines recommend upgrading facilities with efficient, lower-emitting equipment, improving product formulation to reduce energy and natural resource needs, and conducting new research and development into cement and concrete applications that are more energy efficient and durable.[29]

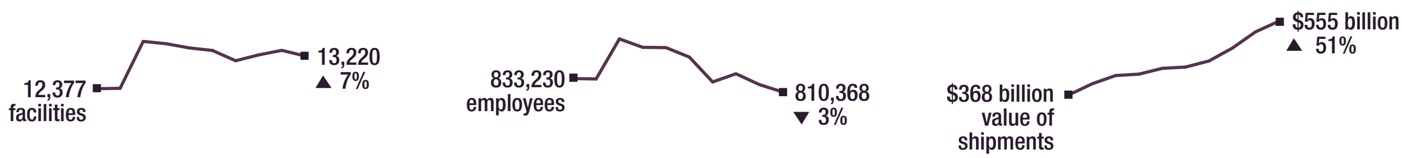
An EMS is a set of processes and practices that enable an organization to reduce its environmental impacts and increase its operating efficiency. PCA adopted a target to have at least 75% of U.S. cement plants use an auditable and verifiable EMS by the end of 2010 and 90% by the end of 2020.

For the energy efficiency performance measure, PCA adopted a year 2020 voluntary target of 20% improvement (from 1990 baseline) in energy efficiency. This is measured by total Btu-equivalent per unit of cementitious product.

CHEMICAL MANUFACTURING

AT A GLANCE 1996-2005[1]





Latest Environmental Statistics[2]

Energy Use: 3.8 quadrillion Btu

Emissions of Criteria Air Pollutants: 1.5 million tons

Releases of Chemicals Reported to TRI: 540.8 million lbs.

Air Emissions: 201 million lbs.

Water Discharges: 42.7 million lbs.

Waste Disposals: 297 million lbs.

Recycling, Energy Recovery, or Treatment: 10.9 billion lbs.

Hazardous Waste Generated: 23.8 million tons

Hazardous Waste Managed: 26.1 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

Chemical Manufacturing facilities transform raw materials (e.g., oil, natural gas, water, minerals, metals) into tens of thousands of different products, including bulk chemicals, plastics, pharmaceuticals, and consumer goods, as well as produce inputs to agriculture, manufacturing, and construction industries. The sector is categorized into "commodity" and "specialty-batch" production.[3]

- Commodity manufacturers create products in large quantities under continuous processing conditions. The small number of shutdowns affects the potential to make adjustments such as equipment retrofits and upgrades.
- Specialty-batch manufacturers develop products for particular "niche" markets, making complex products in small quantities. These manufacturers change their process lines several times per year, providing more opportunities for environmental improvements but also making environmental compliance more complicated. In this report, the specialty-batch subsector is characterized by a facility list based on membership with the Synthetic Organic Chemical Manufacturers Association (SOCMA).[4]

Throughout this chapter, the distinction is made between "all chemical manufacturing" and "specialty-batch manufacturing," whenever separate data are available. "All chemical manufacturing" includes both commodity and specialty-batch processors.

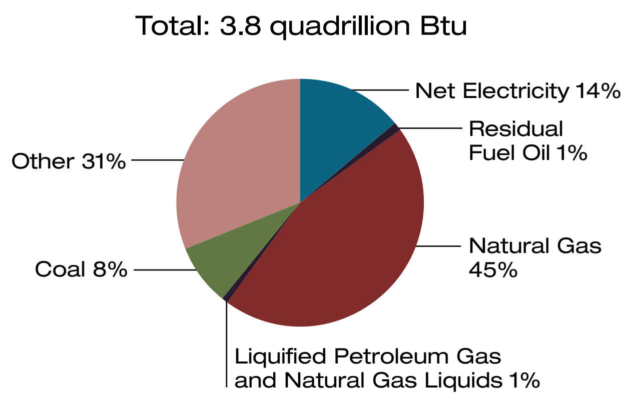
The sector represents about 12% of all U.S. manufacturing revenue based on value of shipments (VOS).

Energy Use

Chemical Manufacturing is an energy-intensive sector, using a total of 3.8 quadrillion Btu in fuel for energy purposes. Along with using fuels to supply the energy needs of facility operations, the sector uses fossil fuels—primarily natural gas and oil—as raw materials in the production of many products. Organic chemicals require the most fossil fuel. Feedstock use of fossil fuels is also common in the bulk petrochemical and fertilizer industries.[5]

FIGURE 1

Fuel Use for Energy 2002



Notes:
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

Chemical facilities purchase electricity and produce energy from a variety of fuels. Natural gas was the primary fuel that the sector used in 2002, as shown in Figure 1. Net electricity was the third largest source of power for the sector in 2002.

Chemical manufacturers have opportunities for short- and long-term fuel switching, whereby they can reduce one energy source in favor of another with fewer emissions or greater efficiency. With the already high prices of natural gas, many facilities that can switch to alternative fuels from natural gas are already doing so.[6] Facilities could switch from emissions-intensive fuels, such as coal, to lower-emission fuels such as natural gas, but they have little cost incentive to do so; natural gas is more expensive than coal. Future energy consumption of all fuels is expected to increase in chemical manufacturing, and long-term fuel switching potential relies heavily on the price of natural gas.[7]

Reducing Electricity Demand

Sometimes the best alternative energy source is not a fuel. Hexion Specialty Chemical, Inc., of South Glens Falls, NY, realized a 21% reduction in electrical demand with no excess emissions when the facility installed a backpressure induction turbine generator powered by excess process steam. In addition to "free" energy, reductions in water usage and boiler treatment chemicals resulted as benefits of this pollution prevention project.[8]

Cogeneration, or combined heat and power (CHP), increases energy efficiency through onsite production of thermal energy and electricity from a single fuel source. Cogeneration and self-generation of electricity are important in the chemical industry. The sector uses cogeneration to generate almost one third of the electricity it consumes.[9] Expanded application and further development offer the potential for additional opportunities in fuel switching and energy savings.

Energy Cogeneration and Conservation

In 1994, Dow committed to reducing the company's global energy intensity by 20% by 2005. In 2005, Dow improved by 22% over 1994, reducing energy use by more than 370 trillion Btu. In 2006, Dow's Freeport, TX, site replaced an older gas turbine with a more efficient steam generating plant and took other steps, such as switching to byproduct fuels, to reduce its energy intensity 2.6% relative to 2005, saving 3.6 trillion Btu and approximately $25 million. Overall, the company saved an estimated 5.4 trillion Btu of energy in 2006, with associated direct carbon dioxide (CO_2) emission reductions of 382,821 tons.[10]

Plant Energy Reduction Program

The DuPont Sabine River Works site, in Orange, TX, achieved major reductions in power generation and transmission using a data-driven approach to process improvement. Operators, supervisors, and engineers created an at-a-glance "dashboard" with data from numerous sources that compares optimal to actual performance, shows real-time cost impacts, and highlights underperforming processes. If improvements are needed, the dashboard lists recommended corrective actions, operating procedures, and diagnostic tools. Operators improved efficiency from 10% below expectations to 15% above, sometimes performing at the theoretical limit. Annualized energy savings have been 25%, with associated CO_2 emissions reductions of 10,962 tons.[11]

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 or fuels used in chemical manufacturing processes, and as intermediates. They can also be byproducts, products from side reactions, or internal end products. CAPs and GHGs are also generated as combustion byproducts from onsite combustion of fuels.

Air Emissions Reported to TRI

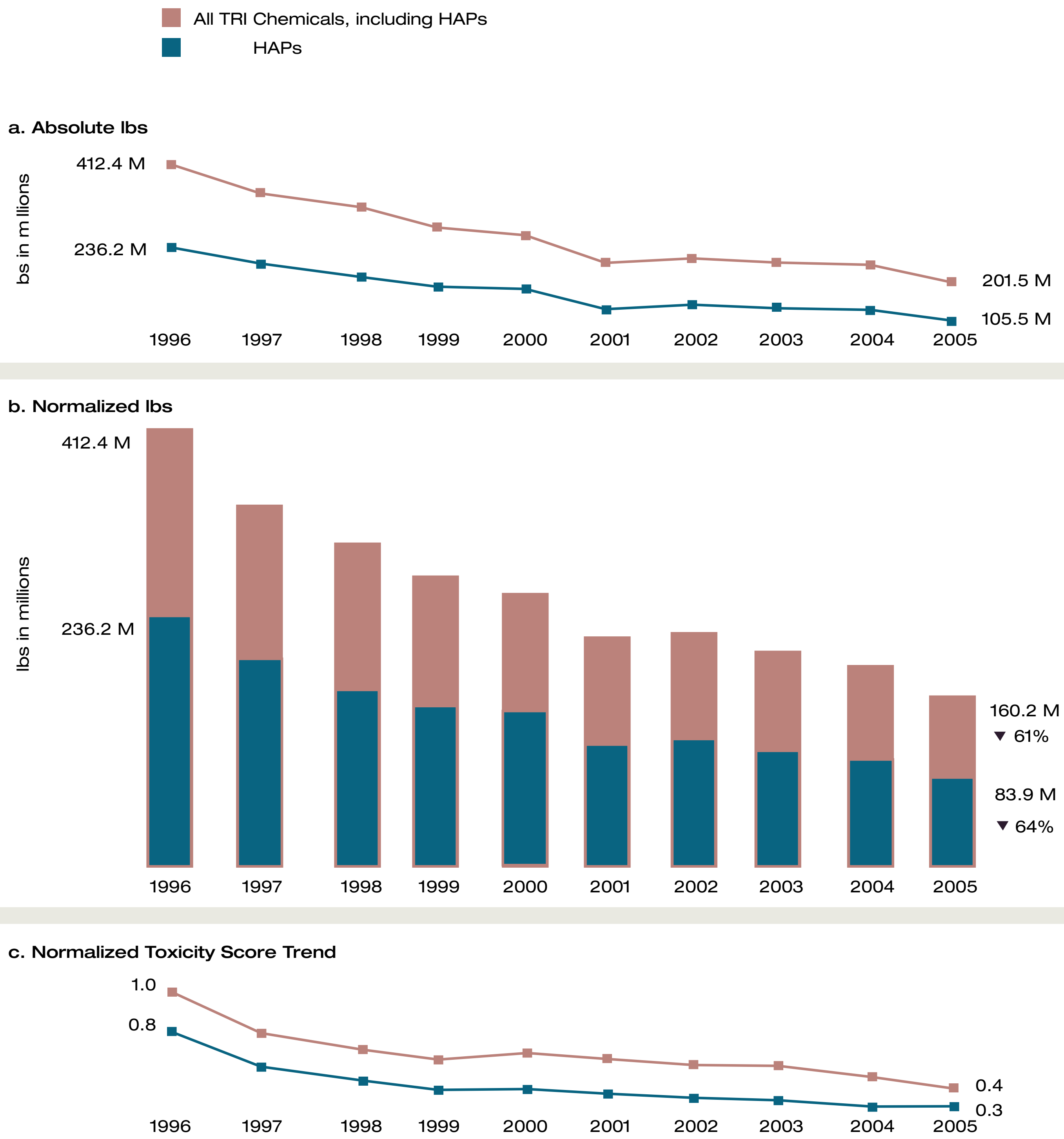
In 2005, 3,096 facilities in the Chemical Manufacturing sector reported 201 million absolute lbs. of air emissions. Between 1996 and 2005, absolute TRI-reported air emissions declined by 51%, as shown in Figure 2a. When normalized by the sector's value of shipments over the period, air emissions decreased 61%, as seen in Figure 2b.[12] Facility-level analysis of TRI data indicate that this reduction was driven by a decline in the quantity of chemicals released by facilities that reported across all years, rather than being driven by a reduced number of reporters.

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

FIGURE 2

Air Emissions Reported to TRI 1996-2005



Note:
Normalized by annual value of shipments.

Sources: U.S. Environmental Protection Agency, U.S. Department of Commerce

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 TRI list of toxic chemicals includes all but 6 of the hazardous air pollutants (HAPs) regulated under the Clean Air Act. In absolute pounds, HAPs accounted for 52% of the sector's air emissions reported to TRI in 2005, and 74% of the sector's total Toxicity Score.[13] Trends in emissions of HAPs, based on pounds and on the Toxicity Scores, showed very similar declines to the trends in air emissions for all TRI chemicals.[14]

Over the same period, air emissions from the specialty-batch subsector declined by 49%.[15] The subsector is considerably smaller than the Chemical Manufacturing sector as a whole, with 185 facilities reporting air emissions to TRI in 2005. The specialty-batch chemical subsector's Toxicity Scores declined 60% from 1996 to 2005. However, because there are fewer facilities, changes at a few sites, particularly those reporting chemicals with a high Toxicity Score, can significantly impact overall subsector trends.[16]

Table 1 presents the top TRI-reported chemicals emitted to air by the chemical manufacturing 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.

1) Absolute Pounds Reported. Ammonia and methanol were the highest-ranking chemicals based on the pounds of each chemical emitted to air in 2005.

2) Percentage of Toxicity Score. The top chemicals based on Toxicity Score included chlorine and sulfuric acid. These chemicals have moderate toxicity weights, but were released in large quantities, resulting in high Toxicity Scores.

TABLE 1

Top TRI Air Emissions 2005

Chemical	Absolute Pounds Reported[1]	Percentage of Toxicity Score	Number of Facilities Reporting[2]
Acrolein[3]	49,000	8%[4]	37
Ammonia	50,421,000	2%	589
Carbon Disulfide	10,111,000	<1%	54
Carbonyl Sulfide	12,852,000	4%	33
Certain Glycol Ethers	600,000	<1%	484
Chlorine	1,048,000	18%	285
Chromium	32,000	5%[5]	103
Ethylene	16,601,000	<1%	143
Manganese	138,000	10%	94
Methanol	19,279,000	<1%	783
Sulfuric Acid	3,586,000	13%	122
Toluene	6,961,000	<1%	693
Xylene (Mixed Isomers)	2,793,000	<1%	585
Percentage of Sector Total	62%[6]	60%[7]	65%[8]

Notes:
1. 201 million pounds total sector air releases.
2. 3,096 total TRI reporters in the sector.
3. *Italics* indicate a hazardous air pollutant under section 112 of the Clean Air Act.
4. Red indicates the chemical is one of the top five chemicals reported in the given category.
5. 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.
6. Chemicals in this list represent 62% of the sector's air emissions.
7. Chemicals in this list represent 60% of the sector's Toxicity Score.
8. 65% of facilities reported emitting one or more chemicals in this list.

Source: U.S. Environmental Protection Agency

Acrolein and chromium were released in smaller quantities but have high Toxicity Scores.

3) Number of Facilities Reporting. Methanol was the most frequently reported chemical, with one-quarter of the TRI-filers in the sector reporting methanol air emissions.

The top 10 chemicals based on Toxicity Scores accounted for 71% of the total Toxicity Scores, with chlorine, sulfuric acid, and manganese accounting for 40% of Toxicity Scores. This list of top 10 has been fairly consistent for the past five years. However, TRI-reported releases of acrolein declined from 1990 until 2001, but then more than doubled to 49,000 pounds in 2005. Facility-level analysis of acrolein releases indicates that the increase may be a result of the growing use of ethanol and biofuels. Both the number of facilities reporting and the volume of releases have increased under SIC 2869 (Industrial Organic Chemicals, NEC) and NAICS 325193 (Ethyl Alcohol Manufacturing). The recent fluctuations in releases of acrolein have been driven generally by 10 or fewer facilities, indicating the potential for targeted reduction efforts.

For the specialty-batch subsector, as with the Chemical Manufacturing sector as a whole, methanol was the most frequently reported chemical released to air in 2005, with 104 facilities reporting, and chlorine was the top-ranked chemical based on Toxicity Scores. The top-ranked chemicals based on pounds of air emissions from facilities in the specialty-batch subsector were ethylene (1.6 million lbs.) and toluene (1 million lbs.).[17]

Criteria Air Pollutants

CAP emissions are generated by onsite energy production using fuels such as coal, oil, and gas, and also by some chemical manufacturing processes.[18] Table 2 shows CAP and volatile organic compound (VOC) emissions from the sector for 2002.

TABLE 2

Criteria Air Pollutant and VOC Emissions 2002

	Tons
SO_2	482,000
NO_X	309,000
PM_{10}	57,000
$PM_{2.5}$	39,000
CO	476,000
VOCs	175,000

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

Source: U.S. Environmental Protection Agency

Reduced Energy Use and CO_2 Emissions

Albemarle Corporation initiated a program in 2006 to reduce energy consumption by 12% over two years. Projects involving preventive maintenance and steam leaks were especially successful. The company used weekly plant audits to evaluate progress, identify opportunities, and establish corrective actions. Using low capital-intensive efficiency improvements and other means, the company achieved 66% of its goal in the first year. Annualized energy savings were more than 8%, representing 603,778 million Btu saved and 35,019 tons of CO_2 emissions avoided.[19]

Greenhouse Gases

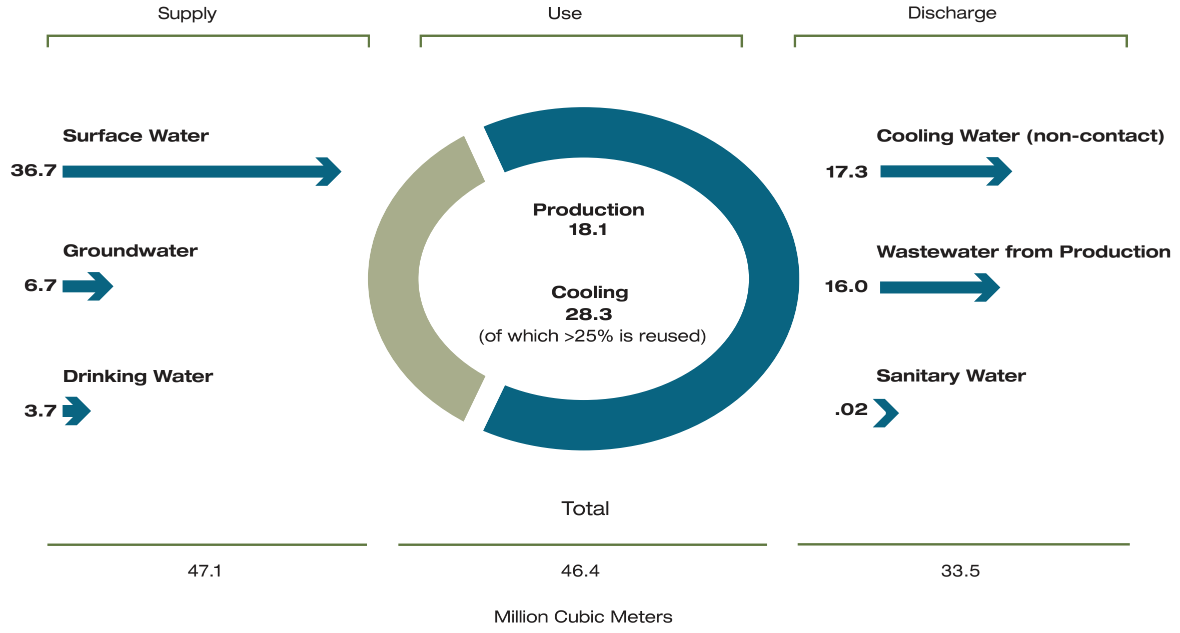
Chemical manufacturers directly emit GHGs from the combustion of fossil fuels and from production processes. Non-combustion emissions occur from the use of fossil fuels as feedstocks and the use of other raw materials. Such emissions include nitrous oxide (N_2O), fluoroform (HFC-23), CO_2, and methane (CH_4). The largest process-related sources of GHG emissions include production of hydrochlorofluorocarbons (HCFCs), ammonia, and acids such as nitric and adipic acid.[20] The generation of electricity purchased by chemical manufacturers also emits GHGs.

The American Chemistry Council (ACC) participates in Climate VISION, a U.S. Department of Energy voluntary partnership effort responding to the President's goal of reducing GHG intensity, that is, the ratio of greenhouse gases to economic output.[21] Through this program, ACC members committed to reduce their GHG emissions intensity 18% from 1990 levels by 2012. ACC reports that members have already achieved this goal.[22] The companies reduced their GHG intensity by more than 30% since 1992; GHG intensity fell 5% between 2003 and 2005.[23]

Water Use and Discharges

Water use varies widely within the sector, depending on the products manufactured and production processes used. The primary uses of water are for non-contact cooling, steam applications, and product processing.[24] The production of various chemicals requires different amounts of water. For example, producing silicon-based chemicals requires large quantities of water, yet the top manufactured chemicals by volume (including nitrogen, ethylene, ammonia, phosphoric acid, propylene, and polyethylene) require far less water during production.[25] Throughout the sector, more than 80% of the water used for cooling and steam is recycled; process water recycling varies widely.[26] There are currently no aggregate data available on the quantity of water used by the sector.

Balanced Water Use at BASF



Source: BASF

Balanced Water Use at BASF

BASF's U.S. operations used an estimated 46.4 million cubic meters of water in 2006. Of that amount, 18.1 million cubic meters of water was used for production and 28.3 million cubic meters for cooling purposes. More than 25% of the cooling water is reused. BASF focuses primarily on water recycling as part of its water conservation measures, including regular maintenance on closed loop systems that circulate water, boiler blowdown and condensate recovery, and water reuse for vessels and piping clean-outs.[27]

Every facility discharging process wastewater directly to waterways must apply for a National Pollutant Discharge Elimination System (NPDES) permit. The permits typically set numeric limits on specific pollutants and include monitoring and reporting requirements. Approximately 1,700 facilities in the sector have NPDES permits.[28] Regulated pollutant discharges can vary depending on the characteristics of chemicals being manufactured. Major factors include total suspended solids, presence of various metals, biological or chemical oxygen demand, and pH levels.[29]

Sector-wide, 801 chemical manufacturing facilities reported water discharges of TRI chemicals in 2005, totaling 42.7 million lbs., including direct discharges to waterways of any TRI chemical and discharges of metals to Publicly Owned Treatment Works (POTWs). This represented a decline of 57% between 1996 and 2005 for the chemical industry as a whole. Specialty-batch manufacturers reported water discharges of 2.7 million lbs., which represented a decline of 81%.[30]

Water Conservation and Efficiency

Arizona Chemical's manufacturing facility in Port St. Joe, FL, reduced well water usage from two onsite water wells. The facility installed multiple heat exchangers, thereby reducing cooling water usage. The company also modified cooling towers to improve efficiency, upgraded and cleaned equipment to improve heat transfer, repaired and upgraded steam traps, implemented a program to identify and repair stream leaks, and changed operating procedures to minimize water usage. The plant reduced its annual well water usage while increasing its annual production. The company reduced its well water use relative to production by nearly 13% from 2002 to 2005.[31]

In addition to being regulated for direct and POTW discharges, facilities with materials exposed to precipitation are regulated for stormwater runoff, usually under a general permit that provides sector-specific limits. While some facilities have stormwater permits, it is not a predominant issue of concern for the sector.

Water conservation and minimization practices for the sector include water measurement and management, water reuse, reducing the use of cooling water, eliminating system leaks, educating employees on conservation techniques, and development of processes that require less water.[32]

Waste Generation and Management

Hazardous Waste Management

In 2005, chemical manufacturers reported to EPA's *National Biennial RCRA Hazardous Waste Report* (BR) generating 23.8 million tons of hazardous waste, accounting for 62% of the hazardous waste generated nationally. At 37% and 32% of the total, respectively, production-related waste and pollution control (e.g., wastes captured in air pollution control equipment and wastewater treatment sludge) were the largest sources of hazardous waste generation. The sector reported managing 26.1 million tons of hazardous waste. According to the reports to BR, most of the sector's hazardous waste was managed through disposal.[33]

The specialty-batch chemicals subsector reported generating 414,000 tons of hazardous waste. For the subsector, 85% of the hazardous waste was generated from product and byproduct processing and pollution control processes (primarily from wastewater treatment operations). Almost 80% of the waste was treated or recovered/reclaimed, while 20% was disposed.[34]

Waste Management Reported to TRI

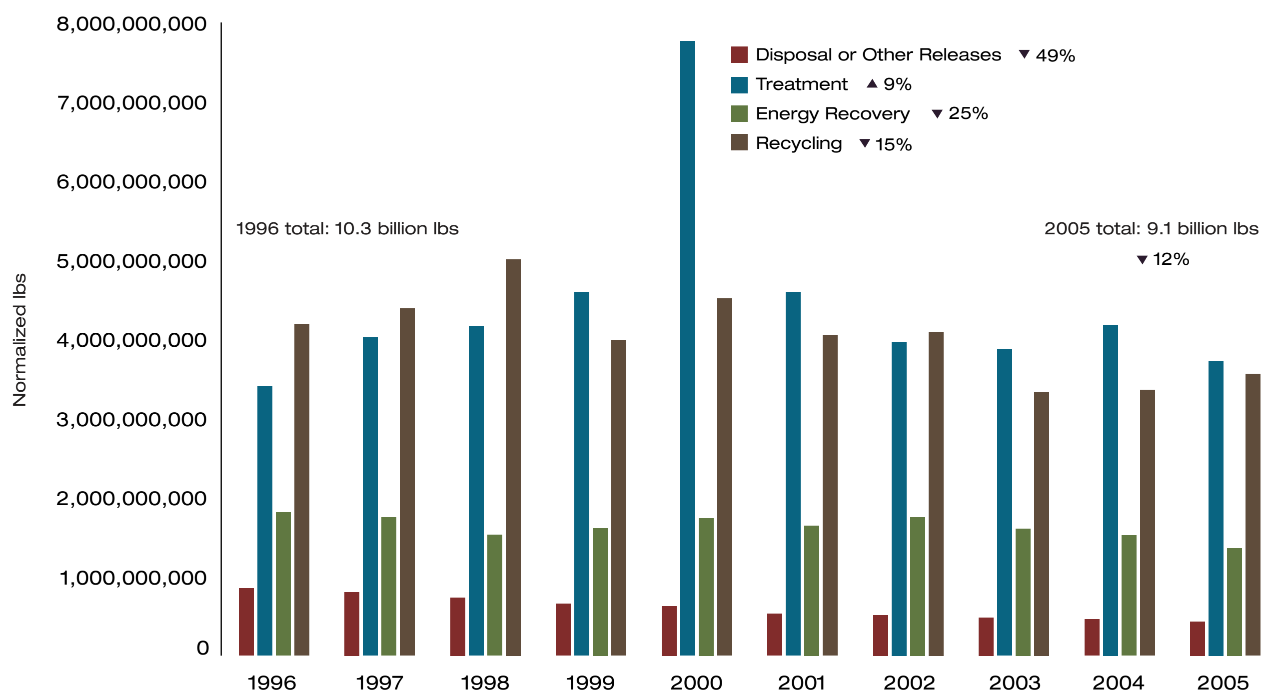
In 2005, chemical manufacturers reported managing 11.4 billion absolute lbs. of TRI chemicals in waste. When normalized by the sector's VOS, this was 12% less than 1996. Figure 3 shows how the sector managed this waste. In 2005, 5% of TRI-reported waste was released or disposed. Most of the waste disposed in 2005 went to underground injection wells, and the remainder was landfilled or placed in surface impoundments. In the same year, 15% was recovered for energy use, 39% was recycled, and 41% was treated.[35] When normalized by VOS between 1996 and 2005, the quantity of waste treated increased while the use of other management activities decreased.

Specialty-batch producers reported 1.2 billion lbs. of total waste managed in 2005. Of this quantity, 1% was released or disposed, 9% was used for energy recovery, 26% was treated, and 65% was recycled.[36]

For the overall sector, nitrate compounds and manganese were disposed in the greatest quantities and accounted for about one-third of disposals, while zinc and ammonia were the most frequently reported chemicals disposed, as indicated in Table 3.

FIGURE 3

TRI Waste Management 1996–2005



Notes:

1. Normalized by annual value of shipments.
2. Disposal and Other Releases includes air emissions, water discharges, and land disposals.
3. The apparent spike in treatment in 2000 was due to the report filed by a single facility.

Sources: U.S. Environmental Protection Agency, U.S. Department of Commerce

TABLE 3

Top TRI Disposals 2005

Chemical	Absolute Pounds Reported[1]	Number of Facilities Reporting[2]
Acetonitrile	16,700,000[3]	22
Ammonia	27,850,000	164
Copper	3,198,000	139
Lead	3,067,000	363
Manganese	49,873,000	91
Methanol	16,452,000	146
Nitrate Compounds	54,996,000	103
Zinc	8,946,000	344
Percentage of Sector Total	61%[4]	27%[5]

Notes:
1. 297 million pounds total sector disposals.
2. 3,096 total TRI reporters in the sector.
3. Red indicates the chemical is one of top five chemicals reported in the given category.
4. Chemicals in this list represent 61% of the sector's disposals.
5. 27% of facilities reported disposals of one or more chemicals in this list.

Source: U.S. Environmental Protection Agency

Waste Minimization and Utility Conservation

The Lockport, NY, facility of Isochem Inc., a phosgene and phosgene derivative manufacturer, implemented utility conservation, CO reduction, phosgene recovery, and distillation and reuse of process solvents. By re-piping process equipment and installing nitrogen flow meters, the facility pinpointed wasted resources, saved energy, and reduced onsite CO_2 emissions. Nitrogen reductions brought significant supplier energy savings and CO_2 reductions. By adding mass flow meters, automatic control valves, and some additional instrumentation, the facility reduced its need for excess CO used in high-quality phosgene production by nearly 15%. The changes also reduced onsite city water, caustic water, and sewer discharges, and reduced company and fuel supplier CO_2 emissions. The company initiated a novel approach of evaporating excess phosgene and recovering it for reuse. The installation of a solvent recovery distillation column permits purification of used organic solvents for reuse as a new raw material stream. This new process has reduced both raw material purchases of solvents and organic waste generation.[37] In 2006 the distillation equipment realized an annual total waste reduction of 609 tons.[38]

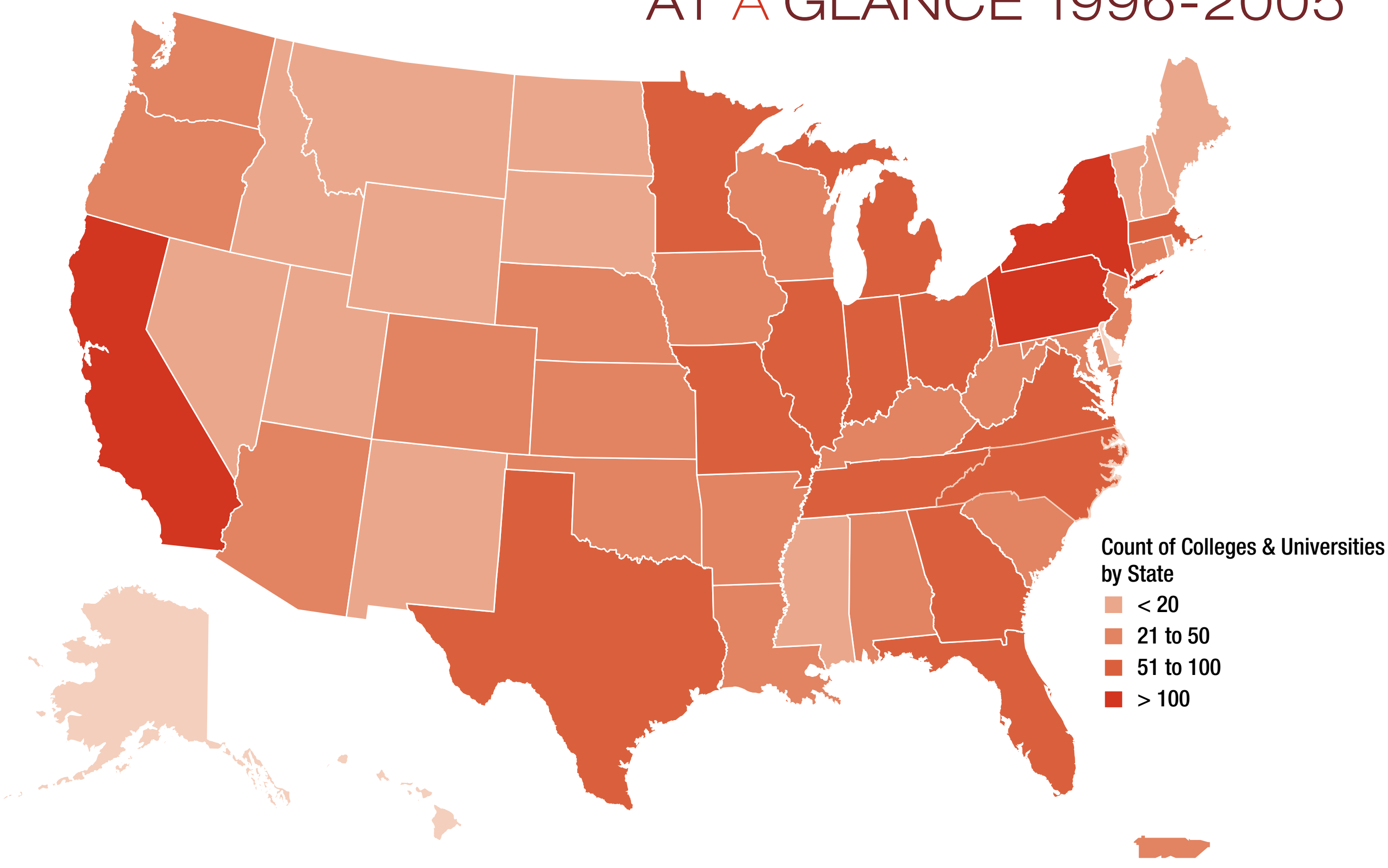
Additional Environmental Management Activities

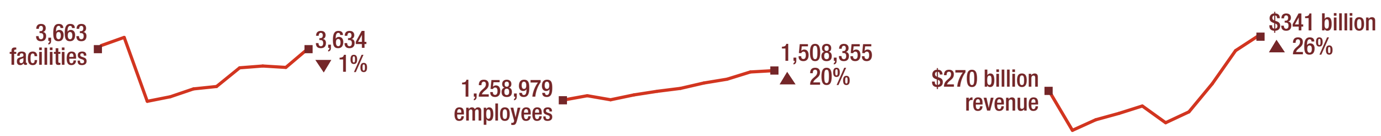
An environmental management system is a set of processes and practices that enable an organization to reduce its environmental impacts and increase its operating efficiency. SOCMA's ChemStewards program is an initiative to manage compliance with federal requirements and improve processes and efficiencies.[39] The three-tiered program allows SOCMA member companies to develop individual environment, health, safety, and security management systems. ChemStewards implementation guidance includes manuals, online assistance, regional meetings, and peer information exchange.

ACC's Responsible Care program offers a system for managing performance in environmental impact, health, safety, and security. All ACC member companies are required to have CEO-level commitments to Responsible Care. Program elements include publicly reporting performance, implementing the security code, applying a management system, and obtaining independent certification for the management system.[40]

COLLEGES & UNIVERSITIES

AT A GLANCE 1996-2005[1]





Latest Environmental Statistics[2]

Emissions of Criteria Air Pollutants: 73,000 tons

Hazardous Waste Generated: 26,000 tons

Hazardous Waste Managed: 24,000 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 Colleges & Universities sector includes schools granting degrees at baccalaureate or graduate levels such as major universities, military academies, business colleges, medical and law schools, music conservatories, and seminaries.

Facilities of the sector have a variety of environmental impacts across all environmental media. Campuses may, for example, operate power plants and wastewater treatment facilities, undertake construction projects, and maintain large areas of landscaping. Many consume large quantities of energy, generate tons of municipal waste and small quantities of hazardous wastes (primarily through laboratories), and manage stormwater runoff.

Energy Use

There are no aggregate national data on energy use at campuses in the United States. Campuses use energy in many types of facilities, including classroom buildings, residences, laboratories, performing arts venues, and sports facilities. Campus parking lots and walkways use electricity to provide lighting. Heating, ventilation, and air conditioning units consume energy from natural gas, liquid propane, and electricity. Activities related to grounds keeping, transportation, and security also consume fossil fuels and electricity.

Many schools are taking action to improve their energy efficiency. For example, more than 75 colleges and universities have pledged to purchase power from renewable energy sources such as solar, wind, geothermal, biomass, and hydroelectric as part of EPA's Green Power Partnership. Schools in the Partnership annually purchase more than 1 billion kilowatt hours of green power, which is enough to power nearly 100,000 average U.S. houses for a year.[3]

Air Emissions

Air emissions from the sector include criteria air pollutants (CAPs), greenhouse gases (GHGs), and others. The sector's air emissions originate primarily from fossil fuel combustion, but also from various sources such as construction, laboratory chemical reactions, and refrigeration systems. Indirect air emissions include emissions related to vehicle use and maintenance, campus transit systems, commuting, deliveries, and generation of purchased electricity. Sector-wide air emission information is not available, although some facilities are conducting emission inventories.

Saving Energy and Reducing Emissions with CHP

Kent State University in Ohio took energy efficiency a step further by generating its own power with a new combined heat and power (CHP) plant that also is a working lab. CHP, also called cogeneration, increases energy efficiency through onsite production of thermal energy and electricity from a single fuel source. The system's 13-megawatt, natural gas-fired turbines produce almost 90% of the university's electricity during the winter and 60% during the summer. The system also uses waste heat from the turbines to produce half of the university's steam. The overall system reduces direct carbon dioxide (CO_2) emissions by an estimated 13,000 tons per year, equivalent to the emissions from 2,100 cars. Kent State received a 2006 EPA ENERGY STAR CHP award for this effort.[4]

Criteria Air Pollutants

Most CAP emissions in the sector result from burning of fossil fuels. In 2002, sulfur dioxide (SO_2) accounted for the largest volume of CAP emissions, and was emitted by 95% of the facilities included in EPA's National Emissions Inventory.[5] Table 1 shows CAP and volatile organic compound (VOC) emissions from 442 facilities in the sector for 2002.

TABLE 1
Criteria Air Pollutant and VOC Emissions 2002

	Tons
SO_2	39,000
NO_X	20,000
PM_{10}	2,000
$PM_{2.5}$	1,000
CO	11,000
VOCs	1,000

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

Source: U.S. Environmental Protection Agency

Greenhouse Gases

Despite the lack of aggregate trend data on GHG emissions, there is a rapidly growing campus awareness of GHG impacts. A growing number of school officials are committing to take action. More than 480 presidents of higher education institutions have committed to the American College and University Presidents Climate Commitment (ACUPCC). ACUPCC's goal is for participating schools to develop plans to achieve climate neutrality, starting with campus-wide GHG emission inventories and institutional action plans. Tangible actions may include green building, use of ENERGY STAR-certified products, the purchase of power from renewable resources, and increased use of public transportation.

Energy Conservation and Sustainability

Arizona State University (ASU) began a program to reduce electricity, natural gas, and water use in 2000. Lighting and system upgrades reduced consumption by 53 million kilowatt-hours per year. From 2002 to 2006, ASU reduced its energy bill by 10%, saving $3.3 million annually. ASU received a 2007 ENERGY STAR CHP Award in recognition of a new natural gas CHP system that reduced fuel use by about 21% and CO_2 emissions by an estimated 16,000 tons per year. In March 2007 the ASU President pledged under ACUPCC, among other things, to develop an action plan within two years to become carbon neutral and to include sustainability in the curriculum. ASU recently set a goal of reducing its energy bill another 10%.[6]

Water Use and Discharges

Sector facilities use water in many ways, including academic and residential buildings, student centers, cafeterias, laboratory and sporting facilities, hospitals and clinics, and landscaping and agricultural operations. For most campuses, clean water comes from publicly owned facilities, and water discharges are sent to Publicly Owned Treatment Works. A mix of modern, efficient water systems and older, inefficient systems exists on campuses.

EPA effluent limitation guidelines vary according to campus makeup. For example, on-campus power plants may be regulated if power is distributed and sold, while effluents from educational research laboratories currently are not regulated.[7] Stormwater discharges may include fertilizers and pesticides from landscaping. Currently, the sector's stormwater discharges are not regulated, although there may be facility-specific requirements for certain industrial operations.[8]

An Educational Green Building

At Oberlin College in Ohio, the Adam Joseph Lewis Center for Environmental Studies is an acclaimed integrated building and landscape system for study and proactive energy and environmental management. The center uses water-saving sinks and toilets. Its "Living Machine" system combines conventional water treatment and the center's wetland ecosystem to remove organic wastes, nutrients, and pathogens, allowing 60% to 80% of the water used to be treated and re-used in toilets and on the center's landscape. Stormwater from the center's roof, sidewalk, and parking lot drains into a wetland (which cleanses it) and into a 9,700-gallon cistern. During drier periods, rainwater stored in the cistern is used to maintain the wetland.[9]

Waste Generation and Management

Although sector-wide information on the management of nonhazardous waste is not available, colleges and universities do generate, and can reduce or recycle, significant amounts of waste.[10]

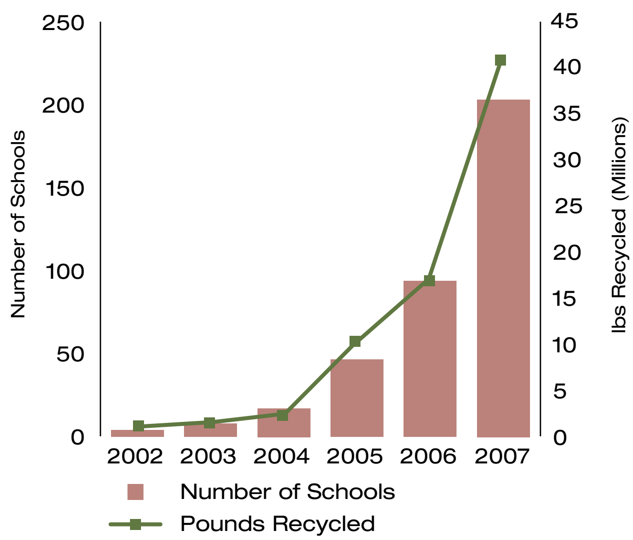
In 2007, more than 200 colleges and universities participated in RecycleMania, sponsored by the National Recycling Coalition in partnership with EPA's WasteWise program, to increase campus recycling.[11] The number of schools participating and the amount of recyclables collected over the 10-week competition has doubled each year since starting in 2001, as shown in Figure 1. The 2007 competition reported a total of 41.3 million pounds of materials recycled. The materials collected prevented the discharge of 15,583 million metric tons of CO_2 equivalent—equating to GHG emissions from approximately 12,367 passenger cars in one year.[12]

Expanding Recycling

Rutgers University in New Jersey was EPA's WasteWise 2007 College/University Partner of the Year.[13] Rutgers recycled 14,356 tons of materials in 2006, an 11% increase over the previous year. As one of many activities, the University installed new pulping and dewatering machines that remove up to 80% of the moisture from food waste; the resulting pulp is donated as livestock feed. In 2006 the machines helped Rutgers recover 3,422 tons of food waste and avoid $758,929 in landfill costs.[14]

FIGURE 1

RecycleMania Participation and Results



Source: U.S. Environmental Protection Agency

Hazardous Waste Management

Colleges and universities generate hazardous waste from a variety of activities, such as laboratories, operation of pollution control devices, or remediation of past contamination.

Some 335 facilities reported to EPA's *National Biennial RCRA Hazardous Waste Report* (BR) generating 26,000 tons of hazardous waste in 2005. Of this total, 64% was material from state-mandated or voluntary cleanups, and 21% was laboratory wastes. More than 66% of the reported hazardous waste for the sector was lead, and more than 6% was ignitable waste, laboratory packs, and mercury.[15] In the same year, the sector reported managing 24,000 tons of hazardous waste.

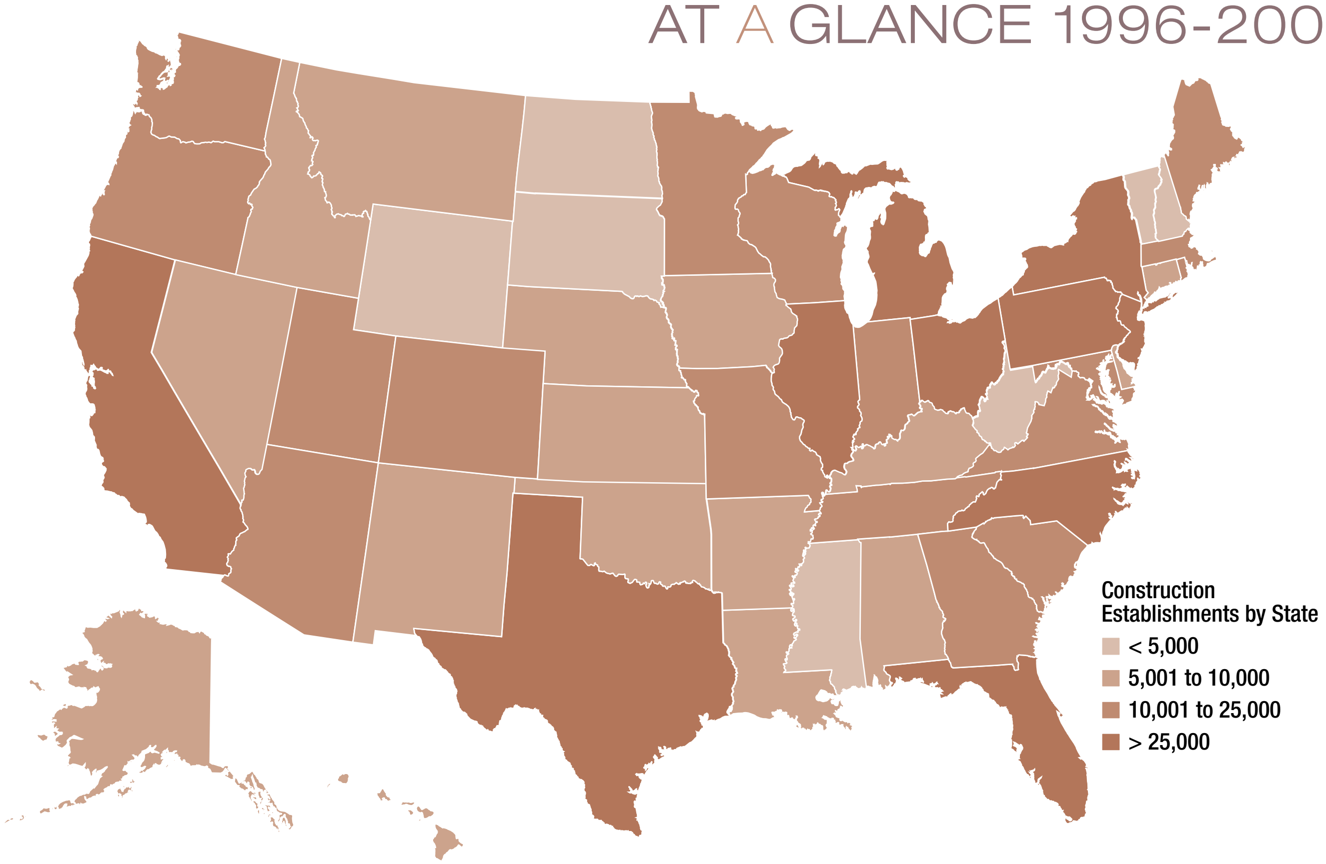
Additional Environmental Management Activities

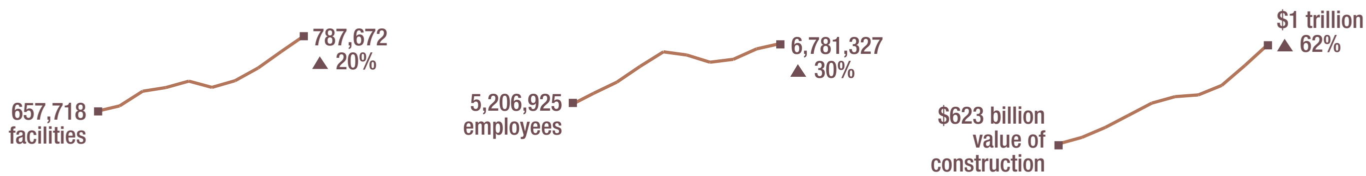
Although the sector lacks metrics for many parts of its environmental and energy footprint, a growing number of schools are developing sustainability programs and actively tracking their individual progress. The nonprofit Sustainable Endowments Institute is evaluating these efforts on the national level in its 2008 College Sustainability Report Card. The report evaluates campus and endowment sustainability activities at the 200 colleges and universities with the largest endowments in the United States and Canada. The Report Card provides information on best operational practices of leading schools in such categories as climate change and energy, food and recycling, green building, and transportation.

The 2008 Report Card shows a growing commitment to sustainability within the sector, with 68% of the evaluated schools showing an improved "grade" from a year ago. Fifty percent of the schools have adopted carbon reduction commitments, and 69% now have green building policies. Some 42% of the schools now have hybrid or electric vehicles in their fleets, and 37% now have full-time staff dedicated to sustainability.[16]

CONSTRUCTION

AT A GLANCE 1996-2005[1]





Latest Environmental Statistics[2]

Energy Use: 1.6 quadrillion Btu

Construction & Demolition Debris Generated: 331 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 Construction sector consists of establishments engaged in constructing, renovating, and demolishing buildings and other engineering structures.[3] The sector includes contractors in commercial, residential, highway, heavy industrial, and municipal utility construction. Specialized trades within the sector include work that is commonly subcontracted, such as plumbing, heating, masonry, and painting.

Although residential construction has slowed in recent years, spending on overall construction nearly doubled over the past decade. In 2006, the value of construction put in place totaled $1.1 trillion, or 9% of the U.S. gross domestic product. Spending on residential construction totaled $647 billion; nonresidential spending totaled $545 billion.[4]

More than 90% of construction companies have fewer than 20 employees.[5] Tracking the environmental performance of the Construction sector presents challenges because of the large number of construction companies and construction sites, the prevalence of small businesses, and the lack of data. Data that are commonly available for manufacturing sectors, such as chemical releases from EPA's Toxics Release Inventory (TRI), are either not applicable to or not available for the Construction sector.

To address the measurement challenge, in September 2007 EPA recommended measures of performance for the sector covering energy use, greenhouse gas (GHG) emissions, diesel air emissions, stormwater compliance, construction and demolition (C&D) debris management, and green building practices.[6]

These measures indicate several trends:

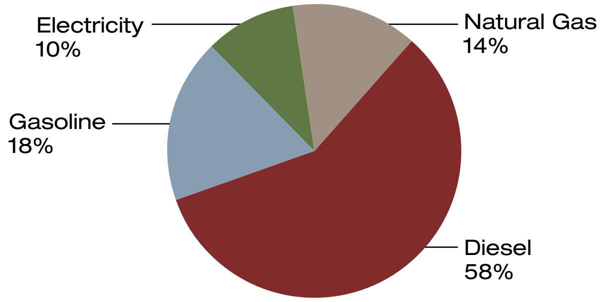
- Construction-related energy use is increasing faster than the growth in construction activity.
- Many construction companies have begun retrofitting older diesel equipment, reducing air pollution.
- More construction sites are complying with the requirement to obtain stormwater permits, although the percentage of construction sites in compliance is still unknown.
- The percentage of C&D materials recycled varies widely from state to state; materials are recycled more in highway construction than building construction.
- In addition to constructing more green buildings, many contractors are "greening" their own operating practices.

Energy Use

The Construction sector uses energy to operate equipment, to transport materials to and from construction sites, and to power facilities. Nonroad (also called "off-road") diesel engines used by construction companies, for example, include a wide variety of loaders, bulldozers, backhoes, excavators, graders, pavers, scrapers, and other specialized equipment.[7] Construction consumed an estimated 1.6 quadrillion Btu in 2002, which was a 28% increase from about 1.25 quadrillion Btu in 1997.[8] During the same

FIGURE 1

Fuel Use for Energy 2002



Source: U.S. Environmental Protection Agency

Reduced Idling Cuts Fuel Use, Costs, and Pollution

Grace Pacific Corporation, a highway contractor in Hawaii, has started a program to reduce unnecessary idling. The company first compiled an inventory of its fuel use, idling time, and air emissions. The inventory provides a baseline for tracking performance. Company officials believe they can cut overall fuel consumption by 10% on Oahu, saving approximately $80,000 in fuel costs and reducing emissions substantially.[9]

period, the value of construction, measured in constant dollars, grew 22%.[10]

The Construction sector could save energy under related efforts to reduce diesel emissions, increase recycling, and otherwise promote green construction. Specific opportunities include reducing idling, maintaining equipment optimally, using biodiesel, buying materials locally (reducing transportation fuel use), improving energy efficiency in company facilities, recycling C&D materials, using industrial byproducts in construction, and using coal fly ash and other supplementary cementious materials (SCM) in the manufacture of concrete. The Construction sector uses more than 100 million tons of cement annually. For every ton of coal fly ash and other SCMs used as an additive to Portland cement, there is an estimated energy savings of 5 million Btu.[11]

Air Emissions

Air emissions from the sector include criteria air pollutants (CAPs) and GHGs. CAPs and GHGs are generated as combustion byproducts from onsite energy production. The primary air pollutants associated with the sector are particulate matter (PM) and nitrogen oxides (NO_X), which are emitted during operation of diesel equipment. Diesel engines also emit sulfur oxides (SO_X), hazardous air pollutants, and GHGs. Some construction sites generate PM as fugitive dust. The Construction sector emits GHGs directly from combustion of fossil fuels.

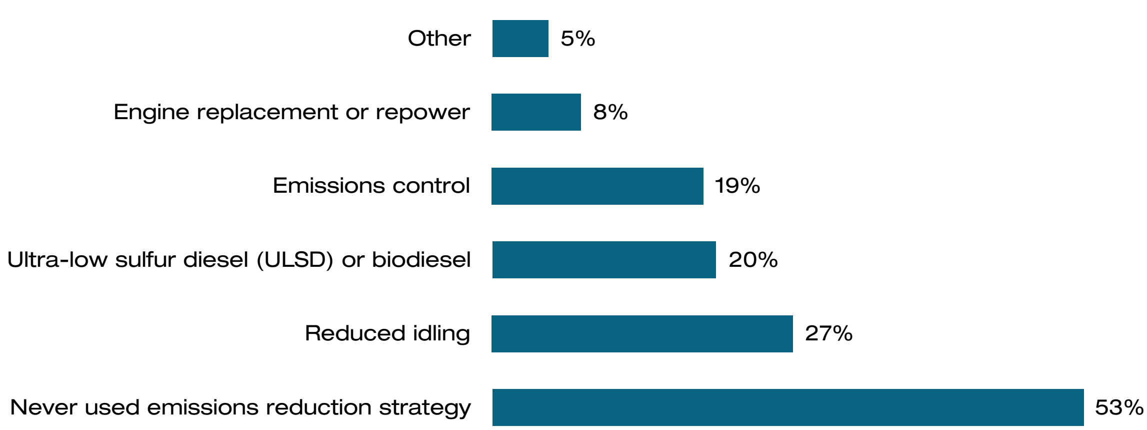
Criteria Air Pollutants

EPA has set standards for PM and NO_X emissions from new nonroad diesel engines. However, the standards will not apply to the approximately two million pieces of construction equipment already in use.

EPA's National Clean Diesel Campaign and various state programs are encouraging voluntary measures to reduce PM and NO_X emissions from existing diesel equipment. Measures include retrofitting with emissions control technologies and replacing or upgrading engines, as well as reducing idling and switching to cleaner fuels such as ultra-low sulfur diesel or biodiesel.

FIGURE 2

Diesel Emissions Reduction Strategies Used by Construction Firms - Industry Survey



Note:
Percentage is of survey respondents.

Source: Associated General Contractors of America

Baseline data indicate that 40 construction equipment retrofit projects eliminated 39,747 tons of NO_X emissions and 7,793 tons of $PM_{2.5}$ emissions from 2003 through 2006.[12]

In 2007, the Associated General Contractors of America (AGC) surveyed its members about clean diesel strategies.[13] As shown in Figure 2, almost half of the 234 companies that responded have employed techniques to reduce emissions. Of those, nearly half undertook those measures voluntarily rather than in response to regulatory or contractual requirements.

Greenhouse Gases

GHG emissions from the Construction sector result from fuel consumed by on- and off-road construction equipment. A preliminary estimate of CO_2 emissions in 2002 from the sector's energy consumption is 114.1 million metric tons of CO_2 equivalent.[14] The generation of electricity purchased to provide power for construction equipment and offices also emits GHGs.

Stormwater Discharges

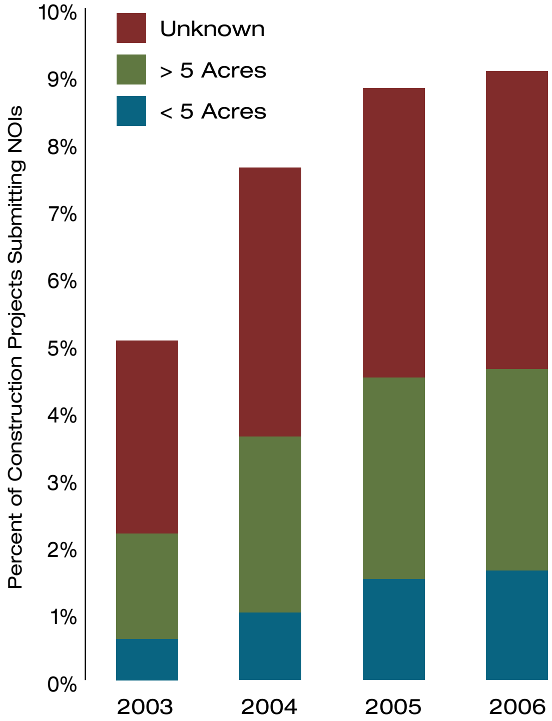
Stormwater runoff is one of the most significant environmental issues for the sector.[15] Runoff from construction sites may contain sediments, oil and grease, other pollutants, and trash. Paved or compacted ground increases the amount and rate of runoff because of reduced rainwater infiltration.

There are currently no EPA effluent limits for construction stormwater. Since the early 1990s, however, EPA has required permits for construction activities that disturb five or more acres and discharge stormwater to surface waters.[16] In 2003, EPA reduced the threshold for permit coverage to one acre. Covered contractors must develop a Stormwater Pollution Prevention Plan, submit an application for permit coverage—or "Notice of Intent" (NOI) form—and install "Best Management Practices" before disturbing the land.

Compliance with the requirement to obtain stormwater permits is improving. As shown in Figure 3, a nationally representative sample of state data reveals that the percentage of construction projects submitting an NOI increased by 63% from 2003 to 2006. The percentage of total construction projects in compliance, however, is unknown, because EPA has no national data on the number of projects that actually require an NOI.[17]

FIGURE 3

Trend in NOI Submissions Based on a Sample of States



Note:
Not all construction projects require an NOI, therefore, the percent of projects does not indicate percent in noncompliance.

Source: U.S. Environmental Protection Agency

Colorado Stormwater Excellence Program

An experiment in construction stormwater "self-policing" is generating impressive results in Colorado. Participating companies commit to certain standards for managing stormwater. State-approved inspectors hired by the companies train construction crews and inspect every site monthly. They report findings to the companies, offer guidance on fixing problems, and return to confirm correction. Companies gain confidence that they are achieving compliance. Nearly 800 inspections were conducted during a 2006 pilot project; average improvements for all sites ranged from 60% to 90%.[18]

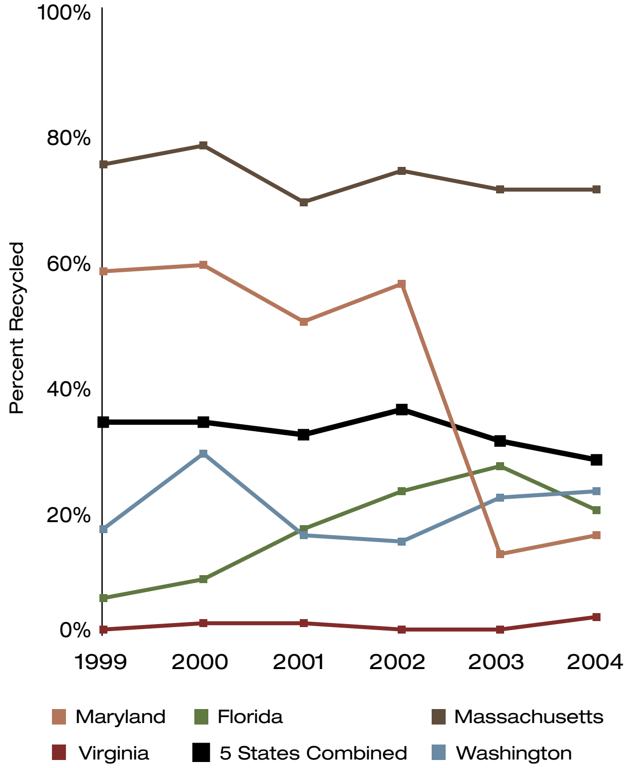
Waste Generation and Management

Constructing, renovating, and demolishing buildings, roads, bridges, and other structures generates large amounts of debris. Most of it is recoverable and some of it can be reused or recycled. Nevertheless, C&D materials such as concrete, asphalt, wood, drywall, and asphalt shingles are a large component of the waste in the nation's landfills.

EPA made a preliminary estimate that 164 million tons of building-related C&D debris were generated in 2003, up from an estimated 136 million tons in 1996.[19] Approximately 40% of this material was recycled, and the remainder disposed.[20] A preliminary estimate of road surface-related C&D debris generation was 167 million tons in 2003, of which 88% was recycled.[21] EPA is in the process

FIGURE 4

Trends in Construction and Demolition Material Recycling in Five States



Source: U.S. Environmental Protection Agency

TABLE 1

Uses of Recycled Construction and Demolition Materials

Recycled Construction and Demolition Materials	Recycling Markets
Concrete is crushed, reinforcement bar is removed, and material is screened for size.	Road base General fill Drainage media Pavement aggregate
Asphalt pavement is crushed and recycled into asphalt, either in-place or at a hot-mix asphalt plant.	Aggregate for new asphalt hot mixes Sub-base for paved road
After removal of nails, asphalt shingles are ground and recycled into hot-mix asphalt.	Asphalt binder and fine aggregate for hot mix asphalt
Clean, untreated wood can be re-milled, chipped, or ground.	Feedstock for engineered particle board Boiler fuel Recovered lumber re-milled into flooring Mulch and compost Animal bedding
Drywall is typically ground or broken up, and the paper removed.	Gypsum wallboard Cement manufacture Agriculture (land application)
Metal is melted down and reformed.	Metal products
Cardboard is ground and used in new pulp stock.	Paper products

Diverting Materials Through Reuse and Recycling

Turner Construction, one of the largest construction companies in the United States, joined EPA's Climate Leaders program in 2007. Turner has a policy to divert construction waste on all projects through reuse and recycling. Substituting reused and recycled materials for virgin materials reduces energy consumption and related GHG emissions. Turner set a goal to divert 50%, or 75,000 tons, of C&D materials in 2007. Over the previous two years, Turner's Construction Waste Management Program diverted more than 83,000 tons.[22]

of revising its methodology for counting C&D debris generation and recycling.

Recycling rates vary from state to state. A number of states periodically track C&D debris disposed and recycled, but few states regularly publish the data. Differences in the ways states count disposal and recycling limit the usefulness of comparisons among states. C&D debris recycling data for five states are shown in Figure 4 above.[23]

Asphalt pavement is heavily recycled. Construction contractors commonly crush and recycle old asphalt back into pavement. This produces large energy savings because of the energy-intensive process of creating new asphalt binder from oil. Estimates suggest that if all used concrete and asphalt pavement generated annually in the United States were recycled, it would save the energy equivalent of one billion gallons of gasoline, the equivalent of removing more than one million cars from the road.[24] When recycling markets and facilities are nearby, recycling can also reduce material hauling and disposal costs.[25] Table 1 illustrates various uses of recycled C&D materials.[26]

Hazardous Waste Management

Two hundred and twenty facilities reported 17,000 tons of hazardous waste generated to EPA's *National Biennial RCRA Hazardous Waste Report* (BR) in 2005.[27] About half of the hazardous waste reported was managed through treatment or destruction, while the other half was disposed. Lead was the predominant hazardous waste type reported (83%), likely due to the removal of old lead paint. With fewer than 0.1% of all construction establishments reporting, these results may not be representative of the sector.[28]

Additional Environmental Management Activities

Green Building Practices[29]

Several types of certification systems now are available to rate green buildings. Of them, the U.S. Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED) Green Building Rating System™ has the most data available.[30]

Construction contractors have influence on whether and how a building earns LEED credits; 22 out of the 69 possible credits have some relationship to construction activities.[31] For example, one prerequisite is a site plan to reduce air, water, and soil pollution from construction activities; projects receive points for practices such as material salvaging and recycling. Between 2000 and 2006, the LEED New Construction (NC) credits for which construction contractors often have responsibility grew rapidly, closely tracking the increase in all LEED-certified projects (new construction, existing buildings, and other categories), which went from 5 in 2002, to 960 in the first 8 months of 2007.[32]

Individuals can earn LEED Professional Accreditation through the USGBC. Of the 25,700 professionals who were LEED accredited by 2006, 610 identified themselves as general contractors.[34]

Energy-Saving Green Building

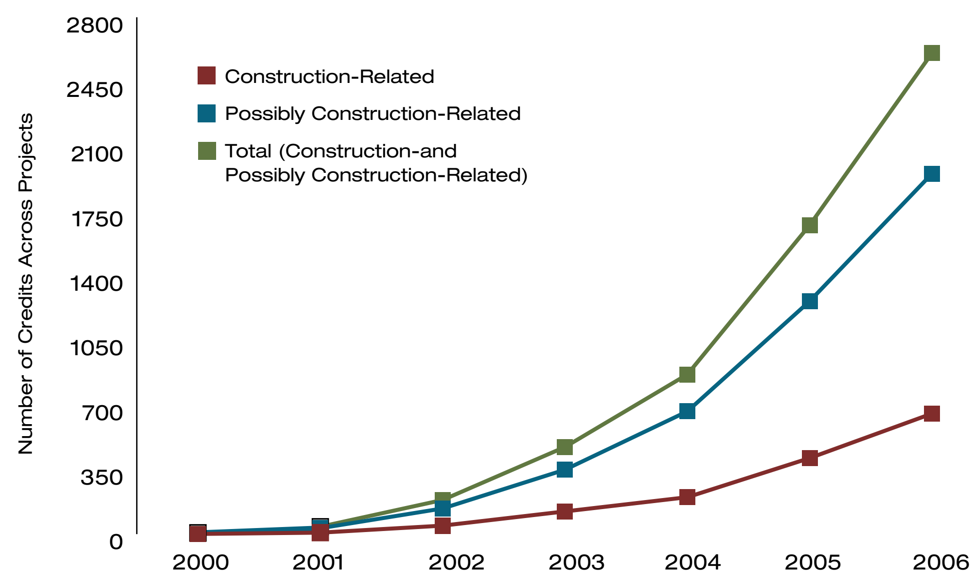
Oscar J. Boldt Construction's regional office in Stevens Point, WI, the company's first LEED project, was a notable success both in design and construction. For example, 79% of the C&D materials generated from construction were recycled, and materials used for construction were high in recycled content and in materials assembled, manufactured, and harvested locally. The building also incorporated numerous environmental improvements, such as energy-saving configurations and equipment that reduced energy use by 58%, resulting in energy costs amounting to only 4% of the building's total operating costs and annual savings of more than $31,000.[33]

Environmental Management Systems

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. Few construction companies operate with an EMS, but more are considering them. In 2004, AGC prepared EMS guidelines and offered training seminars for construction contractors. Since then, the use of EMS appears to be increasing. An AGC survey in 2005 revealed that 13 member companies were developing or operating with an EMS. In 2006, AGC reported the number had grown to 30.[35]

FIGURE 5

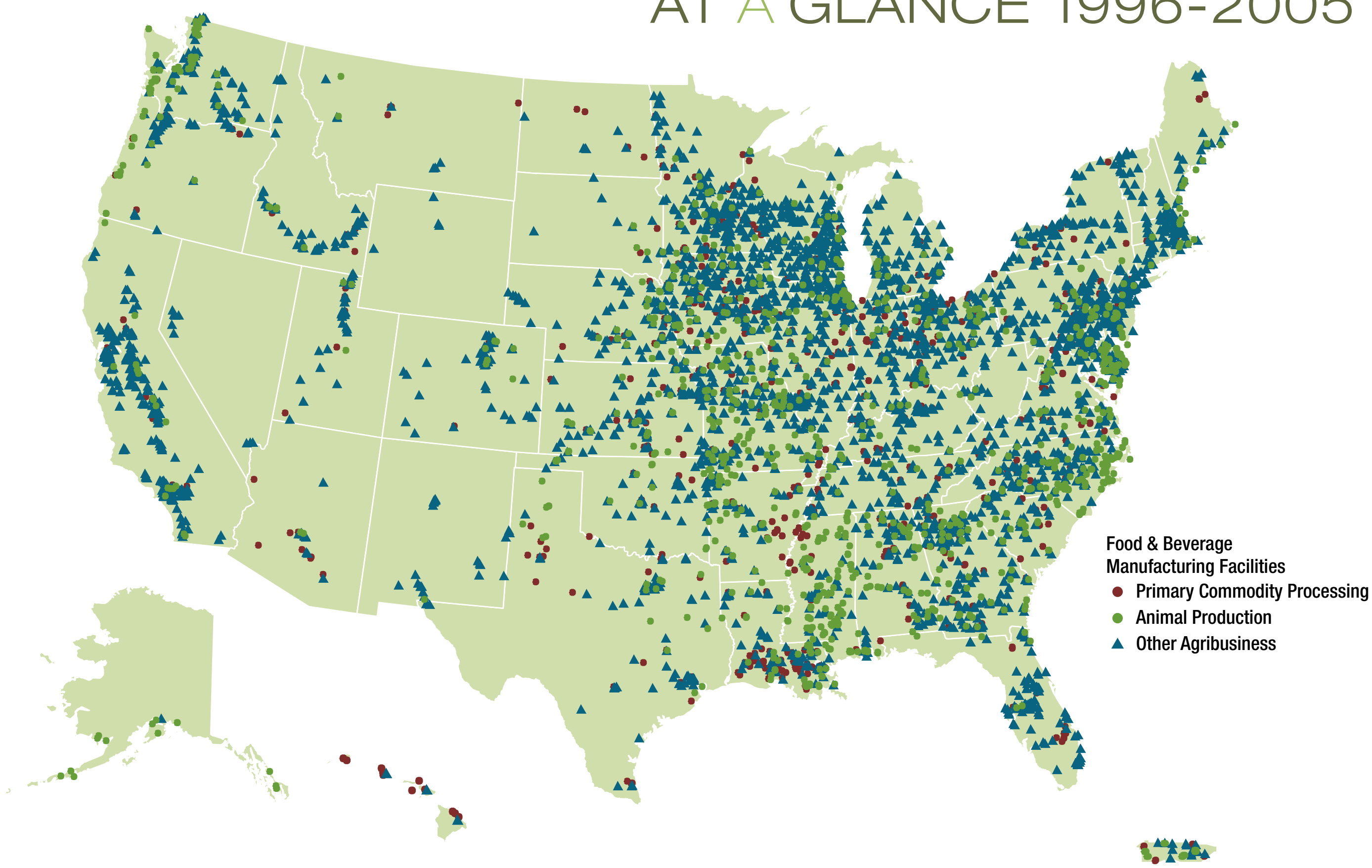
Total LEED-New Construction Credits Received by Construction Contractors

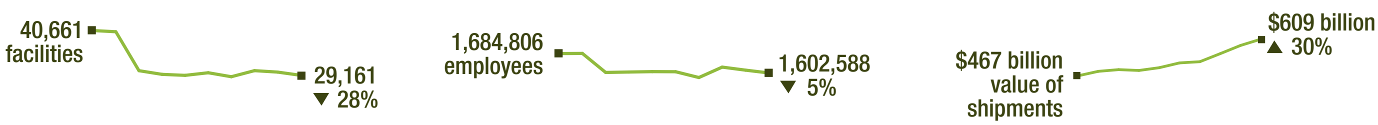


Source: U.S. Green Buildings Council

FOOD & BEVERAGE MANUFACTURING

AT A GLANCE 1996-2005[1]





Latest Environmental Statistics[2]

Energy Use: 1.2 quadrillion Btu

Emissions of Criteria Air Pollutants: 454,000 tons

Releases of Chemicals Reported to TRI: 164.7 million lbs.

Air Emissions: 50.4 million lbs.

Water Discharges: 94.3 million lbs.

Waste Disposals: 20 million lbs.

Recycling, Energy Recovery, or Treatment: 543 million lbs.

Hazardous Waste Generated: 3,100 tons

Hazardous Waste Managed: 2,400 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

Food & Beverage Manufacturing facilities use agricultural commodities as inputs for producing feedstuffs, food ingredients, or byproducts for industry or pharmaceutical applications. The sector contains three subsectors: primary commodity processing facilities, which perform the first stage of processing for all grains and oilseeds; animal production facilities, which process livestock for food, excluding the raising of livestock on farms; and other food production facilities.

In terms of value of shipments (VOS), the sector represents 13% of all U.S. manufacturing shipments.[3]

Energy Use

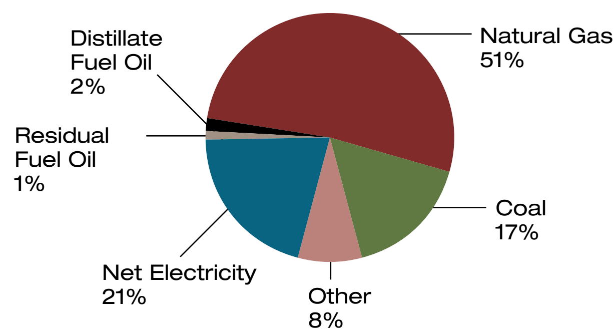
Figure 1 shows the fuels used for energy in the sector in 2002, totaling 1.2 quadrillion Btu. The percentage of energy derived from coal increased during the period covered by this report, coinciding with rising prices for natural gas.[4]

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 raw materials and fuels, and can also be generated in byproducts or end products.

FIGURE 1

Fuel Use for Energy 2002



Notes:
1. Net electricity is an estimation of purchased power and power generation onsite.
2. 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.

Source: U.S. Department of Energy

Innovative Animal Processing Alternative Energy Source

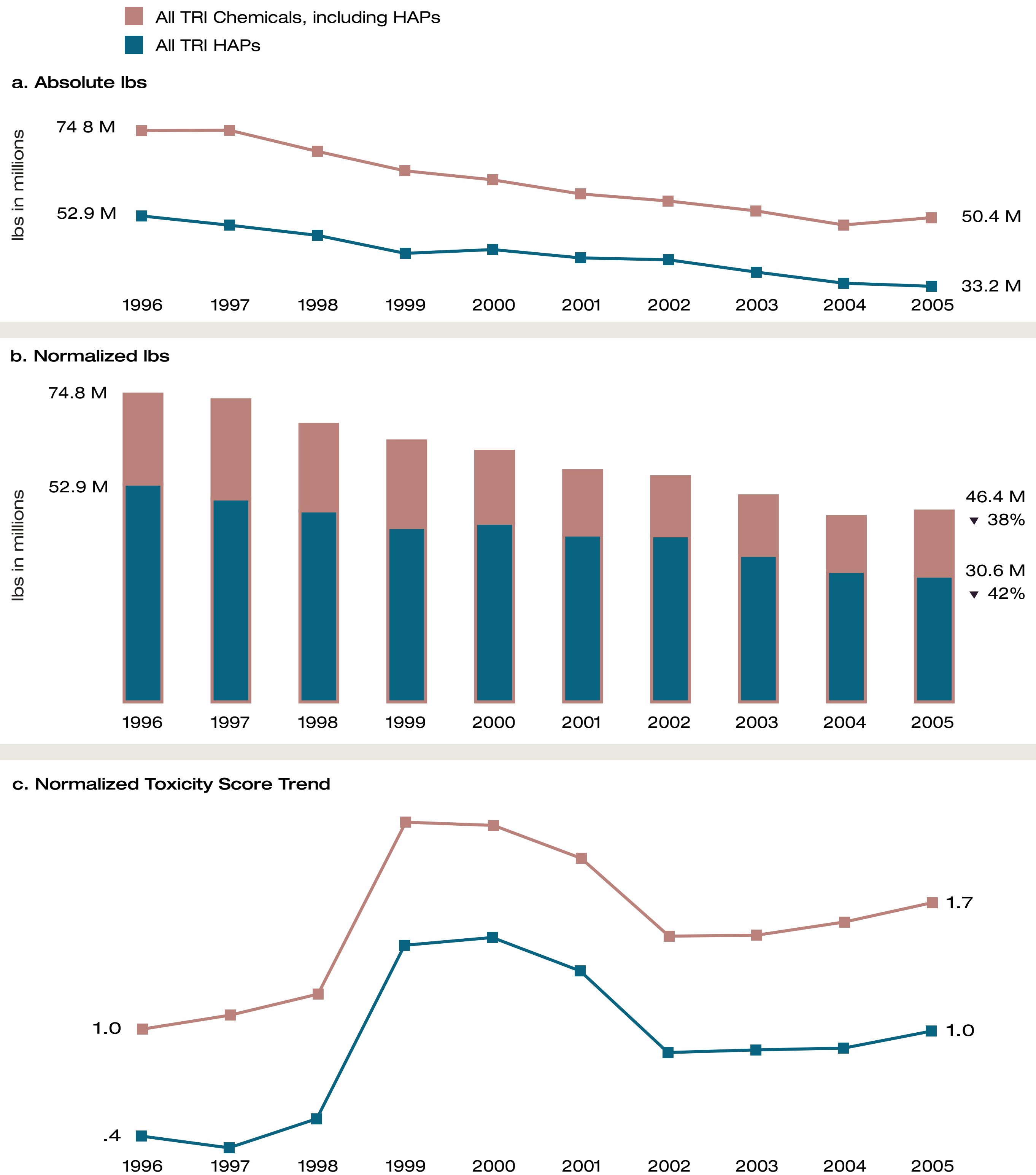
Most new beef and pork slaughter plants have covered anaerobic lagoons, particularly if they treat and discharge their own wastewater. As of 2006, 10 of these 25 beef and pork first processing plants that directly discharge wastewater are capturing methane (CH_4) from covered lagoons to use as fuel, which typically reduces a packing plant's need for natural gas by about 15%.[5]

Air Emissions Reported to TRI

In 2005, 1,195 facilities in the sector reported 50.4 million absolute lbs. of air emissions to TRI. 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 66% of these emissions. Between 1996 and 2005, absolute TRI-reported air emissions declined 33%, as shown in Figure 2a. As shown in Figure 2b, when normalized by the value of shipments, air emissions decreased 38%, largely due to sector-wide reductions of two chemicals, n-hexane and ammonia. Primary commodity processing facilities accounted for 65% of these emissions, and animal production facilities accounted for 14% of the emissions.[6]

FIGURE 2

Air Emissions Reported to TRI 1996–2005

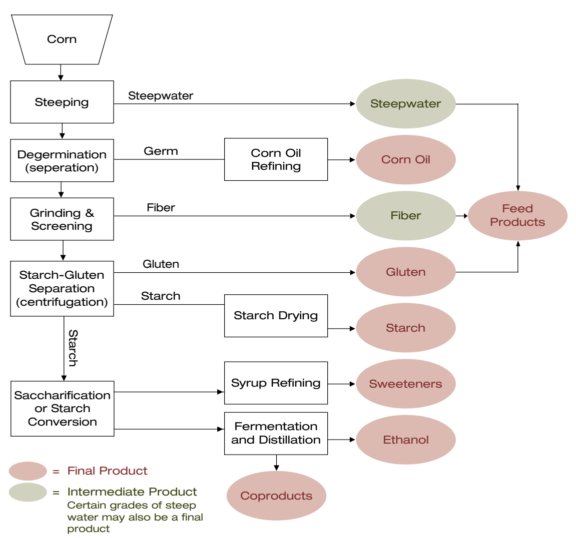


Note:
Normalized by annual value of shipments.

Sources: U.S. Environmental Protection Agency, U.S. Department of Commerce

Improving Corn Refining Energy Efficiency

Corn refining is an energy-intensive industry that processes corn into sweeteners, starches, oils, feed, and ethanol. The variety of products obtained from corn is illustrated below. Since 2003, EPA's ENERGY STAR® program has worked with member companies of the Corn Refiners Association to implement best energy management practices and develop a sophisticated energy performance benchmarking tool. Using this comparative metric, companies can set goals for improved energy efficiency. EPA recognizes plants in the top quartile of energy performance with the ENERGY STAR label. Three plants earned ENERGY STAR awards in 2006, saving an estimated 2.3 trillion Btu of energy and avoiding carbon dioxide (CO_2) emissions of 0.15 million metric tons annually.[7]



Source: U.S. Environmental Protection Agency

N-hexane and ammonia are used as solvents to extract specific properties of grains and oilseeds for use in food processing and industrial applications, such as in the production of corn oil and soybean oil. The industry increased its efficiency in using these two chemicals and has increased the percentage of chemicals that are recycled.

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 Toxicity Score increased by 70% from 1996 to 2005 when normalized by the sector's annual VOS. The increased Toxicity Score from 1999 to 2002 was due to air emissions of three chemicals: acrolein, polycyclic aromatic compounds (PAC), and chlorine.[8]

Acrolein is produced when fats and oils are heated to a high temperature either during oilseed processing or during food cooking in oil. PAC includes a variety of compounds formed during the preservation and processing of food. Chlorine is used in various applications involving food safety and sanitation.

Several factors caused the three-year bubble apparent in Figure 2c. A facility in the Primary Commodity Processing subsector started reporting large releases of acrolein in 2000, and two other subsectors started reporting releases in 2001. Also in 2000, EPA lowered the reporting threshold for PAC to 100 pounds, resulting in an additional 61 facilities reporting releases of these chemicals. Finally, a facility reported a large release of chlorine in 1999. The combination of these factors contributed to the four-year "bubble" in the sector's Toxicity Score shown in Figure 2c.

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

TABLE 1
Top TRI Air Emissions 2005

Chemical	Absolute Pounds Reported[1]	Percentage of Toxicity Score	Number of Facilities Reporting[2]
Acetaldehyde[3]	2,048,000	5%[4]	24
Acrolein	24,000	25%	2
Ammonia	11,956,000	2%	408
Hydrochloric Acid	4,224,000	4%	34
Lead	17,000	2%	68
Methanol	3,002,000	<1%	38
N-Hexane	22,027,000	1%	86
Nitrate Compounds	2,637,000	<1%	14
Polycyclic Aromatic Compounds	59,000	10%	48
Sulfuric Acid	1,774,000	37%	22
Zinc	15,000	<1%	43
Percentage of Sector Total	95%[5]	86%[6]	51%[7]

Notes:
1. Total sector air emissions: 50.4 million lbs.
2. 1,195 total TRI reporters in the sector.
3. *Italics* indicate a hazardous air pollutant under section 112 of Clean Air Act.
4. Red indicates that the chemical is one of the top five chemicals reported in the given category.
5. Chemicals in this list represent 95% of the sector's air emissions.
6. Chemicals in this list represent 86% of the sector's Toxicity Score.
7. 51% of facilities reported emitting one or more chemicals in this list.

Source: U.S. Environmental Protection Agency

associations, or government agencies might use in considering sector-based environmental management strategies.

1) Absolute Pounds Reported. N-hexane and ammonia were the highest-ranking chemicals based on the pounds of each chemical emitted to air in 2005.
2) Percentage of Toxicity Score. The top chemicals based on Toxicity Score included sulfuric acid and acrolein.
3) Number of Facilities Reporting. Ammonia was the chemical reported by the greatest number of facilities, with one-third of the almost 1,200 TRI filers in the sector reporting ammonia air emissions.

Criteria Air Pollutants

Table 2 shows CAP and volatile organic compound (VOC) emissions in 2002, representing emissions from almost 2,500 facilities.[9]

Sixty-three percent of the reported CAP emissions are the result of onsite energy production at Food & Beverage Manufacturing facilities. Process heating and cooling systems account for more than 75% of the sector's energy use and are necessary to meet food safety regulations. About 12% of energy used in this sector supports general facility functions, such as heat, ventilation, and lighting. Energy-intensive processes are required for sugar, malt beverage, corn milling, and meat and poultry processing.[10]

TABLE 2

Criteria Air Pollutant and VOC Emissions 2002

	Tons
SO_2	116,000
NO_X	76,000
PM_{10}	50,000
$PM_{2.5}$	30,000
CO	112,000
VOCs	100,000

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

Source: U.S. Environmental Protection Agency

Greenhouse Gases

Food & Beverage Manufacturing facilities emit GHGs directly from fossil fuel combustion and from non-combustion processes. Non-combustion activities include CH_4 emissions from onsite wastewater treatment at meat, poultry, fruit, and vegetable processing facilities. The generation of electricity purchased by food and beverage manufacturers also emits GHGs.

Reducing Emissions From Food Manufacturing

Frito-Lay, a Climate Leaders member, reported the company's GHG emissions for 2002 and subsequent years. The company set a goal—it reports being on track to achieve that goal—to reduce emissions by 14% per pound of production from 2002 to 2010. The company has focused on improving energy efficiency through, for example, implementing heat recovery projects for boiler stack gases, ovens, and fryers.[11]

Ten Food & Beverage Manufacturing facilities are members of EPA's Climate Leaders program, an industry-government partnership that works with companies to develop long-term, comprehensive climate change strategies.[12] These facilities set GHG reduction goals to be achieved over 5–10 years in either absolute pounds or GHG intensity per production unit.

Water Use and Discharges

Water is integral to food and beverage production processes as an ingredient in products, such as beverages; as a mixing and seeping medium in food processing; and as a medium for cleaning and sanitizing operations. Water conservation is an option for food and beverage production; however, special consideration often is needed to ensure product safety. Water sources include onsite wells, surface water with pre-treatment, and municipal drinking water systems. Table 3 provides water intensity estimates for selected products.

TABLE 3

Estimated Water Intensity of Selected Products

Product	Gallons per Ton of Product
Beer	2,400 to 3,840
Bread	480 to 960
Meat Packing	3,600 to 4,800
Milk Products	2,400 to 4,800
Whiskey	14,000 to 19,200

Source: Metcalf and Eddy

Every facility discharging process wastewater directly to waterways must apply for a National Pollutant Discharge Elimination System (NPDES) permit. The permits typically set numeric limits on specific pollutants and include monitoring and reporting requirements. Regulated

Water Stewardship

- The Farmland Foods subsidiary of Smithfield Foods won the 2006 Illinois Governor's Pollution Prevention Award for water conservation at its facility in Monmouth, IL. The plant retrofitted its water cooling system with closed-loop technology using ethylene glycol, saving an estimated 22 million gallons of water annually.[13]
- Coca-Cola's water stewardship program includes water efficiency targets, a goal to return process water to the environment at a level that supports aquatic life by 2010, and support of watershed protection and community water programs. Coca-Cola reported a 3% improvement in water efficiency in 2006 compared to 2005, and a 19% improvement in efficiency and 6% decrease in total water used since 2002.[14]
- Nestlé Purina's wet pet food facility in Jefferson, WI, improved its water management and processes, lowering water use for cooling and steam production. The changes save more than 20 million gallons of water annually, reducing water use per ton of product by 7%. The facility also reduced its annual use of natural gas by 20 trillion Btu, with corresponding emissions reductions.[15]

pollutants and the associated limits vary depending on the type of manufacturing process (such as grain mill, fats and oils, or meat products manufacturing), but most frequently include total suspended solids, pH, biological oxygen demand, ammonia, and total nitrogen.[16]

Two-hundred thirty Food & Beverage Manufacturing facilities reported water discharges of TRI chemicals in 2005, totaling 94.3 million lbs.[17] Nitrate compounds dominated water discharges, accounting for more than 99% of the lbs. discharged. Although reported total nitrate compound discharges increased more than 100% from 1996 through 2005, the number of reporting facilities also more than doubled (43 to 91), indicating that more facilities met the TRI reporting thresholds. Seventy-two percent of these discharges were from animal production facilities, while primary commodity processing facilities accounted for 14%.[18]

EPA promulgated effluent guidelines for meat and poultry producers in 2004, setting technology-based limits on a number of pollutants, including ammonia and nitrogen. As states and EPA regions incorporate these regulations into NPDES permits, operators will be required to upgrade onsite water treatment to comply with the more stringent effluent limits.

In addition to being regulated for direct discharges and for discharges to Publicly Owned Treatment Works, facilities with materials exposed to precipitation are regulated for stormwater runoff, usually under a general permit providing sector-specific limits. Depending on the type of facility, stormwater requirements for Food & Beverage Manufacturing facilities may include effluent limits on total suspended solids, biochemical or chemical oxygen demand, and nitrate/nitrite nitrogen.[19]

Waste Generation and Management

Wastes generated by the sector vary greatly by facility and process. Production of commodities such as grains, dairy, fruits and vegetables, and food processing have different material and waste management issues, such as pesticide residue, vegetable trim, and used packaging.

Hazardous Waste Management

In 2005, 82 Food & Beverage Manufacturing facilities reported to EPA's *National Biennial RCRA Hazardous Waste Report* (BR) generating 3,100 tons of hazardous waste. At 44% and 42% of the total, respectively, intermittent events (such as discarding off-spec products) and primary production processes were the largest sources of hazardous waste. Facilities reported managing 2,400 tons of hazardous waste, with 50% managed through destruction or treatment and 41% managed through reclamation and recovery.[20]

Waste Management Reported to TRI

In 2005, 1,195 Food & Beverage Manufacturing facilities reported managing 707.8 million absolute lbs. of TRI chemicals in waste. When normalized by value of shipments, this quantity represented 54% more than 1996 quantities, indicating that more waste was generated per dollar of product sold.

Figure 3 shows how the sector managed this TRI waste. In 2005, 39% was recycled, 37% was treated, 23% was

disposed or released to air or water, and less than 1% was recovered for energy use. The pounds managed under each management activity increased over the time period presented. The greatest increase was in recycling, although the annual quantities reported as recycled fluctuated dramatically between 110,000 lbs. and 850,000 lbs.[21]

Of the TRI waste managed in 2005, 52% was reported by primary commodity processing facilities, while animal production facilities accounted for 28%. Over the decade, waste managed by these subsectors increased by 84% and 87%, respectively.[22]

The quantity of waste that Food & Beverage Manufacturing facilities disposed to land, as reported to TRI, increased from 9.1 million lbs. in 1996 to 20 million lbs. in 2005. When normalized by the value of annual shipments, this represented a 102% increase. As shown in Table 4, nitrate compounds remained the chemicals disposed in the greatest quantity over the 10-year period, accounting for about two-thirds of disposals, and were one of the chemicals most frequently reported as disposed for this sector. Ammonia was also one of the chemicals disposed in the greatest quantity and was the second most frequently reported chemical disposed for this sector.[23]

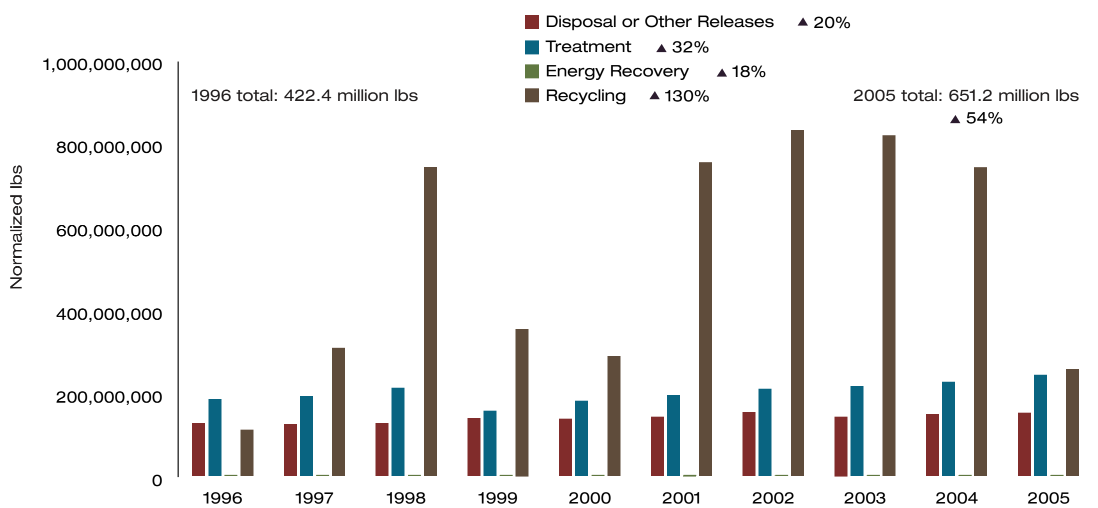
Additional Environmental Management Activities

Supply Chain Sustainability

Sector manufacturers are increasingly working with their suppliers to improve the environmental sustainability of agricultural production. Traditionally, their efforts have focused on reducing pesticide use through Integrated Pest Management. Projects now include improving water quality as well and reducing soil erosion.

FIGURE 3

TRI Waste Management 1996–2005



Notes:
1. Normalized by annual value of shipments.
2. Disposal or other releases include air emissions, water discharges, and land disposals.
3. The fluctuation in recycling was due to the reports filed by a single facility.

Sources: U.S. Environmental Protection Agency, U.S. Department of Commerce

TABLE 4

Top TRI Disposals 2005

Chemical	Absolute Pounds Reported[1]	Number of Facilities Reporting[2]
Ammonia	1,350,000[3]	136
Barium	1,697,000	16
Lead	92,000	37
Manganese	519,000	19
Nitrate Compounds	13,869,000	154
Nitric acid	369,000	29
Zinc	690,000	36
Percentage of Sector Total	93%[4]	26%[5]

Notes:
1. Total sector disposals: 20 million lbs.
2. 1,195 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 93% of the sector's disposals.
5. 26% of facilities reported disposals of one or more chemicals in this list.

Source: U.S. Environmental Protection Agency

Environmental Conservation

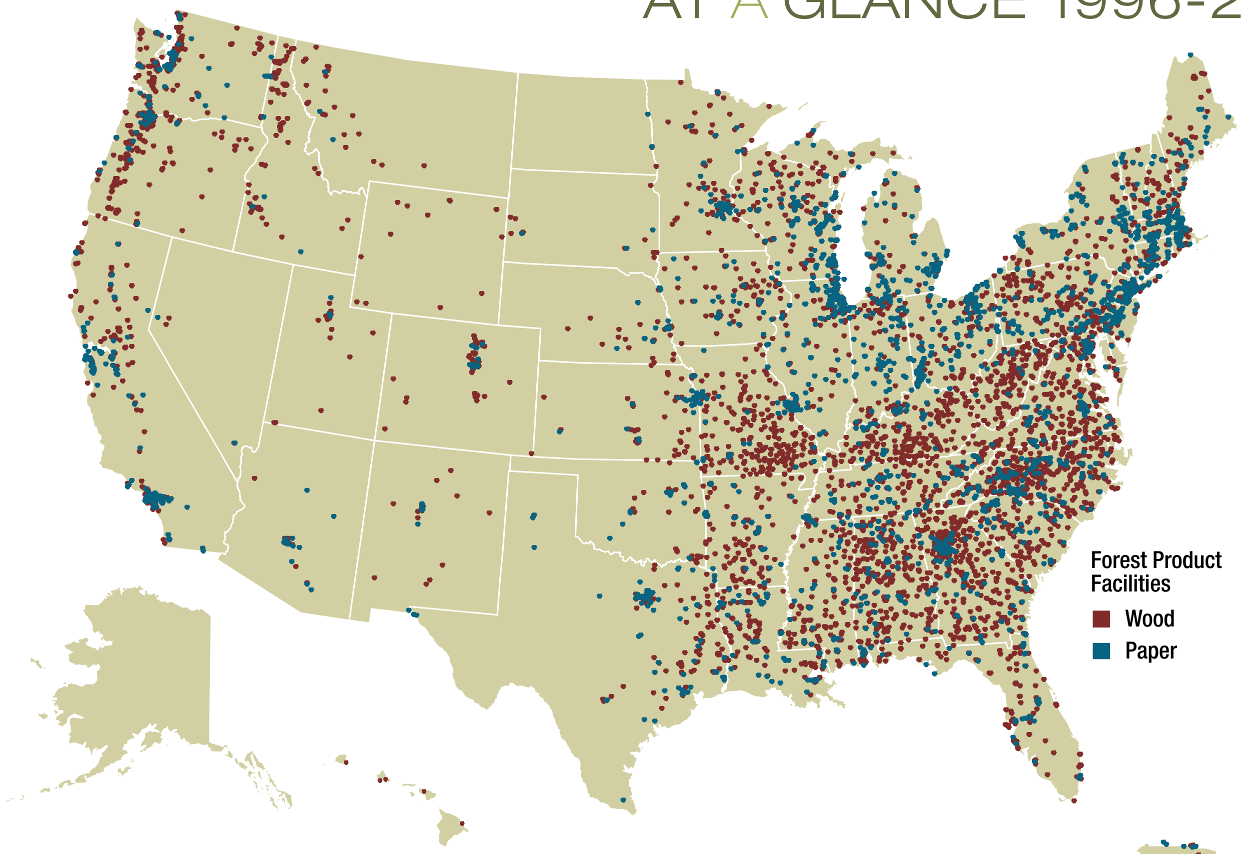
In 1998, Unilever developed its good agricultural practice guidelines for palm oil, tea, tomatoes, peas, and spinach, and promoted them to food growers to track progress with 11 sustainable agriculture indicators, such as water, energy, pesticides, and biodiversity. In 2007, the company established guidelines for tea growers and committed to purchase all of its tea from sources meeting those standards.[24]

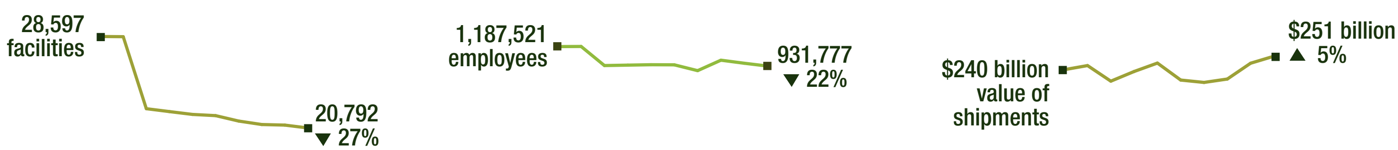
Crop Chemicals Reductions

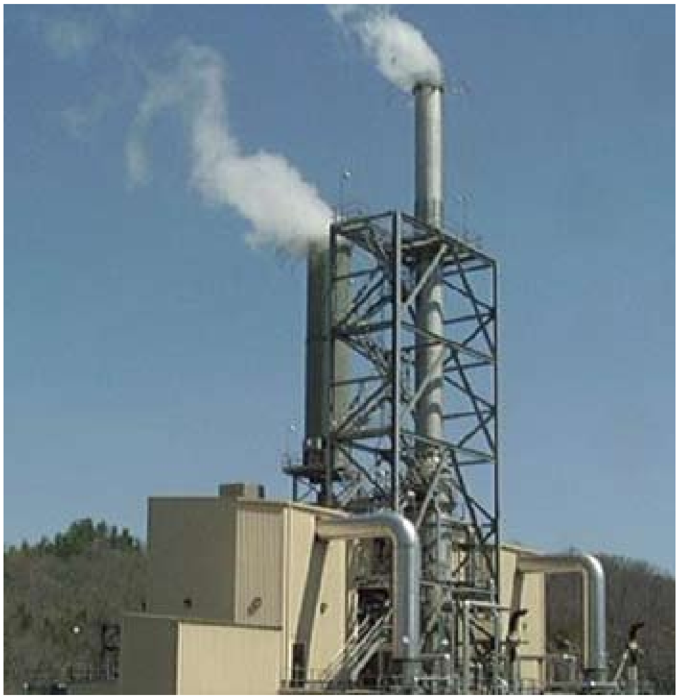
Since 2004, SYSCO has worked with fruit and vegetable suppliers to reduce the use of farm chemicals and fertilizers through pest management techniques and best management practices for fertilizer application. Suppliers report using 100,000 fewer pounds of pesticides and 2.2 million fewer pounds of fertilizers, while improving produce quality and better protecting water quality.[25]

FOREST PRODUCTS

AT A GLANCE 1996-2005[1]







Latest Environmental Statistics[2]

Energy Use: 2.7 quadrillion Btu

Emissions of Criteria Air Pollutants: 1.5 million tons

Releases of Chemicals Reported to TRI: 255.7 million lbs.

Air Emissions: 206 million lbs.

Water Discharges: 20.5 million lbs.

Waste Disposals: 29 million lbs.

Recycling, Energy Recovery, or Treatment: 1.4 billion lbs.

Hazardous Waste Generated: 136,000 tons

Hazardous Waste Managed: 396,000 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 Forest Products sector includes firms that manufacture wood pulp, paper, paperboard, and wood products such as lumber.[3]

- Some facilities of the pulp and paper industry process raw wood fiber or recycled fiber to make pulp and/or paper. Other facilities use these primary materials to manufacture specialized products such as paperboard boxes, writing paper, and sanitary paper.
- Companies in the lumber and wood products industry cut timber and pulpwood, mill raw materials into lumber and building materials, and manufacture finished articles such as wood panels.

Forest Products is the third-largest manufacturing sector in consumption of fossil fuel energy and is a major user of water.[4]

Although the sector is energy intensive, it has a high level of cogeneration and use of biomass to produce energy.

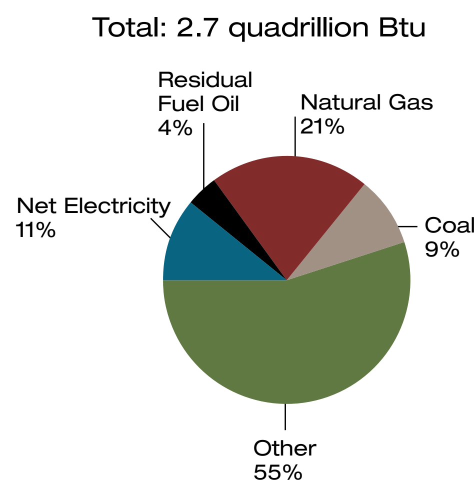
The sector accounts for nearly 6% of the total value of shipments (VOS) in U.S. manufacturing.[5]

Energy Use

Making paper is energy and water intensive. A significant amount of energy is needed, for example, to remove water from the dilute fiber slurry that is the beginning stage of making paper from pulp. The recovery furnaces that regenerate the chemicals that cook wood chips to produce pulp also require large quantities of energy. The pulp and paper portion of the sector is especially energy intensive. In

FIGURE 1

Fuel Use for Energy 2002



Notes:
1. Other is primarily generation from renewables and net steam (the sum of purchases, generation from renewables, and net transfers).
2. Net electricity is an estimation of purchased power and power generation onsite.

Source: U.S. Department of Energy

2002 the manufacture of wood products counted for 375 trillion Btu, or about 14% of the sector's energy use; 2,361 trillion Btu, or 86%, was attributable to pulp and paper mills.[6]

Renewable fuels account for the majority of energy use at Forest Products facilities, which represent 93% of all U.S. manufacturing in use of wood byproduct fuels, such as bark, wood waste, and spent pulping liquor.[7] Bark and wood waste are burned in power boilers to produce electricity and steam for a facility. Pulp manufacturing facilities burn spent pulping liquor, a solution of wood lignin (an organic polymer) from process chemicals, in recovery boilers to produce steam and regenerate the process chemicals. Figure 1 shows fuel used for energy in 2002 in the sector.

The American Forest & Paper Association (AF&PA) and U.S. Department of Energy (DOE) formed the Agenda 2020 Technology Alliance in 1994 to cut energy use and emissions through innovations in technology, manufacturing processes, and market development. The Alliance, now independent of DOE, partners with governments and local and international organizations; shares information on new advances such as biorefineries that produce fuels from wood; and partners on efforts including research and development into renewable, bio-based products such as fibers, fuels, and chemicals.[8]

Many facilities have achieved long-term reductions in energy intensity through process efficiencies and cogeneration.[9] Cogeneration, or combined heat and power (CHP), increases energy efficiency through onsite production of thermal energy and electricity from a single fuel source. Pulp and paper facilities are leaders in using cogenerated energy. About 89% of the electricity generated at paper mills was cogenerated in 2002. Typically, 99% of the electricity generated at wood products facilities is cogenerated.[10] The sector overall produced 37% of all cogenerated energy in manufacturing in 2002, second only to the Chemical Manufacturing sector. Forest Products facilities have opportunities for short-term fuel switching, although fuels with fewer emissions or greater efficiency can be more costly.[11]

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). Fuel combustion and manufacturing contribute to air emissions from this sector. In general, the "toxic chemicals" tracked by TRI are found in the raw materials and fuels used in the manufacturing process, and can be generated in byproducts or end products. Toxic chemicals from this sector may be generated and emitted to the environment during wood processing, chemical recovery, and papermaking operations in pulp and paper mills and during drying and pressing operations in wood products plants. CAPs and GHGs also are generated as combustion byproducts from onsite energy production and from some production processes and other activities.

Air Emissions Reported to TRI

In 2005, 1,144 facilities in the sector reported to TRI 206 million absolute lbs. of air emissions. Between 1996 and 2005, absolute TRI-reported air emissions declined by 24%, as shown in Figure 2a. When normalized by the sector's VOS over the period, air emissions decreased 12%, as seen in Figure 2b.[12] While these 1,144 facilities only accounted for about 5% of Forest Products facilities, this number includes virtually all pulp and paper mills, as well as the larger and more chemically intensive wood products manufacturing facilities.

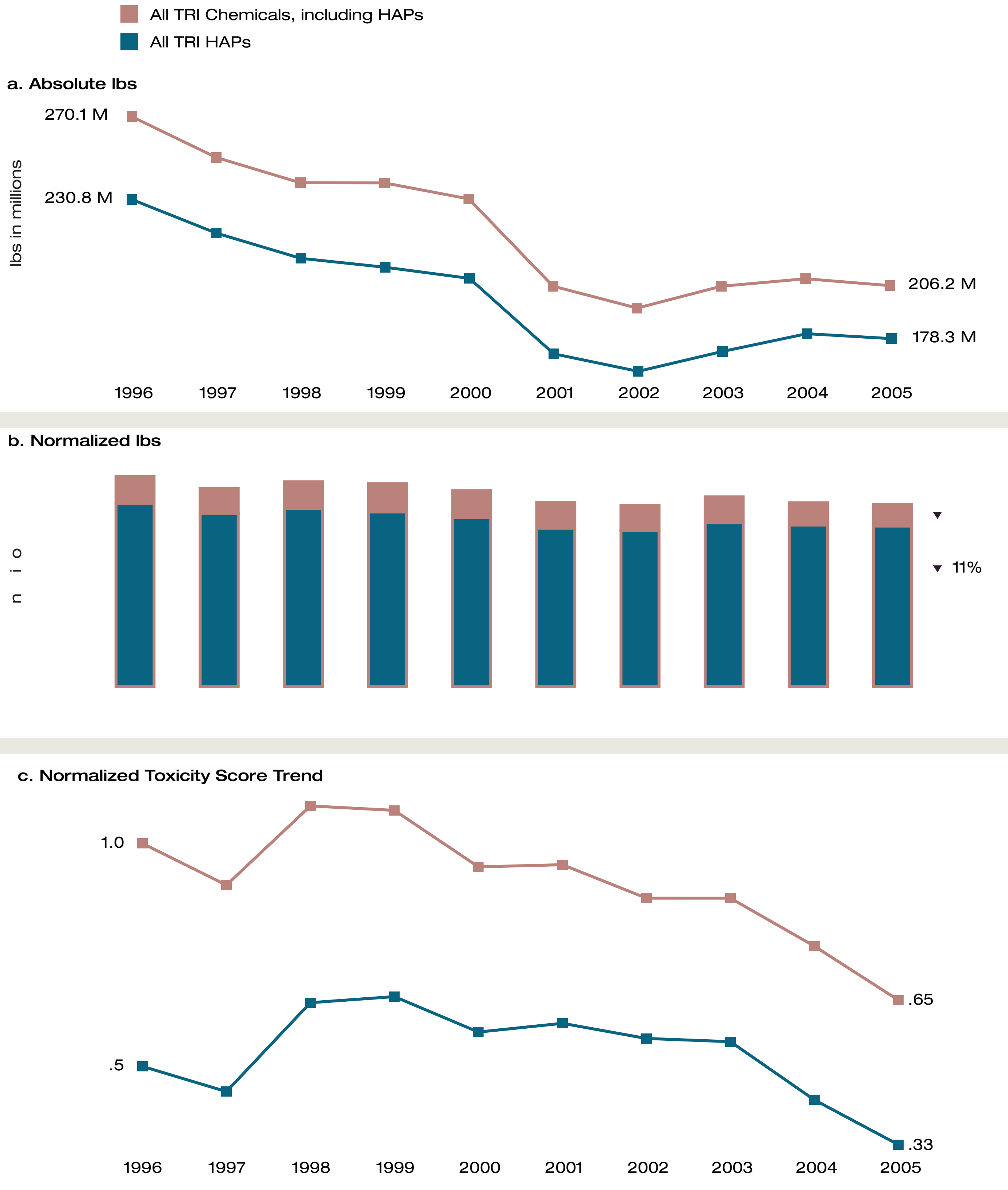
To consider toxicity of air emissions, EPA's Risk-Screening Environmental Indicators (RSEI) model assigns every TRI chemical a relative toxicity weight, then multiplies the pounds of media-specific releases (e.g., pounds of mercury released to air) by a chemical-specific toxicity weight to calculate 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 TRI list of toxic chemicals includes all but six of the hazardous air pollutants (HAPs) regulated under the Clean Air Act. Regulations regarding combustion byproducts, issued in 1997, required pulp and paper mills to add

FIGURE 2

Air Emissions Reported to TRI 1996–2005



Note:
Normalized by annual value of shipments.

Sources: U.S. Environmental Protection Agency, U.S. Department of Commerce

emission controls to the pulping, pulp washing, and pulp bleaching processes. Eighty-six percent of pulp and paper TRI air emissions are also HAPs, so air emission trend lines for all TRI chemicals and for HAPs declined similarly over the past decade.[13]

Absolute TRI air emissions decreased 24% since 1996. When normalized by VOS, absolute emissions fell 12%.[14] Toxicity Scores, when normalized by VOS, decreased 35% over this period, indicating that the falling Toxicity Scores reflect an environmental performance improvement, rather than simply a decline in production levels.[15]

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.

1) Absolute Pounds Reported. Methanol (formed in the pulping of wood chips) and ammonia (formed in the chemical recovery process) were the top-ranking chemicals based on pounds emitted to air in 2005.

2) Percentage of Toxicity Score. Top-ranked chemicals based on Toxicity Scores include sulfuric acid from coal and oil burning in boilers, manganese from burning wood and coal, and chlorine dioxide from pulp bleaching. Together these chemicals accounted for more than half of the sector's overall Toxicity Score in 2005.

3) Number of Facilities Reporting. Lead from fossil fuel boilers, and methanol, were the most frequently reported chemicals. Two-thirds of facilities reporting TRI air emissions reported emissions of at least one of these two chemicals.

When wood and coal are burned, manganese is either emitted or partitioned to ash and subsequently landfilled. In 1997, EPA clarified TRI reporting requirements regarding combustion byproducts. Subsequently, metal byproducts from combustion of coal and oil are considered "manufactured" and therefore included in the reporting threshold calculation. This clarification resulted in new manganese reporting for many facilities and, thus, an increase in the amount reported to TRI.[16]

TABLE 1

Top TRI Air Emissions 2005

Chemical	Absolute Pounds Reported[1]	Percentage of Toxicity Score	Number of Facilities Reporting[2]
Acetaldehyde[3]	8,518,000[4]	4%	156
Acrolein	53,000	11%	6
Ammonia	16,769,000	1%	170
Chlorine Dioxide	546,000	11%	78
Dioxin and Dioxin-Like Compounds	<1	<1%	272
Formaldehyde	6,390,000	9%	217
Hydrochloric Acid	15,979,000	3%	136
Lead	43,000	1%	535
Manganese	184,000	15%	148
Methanol	126,057,000	<1%	362
Polycyclic Aromatic Compounds	96,000	3%	205
Sulfuric Acid	7,886,000	32%	99
Toluene	10,120,000	<1%	175
Percentage of Sector Total	93%[5]	90%[6]	76%[7]

Notes:
1. Total sector air releases: 206 million lbs.
2. 1,144 total TRI reporters in the sector.
3. *Italics* indicate a hazardous air pollutant under section 112 of Clean Air Act.
4. Red indicates that the chemical is one of the top five chemicals reported in the given category.
5. Chemicals in this list represent 93% of the sector's air emissions.
6. Chemicals in this list represent 90% of the sector's Toxicity Score.
7. 76% of facilities reported emitting one or more chemicals in this list.

Source: U.S. Environmental Protection Agency

Criteria Air Pollutants

Table 2 shows CAP and volatile organic compound (VOC) emissions from facilities in the Forest Products sector for 2002.

TABLE 2

Criteria Air Pollutant and VOC Emissions 2002

	Tons
SO_2	366,000
NO_X	277,000
PM_{10}	118,000
$PM_{2.5}$	76,000
CO	460,000
VOCs	245,000

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

Source: U.S. Environmental Protection Agency

The major CAP emissions from Forest Products manufacturing—carbon monoxide (CO), nitrogen oxides (NO_X), and sulfur dioxide (SO_2)—primarily are generated in combustion sources such as power boilers. NO_X and SO_2 can be transported over long distances and contribute to ozone and particulate emissions in urban areas that are downwind of facilities.

More recent data collected by AF&PA indicate a 12% decrease in SO_2 emissions per ton of production from 2002 to 2004, and a 9% decrease of NO_X emissions per ton of production. These reductions were gained through more sophisticated process controls, additional pollution control equipment, and use of low-sulfur fuels.[17]

US EPA ARCHIVE DOCUMENT

Greenhouse Gases

The sector's GHG profile is diverse. It includes direct and indirect carbon dioxide (CO_2) emissions from manufacturing operations. Forests also serve as carbon sinks, absorbing CO_2 from the atmosphere through growth. When harvested, carbon in the trees is transferred to forest products, which can lead to long-term storage of the carbon as in structures such as houses or in disposal sites.[18]

AF&PA participates in Climate VISION, a DOE-industry voluntary partnership to reduce GHG intensity, which is the ratio of GHGs to economic output. AF&PA member companies manufacture more than 80% of the paper and approximately half the wood products produced in the United States. Under Climate VISION, AF&PA members have committed to reduce GHG intensity by 12% by 2012 relative to a 2000 baseline.[19]

AF&PA reported that its members' direct GHG emissions from fossil fuel use and process emissions were 51.4 million metric tons of CO_2 equivalent ($MMTCO_2E$) in 2004, down from 61.2 $MMTCO_2E$ in 2000, and that GHG emissions from the generation of electricity purchased were 26.2 $MMTCO_2E$ in 2004, down from 26.8 $MMTCO_2E$ in 2000.[20] Table 3 presents the estimated GHG emissions for the sector; the estimates did not factor in carbon sequestration or GHG emissions from wastewater treatment.[21]

TABLE 3

Estimated GHG Emissions 2004

	Million Metric Tons of Carbon Dioxide Equivalent
Fossil Fuel Combustion and Process Emissions	51.4
Electricity[1]	26.2
Total	**77.6**

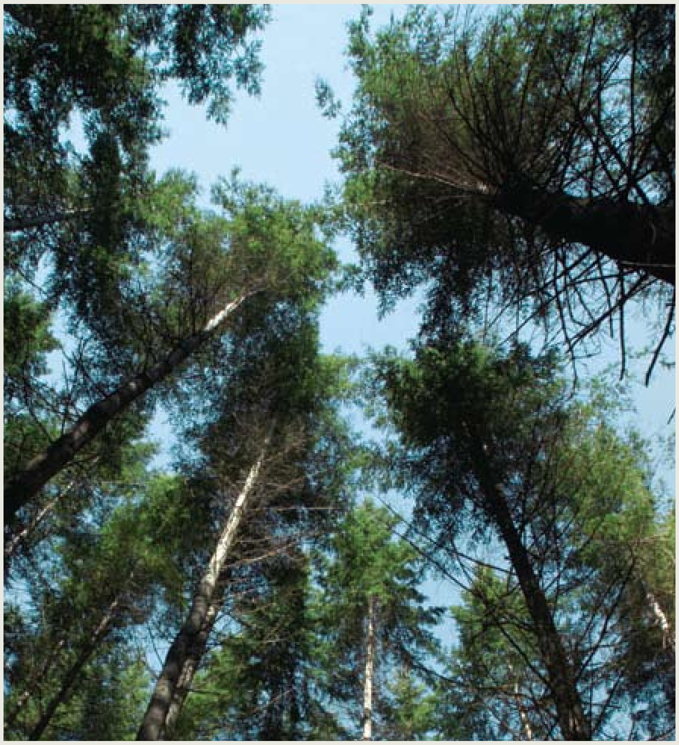
Note:
1. Indirect emissions from generation of purchased electricity.

Sources: American Forest & Paper Association, National Council for Air and Stream Improvement

Water Use and Discharges

As noted above, pulp and paper making is water-intensive. In pulp bleaching, for example, bleaching occurs in stages and the pulp must be washed between the stages. Many facilities are recycling water where possible and attempting to reduce the need for water.

Wastewater discharges are a major focus for this sector. In 2005, 370 Forest Products facilities reported water discharges of TRI chemicals totaling 20.5 million lbs., an 18% increase since 1996, when normalized by VOS over this period.[22] The predominant TRI chemicals discharged in 2005 included nitrate compounds, methanol, manganese, and ammonia. Combined, these chemicals accounted for 91% of the total TRI chemicals discharged to water that year. Pulp and paper mills accounted for almost all of the sector's water discharges.[23]



Forest Products manufacturing facilities discharge wastewater either to Publicly Owned Treatment Works (POTWs) or directly into waterways. Every facility discharging process wastewater directly to waterways must apply for a National Pollutant Discharge Elimination System permit. The permits typically set numeric limits on specific pollutants and include monitoring and reporting requirements. For facilities in this sector, regulated pollutants and the associated limits vary depending on the product being manufactured. For example, permits for wood-preserving facilities limit their discharges to POTWs of oil and grease, copper, chromium, and arsenic, and limit their discharges to waterways of oil and grease and phenols. Permits for pulp and paper mills limit zinc, among other pollutants, in their POTW and direct discharges.[24] The state of the best and most current discharge control technology, pollutant control technology, and economic feasibility also help determine the quantity or quality of discharge limits.

Pulp and paper mills also discharge effluent that lowers oxygen levels in receiving waters. In 1995, pulp and paper mills discharged approximately four lbs. of biochemical oxygen demand (BOD) per ton produced. In 2002–2004, the BOD of their effluent was 2.6 and 2.8 lbs. per ton produced, respectively.[25] The long-term trend toward reduced BOD is due to improved production processes and wastewater treatment, in response to state and federal regulations. The sector also has reported a significant long-term decrease in total suspended solids (TSS) in its discharges due to improved wastewater treatment, also in response to regulatory requirements.

Water discharges became a major focus in the 1980s when dioxins were found in waters that received pulp mill effluent. Since then, elemental chlorine bleaching of pulp has been replaced by bleaching processes based on chlorine dioxide, and dioxin pollution has dropped below detectable levels.[26] Current water toxics concerns are discharges of lead and nitrate compounds; lead accounts for the highest toxicity weighting among the water discharges, and nitrates account for more pounds of discharge than other listed toxins. Conventional discharges of concern are TSS and BOD.

In addition to being regulated for direct and POTW discharges, those facilities with materials exposed to precipitation are regulated for stormwater runoff, usually under a general permit that provides sector-specific limits. Stormwater effluent limits are set for TSS, chemical oxygen demand, arsenic, phenols, and metals—zinc, copper, and chromium.[27]

Reducing Water Use

Stora Enso Duluth Paper Mill and Recycled Pulp Mill, in Duluth, MN, reduced water use relative to production by nearly 25% from 2002 to 2006. The facility focused on water reuse and use of previously sewered water. Instead of using fresh water, for example, the facility's retention aid injection system now uses water that had been going to the sewer. With these and other measures, the mill has saved $398,000 over three years.[28]

Waste Generation and Management

Hazardous Waste Management

In 2005, 403 Forest Products facilities reported to EPA's *National Biennial RCRA Hazardous Waste Report* (BR) generating 136,000 tons of hazardous waste. The number of facilities reporting hazardous waste generation and the quantities reported in this sector were evenly distributed between the wood and paper products subsectors. The predominant source of hazardous waste generation in the sector was ongoing production and service-related processes. The predominant types of hazardous waste reported by the sector in 2005 were F034 (defined as wastewaters, process residuals, preservative drippage, and spent formulations from wood-preserving processes generated at plants that use creosote formulations) and corrosive waste, together representing three-quarters of the total generated wastes.[29] The sector reported managing 396,000 tons of hazardous waste. The difference between wastes generated and waste managed was due to groundwater remediation efforts at two wood products facilities.

Waste Management Reported to TRI

In 2005, the Forest Products sector reported managing 1.7 billion absolute lbs. of TRI chemicals in waste. As shown in Figure 3, when normalized by VOS, the quantity of waste managed by the sector remained relatively steady between 1996 and 2005. In 2005, 15% of the TRI-reported waste was disposed or released, 66% was treated, 12% was recovered for energy, and 6% was recycled. Pulp and paper mills accounted for almost all (95%) of the sector's waste managed.[30] There has been little change in the management methods used by this sector over the last decade.

In 2005, the sector reported disposing 29 million lbs. of TRI chemicals to land, or transferring the chemicals offsite for disposal. As shown in Table 4, manganese accounted for almost half of the total pounds disposed by the sector in waste. Zinc and barium were also disposed in large quantities. Lead was the chemical most frequently reported as disposed, followed by dioxin and dioxin-like compounds.

TABLE 4
Top TRI Disposals 2005

Chemical	Absolute Pounds Reported[1]	Number of Facilities Reporting[2]
Barium	3,638,300[3]	98
Dioxin and Dioxin-Like Compounds	2	204
Lead	587,000	423
Manganese	13,623,400	140
Mercury	1,500	113
Methanol	1,010,700	119
Vanadium	1,397,500	39
Zinc	7,458,600	108
Percentage of Sector Total	96%[4]	43%[5]

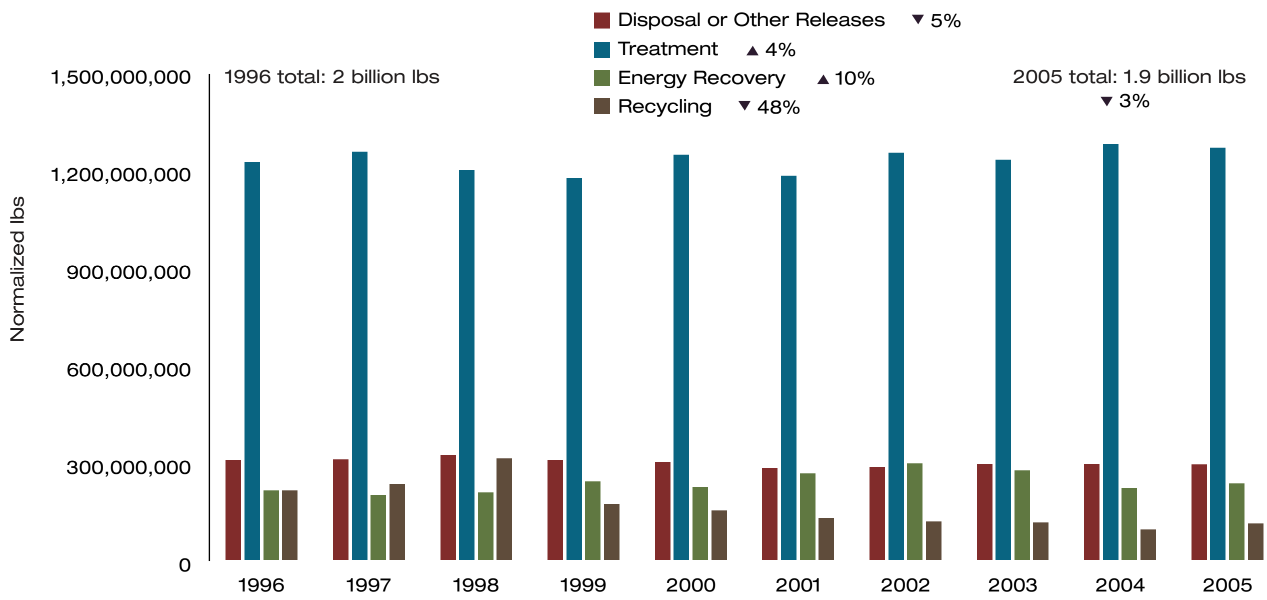
Notes:
1. Total sector disposals: 29 million lbs.
2. 1,144 total TRI reporters in the sector.
3. Red indicates that the chemical is one of the top five chemicals reported in the given category.
4. Chemicals in this list represent 96% of the sector's disposals.
5. 43% of facilities reported disposals of one or more chemicals in this list.

Source: U.S. Environmental Protection Agency

The sector continues to find ways to recycle waste and process byproducts—for energy production, reuse in new products, agricultural applications, and soil enrichment.[31] Kraft pulping mills burn spent pulping mixtures to generate energy and to recover pulping chemicals. Other wastes, such as wastewater treatment residuals and boiler ash, are increasingly being used as soil amendments. From 2002

FIGURE 3

TRI Waste Management 1996–2005



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

Sources: U.S. Environmental Protection Agency, U.S. Department of Commerce

to 2004, the proportion of wastewater treatment residuals used for land application increased from 12% to 16%.[32]

The sector's involvement in resource recovery goes beyond its own industrial processes. About 52% of the paper consumed by all users in the United States is recovered for recycling; AF&PA has a goal to raise that percentage to 55% by 2012.[33]

Additional Environmental Management Activities

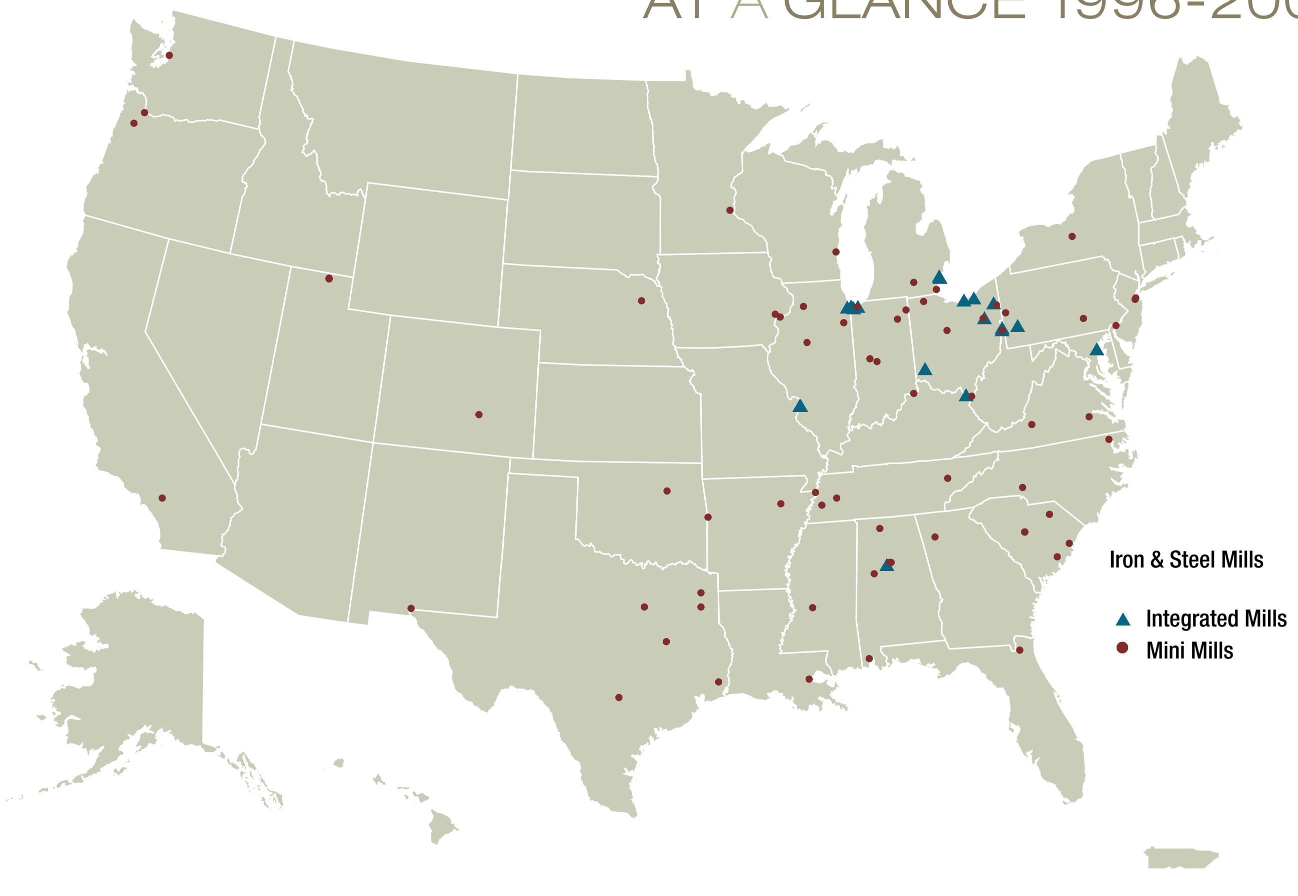
Many of the technology goals and research of the Agenda 2020 Technology Alliance would also improve environmental performance by reducing water use, finding beneficial uses for process wastes, and improving recycling.[34] Breakthrough technologies that would allow for more concentrated slurries at the beginning of the papermaking process, for example, would save both energy and water. Enhancements in chemical recovery that would either improve or eliminate lime kilns could save substantial amounts of fuel.

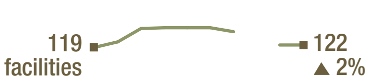
Forest biorefineries (described in the "Energy Use" section) could turn what are currently low-value byproducts and fuels into higher value chemicals and fuels. Wood contains three main chemical components: cellulose, hemicellulose, and lignin. Current pulping technology extracts the cellulose, which is used to make paper pulp; the lignin, which is burned for fuel; and the hemicellulose, which converts to certain sugars. The biorefinery would add three new processes. First, hemicellulose would be extracted from chips before pulping and would be converted either to ethanol fuel or other industrial chemicals. Second, boilers that currently burn waste biomass (e.g., bark, waste chips) would instead convert the biomass to syngas, an intermediate product that could then either be burned as a fuel or further converted to a mixture of fuels and chemicals similar to crude oil. Third, the spent pulping liquor containing lignin and pulping chemicals could itself be gasified for fuel, while continuing to recover pulping chemicals for reuse.[35]

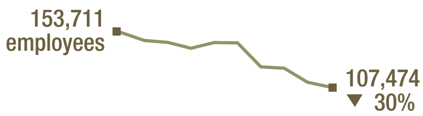
These new technologies are at various stages of research and development. New mandates and market opportunities for renewable fuels are prompting accelerated efforts to commercialize forest-based biofuels, and production plants may start up in the next few years.

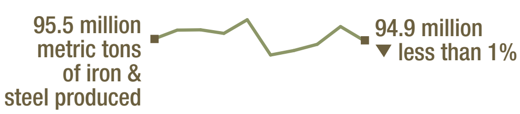
IRON & STEEL

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.

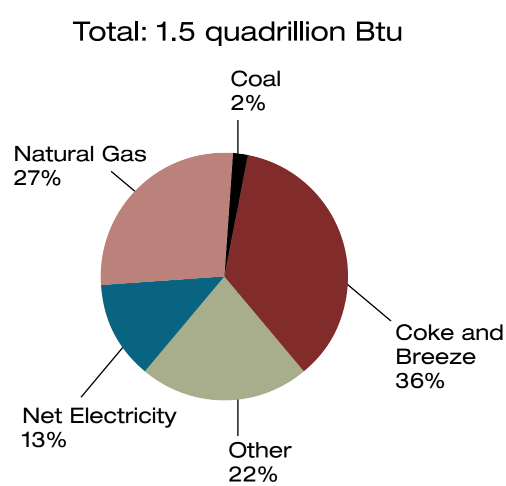
Electric arc furnaces (EAFs) melt steel scrap, along with limited amounts of other iron-bearing materials, to produce new steel. Because scrap can contain a wider range and higher percentage of contaminants, EAF steel requires additional refining to produce some grades of steel that are still made almost 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.

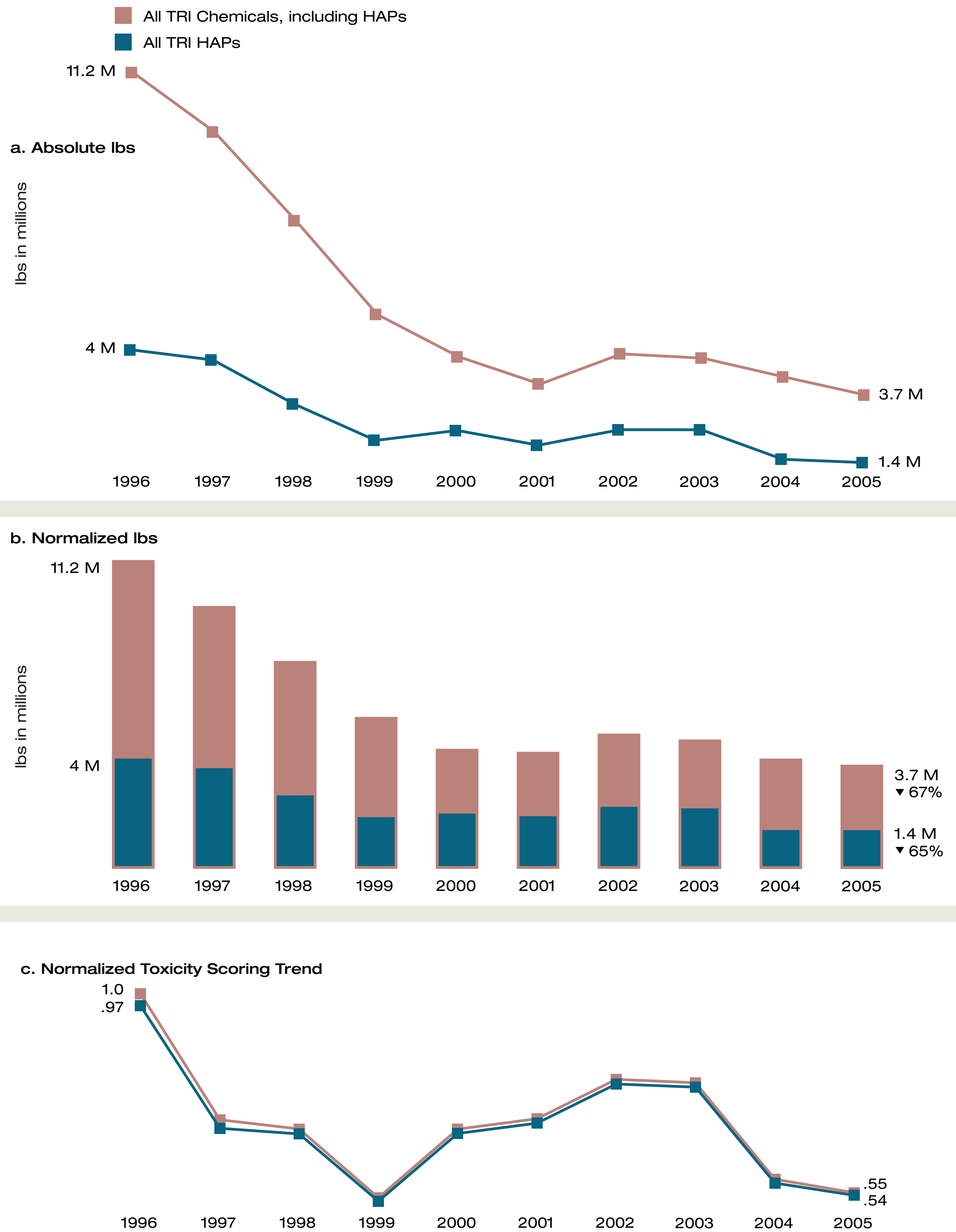
Data are not reported to TRI in sufficient detail to distinguish which forms of certain chemicals within a chemical category are being emitted. For chemical categories such as chromium, the toxicity model conservatively assumes that chemicals are emitted in the form with the highest toxicity weight (e.g.,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

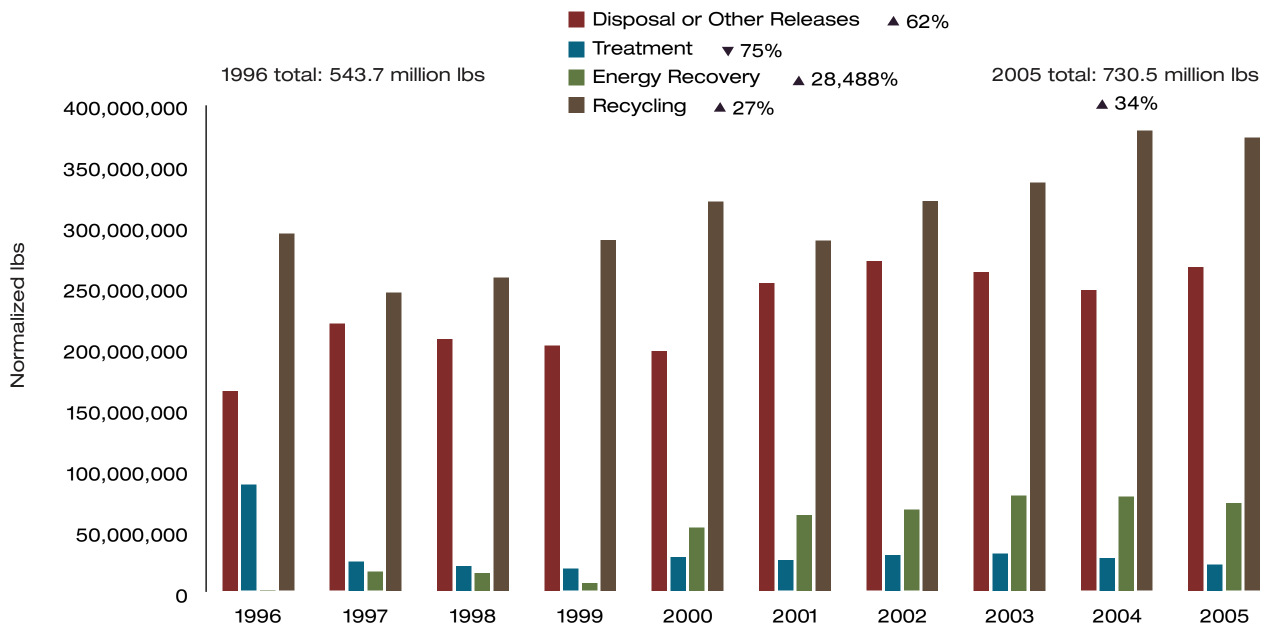
Wastes generated from this sector largely include EAF dust and SPL. The chemical components of EAF dust include zinc (averaging 20%), lead (averaging 5%), chromium (up to 15%), nickel (up to 4%), and cadmium (up to 3%).[48] These same chemicals accounted for nearly half the air emissions and nearly one-quarter 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

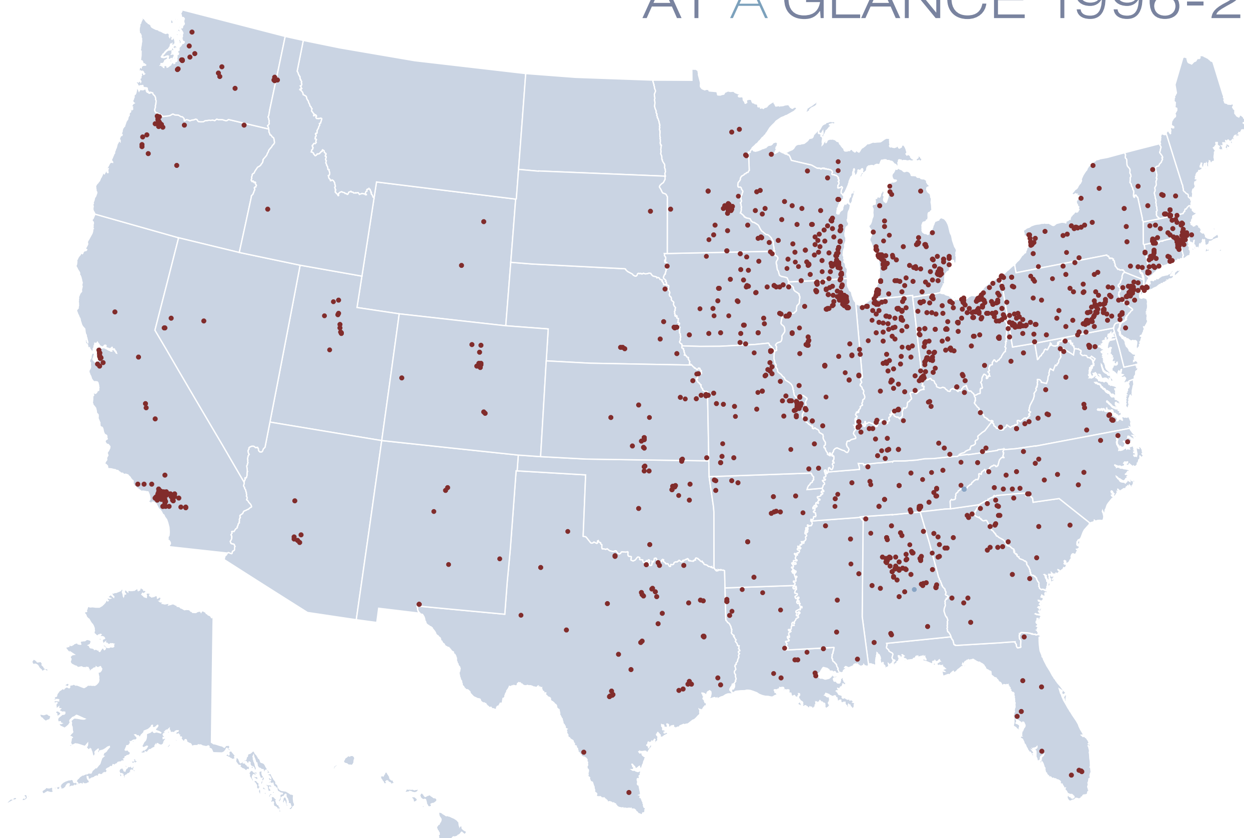
Additional Environmental Management Activities

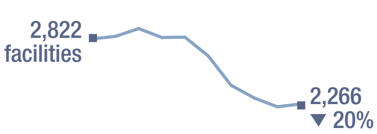
An environmental management system (EMS) is a set of processes and practices that enable an organization to reduce its environmental impacts and increase its operating efficiency. All integrated steel mills in the United States have adopted formal EMSs based on the ISO 14001 standard (the international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

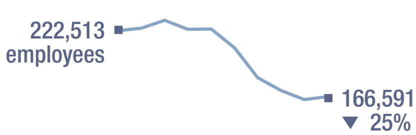
The Steel Manufacturers Association (SMA) has adopted a goal that 25 or more additional EAFs (reaching a total of two-thirds of U.S. mini-mills) will implement EMSs by Earth Day 2009. SMA also has a goal of doubling the number of its members participating in EPA's Performance Track (PT) program in 2008 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.

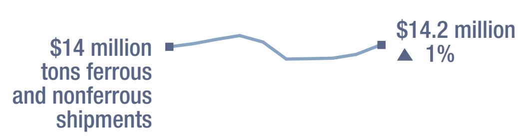
METAL CASTING

AT A GLANCE 1996-2005[1]









Latest Environmental Statistics[2]

Energy Use: 157 trillion Btu

Emissions of Criteria Air Pollutants: 75,000 tons

Releases of Chemicals Reported to TRI: 49.6 million lbs.

Air Emissions: 3.8 million lbs.

Water Discharges: 68,500 lbs.

Waste Disposals: 45.7 million lbs.

Recycling, Energy Recovery, or Treatment: 127.5 million lbs.

Hazardous Waste Generated: 30,000 tons

Hazardous Waste Managed: 28,000 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 Metal Casting sector includes establishments that pour molten ferrous metals (iron and steel) or nonferrous metals under high pressure into molds to manufacture castings.[3]

Ferrous metal casting includes those castings made with grey iron, ductile iron, malleable iron, and steel. Each type of iron contains different elements that affect its characteristics. Nonferrous castings are predominantly aluminum but might also be brass, bronze, zinc, magnesium, and titanium.

More than 90% of all manufactured goods in the United States contain cast metal components.[4] These includes engine blocks, transmission housings, and suspension parts for cars and trucks; undercarriages of farm and construction equipment; and pipes and valves for plumbing fixtures and boilers.

U.S. casting operations are now mostly small businesses, with 80% of facilities employing 100 people or fewer.

Energy Use

In 2002, the Metal Casting sector consumed 157 trillion Btu.[5] The major furnaces that casting operations use are cupola (used primarily for ferrous metal casting), electric, reverberatory, and crucible furnaces.

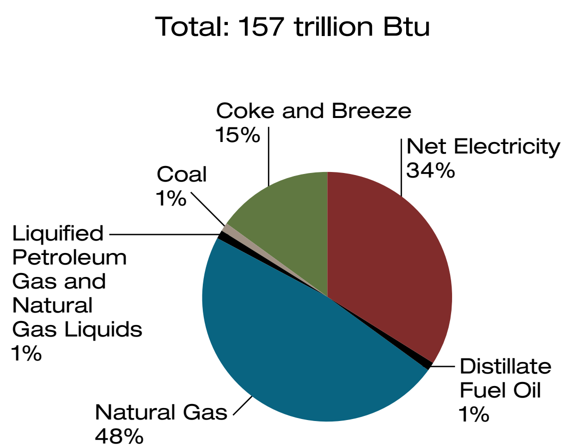
Heating and melting these various metals consumes large amounts of energy, accounting for 72% of the sector's total energy use, according to U.S. Department of Energy (DOE) estimates. Mold and core making account for 7% of the sector's energy use, and finishing accounts for 6%.[6] During molding, foundries use energy for transporting materials, mechanical mixing, and making molds and cores.

As shown in Figure 1, the sector is heavily dependent on natural gas and purchased electricity, making up 48% and 34%, respectively, of the sector's fuel inputs for energy in 2002. Coke, the primary fuel for cupola furnaces, was the third largest energy source, at 15%.[7]

A DOE report on the sector identified several energy-saving opportunities. Casting operations using iron induction can automate furnace temperature and power controls to prevent overshooting temperature settings, and can minimize the time that the lid is open while melting or holding iron. Operations

FIGURE 1

Fuel Use for Energy 2002



Note:
Net electricity is an estimation of purchased power and power generation onsite.

Source: U.S. Department of Energy

using a cupola furnace can dehumidify blast air to reduce coke consumption and can cover coke storage areas to prevent water from being introduced into the charge.[8]

Air Emissions

Air emissions are a primary environmental concern in the sector, and 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 raw materials and fuels used. CAPs and GHGs also are generated from onsite combustion of fuels. The TRI list of toxic chemicals includes all but six of the hazardous air pollutants (HAPs) regulated under the Clean Air Act (CAA). Air pollution is a major environmental impact particularly from ferrous metal casting. Because aluminum, used in nonferrous operations, melts at a lower temperature than ferrous metals, nonferrous casting usually results in lower air emissions.

The sector's air emissions result from the various operations in a facility, including metal melting, mold making, handling foundry sand, and die-casting. The majority of metal emissions come from the metal melting operations, while most organic emissions are from handling the binder that holds sand together to produce the cores and molds. Once the binder is combined with the sand, there may be additional organic, particulate, and carbon monoxide (CO) emissions from pouring the molten metal into the casting and from breaking apart the cast. Handling foundry sand results primarily in particulate emissions.

Air Emissions Reported to TRI

In 2005, 662 facilities reported to TRI air emissions of 3.8 million absolute lbs. Between 1996 and 2005, TRI-reported air emissions, in absolute pounds, declined 63%, as shown in Figure 2a. Because production levels for the sector remained relatively steady over the 10 years, the emissions trend, when normalized by ferrous and nonferrous shipments, was very similar to the trend for absolute emissions, as shown in Figure 2b. Some 75% of the sector's air emissions in 2005 were reported by ferrous metal casting facilities, while nonferrous facilities reported the remaining 25%. In the same year, ferrous metal casting facilities contributed to 62% of the sector's total shipments, while nonferrous contributed to 38%.

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.

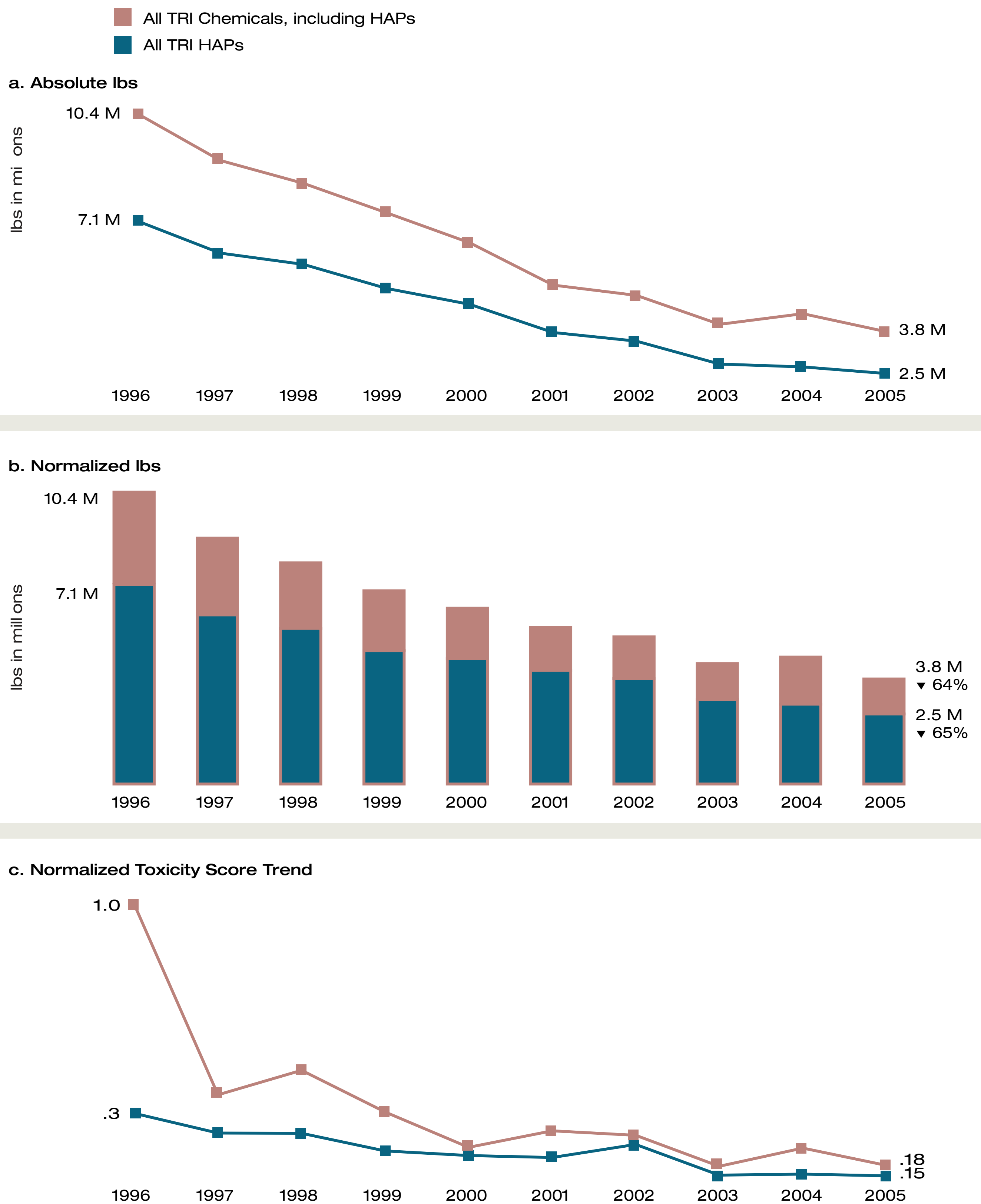
Summing the Toxicity Scores for all of the air emissions reported to TRI by the sector produces the trend illustrated in Figure 2c. The sector's Toxicity Score declined 82% from 1996 to 2005.[9] Three chemicals—manganese, chromium, and diisocyanates—accounted for 81% of the sector's total Toxicity Score. Manganese and chromium emissions result from melting; furnaces melting metal emit dust, metallic particles, and metal oxide fumes, along with the products of combusted fuel. Diisocyanates, associated with binding materials, are emitted as a result of exposure to air. The apparent spike in 1996 was exacerbated by diisocyanates emissions reported by one facility, which, in subsequent years, reported no diisocyanates emissions. The sector's reported emissions of all three chemicals have declined since 1996.

During this same period, regulations led to increased use of pollution control equipment, and to equipment upgrades. Technology related to the binding process has also improved; changes in binder ingredients and processing, for example, have promoted reductions in volatile organic compound (VOC) emissions.

In 2005, 514 facilities reported 2.5 million lbs. of HAP emissions. These HAPs accounted for 66% of the sector's air emissions in 2005 and 83% of the sector's overall Toxicity Score. Over the 10-year period presented, absolute and normalized pounds of HAPs emitted declined by 65%.[10]

FIGURE 2

Air Emissions Reported to TRI 1996–2005



Note:
Normalized by ferrous and nonferrous shipments.

Sources: U.S. Environmental Protection Agency, American Foundry Society

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.

1) Absolute Pounds Reported. Xylene and aluminum were the highest-ranking chemicals based on the pounds of each chemical emitted to air in 2005.
2) Percentage of Toxicity Score. The top chemical based on Toxicity Scores was manganese, which has a high toxicity weight and was emitted in large quantities. Chromium and diisocyanates were emitted in smaller quantities but are among the chemicals with the highest toxicity weights.
3) Number of Facilities Reporting. Lead was the most frequently reported chemical, with more than half the facilities in the sector filing TRI reports for air emissions of lead.

TABLE 1

Top TRI Air Emissions 2005

Chemical	Absolute Pounds Reported[1]	Percentage of Toxicity Score	Number of Facilities Reporting[2]
Aluminum	356,000[3]	1%	49
Benzene[4]	243,000	<1%	9
Chromium	53,000	26%[5]	168
Copper	153,000	1%	322
Diisocyanates	16,000	16%[6]	41
Lead	96,000	5%	372
Manganese	193,000	39%	206
Nickel	47,000	9%	211
Phenol	328,000	<1%	60
Xylene	438,000	<1%	10
Zinc	268,000	<1%	91
Percentage of Sector Total	58%[7]	96%[8]	86%[9]

Notes:
1. Total sector air releases: 3.8 m llion lbs.
2. 662 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. *Italics* indicate a hazardous air pollutant under section 112 of Clean Air Act.
5. 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.
6. Calculation of Toxicity Score for diisocyanates conservatively assumed that all diisocyanates emissions were hexamethylene diisocyanates. Other diisocyanates chemicals with lower toxicity scores may constitute the majority of reported diisocyanates emissions from the sector. Thus, RSEI analyses may overestimate the relative harmfulness of diisocyanates emissions.
7. Chemicals in this list represent 58% of the sector's air emissions.
8. Chemicals in this list represent 96% of the sector's Toxicity Score.
9. 86% of facilities reported emitting one or more chemicals in this list.

Source: U.S. Environmental Protection Agency

Criteria Air Pollutants

Table 2 shows CAP and VOC emissions from the Metal Casting sector for 2002.

TABLE 2

Criteria Air Pollutant and VOC Emissions 2002

	Tons
SO_2	3,000
NO_X	5,000
PM_{10}	18,000
$PM_{2.5}$	13,000
CO	32,000
VOCs	17,000

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

Source: U.S. Environmental Protection Agency

Conversion to Low-Emission Technology Binders and Process

Gregg Industries, in El Monte, CA, received neighborhood odor complaints when using a no-bake casting line using phenolic urethane resin for prototype castings and customer casting qualification. The company replaced the phenolic resin with an inorganic, highly modified sodium silicate resin. The resin dramatically reduced smoke and odor from the no-bake operation. The foundry also replaced an odor-causing organic core resin with a similar modified silicate core resin. After the change to the low-emission technology resins, the foundry saw lower binder costs, fewer labor hours to produce the cores, and lower cleaning room costs. Also, the new low-emission core technology contributes to the continuing decline in casting scrap.[11]

Water Use and Discharges

Metal Casting facilities use water in their production processes and discharge wastewater to either Publicly Owned Treatment Works or directly into waterways. Wastewater from the sector mainly consists of noncontact cooling water and wet scrubber wastewater. Foundries using cupola furnaces also may generate wastewater containing metals from cooling slag with water. Certain finishing operations, such as quenching and deburring, may generate wastewater containing oil and suspended solids.

Every facility discharging process wastewater directly to waterways must apply for a National Pollutant Discharge Elimination System permit. The permits typically set numeric limits on specific pollutants and include monitoring and reporting requirements. For metal casters, regulated pollutants and the associated limits vary depending on the type of casting operation (aluminum, copper, zinc, or ferrous casting), but most facilities are regulated in their discharges of copper, lead, zinc, and total suspended solids (TSS).[12]

In 2005, 236 facilities reported water discharges of TRI chemicals totaling 68,500 lbs.[13] This represented a decline of 52% since 1996.[14]

Facilities with materials exposed to precipitation also are regulated for stormwater runoff, usually under a general permit providing sector-specific limits. Depending on the type of foundry, stormwater requirements for metal casting facilities may include effluent limits on copper, zinc, iron, aluminum, and TSS.

Waste Generation and Management

Waste management is another key environmental issue for Metal Casting facilities. Metal casting wastes fall into four main categories: sand, slag, dust, and other. The sand used to create molds and cores accounts for a large portion of the waste generated at foundries.[15] The high-quality sand required for casting is expensive, so foundries reuse sand to the extent possible. Sand that no longer can be used by iron or steel foundries is often landfilled or beneficially reused.

Slag, which can make up about 25% of a foundry's solid waste stream, is a glassy mass with a complex chemical structure. Slag is composed of metal oxides from the melting process, melted refractories, sand, coke ash (if coke is used), and other materials. Large quantities of slag are generated from iron foundries using cupola furnaces.

During casting, some metal is converted to dust or fumes and collected by pollution control equipment such as baghouses, electrostatic precipitators, or wet scrubbers.

Some processes for making cores require strongly acidic or basic substances for scrubbing the off gases and can generate sludges or liquors. These sludges or liquors are typically pH-controlled prior to discharge to the sewer system.

Hazardous Waste Management

Both ferrous and nonferrous facilities generate hazardous waste, including hazardous waste from finishing operations. Ferrous facilities generate hazardous wastes mostly from pollution control equipment, especially from melting furnaces. Nonferrous facilities tend to produce hazardous wastes as foundry sand contaminated with heavy metals. About 2% of all spent foundry sand is hazardous. Casting sands used in the production of brass or bronze castings may also exhibit toxicity characteristics for lead or cadmium, making them a hazardous waste.

In 2005, 170 facilities reported to EPA's *National Biennial RCRA Hazardous Waste Report* (BR) generating 30,000 tons of hazardous waste. Wastes captured by air pollution control equipment were the largest source of hazardous waste. Facilities reported managing 28,000 tons of hazardous waste in 2005, most of which was managed through destruction or treatment.[16]

Waste Management Reported to TRI

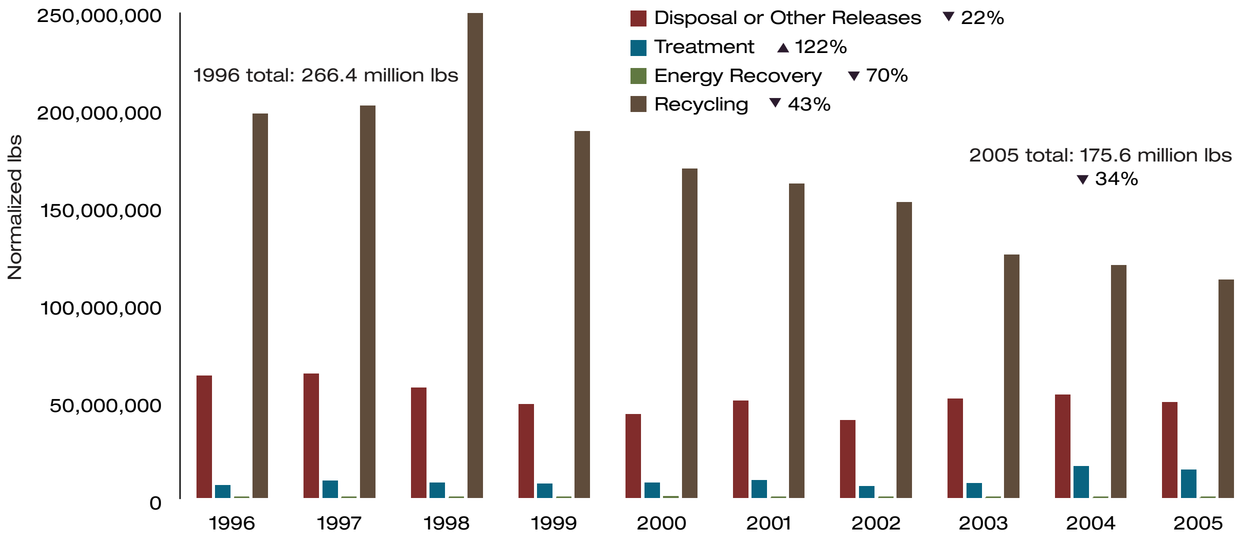
In 2005, the sector reported managing 177 million absolute lbs. of TRI chemicals as waste. Of the TRI waste managed (which included disposal and recycling), 56% was reported by nonferrous facilities; ferrous metal casting accounted for 44%. Both nonferrous and ferrous facilities recycle extensively, though nonferrous facilities recycle a higher percentage. About two-thirds of the materials the sector reported to TRI as waste in 2005 were recycled.[17] The high recycling rate derives partly from the nature of the industry; if a problem occurs in the casting, the defective product can be melted down and cast again, on or offsite.

The quantity of waste managed in 2005 was 34% less than in 1996, with little change in the sector's quantity of product shipped. In 2005, 28% of TRI-reported waste was disposed or released, while 8% was treated and 64% was recycled. Foundry sand was recycled onsite and offsite.[18]

In 2005, 45.7 million lbs. of TRI chemicals were disposed to land or transferred to offsite locations for disposal.

FIGURE 3

TRI Waste Management 1996–2005



Notes:
1. Normalized by ferrous and nonferrous shipments.
2. Disposal or other releases include air releases, water discharges, and land disposals.

Sources: U.S. Environmental Protection Agency, American Foundry Society

Manganese accounted for about one-third of the total pounds disposed. As shown in Table 3, lead and copper were the chemicals most frequently reported as disposed. The sector's disposals and other releases were driven by ferrous metal casting facilities, which accounted for 75% of disposals and releases.

TABLE 3

Top TRI Disposals 2005

Chemical	Absolute Pounds Reported[1]	Number of Facilities Reporting[2]
Aluminum	7,709,000[3]	31
Chromium	7,112,000	149
Copper	1,775,000	210
Lead	1,983,000	270
Manganese	14,938,000	187
Nickel	556,000	162
Zinc	9,636,000	63
Percentage of Sector Total	96%[4]	60%[5]

Notes:
1. Total sector disposals: 45.7 million lbs.
2. 662 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 96% of the sector's disposals.
5. 60% of facilities reported disposals of one or more chemicals in this list.

Source: U.S. Environmental Protection Agency

Promoting the beneficial reuse of foundry sand is a priority for EPA and for the American Foundry Society (AFS). Recent efforts to increase beneficial reuse rates appear to be paying off, as more sand is reused now than ever before. With input from the National Center for Manufacturing Sciences and EPA, AFS developed a survey to help quantify the amount of sand available for reuse, characterize current reuse practices, and identify barriers to reuse. Based on the 244 responses and a broader telephone survey, AFS determined that the industry beneficially reuses 2.6 million tons of sand per year, representing 28% of the total tons of sand available for reuse. The most common barrier to reuse that respondents noted was lack of a local market for used foundry sand.[20]

Other Environmental Management Activity

The North American Die Casting Association (NADCA) promotes environmental management systems for die casting operations, and recently published a book titled Environmental Management for Die Casting. The book has been given away to NADCA corporate members and has been sold to more than 75 other die casting operations around the United States.

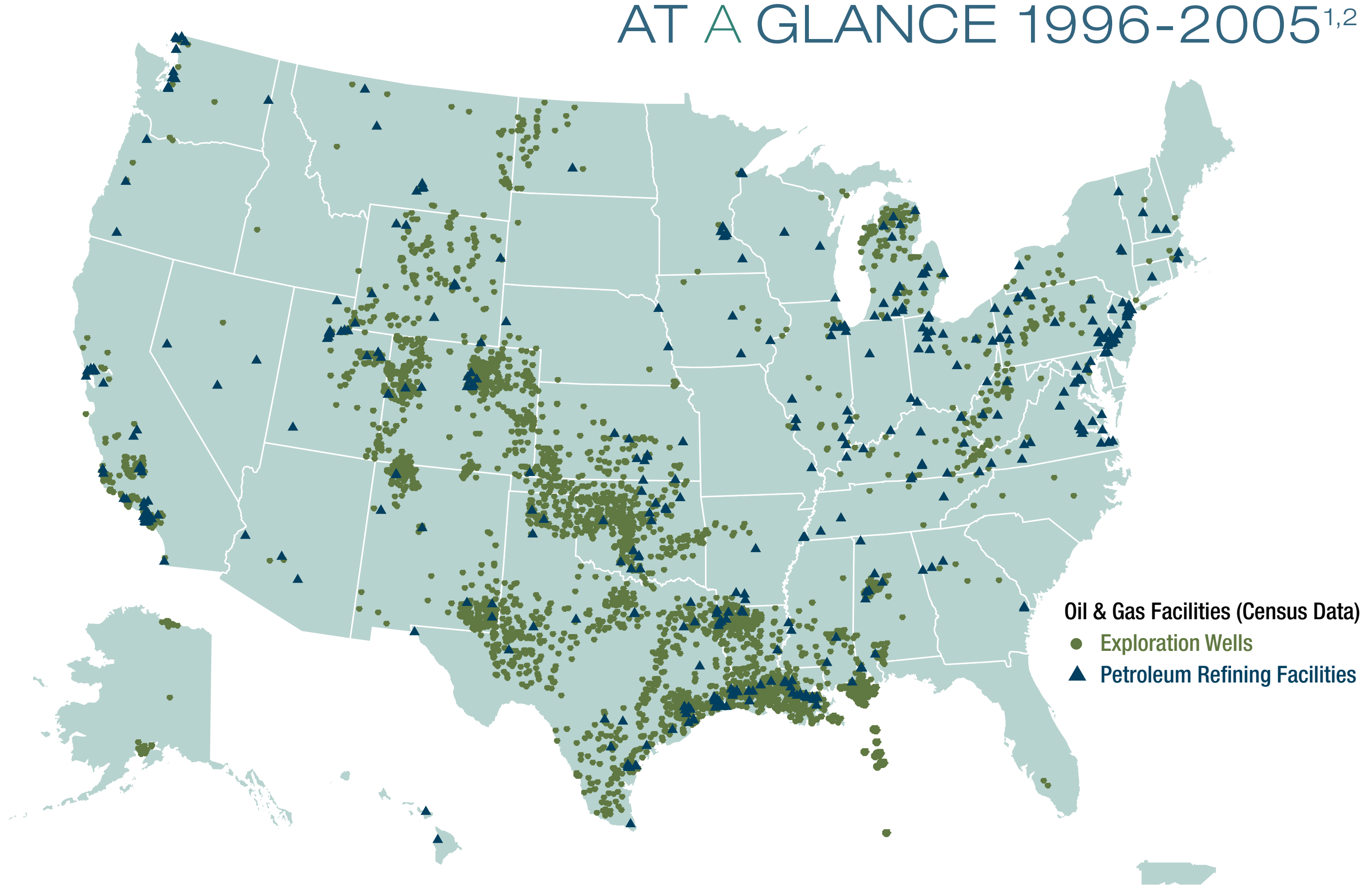
NADCA has further developed a series of questions for owners so they will understand where their operations stand in terms of environmental compliance for air, water, and solid waste. More than 30 companies have used this system to evaluate themselves.[21]

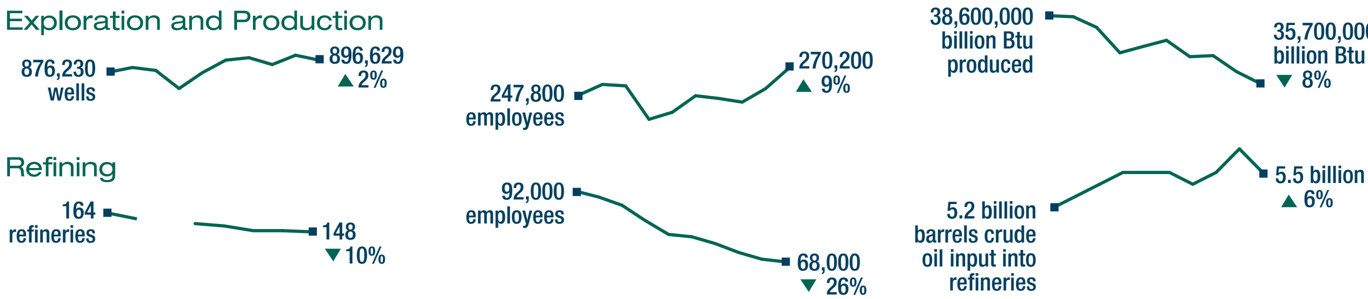
Spent Foundry Sand Used in Rain Gardens

In June 2007, the city of Seven Hills, OH, partnered with a commercial landscaping supply company, Kurtz Bros., Inc., to install a rain garden on community property near City Hall. A rain garden is a landscape that filters stormwater to remove impurities before the water enters storm drains or surface water. Spent foundry sand was key to the rain garden soil mix. By purchasing bioretention soil made with spent foundry sand, the city paid about half as much as it would to purchase soil made with unused sand. Foundries paid less for Kurtz to remove the spent sand than they would to landfill the sand.[19]

OIL & GAS

AT A GLANCE 1996-2005[1,2]





Profile

The Oil & Gas sector includes the following operations, which are subject to a number of federal and state regulations:

- Exploration and Drilling: Onshore and offshore geophysical operations, including seismic studies, engineering, well testing, drilling operations, and transportation of personnel or equipment to and from sites.
- Oil and Gas Production: Operation, maintenance, and servicing of production properties on- and offshore, including transportation to and from sites.
- Petroleum Refining: Distillation, hydrotreating, alkylation, reforming, and other distinct processes for converting crude oil into petroleum products.[3]

In 2005 the Oil & Gas sector included 498,454 oil wells and 398,161 gas wells in operation. The sector employed 1,381 rotary rigs for drilling new wells.[4] The United States is the world's third-largest petroleum producer and second-largest natural gas producer.[5]

Petroleum products derived from crude oil through the refining process include gasoline (motor fuel), distillate (diesel fuel, home heating oil), kerosene (jet fuel), petroleum coke, residual fuel oil (industrial and marine use), petroleum gases (liquified petroleum gas, ethane, butane), elemental sulfur, asphalt and road oils, petrochemical plant feedstocks, and lubricating oils.

The environmental impacts of the sector's activities vary significantly. This chapter is divided into two sections, discussing the environmental implications of exploration and production (E&P), followed by a discussion of petroleum refining.

Exploration and Production[6]

E&P operations locate and extract crude oil and natural gas from geologic formations. Geologic and regional differences, as well as basin-specific approaches to extract the resources available, influence the environmental footprint associated with E&P operations. This section overviews the major processes and factors affecting that footprint.

Exploration and Drilling

Exploration for oil and gas involves geologic testing of prospective formations. These activities often involve construction of new roads in remote areas and air emissions caused by vehicular traffic to, from, and within potential drilling locations. Drilling is done with truck-mounted rigs powered by diesel engines, which also affect air quality. Operators prepare a pad for drilling equipment including creation of pits and ponds to contain various fluids and mud used in drilling and to manage the drill cuttings (rock displaced while drilling the well). Operators also install tanks or pipes to gather the resources produced.

Oil Production

The classifications of light, medium, heavy, or extra-heavy refer to the crude oil's gravity as measured on the American Petroleum Institute (API) scale, and reflect the energy required and environmental impacts inherent in producing and refining the oil. Light crude oil, for example, flows naturally or can be pumped relatively easily to the wellhead. Conversely, heavy crude oil does not flow easily and has higher viscosity than light or medium crudes, requiring enhanced oil recovery (EOR) processes such as heating or diluting.

When crude oil, associated natural gas, and formation water arrive at the wellhead, operators must separate them before further processing and transport. The water is generally high in saline content and may contain hydrocarbons. Separator units near the wellhead separate the oil from the associated natural gas. The natural gas is processed to recover natural gas liquids (mostly propane and butane). Impurities such as carbon dioxide (CO_2) and hydrogen sulfide (H_2S) also are removed from the gas before it is transported. If pipeline access is not available, the gas may be used on location to power production equipment or may be re-injected into the oil reservoir to maintain reservoir pressure.

Water produced with oil must be removed because it is corrosive and an impediment to transportation and storage. Water is separated at gathering stations and oil storage tanks in the field.

Measurable quantities of oil remain in the reservoir once primary production processes have concluded, and additional resources can be recovered through EOR processes. Such processes supplement natural reservoir forces to improve flow rate and recovery. Representative EOR techniques include water flooding, gas injection, and chemical and thermal processes—all of which can have environmental impacts.

Natural Gas Production

Production of gas generally begins as natural flow from the wellhead into the gathering system. As a field matures, reservoir pressure begins to decline and gas compression equipment helps recover the gas. In cases where "pipeline-quality" natural gas is produced at the wellhead, producers move the product directly to the pipeline grid. In most cases, raw gas streams must be treated prior to introduction into the pipeline system.

Water and heavier hydrocarbons are removed at the wellhead, and may result in water discharges and waste disposal issues. Light hydrocarbons are removed at a natural gas processing plant and sold for other uses. In addition, some natural gas production yields "dry gas" with no associated crude oil, condensate, or liquid hydrocarbons. Gas also may contain non-hydrocarbons such as CO_2, H_2S, and nitrogen. If present in sufficient concentrations, these constituents also are removed at natural gas processing plants.

As natural gas supplies from the nation's historic production regions are depleted, the industry's focus has shifted. For example, the Rocky Mountain region contains prospective production areas that are expected to make major contributions to U.S. natural gas reserves. In addition, shale gas production is becoming a key component of U.S. supplies; the Barnett Shale in northern Texas is one of the largest onshore natural gas fields in the country.

Unconventional Oil and Gas Resources and Emerging Technologies

Unconventional oil and gas resources are defined loosely as resources that are deeper or more difficult to recover than those that have been recovered historically. Given the mature state of the domestic petroleum industry and current access limitations (e.g., prohibitions or restrictions on developing offshore and onshore sites within sensitive ecosystems), oil and gas resources from conventional formations within the United States have been largely depleted. Unconventional resources require advanced recovery techniques and may require that extracted material be upgraded to meet relevant fuel specifications. For example, oil shale must be heated to release petroleum-like liquids that can be turned into fuel. Unconventional gas resources usually require more wells (closer well spacing) to recover the gas resource than in recovery of gas from conventional gas resources. Common practice for unconventional gas production can require 8 to 16 times as many wells per area of land as for historical conventional gas recovery. The impact of this greater well density is mitigated by the use of advanced drilling techniques, which allow multiple wells to be drilled from one well pad. To be viable, unconventional resource recovery methods must also address a wide range of socioeconomic and environmental issues. The following are representative of unconventional resources and emerging technologies.

Tight Gas and Coal Bed Methane (CBM)

Tight gas refers to natural gas found in less permeable and porous formations, such as limestone or sandstone. For recovery, the gas-bearing formation must be broken up, or "fractured," to allow gas to flow to the well. This requires many more wells than conventional recovery. CBM refers to natural gas trapped in underground coal seams, which can be extracted before mining the coal. CBM production often requires removing large amounts of water from underground coal seams before the methane (CH_4) in the seams can be released and recovered as an energy source.

Directional and Horizontal Drilling

New methods to reduce the cost and environmental impacts of recovering unconventional resources include directional and horizontal drilling techniques. Directional drilling includes all forms of drilling where the hole is slanted or curved from the drilling site to reach the target reservoir. Directional drilling commonly is used offshore as evolving techniques enable producers to reach oil reserves in extremely sensitive ecosystems while most of the drilling equipment is miles away. In onshore operations, directional drilling greatly reduces the amount of surface disturbance by enabling producers to use a small surface well pad and to drill outward to access larger portions of the target reservoir.

Horizontal drilling enables the wellbore to be shifted from a vertical to a horizontal orientation. By using horizontal drilling techniques, operators can drill many wellbores from a single location, thus reducing the above-ground footprint. Horizontal drilling is used extensively in accessing unconventional natural gas resources; however, due to the lower porosity of the underlying formations, more wells must be drilled (e.g., tighter well spacing) to extract the gas.

Advanced drilling rigs may also be designed to slide on rails to the next destination within a production area, reducing environmental disturbances and improving efficiency.

Energy Use

E&P operations need energy to power oil and gas recovery. Requirements range from prospecting for new wells, to moving trucks and equipment onsite and off, to drilling and pumping the wells. Development drilling can involve numerous wells, and the power used to operate and transport drilling rigs increases the energy intensity of E&P operations. To increase pressure and enhance recovery rates from largely depleted reservoirs, most onshore oil production operations use pumps powered by electricity or natural gas.

The energy required for E&P increases as the resource recovered becomes more difficult to access and produce. For example, approximately two-thirds of U.S. gas wells are now drilled into unconventional formations. While sometimes shallower than conventional wells, unconventional gas wells typically require more energy than conventional wells for well stimulation operations. In the case of CBM and some shale gas operations, energy use for producing, managing, and treating large volumes of produced water is significant.[7]

Air Emissions

Air emissions from E&P operations include criteria air pollutants (CAPs), hazardous air pollutants (HAPs), and greenhouse gases (GHGs). E&P air emissions are generated by combustion in stationary and mobile internal combustion engines, gas processing equipment, and other activities. In addition, E&P operations produce air emissions through venting and flaring. Fugitive emissions of methane are also significant.

Oil and natural gas production is included as an area source category for regulation under EPA's Urban Air Toxics Strategy, is subject to New Source Performance Standards for new or modified stationary sources, and is subject to state and federal operating permit requirements to limit air pollution. E&P operations are not included within the scope of industries that report to EPA's Toxics Release Inventory (TRI), and too few facilities are currently included in the National Emissions Inventory (NEI) to be representative of the sector.

Criteria Air Pollutants

EPA has, however, analyzed the sector's air emissions in Region 8 (Colorado, Montana, North Dakota, South Dakota, Utah, and Wyoming) using state emissions inventory data developed by the Western Regional Air Partnership (WRAP).[8] A draft study prepared by EPA's Sector Strategies Program characterized regional air emissions and non-air pollution from produced water and drilling wastes. Region 8, which includes the Rocky Mountains (Rockies), has experienced tremendous growth in natural gas production activities in the last decade and the trend is likely to increase. Table 1 shows 2002 CAP emissions from oil and gas exploration and production reported by WRAP in Region 8.

TABLE 1

CAP and VOC Emissions in Region 8 2002

Pollutant	Estimated Emissions in Tons
VOCs	262,953
NO_X	87,130
CO	37,880
SO_2	18,385
PM	834

Source: U.S. Environmental Protection Agency

Greenhouse Gases

Major GHG emissions from E&P operations include CO_2 and CH_4. Acid-gas removal units that remove CO_2 from natural gas are the primary source of GHGs from natural gas processing plants. Indirect sources of CH_4 are venting and fugitive emissions. A substantial portion of field production CH_4 emissions come from pneumatic devices such as liquid level controllers, pressure regulators, and valve controllers. Other sources of CH_4 emissions are dehydrators and gas engines.

Table 2 shows estimated GHG emissions from Region 8 for 2002. When CH_4 emissions are weighted by their global warming potential (21 times that of CO_2), CO_2-equivalent methane emissions represent the sector's largest non-CAP emissions, at more than 10 million tons. Although those emissions are not regulated, anticipated GHG regulations affect current and planned E&P activities.

TABLE 2

GHG Emissions in Region 8 2002

Pollutant	Estimated Emissions in Tons
CH_4	10,366,442 (CO_2-equivalent)
CO_2	5,191,897

Note:
Estimated emissions of CH_4 were 493,640 tons.

Source: U.S. Environmental Protection Agency

Water Use and Discharges

E&P operations entail various water uses and discharges, with related environmental implications. EPA data systems contain limited information on discharges to waterways, as most operations are regulated under general permits and report to state, rather than federal, agencies.[9]

Producers use water to assist in resource extraction, from enhanced oil recovery to hydraulic fracturing. Oil and gas operations must also manage "produced water"—water that either occurs naturally in the formation and must be disposed of or reused after extraction, or water that is injected to stimulate production.

Reducing Emissions and Saving Money

In 2005 the Devon Energy Corporation, WY, prevented the release of nearly 6.0 billion cubic feet (Bcf) of CH_4, equivalent in terms of GHG emissions to 2.6 million tons of CO_2. By implementing emissions reduction techniques in concert with various process improvements, Devon retained significant volumes of product (e.g., methane gas in the pipeline) and realized an economic benefit of more than $43 million. Devon received EPA's 2005 Natural Gas STAR Production Partner of the Year award.[10]

The most widely used EOR technique involves injecting water into the reservoir (e.g., "water flooding"). Water, injected under pressure, pushes the oil toward the recovery or producing well. The recovered fluids (water and oil) are separated; oil is sent on to distribution, and water is either treated and reused or disposed in permitted underground injection control wells. Injection wells are permitted through state oil and gas regulatory agencies that place limits on injection volume and pressure. Water flooding represents a major source of produced water managed by producers.

Hydraulic fracturing is the most commonly used method of gas well stimulation. It involves pumping a water-based solution into the formation at pressures up to 10,000 pounds per square inch, which induces fractures in the formation. A material such as silica sand also is pumped in to prop the fractures open, enabling the gas to flow more freely to the wellbore. Fracturing generally is accomplished with large truck-mounted pumps powered by diesel engines. Today, tight sand fracturing in the Rockies typically involves stimulation of many zones in a well with spacing intervals of up to thousands of feet. In shale formations such as the Barnett Shale, several separate fractures are carried out within the horizontal portion of the well.

In 2004, EPA completed its assessment of the potential for contamination of underground sources of drinking water by reviewing existing literature on water quality incidents that potentially were linked to hydraulic fracturing. EPA concluded there were no confirmed cases of drinking water contamination from fracturing fluid injection into CBM wells or from subsequent underground movement of fracturing fluids.

Chemical compositions, and environmental impacts, of produced water vary significantly depending on the geologic characteristics of the reservoir producing the water and the separation and treatment technologies used.[11]

Table 3 shows the amount of produced water from oil and gas extraction activities in Region 8 by state for 2002.[12] Almost 3 billion barrels of produced water were discharged in Region 8, almost 75% of which was in Wyoming.

TABLE 3

Produced Water by State 2002

State	Barrels
Colorado	348,255,005
Montana	123,397,156
North Dakota	98,537,154
South Dakota	8,108,174
Utah	136,296,362
Wyoming	2,091,105,179
Total	2,805,699,030

Source: U.S. Environmental Protection Agency

Oil wells generally discharge more produced water than gas wells. The category "oil with gas wells" (where "associated gas" is also produced) constituted the largest contributor of produced water in Region 8, as shown in Table 4. Oil-only wells released the second largest amount of produced water. Combined, these two well types account for 69% of total produced water in the region. Wyoming is the primary source of produced water in the region for both well types.

In managing produced water, E&P operators use a variety of technologies and techniques. A common approach involves using gravity to separate water from the recovered oil in storage tanks at a production site. The produced water then is stored in separate tanks prior to disposal or beneficial reuse. In some instances, produced water is injected back into formations to be used in enhanced oil and gas recovery.[13] The potential for reusing the water, and relevant environmental impacts, largely depends on the salinity and chlorine content of the water, as well as contaminant concentrations. For example, produced water can contain a mixture of inorganic and organic compounds, and, in many cases, residual chemical additives that are added into the hydrocarbon production process.[14]

TABLE 4

Produced Water by Well Type 2002 (Barrels)

State	Oil-Only Wells	Gas-Only Wells	Oil with Gas Wells	Gas with Oil Wells	Total
Colorado	81,962,976	158,856,545	102,323,995	5,111,489	348,255,005
Montana	50,775,321	16,847,685	55,708,537	65,613	123,397,156
North Dakota	20,953,673	3,521	74,617,442	2,962,518	98,537,154
South Dakota	915,122	614	5,121,998	2,070,440	8,108,174
Utah	21,684,832	31,145,993	79,283,960	4,181,577	136,296,362
Wyoming	601,234,810	569,061,152	853,631,461	67,177,756	2,091,105,179
Total	777,526,734	775,915,510	1,170,687,393	81,569,393	2,805,699,030

Source: U.S. Environmental Protection Agency

These water quality characteristics determine whether the water can be discharged into local rivers and streams or used for irrigation, or must be treated or specially disposed of. Treatment can include evaporation ponds or processing the water to reduce its salinity. This complex issue includes the volume of water being produced, the rate of flow of the streams (e.g., ephemeral or perennial), and the compositional characteristics of the water.

EPA regulates discharges associated with offshore oil and gas activities on the outer continental shelf under the National Pollutant Discharge Elimination System (NPDES) program. Issued permits include Clean Water Act requirements, as well as EPA's guidelines for determining the degradation of marine waters. In addition, new source discharges are subject to provisions of the National Environmental Policy Act.

Waste Generation and Management

After produced water, nonhazardous solid wastes are the second-largest category of wastes resulting from E&P operations. These wastes contain mud, rock fragments, and cuttings from the wellbore, as well as chemicals added to improve drilling-fluid properties. Drilling fluids are used to control downhole pressure, lubricate the drill bit, condition the drilled formations, provide hydraulic pressure to aid drilling, and remove cuttings from the wellbore. Drilling fluid is pumped down the drill pipe and circulated back to the surface where the rock cuttings are removed and the drilling fluid is recirculated.

Devon Increasing Its Water Conservation Efforts

Devon Energy Corporation, WY, is deploying mobile recycling technology to reclaim wastewater produced from gas well completions in the Barnett Shale field. Recycling units treat up to three-quarters of a million gallons of water per day, removing hydrocarbons, dissolved salts, and other impurities, and allowing reuse of 85% of the water. Devon uses freshwater produced from coal bed natural gas wells to create lakes and ponds suitable for wildlife and livestock. Devon received the Wyoming Game and Fish Department's Coal Bed Methane Natural Resource Stewardship Award in 2002 and the Department's Industry Reclamation and Wildlife Stewardship Award in 2004.[15]

Table 5 shows estimated amounts of drilling wastes in Region 8 in 2002.[16] Oil and gas companies can minimize drilling wastes and their environmental impacts through recycling and reuse of certain drilling byproducts, the use of nontoxic drilling fluids, and the employment of a closed-loop drilling fluid system to manage fluid wastes. Potential groundwater contamination from drilling fluids and the amount of area used for disposal of such wastes are also important impacts.

The industry uses water-based and oil-based drilling fluids. Drilling fluids typically are stored at the well site in lined reserve pits or closed-loop systems, depending upon geologic and hydrologic conditions and state requirements. Used drilling fluids typically are disposed of in injection wells or are reformulated and reused. Cuttings typically are collected and stored in lined pits and may be buried onsite (after dewatering), landfilled, or used in agricultural applications depending upon geologic and hydrologic conditions and individual state requirements. Treated drill cuttings have been used beneficially as fill material; daily cover material at landfills; and aggregate or filler in concrete, brick, or block manufacturing. Construction applications for drill cuttings include use in road pavements, asphalt, and in manufacturing cement.

TABLE 5

Estimated Drilling Wastes 2002

State	Barrels
Colorado	6,138,174
Montana	2,741,195
North Dakota	1,484,341
South Dakota	37,451
Utah	4,533,724
Wyoming	10,834,600
Total	25,769,484

Source: U.S. Environmental Protection Agency

Other E&P wastes include:

- **Oily soil:** Soil contaminated with oil, usually resulting from equipment leaks and spills.
- **Tank bottoms:** Heavy hydrocarbons, sand, clay, and mineral scale that deposit in the bottom of oil and gas separators, treating vessels, and crude oil stock tanks.
- **Workover fluids:** Produced from well control, drilling, or milling operations, and stimulation or cleanup of an oil and gas-bearing formation.
- **Produced sand:** Sand and other formation solids built up in the wellbore in both producing and injection wells.
- **Pit and sump waste:** Heavy materials settled on the bottom of pits or sumps used to store production fluids. These materials must be removed.
- **Pigging waste:** Produced when pipelines are cleaned or "pigged." The waste consists of produced water, condensed water, trace amounts of crude oil, and natural gas liquids. It may contain small amounts of solids such as paraffin, mineral scale, sand, and clay.
- **Normally occurring radioactive material:** Occurs where extraction causes a concentration of naturally occurring radiation beyond normal background levels.

Petroleum Refining

Latest Environmental Statistics for Refining[17]

Energy Use: 3.1 quadrillion Btu

Emissions of Criteria Air Pollutants: 832,000 tons

Releases of Chemicals Reported to TRI: 66.1 million lbs.

Air Emissions: 42.2 million lbs.

Water Discharges: 17.7 million lbs.

Waste Disposals: 6.3 million lbs.

Recycling, Energy Recovery, or Treatment: 1 billion lbs.

Hazardous Waste Generated: 5.1 million tons

Hazardous Waste Managed: 5.1 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.*

Energy Use

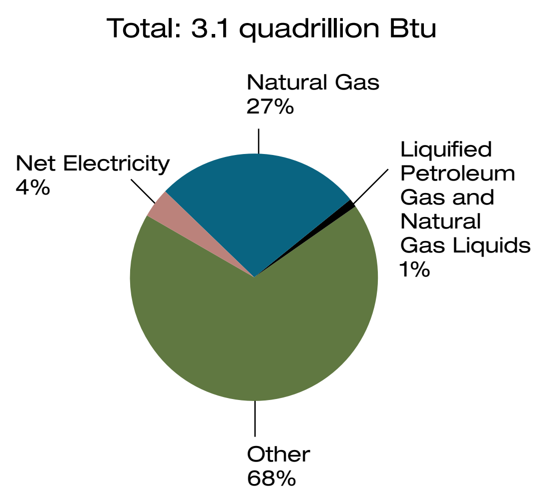
Petroleum refining operations consumed 3.1 quadrillion Btu in 2002.[18] The most energy-intensive processes include distillation, hydrotreating, alkylation, and reforming.[19] After removing salt content from the crude oil feedstock, refiners use atmospheric or vacuum distillation to separate components with varying boiling points. They then restructure the hydrocarbon molecules. Processes such as hydrotreating remove various constituents (e.g., sulfur, nitrogen, and heavy metals) to produce cleaner burning products. Finally, refiners blend the previously distilled fractions of oil into finished products.

Various factors influence the energy required to refine petroleum, including individual product specifications. For example, certain markets require particular blends, or "boutique" fuels. Under the Clean Air Act (CAA), State Implementation Plans may specify using cleaner burning fuels in select locations. Producing those custom fuels generally requires significant energy inputs into the refining process. In addition, national requirements such as those in ultra-low sulfur diesel fuel standards require significant amounts of energy to reduce the sulfur content within the crude feedstock.

Higher sulfur crude oil is increasingly a primary feedstock for refiners, and that trend is likely to increase in the coming decade and beyond, given the relative availability and affordability of these inputs. In response, U.S. refiners have invested in technology to remove sulfur more efficiently. These investments will also enable refiners to meet tightening fuel specification standards to improve air quality.[20]

FIGURE 1

Fuel Use for Energy 2002



Notes:
1. Other is primar ly from refinery gases, generation from renewables and net steam (the sum of purchases, generation from renewables, and net transfers).
2. Net electricity is an estimation of purchased power and power generation onsite.

Source: U.S. Department of Energy

Refinery fuel gas (also called still gas), catalyst coke, and natural gas are the primary fossil fuels consumed by refiners, as shown in Figure 1.[21] Refinery fuel gases, represented by "other" in the figure, result from various petroleum refinery processes such as crude oil distillation, cracking, reforming, and treating. These gases are collected and processed to recover propane or other light hydrocarbons. Refiners then remove sulfur and nitrogen compounds. This cleaner gas is a mixture of CH_4, ethane, and lesser amounts of hydrogen and light hydrocarbons with trace amounts of ammonia and H_2S.

For steam production, petroleum coke, resulting from the coking process, is a free fuel of choice. Petroleum coke, primarily from the fluid catalytic cracking unit (FCCU), is burned continuously to regenerate the FCCU catalyst, with the heat of combustion captured in a steam boiler. The main supplemental fuel for steam generation is natural gas.

Some refineries are major cogenerators of steam and electricity. Cogeneration, or combined heat and power (CHP), increases energy efficiency through onsite production of thermal energy and electricity from a single fuel source. As a result of cogeneration, purchased electricity (primarily used to power machines) is not as significant a source of indirect emissions attributed to petroleum refining as it is in other energy-intensive industries that do not produce their own electricity.

Other factors have influenced efficiency gains in refining plants. Consolidation has resulted in an industry dominated by a relatively small number of large, vertically integrated companies operating multiple facilities.[22] A result of this consolidation was the closing of smaller, less efficient plants over some time. Refineries have maintained a utilization of capacity between 90% and 95% between 1996 and 2005, compared to a rate of about 65% in the early 1980s.[23]

ExxonMobil Decision Tools for Increased Efficiency

In 2000, ExxonMobil developed its Global Energy Management System for energy conservation. Since then, the company's Baton Rouge Refinery has implemented a program for steam trap and steam leak repair, heat exchanger monitoring, and furnace air pre-heater upgrades, improving the refinery's energy efficiency by 12%. In addition, Exxon has achieved reductions in CO_2 and NO_X emissions, improved flare system reliability, increased capacity, and enhanced plant-wide reliability. The refinery received EPA's ENERGY STAR Award for these improvements.[24]

Air Emissions

Air emissions from petroleum refining include CAPs, GHGs, and chemicals reported to TRI. In general, the "toxic chemicals" tracked by TRI are found in the raw materials and fuels used in the refining process, and can be generated in byproducts or end products. CAPs and GHGs are generated as combustion byproducts from onsite combustion of fuels.

Air Emissions Reported to TRI

In 2005, 163 facilities[25] in the petroleum refining industry reported 42.2 million lbs. of absolute air emissions to TRI. Between 1996 and 2005, TRI-reported air emissions declined by 31%, as shown in Figure 2a. When normalized by crude oil inputs into refineries, air emissions decreased by 36% over the 10 years, as shown in Figure 2b.[26]

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.

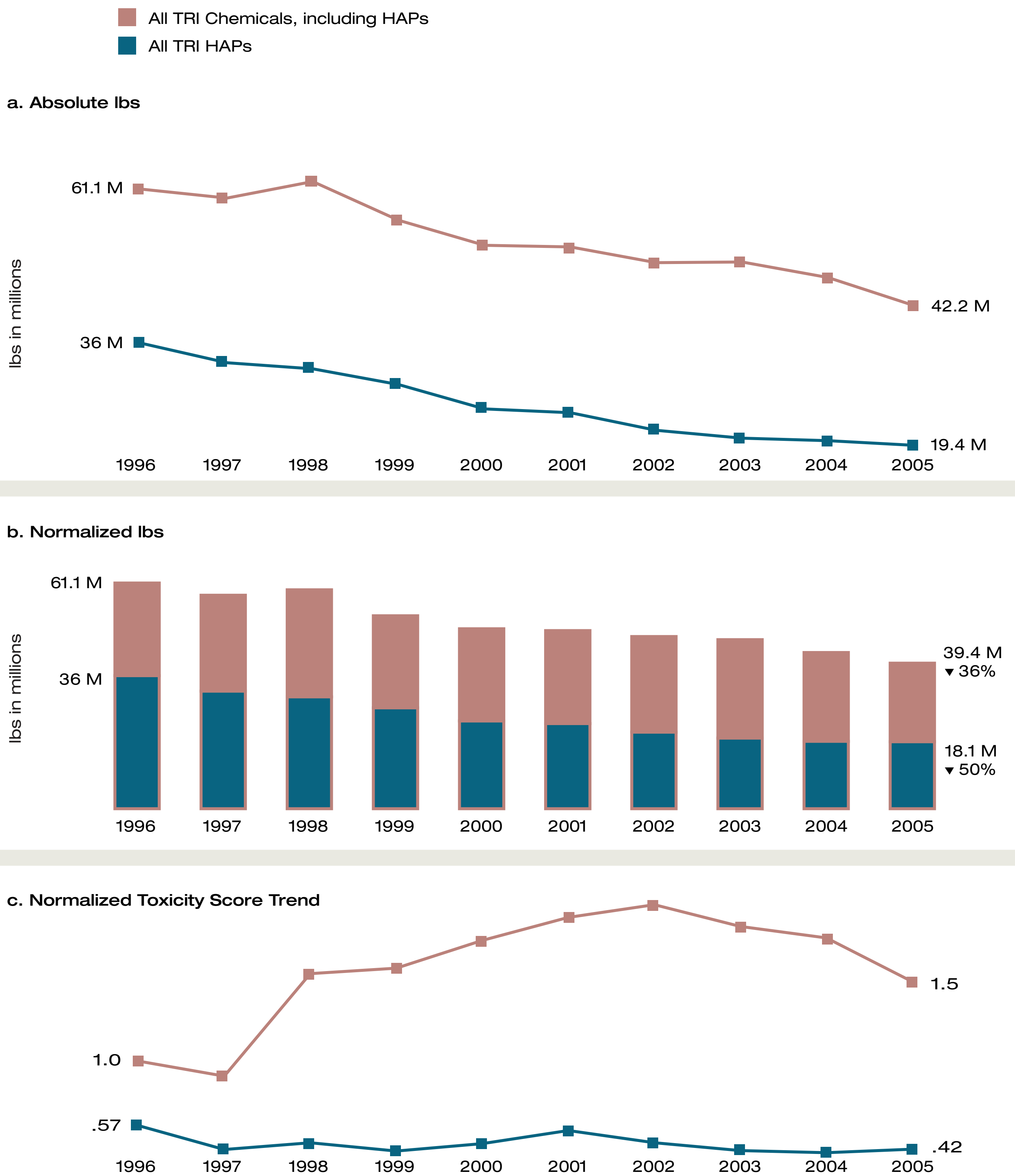
Data are not reported to TRI in sufficient detail to distinguish which forms of certain chemicals within a chemical category are being emitted. For chemical categories such as chromium, the toxicity model conservatively assumes that chemicals are emitted in the form with the highest toxicity weight (e.g., 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. As shown in Figures 2b and 2c, while the normalized reported lbs. of TRI emissions to air decreased 36% since 1996, the normalized Toxicity Score increased overall by 50%. Sulfuric acid, which has a relatively high toxicity weight, drove the Toxicity Score over the 10-year period and accounted for approximately three-quarters of the 2005 Toxicity Score. Sulfuric acid resulting from petroleum refinery operations is related to sulfur dioxide (SO_2) emissions. The presence of sulfur compounds in many refinery processes, together with high temperatures, can result in the formation and release of sulfuric acid. Decreases in refinery SO_2 emissions, then, result in corresponding decreases in the generation of sulfuric acid.

The TRI list of toxic chemicals includes all but six of the HAPs regulated under the CAA. Refinery processes emit a variety of organic, inorganic, and metal HAPs. Process vents, storage vessels, and wastewater streams emit organic HAPs, accounting for most of the total mass of HAP emissions from petroleum refineries. Other sources of HAP emissions are loading racks, marine tank vessel loading operations, and equipment leaks. In absolute pounds, HAPs accounted for 46% of the TRI chemicals emitted to air and 28% of the Toxicity Score in 2005. Between 1996 and 2005, the trend for HAP emissions follows the same declining trend as for all TRI air emissions.[27]

FIGURE 2

Air Emissions Reported to TRI 1996–2005



Note:
Normalized by annual crude oil inputs into refineries.

Sources: U.S. Environmental Prote tion Agency, U S Department of Energy

Table 6 presents the top TRI-reported chemicals emitted to air by petroleum refineries in 2005, 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.

1) Absolute Pounds Reported. Ammonia and sulfuric acid were the top-ranked chemicals based on the pounds of each chemical emitted to air in 2005.
2) Percentage of Toxicity Score. Sulfuric acid was the top-ranked chemical based on Toxicity Score.
3) Number of Facilities Reporting. Benzene and toluene were the most frequently reported chemicals, with almost all the TRI filers in the sector reporting emissions of these chemicals.

The CAA requires refineries to implement a Leak Detection and Repair (LDAR) program to monitor and fix equipment leaking fugitive emissions. In 1997, API commissioned a study of 11.5 million refinery components. The study showed more than 90% of controllable fugitive emissions are from about 0.1% of all components. Analyses also indicated that "Smart LDAR" programs focused on finding and repairing these few high-leak areas could result in significant improvements in environmental performance.

Some Smart LDAR techniques use emerging optical imaging technologies to target significant leakers, with remote sensing and real-time detection capabilities to scan process areas containing potential leaks. Significant leaks are then detected on the spot using infrared light, facilitating rapid repairs and minimizing potential environmental, safety, and health impacts.

TABLE 6
Top TRI Air Emissions 2005

Chemical	Absolute Pounds Reported[1]	Percentage Toxicity Score	Number of Facilities Reporting[2]
Ammonia	8,574,000[3]	1%	107
Benzene[4]	2,099,000	1%	152
Chlorine	146,000	6%	36
Chromium	4,000	2%[5]	20
Ethyl Benzene	624,000	<1%	145
N-Hexane	4,146,000	<1%	147
Nickel	45,000	8%	65
Polycyclic Aromatic Compounds	67,000	5%	129
Propylene	3,121,000	<1%	113
Sulfuric Acid	8,015,000	70%	67
Toluene	3,785,000	<1%	150
Xylene	2,652,000	<1%	147
Percentage of Sector Total	79%[6]	93%[7]	98%[8]

Notes:
1. Total sector air releases: 42 million lbs.
2. 163 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. *Italics* indicate a hazardous air pollutant under section 112 of Clean Air Act.
5. 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.
6. Chemicals in this list represent 79% of the sector's air emissions.
7. Chemicals in this list represent 93% of the sector's Toxicity Score.
8. 98% of facilities reported emitting one or more chemicals in this list.

Source: U.S. Environmental Protection Agency

Criteria Air Pollutants

Table 7 shows CAP and VOC emissions from petroleum refineries for 2002.

TABLE 7
Criteria Air Pollutant and VOC Emissions 2002

	Tons
SO_2	339,000
NO_X	195,000
PM_{10}	28,000
$PM_{2.5}$	23,000
CO	145,000
VOCs	125,000

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

Source: U.S. Environmental Protection Agency

Greenhouse Gases

The combustion of fossil fuels generates direct GHG emissions from petroleum refineries, and steam production and process heating are the two processes requiring the greatest combustion. In CH_4 emissions, petroleum refiners released an estimated 28.4 million metric tons of CO_2 equivalent in 2005, an increase of 7% since 1996.[28] Within refineries, vented emissions account for about 87% of the GHG emissions, while fugitive and combustion emissions account for 6% and 7% respectively. Most fugitive CH_4 emissions are leaks from the fuel gas system.[29]

In response to the U.S. Department of Energy's Climate VISION program, API began a Climate Challenge in which member refineries have committed to improve in energy efficiency 10% by 2012. Representative activities include developing GHG emissions management plans, setting numerical targets for improving energy efficiency, and reducing emissions. Specific strategies include expanding cogeneration, gasifying refinery residuals for use as fuel, reducing venting and flaring as well as fugitive methane emissions, conducting research and development into carbon sequestration and storage, deploying renewable energy technologies, and improving methods for tracking GHG emissions.

Water Use and Discharges

Petroleum refiners use 1-2 billion gallons of water daily, principally for process cooling systems.[30] Because they use relatively large volumes of water, refineries are often located near water sources (e.g., beside riverbanks and other shoreline locations).

Refinery operations generate process wastewater as well as surface water runoff. Wastewater characteristics and quantities differ among facilities and are driven by individual petroleum refining configurations. Processes to refine heavy crude, for example, tend to generate significant amounts of ammonia and suspended solids. In 2005, 121 refineries reported water discharges of TRI chemicals totaling 17.7 million pounds. This was a 52% increase in reported absolute pounds since 1996, and a 42% increase overall, when normalized by crude oil inputs to refineries. Nitrate compounds, reported by 62 facilities, and ammonia accounted for almost all (97%) of the reported discharges.[31]

Wastewater from petroleum refining typically requires multiple steps to remove contaminants, recover product, and recycle process fluids prior to discharge. Refiners often lessen discharge quantities, treatment burdens, and associated costs by separating the various waste streams of cooling and process water, sanitation and sewage, stormwater, and other streams. In addition to being regulated for direct discharges and discharges to Publicly Owned Treatment Works, refineries with materials exposed to precipitation are regulated for stormwater runoff, sometimes under a general permit that provides sector-specific limits on pollutants such as zinc, nickel, lead, ammonia, nitrates, and total suspended solids.

Waste Generation and Management

Wastes from petroleum refining operations can be generated from process-related functions or other activities, such as pollution prevention (e.g., control devices) or remediation of contamination. Refineries also generate wastes from handling petroleum products and treating wastewater. Typical refinery wastes are sludges, spent caustics, spent process catalysts, filter clay, and incinerator ash.

Hazardous Waste Management

In 2005, the sector reported generating 5.1 million tons of hazardous waste. The hazardous waste management method most utilized in refining was disposal, which accounted for 84% of wastes managed in 2005.

Waste Management Reported to TRI

In 2005, refineries reported a total of 1 billion absolute pounds of chemicals released, disposed, or managed through treatment, energy recovery, or recycling. This was a 22% decrease in the reported amount of waste managed since 1996, when normalized by crude oil inputs to refineries.

Figure 3 shows how this waste was managed. In 2005, 54% was treated, 23% was recovered for energy use, and 17% was recycled, while 6% of TRI-reported waste was disposed or released. Energy recovery appeared to be the principal waste management method early in the decade; treatment was the predominant management method in recent years, accounting for 54% of the total pounds of TRI chemicals managed in 2005. Flaring is presently a major means of onsite treatment at many petroleum refineries; the industry is addressing associated GHG emissions under API's Climate Challenge.

In 2005, refineries reported that 6.3 million lbs. of TRI chemicals were disposed to land or transferred to offsite locations for disposal. Ammonia, zinc, and nickel disposals accounted for almost half of the total pounds disposed, as shown in Table 8. Most petroleum refinery TRI hazardous waste disposals utilized underground injection, although 43% relied upon landfill disposal.[32]

TABLE 8

Top TRI Disposals 2005

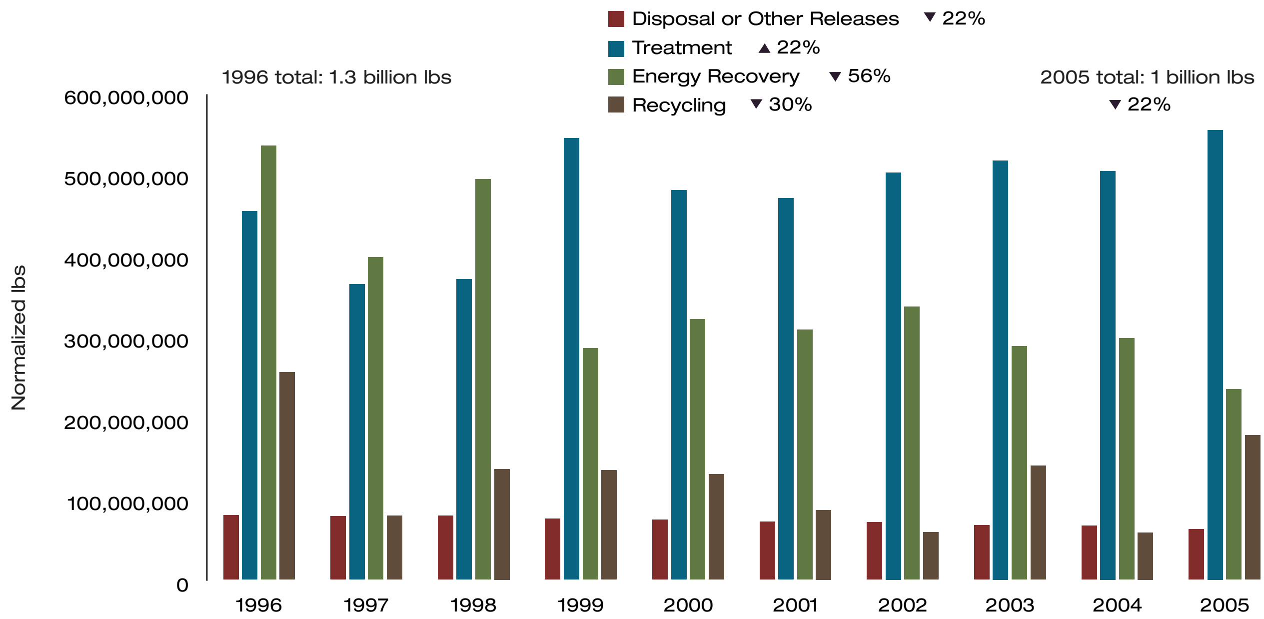
Chemical	Absolute Pounds Reported[1]	Number of Facilities Reporting[2]
Ammonia	1,337,000[3]	29
Asbestos (Friable)	730,000	2
Benzene	107,000	98
Ethylbenzene	22,000	100
Lead	187,000	111
Molybdenum Trioxide	440,000	32
Nickel	817,000	64
Toluene	127,000	101
Xylene (Mixed Isomers)	105,000	104
Zinc	826,000	32
Percentage of Sector Total	74%[4]	81%[5]

Notes:
1. Total sector disposals: 6.3 million lbs.
2. 163 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 74% of the sector's disposals.
5. 81% of facilities reported disposals of one or more chemicals in this list.

Source: U.S. Environmental Protection Agency

FIGURE 3

TRI Waste Management 1996–2005



Notes:
1. Normalized by annual crude oil inputs into refineries.
2. Disposal or other releases include air releases, water discharges, and land disposals.

Sources: U.S. Environmental Protection Agency, U.S. Department of Energy

Additional Environmental Management Activities for E&P and Refining

Several Oil & Gas sector environmental initiatives include both E&P and refining operations. For instance, EPA's Natural Gas STAR program engages all segments of the natural gas industry—production, gathering, processing, transmission, and distribution—to identify and implement technologies and practices to reduce emissions of CH_4. Natural Gas STAR identifies best management practices (BMPs) selected through a collaborative process involving EPA and natural gas industry advisers. The BMPs identify areas of operation where emissions can be reduced cost effectively.

In 1999, Natural Gas STAR producer partners reported saving 17.4 Bcf of CH_4, representing emissions that were prevented and natural gas that was retained in the system to be sold. EPA expanded the program in 2000 to include companies that gather and process natural gas. In 2005, partners reported more than 33.2 Bcf of CH_4 emissions reductions.[33]

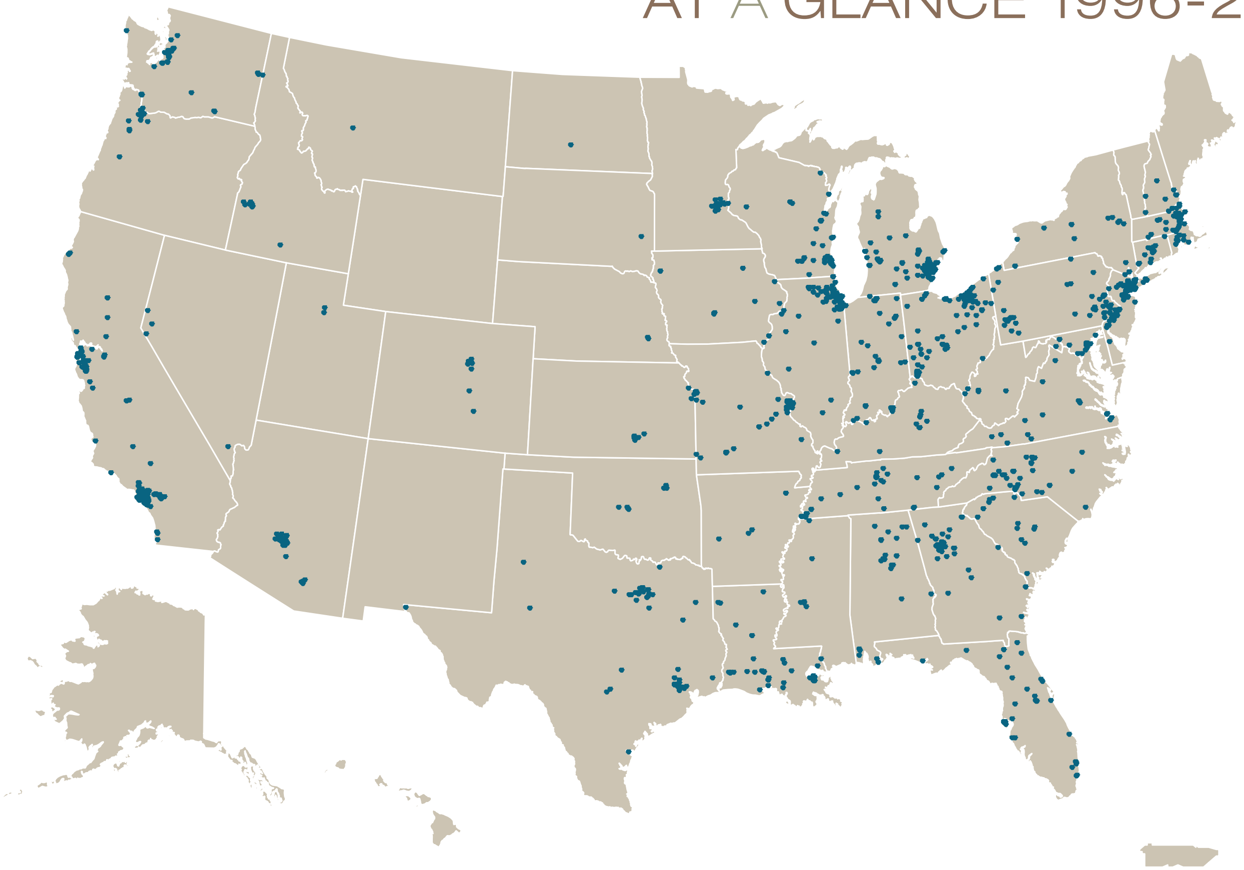
The American Exploration & Production Council (AXPC) is an official endorser of the Natural Gas STAR program, in which 16 AXPC member companies actively participate. Implementing Natural Gas STAR–recommended technologies and management practices, these AXPC member companies collectively reduced CH_4 emissions by 103 Bcf, representing savings of $720 million.

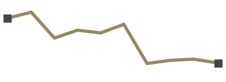
Marathon's Multi-Media Environmental Management Approach

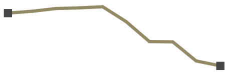
Marathon Petroleum Company–Louisiana Refinery Division in Garyville, LA, is the last petroleum refinery built in the United States (1976) and the only refinery in EPA's Performance Track program.[34] In 2005, Marathon-Garyville announced plans for a major expansion to add 185,000 barrels per stream day of crude oil capacity. During the permitting process, Marathon agreed to reduce NO_x emissions beyond Best Achievable Control Technology requirements and to impose CO limits below burner manufacturer specifications. Marathon also installed four real-time ambient air monitoring stations and plans to upgrade the wastewater treatment system to ensure no additional NPDES permit allocations will be necessary. Marathon already has an onsite wastewater treatment plant that uses water from the adjacent Mississippi River and returns it to the river cleaner than it was when withdrawn.[35]

PAINT & COATINGS

AT A GLANCE 1996-2005[1]







Latest Environmental Statistics[2]

Emissions of Criteria Air Pollutants: 10,300 tons

Releases of Chemicals Reported to TRI: 5.3 million lbs.

Air Emissions: 4 million lbs.

Water Discharges: 9,900 lbs.

Waste Disposals: 1.3 million lbs.

Recycling, Energy Recovery, or Treatment: 116.3 million lbs.

Hazardous Waste Generated: 146,000 tons

Hazardous Waste Managed: 148,000 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 Paint & Coatings sector[3] manufactures a variety of products that preserve, protect, and beautify the objects to which they are applied. The main types of Paint & Coatings products include:

- **Architectural coatings**—interior and exterior paints, primers, sealers, and varnishes.
- **Industrial coatings**—factory-applied to manufactured goods during production.
- **Special-purpose coatings**—aerosol paints, marine paints, high-performance coatings, and automotive refinish paints.
- **Allied paint products**—putties, paint and varnish removers, paint thinners, pigment dispersions, paint brush cleaners, and frit (ground glass or glaze).

Energy Use

In 2002, the Paint & Coatings sector purchased about 1.6 billion kilowatt hours of electricity for heat and power, which represented well under 1% of the total quantity of electricity purchased for heat and power by U.S. manufacturers.[4] Data on fossil fuel consumption are not currently available.

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 used as formulation ingredients in the manufacturing process.

Air Emissions Reported to TRI

In 2005, 441 facilities in this sector reported 4 million lbs. of absolute air emissions to TRI. Between 1996 and 2005, absolute TRI-reported air emissions declined by about 57%, as shown in Figure 1a. When normalized by the value of shipments VOS over this period, air emissions declined by about the same amount, as seen in Figure 1b. The normalized and absolute data are similar because production remained relatively steady over the period.

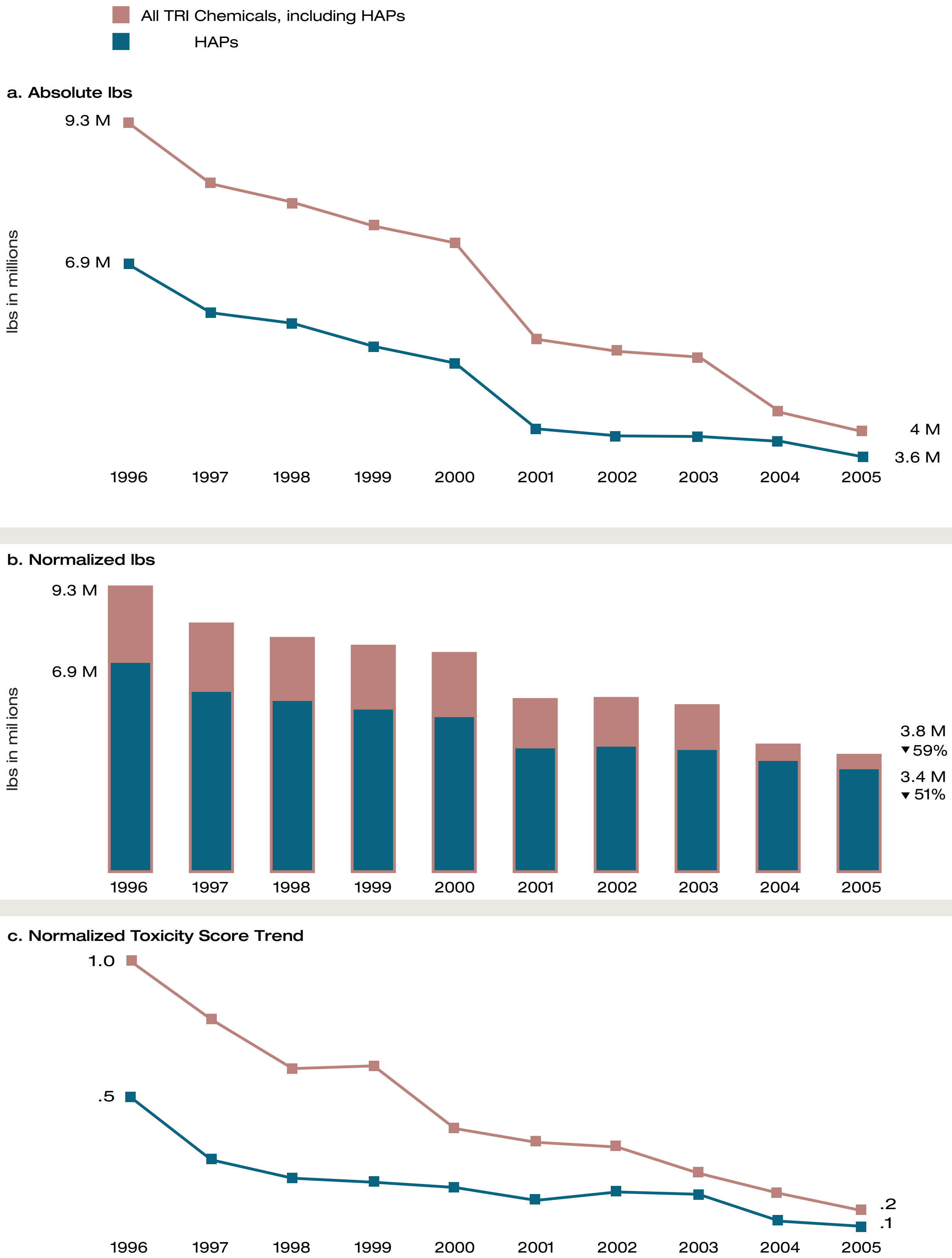
To consider toxicity of air emissions, EPA's Risk-Screening Environmental Indicators (RSEI) model assigns every TRI chemical a relative toxicity weight, then multiplies the pounds of media-specific releases (e.g., pounds of mercury released to air) by a chemical-specific toxicity weight to calculate 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

FIGURE 1

Air Emissions Reported to TRI 1996–2005



Note:
Normalized by annual value of shipments.

Sources: U.S. Environmental Protection Agency, U.S. Department of Commerce

in Figure 1c. The sector's total Toxicity Score, normalized by value of shipments, declined by more than 80% from 1996 to 2005.[5]

The TRI list of toxic chemicals includes all but six of the hazardous air pollutants (HAPs) regulated under the Clean Air Act. In absolute pounds, HAPs accounted for most (90%) of the sector's pounds of air emissions reported to TRI in 2005; therefore, trends in HAP emissions showed very similar declines to the trends in air emissions for all TRI chemicals when based on either pounds reported or the Toxicity Scores.[6]

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.

1) Absolute Pounds Reported. Xylene and toluene, organic solvents used as carriers in paints, were the highest-ranking chemicals based on the pounds of each chemical emitted to air in 2005.

TABLE 1

Top TRI Air Emissions 2005

Chemical	Absolute Pounds Reported[1]	Percentage Toxicity Score	Number of Facilities Reporting[2]
1,2,4-Trimethylbenzene	142,000	14%[3]	113
Certain Glycol Ethers	232,000	7%	193
Chromium	860	24%[4]	29
Diisocyanates	140	8%[5]	10
Ethyl Benzene[6]	215,000	<1%	136
Methanol	408,000	<1%	68
Methyl Isobutyl Ketone	189,000	<1%	114
Nickel	1,400	16%	6
Toluene	859,000	<1%	216
Xylene (Mixed Isomers)	1,140,000	7%	275
Percentage of Sector Total	80%[7]	75%[8]	82%[9]

Notes:
1. Total sector air releases: 4 million lbs.
2. 441 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. The toxicity score for chromium was based on the conservative assumption that all of the chromium air emissions by TRI reporting facilities in the Paint and Coatings sector are hexavalent chromium. EPA's National Emissions Inventory estimates that only 25% of the chromium emissions from this sector are hexavalent chromium, and the balance are trivalent chromium, which has a substantially lower toxicity weight.
5. The toxicity score for diisocyanates was based on the conservative assumption that all of the diisocyanates emitted to air by TRI reporting facilities in the Paint & Coatings sector are hexamethylene diisocyanate. Preliminary analysis indicates that methylene diphenyl diisocyanate, and other diisocyanate chemicals that have lower toxicity weights, may constitute the majority of the reported diisocyanate emissions from this sector.
6. *Italics* indicate a hazardous air pollutant under section 112 of Clean Air Act.
7. Chemicals in this list represent 80% of the sector's air emissions.
8. Chemicals in this list represent 75% of the sector's Toxicity Score.
9. 82% of facilities reported emitting one or more chemicals in this list.

Source: U.S. Environmental Protection Agency

2) Percentage of Toxicity Score. The top chemicals based on Toxicity Scores included chromium, nickel, and 1,2,4-trimethylbenzene.

3) Number of Facilities Reporting. Xylene and toluene were also the most frequently reported chemicals, with approximately half of the TRI-reporting facilities in the sector reporting air emissions of each of these chemicals.

Criteria Air Pollutants

Table 2 shows CAP and volatile organic compound (VOC) emissions from the sector for more than 340 manufacturers in 2002.[7] VOCs emitted during the production and use of the sector's products have the largest impact on ambient air quality of any of the pollutants listed in Table 2. VOC emissions result primarily from the use of organic solvents to formulate paint and coating products.

TABLE 2

Criteria Air Pollutant and VOC Emissions 2002

	Tons
SO_2	50
NO_X	400
PM_{10}	600
$PM_{2.5}$	400
CO	3,000
VOCs	6,000

Notes:
1. PM_{10} includes $PM_{2.5}$ emissions.
2. The majority of CO emissions in 2002 were reported by a single fac lity.

Source: U.S. Environmental Protection Agency

Recent regulatory developments and the continuing market trend toward water-based coatings, powder coatings, ultraviolet cure coatings, and other lower-emitting coating products have contributed to reductions in VOC emissions from production in recent years. Still, VOC emissions from the sector's production activities continue to be dwarfed by VOC emissions that occur at the point of use. In 2002, Paint & Coatings manufacturers emitted 6,000 tons of VOCs, while VOC emissions resulting from the use of paint and coating products was over 2 million tons.[8]

Water Use and Discharges

Water serves as a major formulation ingredient in many of the sector's products. Water-based products include many paints, aerosols, inks, and coatings. Additionally, many types of manufacturing cleanup processes require water. The sector's wastewater is usually discharged to Publicly

US EPA ARCHIVE DOCUMENT

Owned Treatment Works, but may also be discharged directly to waterways, necessitating a National Pollutant Discharge Elimination System permit.

TRI tracks TRI chemicals discharged to water from those facilities in the sector subject to TRI reporting requirements. In 2005, 39 facilities in this sector reported water discharges of TRI chemicals totaling 9,900 lbs.[9] This quantity represents a decline of almost 50% between 1996 and 2005.[10] In 2000, EPA randomly surveyed 292 Paint & Coatings facilities to collect data for its Paint Production Waste Listing Determination.[11] EPA extrapolated from this survey to estimate that the quantity of wastewaters (both nonhazardous and hazardous) generated in 1998 from all facilities in the targeted paint manufacturing industry was approximately 15.6 million gallons.[12]

Waste Generation and Management

Wastes in the Paint & Coatings sector can be generated from process-related functions or from other activities, such as operation of pollution control devices or remediation of past contamination.

Hazardous Waste Management

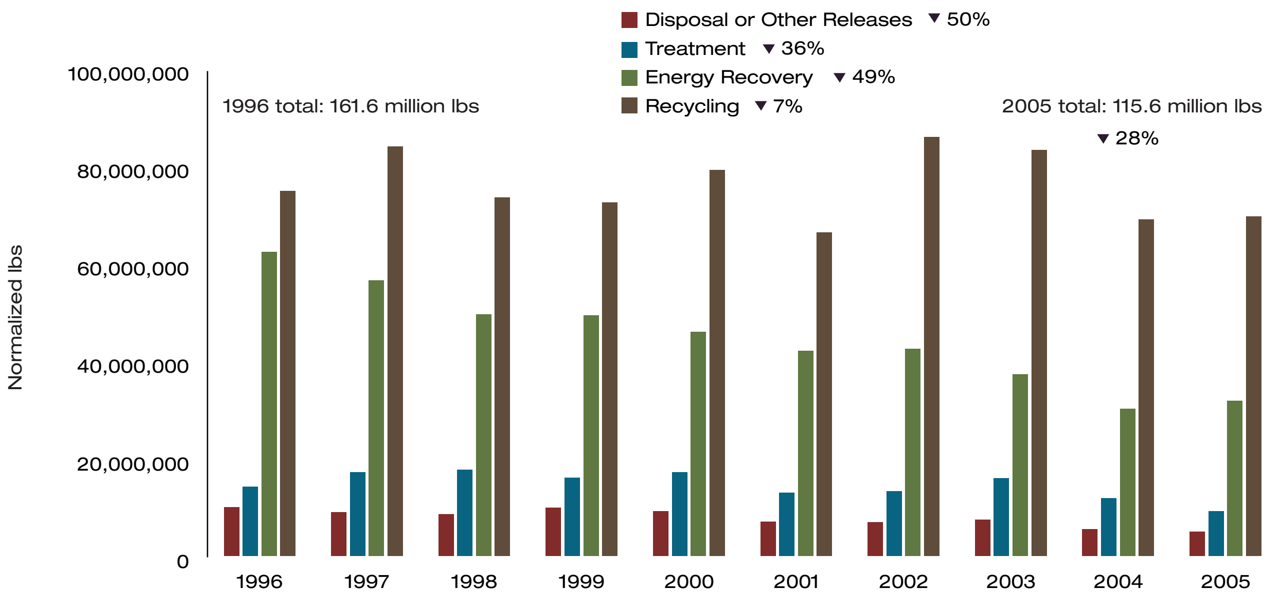
In 2005, 396 Paint & Coatings manufacturers reported to EPA's *National Biennial RCRA Hazardous Waste Report* (BR) generating 146,000 tons of hazardous waste.[13] Cleaning out equipment (e.g., cleaning out mixing tanks between batches), solvent distillation, and discarding off-spec chemicals (e.g., off-spec or out-of-date products) accounted for approximately half of the industry's hazardous waste generation. A large portion of the remaining hazardous waste generation appears to be attributable to a small number of resin or other chemical manufacturing operations that are co-located within the sector's facilities.[14] The sector reported managing 148,000 tons of hazardous waste. Most of the sector's hazardous waste, regulated by the Resource Conservation and Recovery Act (RCRA), was managed through reclamation and recovery activities (predominantly fuel blending and solvents recovery), and treatment.[15]

Waste Management Reported to TRI

In 2005, facilities in the Paint & Coatings sector reported managing 121.5 million absolute lbs. of TRI chemicals in waste. As shown in Figure 2, when normalized by annual VOS, total waste managed declined 28% between 1996 and 2005. Figure 2 also shows how the sector has managed this waste over time.[16] In 2005, 4% of the absolute pounds of TRI-reported waste was released (to air or water) or disposed, while 8% was treated, 28% was recovered for energy use, and 60% was recycled, demonstrating the importance of recycling and fuel blending (a form of energy recovery) in the sector's waste management practices.

FIGURE 2

TRI Waste Management 1996–2005



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

Sources: U.S. Environmental Protection Agency, U.S. Department of Commerce

TABLE 3

Top TRI Disposals 2005

Chemical	Absolute Pounds Reported[1]	Number of Facilities Reporting[2]
Barium	163,000[3]	20
Certain Glycol Ethers	31,000	32
Chromium	79,000	32
Copper	79,000	22
DI(2-Ethylhexyl) Phthalate	93,000	4
Ethylene Glycol	86,000	31
Lead	47,000	75
Zinc	464,000	99
Percentage of Sector Total	83%[4]	35%[5]

Notes:
1. Total sector disposals: 1.3 million lbs.
2. 441 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 83% of the sector's disposals.
5. 35% of facilities reported disposals of one or more chemicals in this list.

Source: U.S. Environmental Protection Agency

For the 1.3 million lbs. of waste that was disposed (not including releases to air or water), zinc accounted for about one-third of the pounds disposed, as shown in Table 3. Zinc and lead were the chemicals most frequently reported as disposed by the sector.[17]

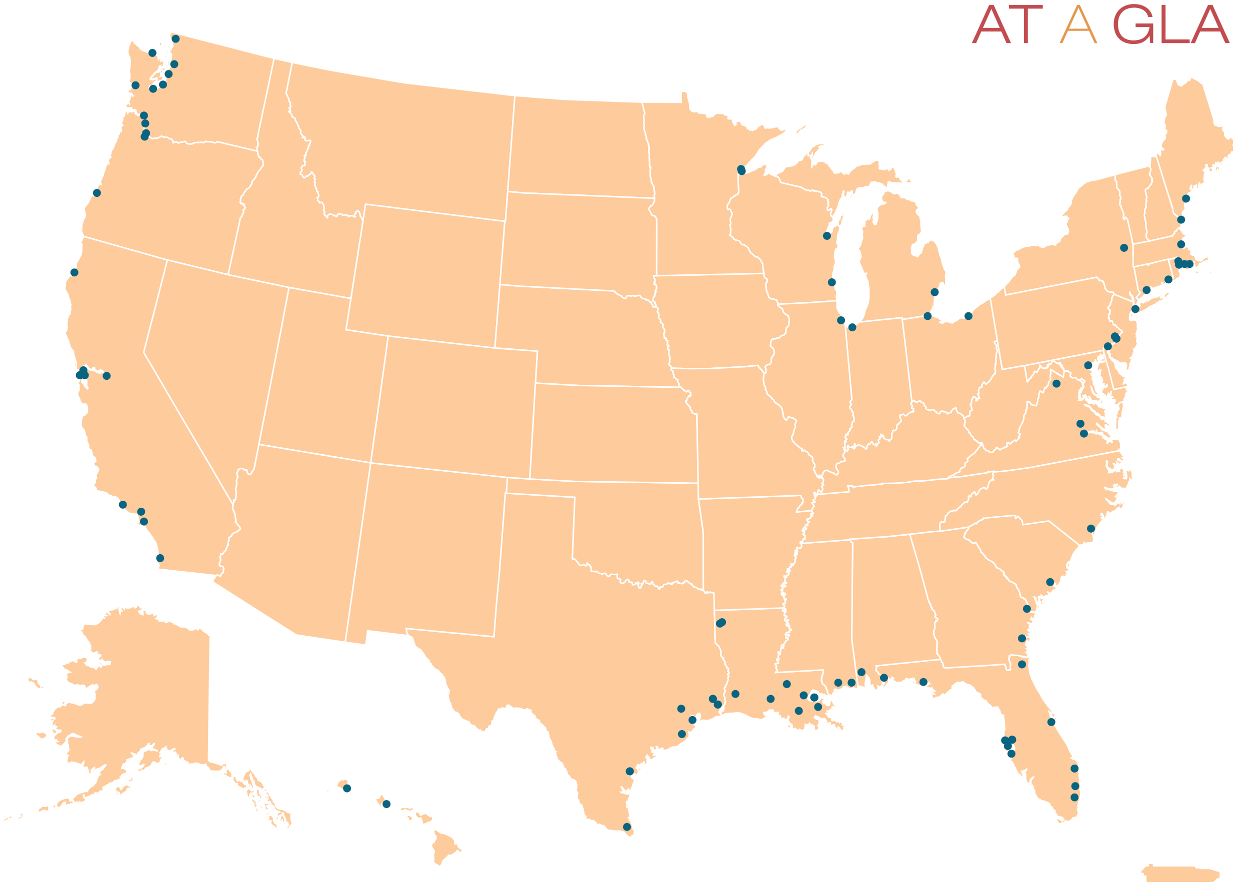
Additional Environmental Management Activities

Coatings Care® is a comprehensive stewardship program developed by the National Paint & Coatings Association (NPCA) to assist its members with integrating environmental, health, and safety (EH&S) activities into corporate planning and operations. Organizations make a commitment to Coatings Care as a required part of their membership in NPCA. Coatings Care organizes EH&S activities into five codes of management practice—Manufacturing Management, Transportation and Distribution, Product Stewardship, Community Responsibility, and Security—and NPCA provides extensive support to its members in these areas. Coatings Care integrates EH&S practices that are consistent with other industry standards, such as those found in the ISO 14000 series.[18]

In addition, since December 2003, NPCA and its members have been actively participating in the Paint Product Stewardship Initiative (PPSI), a collaborative multi-stakeholder effort to promote leftover paint management solutions that are both financially and environmentally sustainable. Unused or leftover paint is a major focus of product stewardship efforts because of its high volume in the household hazardous waste stream, its high cost to manage, and the potential for increased reduction, recovery, reuse, and recycling.[19] EPA estimates that between 6% and 16% of the household paint sold each year becomes leftover paint, with a best estimate of 10%.[20] The stakeholders have completed a $1 million joint research program and are now working to develop a new nationally coordinated system for managing leftover paint with the goal of reducing paint waste; establishing mechanisms for efficient collection, reuse, recycling, or disposal of leftover paint; and for putting in place a sustainable financing system to cover the costs of such a system.[21]

PORTS

AT A GLANCE[1]



2005: 360 public and private ports; map shows large, deep water, public port authorities

1999: 422,578 employees

2006: 507,448 employees ▲ 20%

1997: $5.3 billion in revenue

2002: $6.2 billion ▲ 16%

Latest Environmental Statistics

Because of the relative lack of sector-level data on the environmental performance of ports, this chapter relies in part on survey information that the American Association of Port Authorities (AAPA) collected in 2005 and 2007 from its U.S. members, the country's 86 largest port authorities. Thirty-eight ports completed the 2007 survey, representing a 44% response rate.[2] They represented 19 of the top 30 U.S. container ports in 2006, and 20 of the top 30 U.S. ports for total trade tonnage in 2005.[3] Although these large public ports are only one component of the U.S. port industry, they handle the majority of U.S. overseas freight. Understanding their performance is key to understanding the environmental performance of the entire sector. The chapter also highlights commitments ports are making, individually and collectively, to better understand and improve their environmental performance.

Profile

More than 360 commercial ports serve the United States with approximately 3,200 cargo and passenger handling facilities employing more than 507,000 people, contributing an estimated $1.3 trillion to the Gross Domestic Product, and generating an estimated $21.4 billion in U.S. Customs revenue.[4]

The Ports sector includes public and private marine facilities along sea coasts, on estuaries and rivers, and around the Great Lakes. Ports develop and maintain shoreside facilities for intermodal transfer of cargo between ships and other modes of transportation, such as barges, trucks, railroads, and pipelines. They may also operate other facilities, such as airports, world trade centers, and recreational facilities.

U.S. ports and waterways handle more than 2 billion tons of domestic and import/export cargo annually.[5] Ports handle 78% of all U.S. foreign trade by weight and 44% by value.[6] Forty-nine U.S. ports also have passenger cruise terminals, from which more than 9 million passengers embarked in 2006.[7]

U.S. ports are expected to experience unprecedented growth in overseas trade and continuing growth in the cruise industry. Forecasts call for a doubling in the volume of containerized cargo and in the number of cruise passengers between 2005 and 2020.[8]

Energy Use

Energy use at ports consists mainly of electricity for facility operations and fuel for vehicles and cargo-handling equipment. The most common fuel used is petroleum-based diesel, although ports are beginning to use other fuels. To reduce air emissions, some ports have switched to electric-powered cargo handling equipment, while others are using propane, liquefied natural gas (LNG), or biodiesel blends in vehicles and equipment. A few ports, including Juneau, AK, Long Beach and Los Angeles, CA, and Seattle, WA, have installed shoreside power (or "cold ironing") at some of their terminals so that oceangoing vessels can connect to the landside electric grid while at the dock rather than running their auxiliary diesel engines. The Port of Seattle has cold ironing infrastructures in place for the two berths. The Port of Oakland, CA, has successfully tested a mobile power unit that produces electricity onsite for ships at dock using LNG.[9] A 2004 study for the Port of Long Beach estimated that shoreside power would reduce nitrogen oxide (NO_X) emissions by 99% and particulate matter (PM) emissions by up to 97% per vessel, while a vessel is hotelling.[10]

Ports have some potential for fuel switching, especially if they have direct control over the diesel-powered vehicles and equipment onsite. However, even "landlord" ports, whose tenants own and operate the majority of vehicles and equipment, can influence fuel use through voluntary programs or means such as lease specifications or preferential fees when new leases are being negotiated or old leases are being renegotiated.[11]

Air Emissions

Ports have a diversity of activities and a multitude of emissions sources; there are currently no sector-level estimates of port air emissions. However, EPA is working with AAPA to encourage individual ports to prepare emissions inventories, develop and implement emission reduction strategies, and measure progress against the baseline.[12] EPA also is working with ports and other stakeholders to develop modeling tools for port-related

Increasing Use of Biodiesel

Compared to burning standard diesel, the use of biodiesel results in reductions in direct emissions of carbon monoxide (CO), PM, sulfates, volatile organic compounds (VOCs), and greenhouse gases (GHGs). In 2006, the Port of Seattle, WA, and SSA Marine, the port's largest maritime customer, switched their maintenance vehicles and container-handling equipment from standard diesel fuel to biodiesel. Another terminal operator, APL, also switched to biodiesel. Both terminal operators use B20, a blend of 20% biodiesel and 80% ultra-low-sulfur (ULSF) diesel. The port uses B99 (99% biodiesel) in its maintenance equipment. During cold periods, the port and SSA switch to lower blends of biodiesel (B50 and ULSF, respectively) to cope with gelling problems.[13] Together, the port and SSA use about 1 million gallons of fuel per year in the vehicles now powered by biodiesel.[14] Annual emissions reductions from this switch are estimated to be 2.1 tons of CO, 1.5 tons of VOCs, 0.3 ton of PM, and nearly 1,300 tons of GHGs.[15]

Increasing Use of Solar Power

The Port of New York and New Jersey East Coast Warehouse Facility at Elizabeth Port Authority Marine Terminal has been equipped with more than 5,000 flexible solar panels, covering about 37% of its roof and designed to produce more than 810,000 kilowatts (kW) of electricity. The Ports of Oakland and Los Angeles, CA, both recently committed to deploying solar power systems onsite to supply electricity for their operations. In December 2007, the Port of Los Angeles agreed to construct a 10-megawatt solar photovoltaic system as part of the mitigation package for a major expansion of one of the port's container terminals. The port expects the system to offset nearly 17,000 metric tons of GHG emissions annually.[16] In November 2007, the Port of Oakland arranged for deployment of a new 756-kW solar photovoltaic power system on its property, which it expects to generate more than 1 million kW hours of electricity annually. The port expects the system to reduce its GHG emissions by 850 metric tons per year.[17]

air emissions. Many of the nation's ports are located in areas that do not meet EPA National Ambient Air Quality Standards for ozone (eight-hour standard) and $PM_{2.5}$.[18]

Diesel Emissions

The primary sources of air emissions from the Ports sector are diesel engines, which are used in ships, trucks, trains, cargo-handling equipment, and harbor craft. Diesel emissions include PM, NO_X, sulfur oxides (SO_X), hazardous air pollutants, and GHGs. As shown in Table 1, more ports are taking steps to quantify and reduce air emissions.

TABLE 1

Emission Reduction Strategies Reported by Ports

	2005	2007
Have an emissions inventory	23%	42%
Have an emissions control or reduction strategy	25%	37%
Are using low-emission fuels	29%	47%
Have implemented program for diesel retrofits or replacements	NA	34%
Are using alternative energy sources	NA	26%

Source: American Association of Port Authorities

As shown in the table, some ports are reducing emissions from existing diesel engines through engine replacements or retrofits. To assist with this effort, EPA worked with AAPA and other stakeholders to create Clean Ports USA. Launched in 2004 as part of EPA's National Clean Diesel Campaign, this incentive-based program is designed to reduce diesel emissions from existing vehicles and equipment at ports. Clean Ports USA has funded 11 port-related projects with $1.9 million in federal dollars and $2.5 million in matching funds provided by partners.[20] Ports, EPA, and other stakeholders also are collaborating through five regional partnerships that are encouraging voluntary diesel emissions reductions.

Ports With Emissions Inventories[19]

Anacortes (WA)
Baltimore (MD)
Coos Bay (OR)
Corpus Christi (TX)
Everett (WA)
Houston (TX)*
Lake Michigan Ports
Long Beach (CA)*
Los Angeles (CA)*
Lower Mississippi River Ports (LA)
New York/New Jersey (NY/NJ)*
Oakland (CA)*
Olympia (WA)
Philadelphia and Delaware River Ports (PA, DE)
Port Angeles (WA)
Portland (OR)
San Diego (CA)
Savannah (GA)*
Seattle (WA)*
South Carolina State Port Authority (SC)*
South Louisiana (LA)
Tacoma (WA)*
Tampa (FL)
Virginia Port Authority (VA)*

Note: * = top 10 U.S. container ports in 2006

Source: U.S. Environmental Protection Agency

Ports are reducing diesel emissions from trucks by implementing operational changes that reduce waiting times and the number of truck trips. One such change is the establishment of common pools for the chassis that are used to haul intermodal containers. Most chassis are owned and maintained by individual terminal operators or shipping lines, which typically do not allow them to be used with another carrier's containers. Requiring drivers to switch chassis can add up to one hour per trip, increasing fuel use and air pollution. Chassis pools reduce the number of truck movements and the amount of idling, resulting in lower emissions and greater productivity. In 2004, the Virginia Port Authority established a chassis pool at the Port of Virginia, which became the first U.S. port to achieve 100% participation from the port's shipping lines.[21] In the Port of New York and New Jersey, the Maher Container Terminal at the Elizabeth Port Authority Marine Terminal utilizes a 31-acre chassis pool yard. Ports also are

San Pedro Bay Ports Clean Air Action Plan

In November 2006, the Ports of Los Angeles and Long Beach, CA, adopted a comprehensive strategy to reduce air emissions from freight transportation in a region that has some of the worst air quality in the nation. Their goal is to reduce emissions of PM, SO_X, and NO_X (a precursor to smog) from port-related operations by 45% or more within five years.[22] By the fifth year, the ports plan to achieve annual emission reductions of 1,200 tons of PM, 12,000 tons of NO_X, and 8,900 tons of SO_X.[23] Under the plan, the ports will:

- Phase out the oldest (and therefore dirtiest) trucks servicing the ports,
- Equip all major terminals with shoreside electricity for vessels at berth,
- Require ships to use low-sulfur fuels and reduce speeds when entering or leaving the harbor region, and
- Replace or retrofit all switching locomotives and cargo-handling equipment to meet EPA's toughest emissions standards for new equipment.

The ports are actively implementing the plan. For example, all diesel-powered Class 1 switcher and helper locomotives entering the Port of Los Angeles have been using ULSF diesel fuel since the beginning of 2007.[24] The plan built upon previous efforts by the ports. For example, between 2001 and 2005, the Port of Los Angeles reduced emissions of PM, SO_X, and NO_X by 17% to 27% on a per-container basis.[25]

South Carolina State Ports Authority (SCSPA)

Even though the southeastern coast of the United States is currently in attainment with federal air quality standards, SCSPA developed a voluntary air quality program to minimize air emissions from existing terminals and a new container terminal it is building. The port committed to activities such as conducting an emissions inventory of existing facilities, funding a PM monitoring station, and including clean air guidelines in construction bid documents.[26] SCSPA also switched to ULSF diesel in September 2007, three years ahead of federal requirements.[27] Emissions reductions over those three years will be an estimated 1,100 pounds of NO_X and 30 pounds of SO_X.[28]

Northwest Ports Clean Air Strategy

The Northwest Ports Clean Air Strategy is a joint effort of the Ports of Seattle and Tacoma, WA, and Vancouver Fraser Port Authority (British Columbia) to reduce maritime and port-related emissions that affect air quality and contribute to climate change. A key goal is to stay in attainment of ambient air quality standards. The strategy establishes measurable short- and long-term performance measures for trucks, rail, water vessels, oceangoing vessels, and cargo-handling equipment.[29]

developing retrofit and replacement programs for drayage trucks to reduce emissions.

Oceangoing vessels, which burn bunker fuel while at sea and run auxiliary diesel engines in port, are a major source of emissions at ports. The International Convention for the Prevention of Pollution from Ships (also known as MARPOL) governs vessels' environmental performance. In October 2007, AAPA's members agreed to support the U.S. government proposal to the International Maritime Organization (IMO) to amend MARPOL Annex VI and establish more stringent air emission standards for oceangoing vessels.[30]

Greenhouse Gases

There are no sector-level estimates of GHG emissions from ports, but many ports are estimating GHGs when conducting emissions inventories. For example, the Ports of Seattle, Tacoma, and Everett, WA, jointly estimated GHG emissions of 397,033 tons of carbon dioxide (CO_2) equivalent in 2005, with overall Puget Sound maritime emissions of 1.9 million tons of CO_2 equivalent.[31] The Port of San Diego, CA, a relatively small port, estimated GHG emissions of 128,000 tons of CO_2 equivalent in 2006.[32]

Increasingly, shippers are expecting organizations in the transportation supply chain to measure, report, and improve their environmental performance. For example, through EPA's SmartWay Transport Partnership, companies commit to shipping higher percentages of freight with truck and rail carriers that are SmartWay partners. In turn, participating carriers agree to estimate their emissions and reduce them over time. EPA is working with the freight industry to expand the program and develop tools that will help companies measure and reduce GHG and criteria air pollutant emissions from their entire transportation supply chain (including ports).

SmartWay already includes some drayage carriers, which are truck companies that deliver freight to and from port facilities. Seeking more ways to improve the environmental performance of drayage fleets, which typically consist of older trucks, SmartWay is working with ports such as the Virginia Port Authority to offer low-cost loans to drayage carriers for cleaner and more fuel-efficient trucks.[33]

Water Use and Discharges

Located on coasts and inland waterways, ports are caretakers for coastal resources. Public ports regularly develop wetland sites; create, restore, and enhance habitat; and monitor water quality. The transport of invasive species in ships' ballast water and oil spills from ships or landside facilities can significantly affect local water quality and wildlife. Dredging of channels and harbors can affect water quality, although dredging permits require mitigation plans.

Stormwater

Stormwater can pick up pollutants from paved surfaces before entering waterways. Most port facilities for cargo handling include large expanses of paved surface, which,

Reducing Discharges With Permeable Asphalt

In 2006, the Port of Portland, OR, installed 35 acres of porous asphalt at one of its auto-import facilities. Unlike traditional asphalt, porous asphalt allows stormwater to soak into the underlying soil. The porous asphalt, along with a system of swales and natural vegetation to handle runoff from heavy rain, treats all stormwater onsite. The port saved $250,000 and nearly a year of time for obtaining an NPDES permit. The port also receives a discount on the city's storm sewer fee and will have lower maintenance costs over time.[34]

along with the possibility of spills of bulk or liquid freight, makes stormwater management very important. Most stormwater discharges from ports are considered point sources and require a National Pollutant Discharge Elimination System (NPDES) permit. Many NPDES permits require preparation of a Stormwater Pollution Prevention Plan. In the 2007 AAPA survey, 68% of the ports responding indicated that they have such a plan; 61% indicated that they advise tenants periodically on stormwater compliance responsibilities.

Restoration of Aquatic Habitat

Ports often restore coastal habitat as mitigation for development activities and in broader stewardship efforts.

Restoring Fish Habitat

Most of the east side of Puget Sound is hardened with riprap and bulkheads. Restoration of more natural shoreline habitats is critical to the recovery of Puget Sound salmon. In part to mitigate the impacts of a new pier, the Port of Everett, WA, used a new method for pebble/sand beach construction to restore 1,100 feet of shoreline habitat in front of a rock bulkhead supporting a BNSF railroad line. Biological monitoring has already shown a high level of activity by juvenile salmon and forage fish along the restored shore.[35]

Invasive Species

Ships take on or discharge ballast water to accommodate changes to their displacement and trim as they load or unload cargo or take on or consume fuel.[36] As vessels transit the globe, they collect and discharge water many miles apart, and in the process can introduce nonindigenous species. These species are considered "invasive" if they are capable of exploiting their new environment and causing economic or environmental harm. Ships discharge an estimated 80 million tons of ballast water into U.S. waters each year.[37]

To combat the spread of invasive species, ships are required to take steps such as exchanging ballast water while at sea. However, management methods still need to be improved. EPA and AAPA are working with the U.S. Coast Guard, IMO, and others to promote effective policies and technologies for ballast water management and treatment. For example, the Duluth Seaway Port Authority, MN, hosts the world's first freshwater test facility for ballast water treatment technology. The facility, completed in June 2007, is part of the Great Ships Initiative, a cooperative research effort to which nine U.S. and Canadian ports have provided monetary or in-kind support.[38]

Waste Generation and Management

Dredged Material

Because of the natural process of sedimentation, periodic dredging of channels and shipping berths is necessary to ensure that vessels can continue to reach ports. Existing channels and berths must also be deepened and widened for U.S. ports to accommodate the largest container ships coming into use. Few U.S. ports have the channel depth of up to 55 feet that these vessels require.[39]

Although the U.S. Army Corps of Engineers is responsible for dredging navigation channels, ports and their tenants dredge 100 million cubic yards annually from vessel berths and private terminals.[40] Ports must dispose properly of both clean and contaminated dredge material, and are increasingly seeking beneficial reuses of this material.[41]

Beneficially Using Dredged Material

The Port of Fourchon, LA, is using dredged material to rebuild a natural forest ridge reduced by coastal erosion. Such forest ridges serve as buffers between the Gulf of Mexico and the coastal marsh habitats for fish, shellfish, and other wildlife. Working with volunteers and several private and governmental entities, the port has created 60 acres of forest habitat and 60 acres of salt marsh.[42]

Brownfields

Although ports will be able to accommodate some of the expected increase in trade volume by improving the efficiency of current operations, they sometimes need to build new facilities. Many ports seeking to expand existing facilities have revitalized nearby "brownfields," which are unused or underused industrial sites. In doing so, the ports must first address any environmental contamination. For example, the Port Authority of New York and New Jersey is remediating and developing a contaminated site on Staten Island, NY, in connection with the intermodal rail facility supporting the New York Container Terminal. Fifteen of the 38 ports that responded to AAPA's 2007 survey had participated in brownfields redevelopment in the past 5 years, contributing to redevelopment of more than 3,200 acres of brownfields.[43]

Disposal and Recycling

Ports handle a variety of materials and wastes, both generated onsite and from vessels. Since inception in 2005, the Port of Corpus Christi Authority, TX, recycling program has recycled 327,055 lbs. of materials, including 96,470 lbs. in 2007. The program includes recycling paper, plastic, cardboard, metal, batteries, tires, oil, oil and fuel filters, antifreeze, and capacitors. Cruise ships return to port with recyclable materials such as metal cans, glass, and batteries. They also offload hazardous wastes while at dock, such as waste generated during photo processing, dry cleaning, and ship maintenance. There are no estimates of the total volumes of solid and hazardous wastes brought into U.S. ports by cruise ships, although EPA is developing a "Cruise Ship Discharge Assessment Report" to address solid and hazardous waste.[44]

Hazardous Waste Management

Port facilities generate various hazardous wastes. Vessel refurbishing and maintenance operations generate spent solvents and caustics, and paints and paint sludge. Examples of other marine facility wastes that may be hazardous include vehicle maintenance fluids, near-empty paint cans, and paint-stripping residue.[45] In AAPA's 2007 survey, 17 of 38 ports (45% of respondents) indicated that they generate enough hazardous waste to require tracking and reporting.[46]

Additional Environmental Management Activities

Environmental Management Systems

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. The Ports EMS Assistance Project, which EPA helped AAPA launch, has guided 13 ports in developing EMSs over 4 years.[47] The Ports of Boston, MA, Corpus Christi and Houston, TX, and Los Angeles, CA, have each received third-party ISO 14001 certification, and other ports are working toward this recognition.[48] In AAPA's survey, the percentage of ports with an EMS in place or under development increased from 29% in 2005 to 47% in 2007. The number of ports publishing an annual environmental review or report also increased from 4% in 2005 to 29% in 2007.[49] AAPA also assisted EPA in development of *An EMS Primer for Ports: Advancing Port Sustainability.*[50]

Voluntary Sustainability Partnership

Green Marine is a new, voluntary sustainability initiative designed to help the marine transportation industry between the Gulf of St. Lawrence and the Great Lakes minimize its environmental footprint without compromising economic viability. The initiative, officially announced in October 2007, includes U.S. and Canadian carriers and ports. Priority issue areas include air emissions, discharges to water, and invasive species. The partnership has published an action plan and will enlist a third party to evaluate and report on the conformance of the program's corporate members.[51]

Sustainability

Some ports are building on the systems-based management approach of EMSs to address broader aspects of sustainability. AAPA is working to develop a sustainability framework. AAPA members approved a sustainability resolution and principles in October 2007. The resolution states, "Sustainability involves the simultaneous pursuit of economic prosperity, environmental quality and social responsibility," and AAPA "embraces the concept of sustainability as a standard business practice for ports and the Association."[52]

Community Involvement

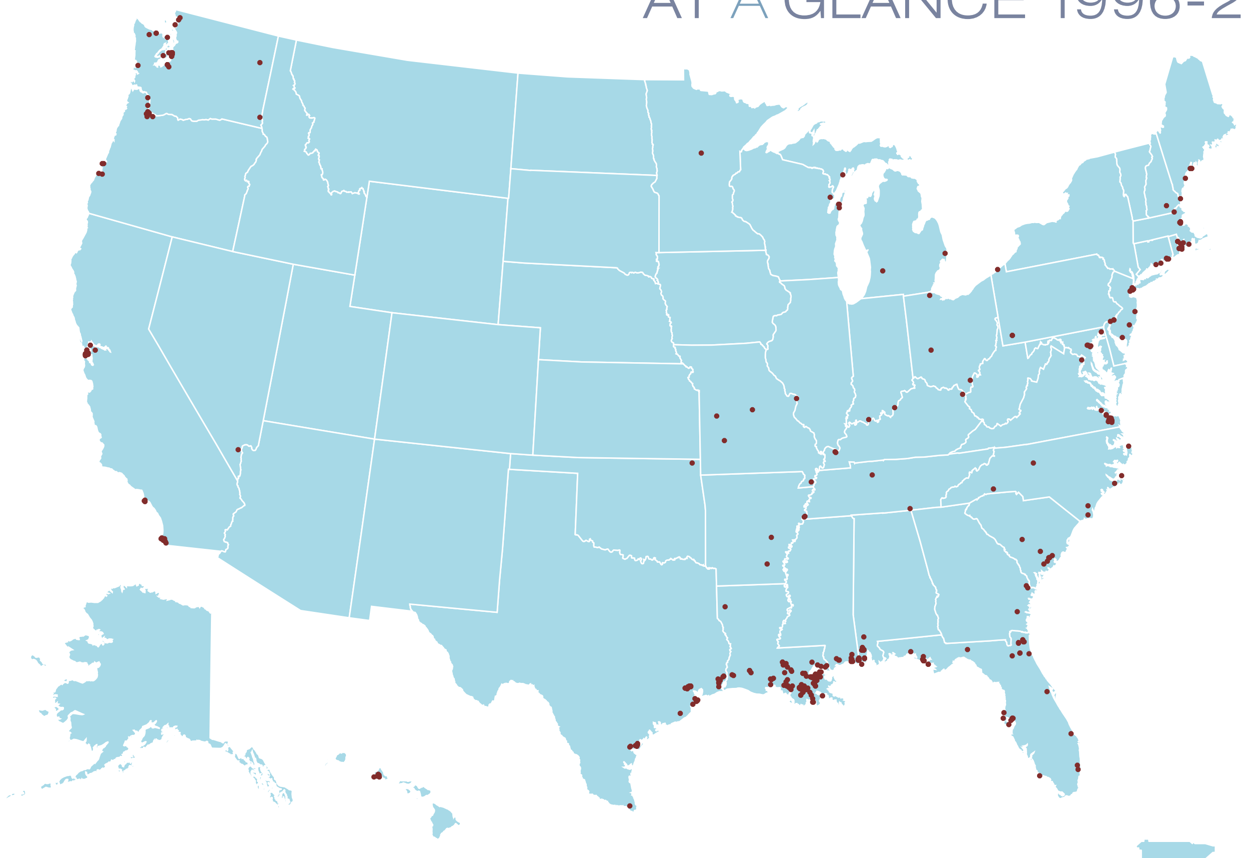
Because of their size, location, and high profile, ports increasingly recognize the importance of effectively communicating with surrounding communities about the environmental aspects of port operations.

Environmental Outreach

The Port of Portland, OR, has created a position within its Community Affairs Department specifically for environmental outreach and communication. The port also provided its staff with "Community Integration Guidelines," an extensive menu of outreach approaches and tools to use when engaging the public. Several of these tools have been used effectively during the decisionmaking process for cleanup of contaminated sediment at the port's Terminal 4. For example, the port has hosted five open houses corresponding to different phases of the project, and it arranged for stakeholders to visit two confined disposal facilities in the Puget Sound area. The port's outreach efforts have reached more than 300 stakeholders and identified specific areas of citizen concern that the port might otherwise have overlooked.[53]

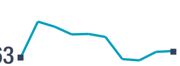
SHIPBUILDING & SHIP REPAIR

AT A GLANCE 1996-2005[1]



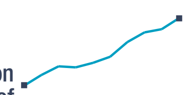
2005: 346 facilities

98,063 employees



86,134 ▼ 12%

$10 billion value of shipments



$14 billion ▲ 47%

Latest Environmental Statistics[2]

Emissions of Criteria Air Pollutants: 5,900 tons

Releases of Chemicals Reported to TRI: 2 million lbs.

Air Emissions: 1.8 million lbs.

Water Discharges: 19,000 lbs.

Waste Disposals: 226,000 lbs.

Recycling, Energy Recovery, or Treatment: 5.1 million lbs.

Hazardous Waste Generated: 7,000 tons

Hazardous Waste Managed: 6,000 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

Facilities in the Shipbuilding & Ship Repair sector build, repair, or alter ships, barges, and other large vessels for military and commercial clients. Most facilities that build ships can also repair them, but some smaller shipyards only perform ship repair work.

Shipyards typically include drydocks, shipbuilding positions, berthing positions, piers, workshops, and warehouses.

Most domestic shipbuilders make and repair ships for the U.S. Navy, U.S. Coast Guard, and other government agencies. The sector has less than a 1% share of the world's market for commercial vessels of more than 100 gross tons.[3]

Energy Use

According to the U.S. Department of Energy (DOE), energy use for the transportation equipment manufacturing sector, which includes shipbuilding activities as well as motor vehicle manufacturing, totaled 424 trillion Btu in 2002. There are not sufficient data to determine the proportion of energy used by the Shipbuilding & Ship Repair sector alone.[4]

Shipbuilding and ship repair processes that use the most energy are welding (most often electric arc welding), forging, abrasive blasting, and application of marine coatings. Electricity purchases represented 75% to 80% of the sector's expenditures for energy in 2004.[5] The sector's remaining energy expenditures were for fossil fuels such as natural gas, coal, and petroleum. Between 1998 and 2004, shipbuilders use of electricity per dollar value of shipments (VOS) fell 10%.[6]

There are opportunities for shipbuilders to reduce one energy source in favor of another with fewer emissions or greater efficiency. One option is for facilities to replace equipment that consumes fossil fuels with electric-powered equipment. For example, in the forging process, facilities can replace gas-fired heating with electric induction heating, which has lower operational costs and requires less energy. The environmental benefits of switching equipment to electric power will depend in part on the fuels used by the electricity provider.

Air Emissions

Air emissions in 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, and can also be generated by their use. Major sources of air emissions for this sector are welding, abrasive blasting, and application

Biodiesel Use

In 2006, Atlantic Marine Alabama, LLC, a shipbuilder headquartered in Mobile, AL, measured the performance of two forklifts powered by a biodiesel blend (B20) against the performance of two forklifts fueled with regular diesel. During the four-month trial, the biodiesel-powered forklifts used nearly 9% less fuel per hour with no difference in performance or the visibility of emissions between the two sets of forklifts. In addition, over the course of the trial, the B20 cost an average of 50 cents less per gallon than standard diesel. Based on these results, Atlantic Marine plans to convert all of its diesel-powered yard equipment to B20 within the next five years.[7]

of marine coatings. CAPs and GHGs are also generated as combustion byproducts from onsite combustion of fuels.

Air Emissions Reported to TRI

In 2005, 54 facilities reported 1.8 million absolute lbs. of air emissions of TRI chemicals, as shown in Figure 1a. TRI-reported air emissions decreased by 44% in absolute pounds from 1996 to 2005. When normalized by the sector's increasing VOS, air emissions decreased 54% from 1996 to 2005.[8]

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 1c. When normalized by the sector's VOS, the sector's Toxicity Scores fluctuated between 1996 and 2005, declining overall by 34%. Fluctuations in the Toxicity Scores were driven by changes in the quantities of manganese and chromium emitted to air over the years, as discussed below.

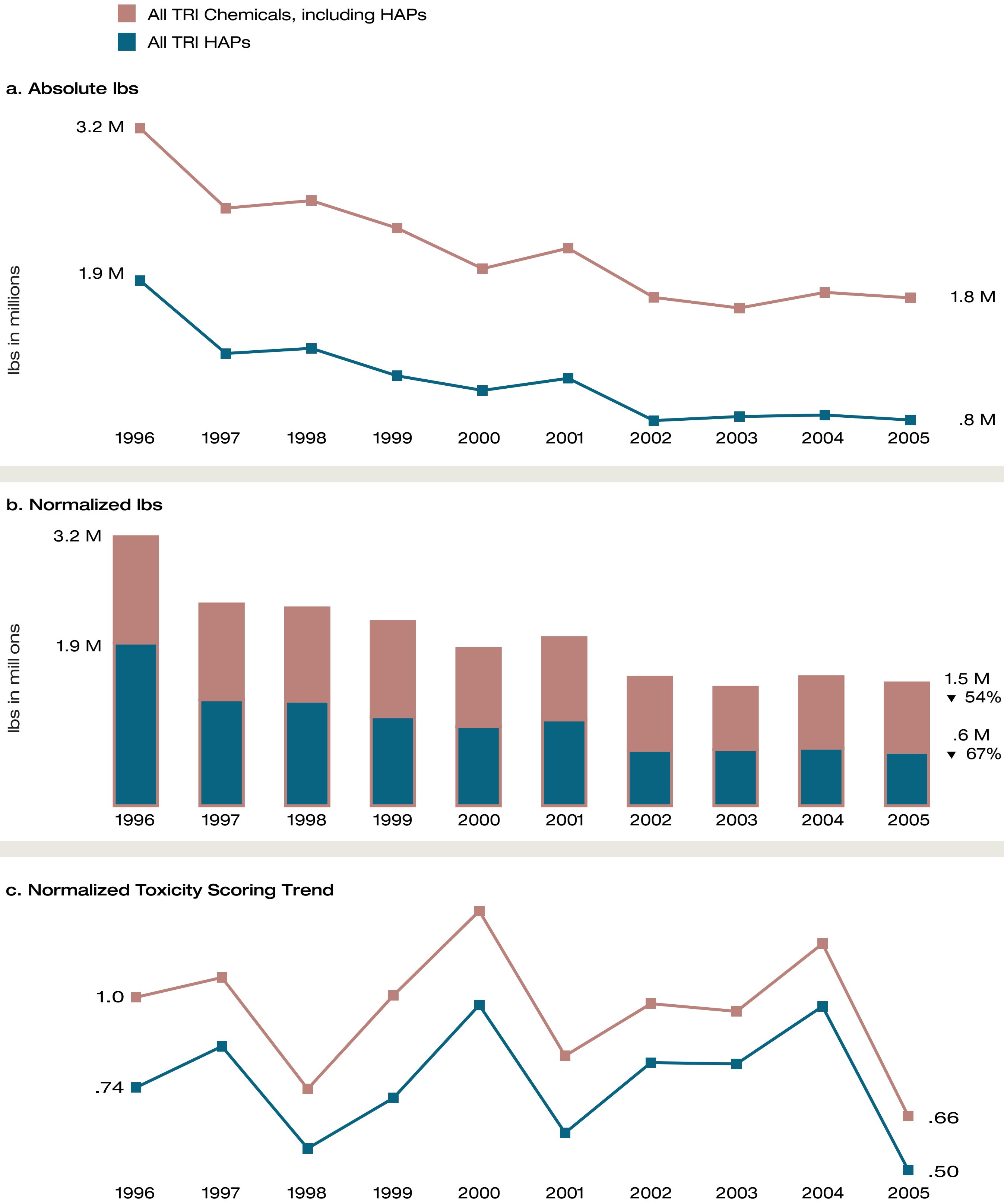
The TRI list of toxic chemicals includes all but six of the hazardous air pollutants (HAPs) regulated under the Clean Air Act. In 2005, 47 Shipbuilding & Ship Repair facilities reported about 800,000 lbs. of HAPs emitted to air, representing 43% of the total pounds of air emissions that the sector reported to TRI for 2005, and 76% of the Toxicity Score.

As with overall TRI air emissions, manganese and chromium, both classified as HAPs, drove the sector's Toxicity Scores for HAPs.[9] Welding activities and the use of certain abrasives such as coal and smelter slags can result in air emissions of these metals. In addition, in 1999 and 2000, a major source of chromium air emissions from repair shipyards was related to a primer called Ameron 385. The U.S. Navy required the use of this primer on Military Sealift Command ships. In 2001, the primer was reformulated to remove chromium, resulting in a significant drop in the quantity of chromium emitted by the sector.[10]

Table 1 presents the top TRI-reported chemicals emitted to air by the Shipbuilding & Ship Repair sector based on three indicators. Each indicator provides data that environmental

FIGURE 1

Air Emissions Reported to TRI 1996–2005



Note:
Normalized by annual value of shipments.

Sources: U.S. Environmental Protection Agency, U.S. Department of Commerce

TABLE 1

Top TRI Air Emissions 2005

Chemical	Absolute Pounds Reported[1]	Percentage of Toxicity Score	Number of Facilities Reporting[2]
1,2,4-Trimethylbenzene	185,100[3]	9%	8
Chromium	1,397	19%[4]	17
Ethyl Benzene[5]	91,900	<1%	7
Manganese	8,077	45%	19
N-Butyl Alcohol	606,700	<1%	21
Nickel	1,798	10%	17
Propylene	106,900	<1%	11
Sulfuric Acid	30,400	8%	1
Xylene	529,700	1%	28
Percentage of Sector Total	87%[6]	92%[7]	91%[8]

Notes:
1. Total sector air releases: 1.8 m llion lbs.
2. 54 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 87% of the sector's air emissions.
7. Chemicals in this list represent 92% of the sector's Toxicity Score.
8. 91% of facilities reported emitting one or more chemicals in this list.

Source: U.S. Environmental Protection Agency

managers, trade associations, or government agencies might use in considering sector-based environmental management strategies.

1) Absolute Pounds Reported. N-butyl alcohol and xylene were the highest-ranking chemicals based on the pounds of each chemical emitted to air in 2005.
2) Percentage of Toxicity Score. The top chemicals based on Toxicity Scores were dominated by metals, as described above.[11]
3) Number of Facilities Reporting. Xylene and n-butyl alcohol were also the most frequently reported chemicals, with most of the TRI-filers in the sector reporting air emissions of at least one of these chemicals.

Criteria Air Pollutants

Table 2 shows CAP and volatile organic compound (VOC) emissions for 81 facilities in the sector in 2002.[12]

To prepare vessel surfaces for coatings, shipyards typically apply a dry abrasive material at high velocity. This blasting process, which is usually performed outside due to the size of the ships, generates particulate matter (PM) emissions from both the break-up of the abrasive material and the removal of the existing coatings. Common blasting abrasives include coal slag, copper slag, garnet, and other metallic grit and shot.[13] To reduce PM emissions, shipyards shrink-wrap vessels or use shrouds to reduce wind speed in the blasting area. In addition, some shipyards use alternative technology such as ultra-high pressure water blasting to reduce PM emissions.

TABLE 2

Criteria Air Pollutant and VOC Emissions 2002

	Tons
SO_2	1,000
NO_X	900
PM_{10}	800
$PM_{2.5}$	400
CO	200
VOCs	3,000

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

Source: U.S. Environmental Protection Agency

The coatings applied to a vessel's surface typically contain VOCs that are emitted to the environment during application. To reduce VOC emissions, shipyards have been working with coatings manufacturers to reformulate coatings to reduce the content of VOCs and other air toxics. In addition, shipyards are using new application technologies that reduce overspray and waste, resulting in less paint used overall.

Greenhouse Gases

Shipbuilding & Ship Repair GHG emissions are primarily attributable to fossil fuel combustion for non-road equipment. Other likely GHG sources include refrigerants, welding gases, thermal oxidizers to destroy VOCs, and CO_2-based fire extinguishers. However, there are currently no data available on the quantity of such emissions. The generation of electricity purchased by sector facilities also emits GHGs.

To reduce their GHG footprint, facilities in the sector could improve on-site energy efficiency and could purchase electricity produced without combustion of fossil fuels. The American Shipbuilding Association and the Shipbuilders Council of America are working with EPA to develop a tool to measure GHG emissions, which should provide better data on the sector's GHG emissions in the future.

Water Use and Discharges

Shipbuilding & Ship Repair firms typically obtain water from public water systems, and sometimes pull water directly out of the rivers for non-contact cooling. There are currently no aggregate data available on the quantity of the sector's water use.

In 2005, 16 facilities reported water discharges of about 19,000 lbs. of TRI chemicals. When normalized by VOS, water discharges declined by 30% from 1996 to 2005.[14] The sector discharges water to Publicly Owned Treatment Works and, in some cases, directly to water bodies. Stormwater run-off is also an important issue for the sector.

Proper management of stormwater is a concern for the sector because shipyards are adjacent to major water bodies and include outdoor operations where materials and equipment can be exposed to precipitation. Chemicals discharged in stormwater primarily consist of blasting and painting materials. Of particular interest are discharges of copper, zinc, and lead from anti-foulant coatings, which retard the growth of aquatic organisms.

Best Management Practices (BMPs) for Cleaning Drydocks

Drydocks, which are typical features of shipyards, are work areas that can be flooded to allow a vessel to enter or leave. The industrial activities that take place on drydocks (e.g., abrasive blasting, painting) can generate significant concentrations of pollutants such as heavy metals, oil and paint residues, spent abrasive, and other debris. Thorough cleaning of the drydock prior to its submergence ensures that these pollutants are not discharged to receiving waters.

BAE Systems San Diego, CA, has implemented BMPs to ensure that its dry docks are clean before they are submerged, thus preventing particles generated during ship construction and maintenance from being discharged into nearby waters.

Before clean-up activities begin, the company inspects the drydock and determines clean-up details, such as number and size of hoses for washing, number of pumps to collect washwater, and number and capacity of tanks to hold washwater. Some notable practices utilized by BAE Systems during drydock cleaning include:

- Ensuring proper trim of the drydock,
- Installing splash boards to prevent washwater from spilling into the bay when washing near the edge of the dock,
- Monitoring the trough and sump to prevent overflows,
- Ensuring sufficient holding capacity for washwater (including planning for rain),
- Thoroughly inspecting the drydock after cleaning and before submergence, and
- Documenting all of the above actions.[15]

Shipyards' stormwater runoff is typically regulated under a multi-sector general industrial stormwater permit. However, some states require facilities to have individual National Pollutant Discharge Elimination System permits for stormwater and to meet discharge limits. Permit requirements vary from state to state and can range from requiring a stormwater management plan, to using BMPs, to requiring zero discharges.

Waste Generation and Management

Wastes in the sector can be generated from process-related functions or from other activities such as operation of pollution control devices or remediation of past contamination. Spent abrasives and oil or oily water are typically the largest volumes of waste generated in shipyards.

Hazardous Waste Management

In 2005, 96 facilities in the sector reported to EPA's *National Biennial RCRA Hazardous Waste Report* (BR) generating about 7,000 tons of hazardous waste. Waste paint and spent solvents, although produced less than spent abrasive and oily waste, generally constitute the sector's largest hazardous waste stream. In 2005, painting and coating processes accounted for 42% of the total hazardous waste generated (about 3,000 tons).[16]

Improvements in process management of coating application and equipment cleaning have resulted in reductions in the amount of painting and coating waste. For instance, in-line plural component mixers prepare coatings as they are required. This prevents the generation of paint waste from mixing more paint than is required to complete a job. Additionally, paint waste is now used in fuel blending, whereas previously it would have been solidified for land disposal. Shipyards are also reclaiming and reusing solvents used to clean spray paint equipment.

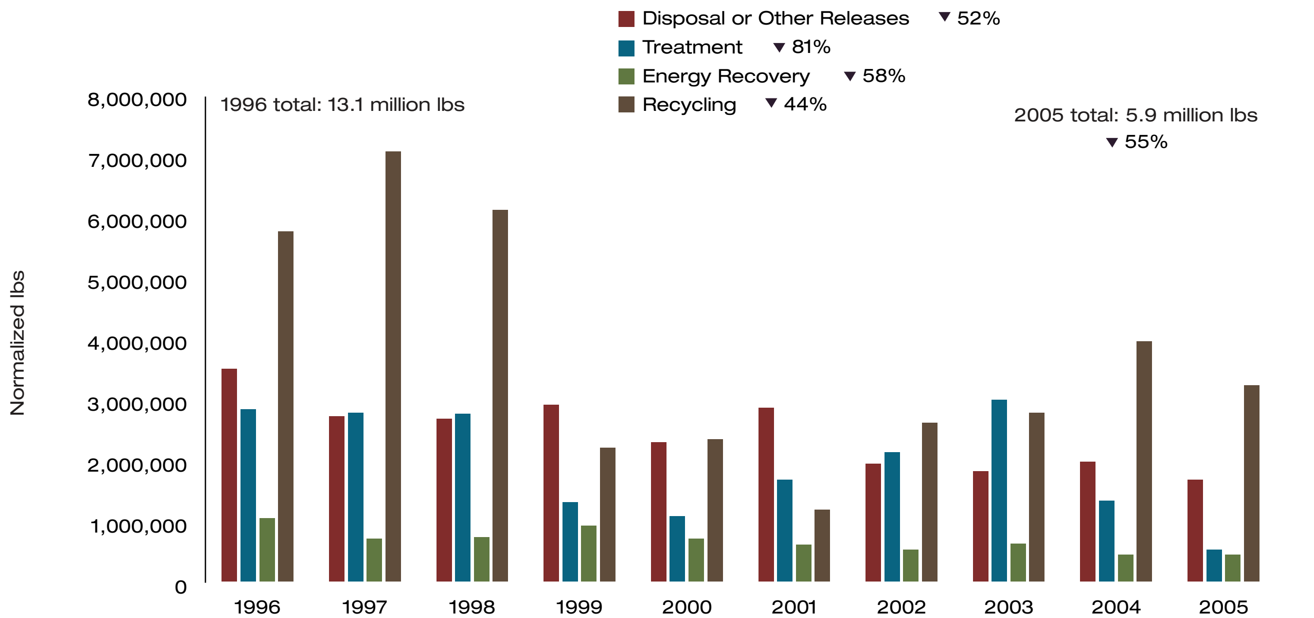
The sector managed its hazardous waste in 2005 through disposal, treatment, and reclamation and recovery, in roughly equal proportions. The sector reported managing 6,000 tons of hazardous waste. The primary method of reclamation and recovery used by the sector was fuel blending.

Waste Management Reported to TRI

In 2005, the sector managed 7.2 million absolute lbs. of TRI-reported chemicals. When normalized by VOS, this was 55% less than in 1996. Figure 2 shows the trends in waste management by the sector. In 2005, 29% of the TRI-reported waste was disposed to land or released, 9%

FIGURE 2

TRI Waste Management 1996–2005



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

Sources: U.S. Environmental Protection Agency, U.S. Department of Commerce

was treated, 8% was used for energy recovery, and 55% was recycled. Of the waste disposed or released, 11% was disposed. As shown in Table 3, copper and zinc accounted more than half of the total disposals in 2005; copper and nickel were the most frequently reported chemicals for this sector during the same year.[17]

The quantity of waste that shipyards disposed, as reported to TRI, decreased from about 251,000 lbs. in 1996 to about 226,000 lbs. in 2005. The chemicals were disposed to land or transferred to offsite locations for disposal.

TABLE 3

Top TRI Disposals 2005

Chemical	Absolute Pounds Reported[1]	Number of Facilities Reporting[2]
Chromium	12,900[3]	13
Copper	69,100	14
Lead	8,900	9
Manganese	7,300	9
Nickel	10,400	14
Phenol	21,000	1
Xylene	13,600	3
Zinc	46,100	7
Percentage of Sector Total	84%[4]	54%[5]

Notes:
1. Total sector disposals.: 226,000 lbs.
2. 54 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 84% of the sector's disposals.
5. 54% of facilities reported disposals of one or more chemicals in this list.

Source: U.S. Environmental Protection Agency

DATA SOURCES, METHODOLOGIES, AND CONSIDERATIONS

Important public sources of data used in this report—discussed in the Data Guide—include the U.S. Department of Energy's (DOE) Manufacturing Energy Consumption Survey (MECS), EPA's Toxics Release Inventory (TRI) and relative Toxicity Scores from EPA's Risk-Screening Environmental Indicators (RSEI) model, EPA's National Emissions Inventory (NEI), EPA's *National Biennial RCRA Hazardous Waste Report* (BR), production data from the U.S. Geological Survey's (USGS) Mineral Commodity Summaries, and economic data from U.S. Department of Commerce (U.S. Census Bureau and Bureau of Economic Analysis).

Private sources of data are sector-specific; for example, cement kiln dust surveys for Cement Manufacturing, and information from the American Forest & Paper Association's Environmental, Health, and Safety Verification Program for Forest Products. These data sources are referenced in the sector chapter endnotes.

Normalization

The best available data for each sector are used to normalize the sectors' pollutant releases and management over time as described in the Data Guide.

As an example, the sector air emissions figures show air emissions from 1996 through 2005. In sections (b) and (c) of the figure showing trends in air emissions, data were normalized, often using the annual value of shipments (VOS), adjusted for inflation using 1996 dollars as the base year, or productivity data adjusted against the 1996 starting quantity. The formula for this adjustment is:

$$\text{Measures for Year `A'} \times \frac{\text{1996 Normalized Data (\$ or production value)}}{\text{Year `A' Normalizing Data (\$ or production value)}}$$

Dollars, when used for normalizing, are adjusted for inflation using U.S. Department of Commerce's Gross Domestic Product data, available at: http://bea.gov/national/xls/gdplev.xls.

For most sectors, value of shipment data are compiled based on the primary Standard Industrial Classification (SIC) (pre-1998) and North American Industry Classification System (NAICS) codes (1998 forward). For all other sectors, data are compiled directly from the source listed in the table in the Data Guide.

Production Data

The "At-a-Glance" section of each sector chapter presents a measure of the sector's output. As with normalizing, production data (e.g., tons of product produced annually by the sector) were the preferred metric for depicting the output of the sector. When production data were not available, alternate metrics were identified, as noted in the sector chapter endnotes.

Employment and Facility Counts

Data Processing

The County Business Patterns (CBP) data have been tabulated on a NAICS basis since 1998. Data for each sector are compiled for each metric based on the NAICS codes defining the sector. Data are available at: http://www.census.gov/epcd/cbp/view/cbpview.html.

Mapping

For most NAICS/SIC-defined sectors, the maps present facilities in the sector that are in one of EPA's data systems. EPA's data systems provide location information that can be used for mapping, although smaller facilities without federal permits or IDs are under-represented. For list-defined sectors (Cement Manufacturing and Iron & Steel), the maps present those facilities comprising the sector. For several sectors that are not well represented in EPA data systems, alternative data sources were used for developing the sector maps. These sectors are Construction, Colleges & Universities, and Ports. For Construction, U.S. Census Bureau information on the number of construction establishments per state was mapped. For Colleges & Universities, the map represents the institutions listed on www.collegeboard.com, maintained by the not-for-profit College Board association. For Ports, the map shows the U.S. ports listed on the American Association of Port Authorities website, available at: http://www.aapa-ports.org.

Energy Use

This report uses energy consumption data from the 2002 MECS published in 2005. DOE's Energy Information Administration (EIA) conducts the survey and defines the manufacturing sector as all manufacturing establishments (NAICS codes 31-33) in the 50 states and the District of Columbia.

Considerations

Detail of data

The Sector Strategies Program defines sectors based on 3-, 4-, 5-, and/or 6-digit NAICS code combinations. MECS energy consumption estimates for most manufacturing industries are only available at the 3-digit NAICS code level, although data for some select manufacturing sectors are available at the 6-digit NAICS code level. For the sectors in this report, 2002 data at the 6-digit level are available for the Cement Manufacturing, Forest Products, Iron & Steel, and Metal Casting sectors.

Historical and current energy consumption data

The 2002 MECS sample size was approximately 15,500 establishments drawn from a sample frame representing 97-98% of the manufacturing payroll, which is approximately 60% of the establishments of the manufacturing sector. MECS data provide energy consumption by fuel type, including electricity, natural gas, residual fuel oil, distillate fuel oil, liquid petroleum gas, coal, coke, and other. The composition of the "other" fuels category varies from sector to sector. More detail is provided in individual sector chapters.

Although the 2002 MECS provides the most recent publicly available data on sector energy consumption, energy prices have undergone major changes in the last 6 years; the effects of such changes on sector energy consumption since 2002 are not reflected in the 2002 MECS data used in this analysis.

Energy consumption projections

For an overview of expected future trends for industrial energy consumption and associated carbon dioxide (CO_2) emissions, as well as energy projections for specific sectors, we referenced EIA's 2006 Annual Energy Outlook (AEO), EIA's most recent annual forecast of energy demand, supply, and prices through 2030.[1]

Energy efficiency and clean energy opportunities for manufacturing industries

We consulted industry-specific research conducted by DOE and research institutions such as the Ernest Orlando Lawrence Berkeley National Laboratory, as well as a number of online and hard-copy materials produced by industry trade associations that describe technological and process opportunities for increasing energy efficiency.

Industry commitments to environmental improvement with respect to energy use

We reviewed public-private partnership programs such as Climate VISION, which is supported by DOE, EPA, and the U.S. Departments of Transportation and Agriculture, and DOE's Industrial Technologies Program, for information on emerging industrial energy-efficient and clean energy opportunities for energy-intensive sectors, including developing technologies. Note that individual companies/facilities within each sector may also participate in other voluntary programs (e.g., ENERGY STAR, Performance Track, Climate Leaders, etc.).

Small businesses not included

MECS does not include small establishments, including those with fewer than 5 employees or those with 5 to 20 employees with annual payrolls and shipments below certain minimums.

Data Processing

This report uses MECS data on energy consumed for fuel-related purposes only (presented in MECS Table 3.2). MECS data are also available in terms of energy consumed for all purposes (or "first use," which includes fuels used as feedstocks); in terms of energy consumed for nonfuel purposes (primarily feedstocks); and in terms of consumption of fuels. While some industries use fuels as feedstocks—raw material inputs in the manufacturing process—feedstock-related fuel use may or may not contribute to criteria air pollutant (CAP) and greenhouse gas (GHG) emissions. As feedstock fuel use does not represent an opportunity for reducing the environmental impacts associated with energy consumption, the energy use sections of this report focuses on energy inputs for fuel use only. Units of measure are maintained in British thermal units (Btu). Data and documentation of EIA's data processing methodology used to develop sector energy consumption estimates are available online at: http://www.eia.doe.gov/emeu/mecs.

Air Emissions Reported to TRI

TRI was established under the Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA) and expanded by the Pollution Prevention Act of 1990. Section 313 of EPCRA provides three criteria defining the scope of facility owners/operators that report to EPA's TRI program:

1. The facility has 10 or more full-time employees, or the equivalent of 20,000 employee hours per year.
2. The facility is included in a list of applicable NAICS codes. The NAICS codes correspond to the following SIC codes: SIC 10 (except 1011, 1081, and 1094); 12 (except 1241); 20-39; 4911 (limited to facilities that combust coal and/or oil for the purpose of generating electricity for distribution in commerce); 4931 (limited to facilities that combust coal and/or oil for the purpose of generating electricity for distribution in commerce); 4939 (limited to facilities that combust coal and/or oil for the purpose of generating electricity for distribution in commerce); 4953 (limited to facilities regulated under the Resource Conservation and Recovery Act (RCRA) Subtitle C, 42 U.S.C. section 6921 et seq.); 5169; 5171; and 7389 (limited to facilities primarily engaged insolvent recovery services on a contract or fee basis). Executive Order 13423 extended these reporting requirements to federal facilities, regardless of their SIC or NAICS code.
3. The facility manufactures (defined to include importing), processes, or otherwise uses any of the toxic chemicals listed on the EPCRA section 313 in amounts greater than the threshold quantities established in 40 Code of Federal Regulations (CFR) 372.25 and 372.28 in the course of a calendar year.

Facilities described above must report their releases and waste management quantities for a chemical included on the TRI list of toxic chemicals if they manufacture or process that chemical in quantities exceeding 25,000 lbs. within a calendar year, or otherwise use that chemical in quantities that exceed 10,000 lbs. per year in a calendar year. Reporting thresholds for TRI-listed chemicals designated by EPA as persistent bioaccumulative toxic (PBT) chemicals, such as lead and mercury, are lower.

In 2005, more than 23,000 facilities reported to EPA's TRI program. These facilities reported 4.4 billion lbs. of onsite and offsite disposal or other releases, which included 1.5 billion lbs. of air emissions, 242 million lbs. of water discharges, and 2.7 billion pounds of disposals. They also reported 25.1 billion lbs. of production-related waste managed.

Considerations

Comprises a list of reportable chemicals

Facilities in the TRI-reporting industry sectors must file if they exceed the reporting thresholds for any of the 600+ chemicals.

Only captures facilities above threshold

Note that only those facilities that exceed the TRI reporting thresholds are required to report to TRI; thus, TRI-reported trends may not be representative of the sector as a whole.

Small businesses not included

TRI excludes smaller facilities, that is, those with fewer than 10 employees.

Multimedia coverage

TRI reporting covers releases and other disposal to all environmental media (air, water, and land).

Changes in TRI requirements

Reporting thresholds for PBTs were lowered in reporting year 2000 (in 2001 for lead and lead compounds) to 10 lbs. or 100 lbs., depending on the chemical. These lower thresholds resulted in more facilities reporting, and caused significant increases in the quantities of some of the specific PBTs reported as released (including disposed) or managed as waste, such as lead and polycyclic aromatic compounds. However, given that the thresholds are so much lower than thresholds for non-PBTs, the increased quantities for this small group of chemicals usually did not influence overall sector trends for air emissions or waste management. The lower reporting threshold could also influence trends in hazardous air pollutants (HAPs), as many of the PBTs are also HAPs. The PBTs that are also HAPs are: chlordane, heptachlor, hexachlorobenzene, lead and lead compounds, mercury and mercury compounds, methoxychlor, polychlorinated biphenyls, polycyclic aromatic compounds, toxaphene, and trifluralin. Other changes to the TRI program, such as the addition of non-manufacturing industries in 1998, are not expected to influence trends for the sectors presented in this report.

Data accuracy

Facility owners/operators are responsible for TRI reporting using their best available information. The data facilities submit on releases and waste management quantities are calculated using one of the following methods: monitoring or measurement; mass balance calculations; emission factors; or engineering estimates. There is no independent verification of the accuracy of the submissions. The increasing use of direct electronic filing of TRI reports may reduce the potential for data processing errors. In 2005, 95% of the facilities submitting reports to TRI used electronic reporting.

Changes in best available information

Facilities are required to complete their TRI forms using their best available information. Industry representatives have pointed out that estimates of releases might change over time as more information becomes available. For example, while conducting measurements required by another regulation, such as emissions testing required by a National Emission Standard for Hazardous Air Pollutants, a facility may find a TRI-reportable chemical in its releases that it was not aware of previously. As facilities learn of the existence of various chemicals, they are then required to report those releases to TRI. This situation would result in an increased level of reported releases that is not necessarily accompanied by an increase in actual emissions.

Some sectors do not report

Facilities involved in oil and gas exploration and transportation, for example, are exempt from both TRI and BR. The publicly and privately owned marine facilities discussed in the Ports chapter also do not report to TRI, although their tenants may.

Data Processing

TRI data for reporting years 1996-2005 are sourced from the 2005 Public Data Release (PDR) for all but two sectors; data for Paint & Coatings and Shipbuilding & Ship Repair are drawn from the 2006 PDR. "Frozen" data are used to ensure reproducibility and to support later revisions of the analysis.

Trend data are normalized by changes in VOS or production, with 1996 as the baseline year.

For most sectors, data are compiled based on the most current primary SIC code reported on the TRI Form R. For example, if a facility reported differing primary SIC codes in reporting year 2004 and 2005, the primary SIC code from the most current available year (in this case 2005) was used. Similarly, if a facility did not report to TRI in 2005, data from the most recent year of available primary SIC code data were used. For the Cement Manufacturing and Iron & Steel sectors, and for the specialty-batch chemicals subsector, the sector TRI data are extracted based on predetermined facility lists. The count of the number of facilities reporting to TRI is a total of the number of unique

TRI identification numbers (IDs) in the sector. Each facility, as defined by the TRI program, should have one TRI ID.

For air emissions, TRI data elements for this report include:

- **Air Releases**—stack and fugitive emissions as reported in sections 5.1 and 5.2 of TRI Form R, respectively.
- **HAPs**—TRI includes all but six of the chemicals designated as HAPs, also known as "air toxics," by the Clean Air Act (CAA) Section 112b. HAPs are air pollutants that pose a direct threat to human health. TRI, rather than NEI, was used as the source for sector-level HAPs data; see discussion of "Criteria Air Pollutants" below. TRI was chosen as the data source primarily because TRI allows for an analysis of annual trends over a 10-year period, whereas NEI HAP data are available for 1999 and 2002 only. HAPs emissions include stack and fugitive emissions of the subset of TRI chemicals that are designated as HAPs, as reported in sections 5.1 and 5.2 of TRI Form R. The TRI HAP analysis in this report excludes three additional HAPs (4,4'-methylenediphenyl diisocyanate, hexamethylene-1,6-diisocyanate, and 2,3,7,8-tetrachlorodibenzo-p-dioxin), because these chemicals are reported to TRI only as part of larger chemical categories, and quantities of the individual chemicals released are not included in TRI.

For releases and management, data are presented in pounds (lbs). For toxicity-weighted results, data are presented as a ratio using 1996 as the baseline year.

Beginning with the 2006 reporting year, facilities reporting to TRI are required to use NAICS codes in place of the SIC codes previously used on TRI reporting forms. Facilities that report to TRI are required to use 2002 NAICS codes on reporting Form R and the Form A Certification Statement.[2]

Toxicity of Air Emissions

Aspects of RSEI influence the use of these modeled TRI data for EPA's Sector Strategies Program. Extensive documentation is available on the development of RSEI. Some of this information is summarized below. For more details, refer to EPA's Risk-Screening Environmental Indicators (RSEI) Methodology, Version 2.1.5, October 2007, available at: http://www.epa.gov/opptintr/rsei/pubs/method_oct2007.pdf.

Considerations

Uses highest relative toxicity weight for chemical categories

Because information on the chemical form released is not reported to TRI, chemicals within a chemical category (e.g., metal compounds, diisocyanates) are assumed to be released in the chemical form associated with the highest relative toxicity weight. The form of a chemical compound can affect its toxicity. For example, hexavalent chromium has an oral relative toxicity weight of 170 and an inhalation relative toxicity weight of 86,000; whereas trivalent chromium has an oral and inhalation relative toxicity weight of 0.33. TRI reports filed for "chromium" do not specify the valence, so all reported pounds of chromium are more conservatively assigned the relative toxicity weight of hexavalent chromium. In cases where a facility is releasing the chemical in the lower toxicity form, RSEI would overestimate toxicity-weighted results.

Comparing RSEI results

The numeric RSEI output depicts the relative toxicity of TRI releases for comparative purposes and is meaningful only when compared to other values produced by RSEI.

Excludes certain chemicals

There are 611 chemicals and chemical categories on the 2005 TRI Chemical List. Toxicity weights are available for 429 of these chemicals and chemical categories. Chemicals with relative toxicity weights account for more than 99% of the reported pounds for all on-site releases in 2005. If there is no relative toxicity weight available for a chemical, then the default Toxicity Score is zero. Examples of chemicals that do not have an assigned relative toxicity weight in RSEI include: dioxin and dioxin-like compounds, phenol, benzo(g,h,i)perylene, and tetrabromobisphenol-A.

Currently excludes toxicity weights for chemicals disposed

An inhalation relative toxicity weight is used for fugitive and stack air releases. An oral relative toxicity weight can be used for direct water releases, but is not included in this report. Releases to land and other disposal are not modeled because necessary data on site-specific conditions are lacking.

Acute human or environmental toxicity not addressed

RSEI addresses chronic human toxicity (cancer and non-cancer effects, e.g., developmental toxicity, reproductive toxicity, neurotoxicity, etc.) associated with long-term exposure but does not address concerns for either acute human toxicity or environmental toxicity.

Results presented do not include a risk perspective

Toxicity weighting of a chemical is not the same as identifying the risk potentially posed by a release of the chemical to the environment. "Risk" in that context would rely on additional information, such as the fate and transport of the chemical in the environment after it is released, the pathway of human exposure, the amount of chemical to which human subjects are exposed, the duration of exposure, and the amount of the chemical that enters the human body following exposure. Although the RSEI model can provide a relative risk-related perspective for air releases, only the toxicity portion of the model was used in the analysis for this report. Risk-related factors were not considered. Readers interested in the risk perspective for a facility or sector can use the publicly available RSEI model to conduct this screening-level risk analysis.

Data Processing

RSEI calculates toxicity-weighted results for each chemical by multiplying the quantity of chemical released to air by a chemical-specific toxicity weight. Results are then summed across chemicals to present overall sector-wide results. The toxicity weight is a relative value and is presented in this report relative to the sector's total 1996 toxicity-weighted results for all air emissions. Focusing on toxicity provides an alternative perspective to typical quantity-based environmental loadings and moves the discussion forward towards an impact-based assessment.

TRI documentation is available at: http://www.epa.gov/tri. RSEI model documentation is available at: http://www.epa.gov/opptintr/rsei.

Criteria Air Pollutants

EPA prepares the NEI based on input from numerous state, tribal, and local air pollution control agencies; industry-submitted data; data from other EPA databases; as well as emission estimates. State and local emissions inventories are submitted to EPA once every three years for most point sources contained in NEI. Through the 1999 NEI, EPA estimated emissions for any jurisdiction that did not submit an emissions inventory and where data were not available through industry submissions or other EPA databases. As a result of the Consolidated Emissions Reporting rule, NEI updates for 2002 and beyond are expected to include data uploads from all jurisdictions. The CAP and volatile organic compound (VOC) data presented in the sector chapters include emissions from point sources, and not emissions from area and mobile sources.

Considerations

Frequency of NEI

NEI data are released triennially, which limits the number of data points for a time-series analyses. The report includes data only from 2002, because data from prior years are not comparable or present other data challenges.

NEI HAP data

In addition to CAP data, NEI also includes data on the CAA designated HAPs. This report presents HAP data from TRI rather than NEI, primarily because TRI allows for annual trend analyses. NEI, in contrast, is generated every three years. Currently, the 1990 and 1996 NEI databases are not recommended for use due to unusable format or data quality concerns.

Data Processing

Final v3 2002 NEI Point Source CAP data were obtained from EPA's Clearinghouse for Inventories & Emissions Factors (CHIEF). Data and documentation are available at: http://www.epa.gov/ttn/chief/net/index.html.

For most sectors, data are compiled based on the facilities' SIC or NAICS codes as included in the NEI. For the Cement Manufacturing and Iron & Steel sectors and for the specialty-batch chemicals subsector, NEI data are extracted based on a predetermined list of facilities.

For particulate matter (PM) emissions, this report presents PM-Primary, which includes both the filterable and condensable portions of PM emissions.

Greenhouse Gases

For information regarding GHGs, this report relies on the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005* (Inventory), and other public and private data sources. EPA prepares the Inventory to comply with existing commitments under the United Nations Framework Convention on Climate Change (UNFCCC).[3]

The edition of the Inventory used in this report summarizes the latest information on U.S. anthropogenic GHG emission trends from 1990 through 2005. To ensure that it is comparable to those of other UNFCCC Parties, the estimates presented in the Inventory were calculated using methodologies consistent with those recommended by the Intergovernmental Panel on Climate Change (IPCC) in the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC/UNEP/OECD/IEA 1997), the IPCC *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC 2000), and the *IPCC Good Practice Guidance for Land Use, Land-Use Change, and Forestry* (IPCC 2003).

Water Use and Discharges

There is no national database for water withdrawals. Such information, which DOE is starting to collect, is usually kept at the state level.[4]

Facilities discharging directly into the waters of the United States (e.g., "direct dischargers") are required to obtain a National Pollutant Discharge Elimination System (NPDES) permit. Data on discharges from NPDES-permitted facilities are entered into an EPA data system. EPA also develops the Effluent Data Statistics (EDS), which is a static file of annual loadings derived from the concentration and flow data submitted by NPDES facilities. The EDS file contains annual pollutant loadings (including for conventional pollutants) and flow at the permit level.

The Permit Compliance System (PCS) is the national database used to track compliance with NPDES, but it is being gradually phased out and replaced by a modernized system called the Integrated Compliance Information System (ICIS)-NPDES. Twenty-six states, territories, and tribes started using ICIS-NPDES in June 2006, and thus are not entering data into PCS.

Data on pollutant discharges to sewage treatment plants are collected by local pretreatment programs, but these data are not systematically electronically transmitted to the states or EPA. There is no national database for these indirect discharges of wastewater pollutants.

TRI Water Discharges

Considerations

While TRI chemicals discharged to water are a key issue for some sectors (e.g., Food & Beverage Manufacturing, Forest Products), for most sectors, toxic chemicals emitted to air and/or disposed are a larger concern. Depending on the sector, this report describes TRI water discharges from 1996 through 2005 (the most current data available at the time of the analyses presented in this report), with a focus on current (2005) discharges. We do not present toxicity-weighted discharge values, because the RSEI methodology does not account for ecological toxicity, which is an important impact of water discharges.

Data Processing

Water discharges includes discharges to water (from section 5.3 of TRI Form R) and to Publicly Owned Treatment Works for metals only (from section 6.1 of TRI Form R).

Hazardous Waste Management

Several aspects of the BR influence the use of these data for EPA's Sector Strategies Program.

Considerations

Large quantity generators (LQGs) and RCRA hazardous waste treatment, storage and disposal facilities (TSDFs) are covered. Small quantity generators (SQGs) are not included.

LQGs and TSDFs are required to submit a biennial hazardous waste report. LQGs have one or more of the following characteristics: the site generated, in any single calendar month, 1,000 kg (2,200 lbs.) or more of RCRA hazardous waste; the site accumulated, during any calendar month, more than 1 kg (2.2 lbs.) of RCRA acute hazardous waste; or the site generated, in any single calendar month, or accumulated at any time, more than 100 kg (220 lbs.) of spill cleanup material contaminated with RCRA acute hazardous waste.

Note that many facilities in the sectors discussed in this report may not be required to report to BR; thus, the BR data presented may not cover all the activities of the entire sector.

Data Processing

This report describes hazardous waste generation in 2005 (the most current data available at the time of the analyses presented in this report), with a focus on the largest sources of hazardous waste generation. Data and documentation can be found at: ftp.epa.gov/rcrainfodata/.

For this report, data are compiled based on the primary 3-, 4-, 5-, and/or 6-digit NAICS codes reported to BR. For the Cement Manufacturing and Iron & Steel sectors, and specialty-batch chemicals subsector, data are compiled based on predetermined facility lists. The count of the number of facilities reporting hazardous waste data is a total of the number of unique RCRA IDs in the sector.

Only data flagged for inclusion in the National Biennial Report are included. States may submit information on facilities with other status designations, such as SQGs, as well as data on other state-regulated wastes that are exempt from federal regulation. These data, while submitted to BR, are not always included in the National Biennial Report. To mimic the National Biennial Report methodology, only data flagged for inclusion are included in the analysis conducted for this report.

Waste associated with source code G61 and management code H141 are excluded from this analysis to avoid double counting of stored wastes. This is consistent with the National Biennial Report methodology.

Waste Management Reported to TRI

Considerations

TRI reporting typically presents air and water releases in the broader category "Disposal or Other Releases." This report distinguishes waste management and disposal from releases to air and water, above, and presents the data in the categories discussed below.

Data Processing

"Recycling" means the quantity of the toxic chemicals that is either recovered at the facility and made available for further use or sent offsite for recycling and subsequently made available for use in commerce, as reported in sections 8.4 and 8.5 of TRI Form R.

"Energy Recovery" means the quantity of the toxic chemicals combusted in an onsite or offsite energy recovery device, such as a boiler or industrial furnace, as reported in sections 8.2 and 8.3 of TRI Form R.

"Treatment" means the quantity of chemicals destroyed in onsite or offsite operations such as biological treatment, neutralization, incineration, and physical separation, as reported in sections 8.6 and 8.7 of TRI Form R.

"Disposal" includes data from the following sections of TRI Form R:

- Section 5.4: Underground Injection onsite to Class I, II-V Wells
- Section 5.5: Disposal to land onsite

- Section 6.2: Transfers to other offsite locations, for disposal codes only. The disposal codes are as follows:
    - M10 Storage only
    - M40 Solidification/Stabilization—Metals and Metal Compounds only
    - M41 Solidification/Stabilization—Metals and Metal Compounds only
    - M61 Wastewater Treatment (excluding POTW)—Metals and Metal Compounds only
    - M62 Wastewater Treatment (excluding POTW)—Metals and Metal Compounds only
    - M63 Surface Impoundment Recycling
    - M64 Other Landfills
    - M65 RCRA Subtitle C Landfills
    - M66 Subtitle C Surface Impoundment
    - M67 Other Surface Impoundment
    - M71 Underground Injection
    - M72 Offsite Disposal in Landfills
    - M73 Land Treatment
    - M79 Other Land Disposal
    - M81 Underground Injection to Class I Wells
    - M82 Underground Injection to Class II–V Wells
    - M90 Other Offsite Management
    - M91 Transfers to Waste Broker—Disposal
    - M94 Transfers to Waste Broker—Disposal
    - M99 Unknown

Comparing TRI and BR

Both TRI and BR contain information on waste. TRI includes information on toxic chemicals managed as waste. BR includes information on hazardous waste generated and managed. The quantities of hazardous waste reported to BR differ from those reported to TRI, because of numerous differences between the two systems, several of which are discussed below.

Differences in what is reported

TRI reporting is required for any toxic chemical (from a list of more than 600 chemicals) for which manufacturing, processing, or other use exceeds a reporting threshold. BR reporting is required for RCRA listed and characteristic hazardous wastes.

Differences in how quantities are reported

TRI includes the weight of the toxic chemicals within a waste stream, while RCRA reporting on hazardous wastes encompasses the weight of the entire waste or waste stream that meets the definition of RCRA hazardous waste. Therefore, hazardous wastes included in BR could be aqueous, solids, or sludges, weighing more than the toxic components portion alone. In addition, the waste streams reported to BR are considered hazardous, but may not contain constituents that are considered toxic as defined in TRI (e.g., waste streams may be hazardous to humans based on their ignitability, corrosivity, reactivity, toxicity, or hazardous constituents listed in 40 CFR 261 Appendix VIII).

Differences in reporting universes

There is overlap with some facilities reporting to both systems.

Differences in reporting frequency

TRI is annual; BR is every other year.

APPENDIX: ENDNOTES

US EPA ARCHIVE DOCUMENT

Preface

1. The 2004 and 2006 *Performance Reports* are available on the EPA website, http://www.epa.gov/sectors/performance.
2. See the Data Sources, Methodologies, and Considerations chapter for a discussion of normalization and for sources of normalizing data for each sector.
3. For more information on MECS, see the Data Sources, Methodologies, and Considerations chapter and http://www.eia.doe.gov/emeu/mecs/.
4. For more information on NEI, see the Data Sources, Methodologies, and Considerations chapter and http://www.epa.gov/ttn/chief/trends/.
5. For more information on TRI, see the Data Sources, Methodologies, and Considerations chapter and http://www.epa.gov/tri.
6. For more information on RSEI, see the Data Sources, Methodologies, and Considerations chapter and http://www.epa.gov/oppt/rsei/.
7. For more information on BR, see the Data Sources, Methodologies, and Considerations chapter and http://www.epa.gov/epaoswer/hazwaste/data/biennialreport/.

Executive Summary

1. *Number of Facilities:* Census Bureau, County Business Patterns (CBP), 2004, http://www.census.gov/epcd/cbp/view/cbpview.html, except as noted for sectors such as Cement Manufacturing and Iron & Steel (see Data Guide for more information); *Employment:* Census Bureau, CBP, 2004, except as noted for particular sectors (see Data Guide); *Value of Construction put in place:* Census Bureau, Value of Construction Put in Place, http://www.census.gov/const/C30/totsa.pdf; *Revenue for Colleges & Universities:* National Center for Education Statistics, "Postsecondary Institutions, Fall 2005; Graduation Rates, 1999 & 2002 Cohorts; and Financial Statistics, Fiscal Year 2005," http://nces.ed.gov/pubs2007/2007154.pdf; *Revenue for Ports:* Census Bureau, 1997 and 2002 Economic Census, http://www.census.gov/econ/census02, North American Industry Classification System (NAICS) codes 48831 and 48832; *Energy Use:* Department of Energy (DOE), Energy Information Administration (EIA), Manufacturing Energy Consumption Survey (MECS), 2002; *Emissions of Criteria Air Pollutants*: EPA, National Emission Inventory (NEI) for Point Sources: Final v3 2002; *Air emissions; water discharges; land disposals; recycling, energy recovery, and treatment*: EPA, Toxic Release Inventory (TRI), 2005 Public Data Release (PDR), freeze date: December 19, 2006; *Hazardous Waste Generated*: EPA, *National Biennial RCRA Hazardous Waste Report,* 2005, http://www.epa.gov/epaoswer/hazwaste/data/biennialreport; *Global Standing—Food & Beverage Manufacturing Ranking*: Confederation of the food and drink industries of the EU, "Data and Trends of the European Food and Drink Industry," 2006, (citing ABIA; Japanese Ministry of Economy Trade and Industry, Department of Commerce, INEGI, National Bureau of Statistics of China, Canada's business and consumer site, New Zealand's Economic Development Agency, AFFA), page 18, http://www.ciaa.be/documents/brochures/Data_&_Trends_2006_FINAL.pdf; additional information on European Union value of output: E-mail correspondence from E. Dollet, Manager Economic Affairs, Confederation of the Food and Drink Industries of the EU, to D. Kaiser, EPA, May 19, 2008; *Global Standing—Steel*: International Iron and Steel Institute, "World crude steel output increases by 7.5% in 2007," January 23, 2008, http://www.worldsteel.org/?action=newsdetail&id=228; *Global Standing—Cement*: Portland Cement Association, "About the Cement Industry," http://www.cement.org/manufacture/; *Global Standing—Forest Products sector*: AF&PA submission to USTR, December 2005, http://www.afandpa.org/Template.cfm?Section=international2&template=/ContentManagement/ContentDisplay.cfm&ContentID=12382; *Global Standing—Construction*: "Construction Services Sector, 2007; U.S. Market Overview", International Trade Administration, Department of Commerce, http://trade.gov/investamerica/construction.asp; *Global Standing—Chemical Manufacturing*: Amercan Chemistry Council, "essential2economy", http://www.americanchemistry.com/s_acc/sec_topic.asp?CID=5&DID=8; *General Comparisons and Examples of Economic Trends*: see individual sector chapters for examples referenced and data citations.
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9. DOE, EIA; MECS, 2002 Data Tables, Table 3.1, Energy Consumption as a Fuel (physical units) and Table 11.3, Components of Onsite Generation of Electricity, http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/shelltables.html.

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13. Associated General Contractors Survey, as reported in *2008 Associated Equipment Manufacturers Outlook*, p. 11, November 2007, http://www.aem.org/Trends/Reports/IndustriesOutlook/PDF/2008-Industries_Outlook.pdf. In sum, 17,596 AGC general contractor and specialty contractor member companies were surveyed by email.

14. EPA, *Measuring Construction Industry Environmental Performance*, September 2007, p. 35, http://www.epa.gov/ispd/construction/perfmeasures.pdf.

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17. Data in the figure were adjusted to account for multiple NOI submissions for the same construction project and for projects not requiring an NOI because of acreage thresholds or waivers. However, the denominator (number of projects) overestimates the number of projects requiring an NOI because (1) a single construction site may be counted multiple times if it happens to include multiple project types, and (2) the number of projects includes renovations and additions, which may not require an NOI.

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19. Currently, there is no centralized source of data on quantities of C&D materials generated or recycled. Source of estimates: EPA's Municipal and Industrial Solid Waste Division, Office of Solid Waste. *Characterization of Building-Related Construction and Demolition Debris Materials in the United States (DRAFT)*, July 2006. Considerable uncertainties are associated with these estimates; EPA is seeking to develop a methodology for more accurate measurement.

20. Kim Cochran, EPA Office of Solid Waste, communication with Peter Truit, EPA.

21. EPA's Office of Solid Waste. *Characterization of Road and Bridge Related Construction and Demolition Debris Materials in the United States (DRAFT)*, October 2005.

22. Turner Construction Company, Green Buildings website, http://www.turnerconstruction.com/greenbuildings/content.asp?d=2199.

23. These examples are state-specific, and further research must address the variation among the states and the reasons for short-term anomalies, such as the sudden drop in recycling in Maryland in 2003. Additional information on C&D recycling is available on EPA's website, http://www.epa.gov/epaoswer/non-hw/debris-new/index.htm.

24. *Recycling Construction Materials—An Important Part of the Construction Process*, by Kimberly Cochran and Nicole Villamizar, in Construction Business Owner magazine, July 2007, http://www.constructionbusinessowner.com/topics/environment-and-compliance/recycling-construction-materials-an-important-part-of-the-construction-process.html.

25. *Recycling Construction Materials—An Important Part of the Construction Process*, by Kimberly Cochran and Nicole Villamizar, in Construction Business Owner magazine, July 2007, http://www.constructionbusinessowner.com/topics/environment-and-compliance/recycling-construction-materials-an-important-part-of-the-construction-process.html.

26. Excerpted from "Recycling Construction Materials—An Important Part of the Construction Process," by Kimberly Cochran and Nicole Villamizar, in *Construction Business Owner* magazine, July 2007, http://www.constructionbusinessowner.com/topics/environment-and-compliance/recycling-construction-materials-an-important-part-of-the-construction-process.html.

27. EPA, *National Biennial RCRA Hazardous Waste Report*, 2005, http://www.epa.gov/epaoswer/hazwaste/data/biennialreport/.

28. EPA, *National Biennial RCRA Hazardous Waste Report*, 2005.

29. "Green building" in this chapter focuses on measuring performance only during the construction phase of the built environment. It does not address activities prior to construction such as siting and design, or post-construction activities such as the operation of structures.

30. Green Building Council, LEED Rating Systems, http://www.usgbc.org/LEED. See also, https://www.usgbc.org/ShowFile.aspx?DocumentID=1095. Other programs include the Green Building Initiative's Green Globes system and the National Association of Homebuilders' Model Green Home Building Guidelines.

31. EPA, Sector Strategies Program, *Measuring Construction Industry Environmental Performance*, September 2007, http://www.epa.gov/sustainableindustry/construction/perfmeasures.pdf.

32. EPA Sector Strategies, *Measuring Construction Industry Environmental Performance,* September 2007, p. 10, http://www.epa.gov/sectors/construction/.

33. Adapted from paper submitted by Oscar J. Boldt Construction Company to Melinda Tomaino, AGC of America, for a future publication on green construction.

34. The LEED Professional Accreditation program is now managed by the Green Building Certification Institute (GBCI), http://www.gbci.org/.

35. Melinda Tomaino, AGC of America, personal communication with Peter Truitt, EPA.

Food & Beverage Manufacturing

1. *Facilities:* Census Bureau, CBP, 2005 (*Facilities:* Primary commodity processing (PCP)=800, Animal production (AP)=5,000, Other agribusiness (OT)=24,000); *Employment:* PCP=45,000, AP=545,000, OT=1 million.); *Value of shipments:* DOC, BEA: Industry Economic Accounts, http://www.bea.gov/industry/ (*Value of shipments:* PCP=$43.4 billion, AP=$171.9 billion, OT=$394 billion).

2. *Energy Use:* DOE, EIA, MECS, 2002, Table 3.1, http://www.eia.doe.gov/emeu/mecs/contents.html; *Emissions of Criteria Air Pollutants:* EPA's NEI for Point Sources: Final v3 2002; *Releases of Chemicals reported to TRI:* EPA, TRI, 2005 PDR, freeze date: December 19, 2006; *Hazardous Waste Generated and Managed:* EPA, *National Biennial RCRA Hazardous Waste Report*, 2005, http://www.epa.gov/epaoswer/hazwaste/data/biennialreport.

3. DOC, BEA, Industry Economic Accounts, http://www.bea.gov/Industry/Index.htm. This sector is defined by SIC codes 20 and 5461; NAICS codes 311 and 3121.

4. DOE, EIA, MECS, 2002 Data Tables, as discussed in EPA Sector Strategies Program, *Energy Trends in Selected Manufacturing Sectors: Opportunities and Challenges for Environmentally Preferable Energy Outcomes*, March 2007, p. 3-31, 3-32.

5. Willis Sneed, Project Manager, HDR Engineering, Inc., personal communication with Daniel Kaiser, EPA, January 4, 2008.

6. EPA, TRI, 2005 PDR.

7. Walt Tunnessen, EPA, Climate Protection Partnership Division, personal communication with Daniel Kaiser, EPA, October 4, 2007.

8. EPA, TRI, 2005 PDR, modeled through EPA's RSEI. Includes facilities that report primary SIC codes 20 and 5461 on their Form R.

9. EPA's NEI for Point Sources: Final v3 2002. Data compiled from EPA's facility summary datasets. Includes facilities with NAICS codes 311 and 3121 or SIC codes 20 and 5461.

10. EPA Sector Strategies Program, *Energy Trends in Selected Manufacturing Sectors: Opportunities and Challenges for Environmentally Preferable Energy Outcomes*, March 2007, p. 3-32.

11. Bella Tonkonogy, EPA Climate Leaders program manager, personal communication with Daniel Kaiser, EPA, October 10, 2007.

12. EPA, Climate Leaders program, http://www.epa.gov/climateleaders.

13. Smithfield, *Smithfield Corporate Social Responsibility Report 2006/2007*, http://www.smithfieldfoods.com/responsibility/reports.aspx.

14. Coca-Cola, 2006 Corporate Responsibility Review, "Water Stewardship," http://www.thecoca-colacompany.com/citizenship/pdf/corporate_responsibility_review2006.pdf.

15. Nestlé Purina Corporation, personal communication with Daniel Kaiser, EPA, October 2, 2007.

16. 40 CFR §414.

17. TRI water discharges include direct discharges to waterways of any TRI chemical and discharges of metals to publicly owned treatment works.

18. EPA, TRI, 2005 PDR.

19. EPA, Office of Water, Wastewater Management, "Factsheet: Proposed MSGP 2006," p. 6, http://www.epa.gov/npdes/pubs/msgp2006_factsheet-proposed.pdf.

20. EPA, *National Biennial RCRA Hazardous Waste Report*, 2005, http://www.epa.gov/epaoswer/hazwaste/data/biennialreport.

21. EPA, TRI, 2005 PDR.

22. EPA, TRI, 2005 PDR.

23. EPA, TRI, 2005 PDR.

24. Unilever Corporation, personal communication with Daniel Kaiser, EPA, October 2, 2007.

25. *SYSCO Sustainable/Integrated Pest Management Initiative, Environmental Indicator Report Summary for the 2006 Processing Season*. For more information, visit the SYSCO website, http://www.sysco.com/aboutus/aboutus_pestm.html.

Forest Products

1. *Facilities:* Census Bureau, CBP, 2005, http://www.census.gov/epcd/cbp/view/cbpview.html; *Employment:* Census Bureau, CBP, 2005; *Value of shipments:* DOC, BEA: Industry Economic Accounts, 2005, http://www.bea.gov/industry/xls/GDPbyInd_SHIP_NAICS_1998-2005.xls. Forest (Wood) Products defined by NAICS codes 3211, 3212, 32191, 32192, 321999 or SIC codes 242, 243, 244, 249; and Forest (Paper) Products defined by NAICS codes 3221, 32221, 322221-322224, 322226, 32223, 32229 or SIC code 26.
2. *Energy use:* DOE, EIA, MECS, 2002 Data Tables, Table 3.2, Energy Consumption as a Fuel, http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/shelltables.html; *Emissions of Criteria Air Pollutants:* EPA's NEI for Point Sources: Final v3 2002. *Releases of Chemicals reported to TRI: Air Emissions*, EPA, TRI, 2005 PDR, freeze date: December 19, 2006; *Hazardous Waste Generated and Managed:* EPA, *National Biennial RCRA Hazardous Waste Report*, 2005, http://www.epa.gov/epaoswer/hazwaste/data/biennialreport.
3. Sector defined by SIC code 26 (pulp, paper, and packaging) and SIC codes 242, 243, 244, 249 (wood products).
4. EPA, Sector Strategies Program, Forest Products, http://www.epa.gov/sectors/forest/index.html.
5. EPA, Sector Strategies Program, Forest Products, http://www.epa.gov/sectors/forest/index.html.
6. DOE, EIA, MECS, 2002 Data Tables, Table 3.2, Energy Consumption as a Fuel, and Table 6.1, Ratios of Manufacturing Fuel Consumption to Economic Characteristics, http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/shelltables.html.
7. DOE, *Forest Products Industry of the Future: Fiscal Year 2004 Annual Report*, February 2005, p. 2, http://www1.eere.energy.gov/industry/forest/tools.html.
8. AF&PA, Agenda 2020 Technology Alliance, http://www.agenda2020.org.
9. DOE, *Forest Products Industry of the Future: Fiscal Year 2004 Annual Report*, February 2005, http://www1.eere.energy.gov/industry/forest/tools.html.
10. AF&PA, Environmental, Health, & Safety (EHS) Verification Program, p. 23, http://www.afandpa.org/Content/NavigationMenu/Environment_and_Recycling/Environment,_Health_and_Safety/EHS2004Final.pdf.
11. DOE, EIA, MECS, 2002 Data Tables, Table 10.2, Capability to Switch From Natural Gas to Alternative Energy, http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/shelltables.html. Summarized in EPA Sector Strategies Program, *Energy Trends in Selected Manufacturing Sectors: Opportunities and Challenges for Environmentally Preferable Energy Outcomes*, March 2000, p. 3-41.
12. EPA, TRI, 2005 PDR.
13. EPA, TRI, 2005 PDR.
14. EPA, TRI, 2005 PDR, modeled through EPA's RSEI.
15. EPA, TRI, 2005 PDR, modeled through EPA's RSEI.
16. Prior to the 1997 clarification, most mills would not have reported these metals to TRI based on the "de minimis" exemption. For additional information, please see the final Federal Register notice, published May 1, 1997, 62 FR 23834.
17. AF&PA, Environmental, Health, & Safety Verification Program, Biennial Report, 2006, p. 2, http://www.afandpa.org.
18. Loren Blosse, AF&PA, "AF&PA Members Reduce Greenhouse Gas Emissions," press release, October 29, 2007.
19. AF&PA member companies manufacture more than 84% of the paper and 62% of the wood products made in the United States. These numbers were developed under the protocol developed by AF&PA and the forest industry's environmental research organization, the National Council for Air and Stream Improvement (NCASI) for DOE's Climate VISION program.
20. Loren Blosse, AF&PA, "AF&PA Members Reduce Greenhouse Gas Emissions," press release, October 29, 2007.
21. These numbers were developed under the protocol developed by AF&PA and NCASI for the Climate VISION program.
22. Includes direct discharges to waterways of any TRI chemical and discharges of metals to POTWs.
23. EPA, TRI, 2005 PDR.
24. 40 CFR 401.12(i) and 40 CFR 122.28(b)(3)(ii).
25. AF&PA, EHS Verification Program, BR, 2006.
26. EPA, *Final Report: Pulp, Paper, and Paperboard Detailed Study* (EPA-821-R-06-016), November 2006, p. 5-4, http://www.epa.gov/guide/304m/pulp-final.pdf.
27. EPA, Office of Water, Industrial Water Pollution Controls, Effluent Limitation Guidelines, http://www.epa.gov/guide.
28. Diane Gobin, Stora Enso Duluth Paper Mill and Recycled Pulp Mill, personal communication with Paula VanLare, EPA, September 19, 2007.
29. EPA, *National Biennial RCRA Hazardous Waste Report*, 2005, http://www.epa.gov/epaoswer/hazwaste/data/biennialreport. This sector is defined by NAICS codes: 3211, 3212, 32191, 32192, 321999, 3221, 32221, 322221-322224, 322226, 32223, and 32229.
30. EPA, TRI, 2005 PDR.
31. AF&PA, AF&PA Environmental, Health, & Safety Verification Program, Biennial Report, 2006, http://www.afandpa.org.
32. AF&PA, AF&PA Environmental, Health, & Safety Verification Program, Biennial Report, 2006, http://www.afandpa.org.
33. AF&PA, Environment & Recycling, http://www.afandpa.org/Content/NavigationMenu/Environment_and_Recycling/Recycling/Recycling.htm.
34. AF&PA, Agenda 2020 Technology Alliance.
35. Department of Agriculture, Agricultural Research Service, Hemicellulose Bioconversion, http://www.ars.usda.gov/research/publications/publications.htm?SEQ_NO_115=142871.

Iron & Steel

1. *Facilities:* Facility trend information is from U.S. Geological Survey, Mineral Commodity Summaries, Iron and Steel, 1996-2005, http://minerals.usgs.gov/minerals/pubs/commodity/iron_&_steel/. Some apparent shifts in facility totals over time are attributable to changes in data sources and in methodology used for estimation. The reported facility total for 2004, which was apparently anomalous, is not included in the trend line presented in this report. *Employment:* Census Bureau, County Business Patterns (CBP), 2005, defined by NAICS code 331111, http://www.census.gov/epcd/cbp/view/cbpview.html; *Production:* USGS, Mineral Commodity Summaries, http://minerals.usgs.gov/minerals/pubs/commodity//iron_&_steel/index.html.
2. *Energy Use:* DOE, EIA, Manufacturing Energy Consumption Survey (MECS), 2002, Table 3.1, http://www.eia.doe.gov/emeu/mecs/contents.html; *Emissions of Criteria Air Pollutants:* EPA, National Emission Inventory (NEI) for Point Sources: Final v3 2002. *Chemicals Reported to TRI:* EPA, TRI, 2005 Public Data Release (PDR), freeze date: December 19, 2006; *Hazardous Waste Generated and Managed:* EPA, 2005 National Biennial RCRA Hazardous Waste Report, http://www.epa.gov/epaoswer/hazwaste/data/biennialreport.
3. USGS, Iron and Steel, January 2007, http://minerals.usgs.gov/

minerals/pubs/commodity/iron_&_steel/festemcs07.pdf; see 2006 report for comparable narrative and sources.

4. All facilities in the sector fall within the scope of NAICS 331111, but the sector does not include all businesses within that code. For instance, the sector does not include facilities that make products from steel without making new steel from either iron ore or steel scrap. For more information, visit the Census website, http://www.census.gov/epcd/ec97/def/331111.htm.

5. DOE, EIA, MECS, 1998 Energy Consumption by Manufacturers, http://www.eia.doe.gov/emeu/mecs/mecs98/datatables/contents.html#fuel.

6. DOE, EIA, MECS, 2002 Data Tables, Table 3.2, Energy Consumption as a Fuel, http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/shelltables.html.

7. EPA, *Energy Trends in Selected Manufacturing Sectors: Opportunities and Challenges for Environmentally Preferable Energy Outcomes*, March 2007, p. 3-53, http://www.epa.gov/opispdwb/energy/index.html.

8. EPA, *Environmental Benefits of Recycle on the Go*, http://www.epa.gov/epaoswer/osw/conserve/onthego/benefits/index.htm#steel.

9. AISI, personal communication with Tom Tyler, EPA, February 4, 2008.

10. EPA, *Energy Trends in Selected Manufacturing Sectors: Opportunities and Challenges for Environmentally Preferable Energy Outcomes*, p. 3-55. Fractions based on 1998 MECS data.

11. DOE, Office of Energy Efficiency and Renewable Energy, Industrial Technologies Program; *Steel Industry Marginal Opportunity Study*, September 2005, p. 8, http://www1.eere.energy.gov/industry/steel/pdfs/steelmarginalopportunity.pdf.

12. AISI, *Saving One Barrel of Oil per Ton, A New Roadmap for Transformation of Steelmaking Process*, October 2005, http://www.steel.org/AM/Template.cfm?Section=Articles7&TEMPLATE=/CM/ContentDisplay.cfm&CONTENTID=12358.

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14. DOE, Interlaboratory Working Group, Scenarios for a Clean Energy Future (Oak Ridge, TN, Oak Ridge National Laboratory; and Berkeley, CA, Lawrence Berkeley National Laboratory), ORNL/CON-476 and LBNL-44029, November 2000. CEF projects' energy intensity will decline by 1.4% per year through 2020, though gains will be incremental without some new, more energy efficient steel production technique. Concerning research into transformational methods of steelmaking, see "North American Steel Industry Searches for Steelmaking Breakthrough," Lou Schorsch, AISI, April 2008, http://www.steel.org/AM/Template.cfm?Section=Metal_Forum&TEMPLATE=/CM/HTMLDisplay.cfm&CONTENTID=23373.

15. EPA Combined Heat and Power Partnership, past winners of CHP Award, http://www.epa.gov/CHP/public-recognition/current_winners.html.

16. Facility count is by TRI ID. A facility can have more than one TRI ID.

17. EPA, TRI, 2005 PDR.

18. EPA, TRI, 2005 PDR, modeled thrugh EPA's RSEI.

19. EPA, "Profile of the Iron and Steel Industry," September 1995, http://www.epa.gov/compliance/resources/publications/assistance/sectors/notebooks/iron&stl.pdf. See also AISI, *The Steel Industry Technology Roadmap for Automotive*, http://www.steel.org/AM/Template.cfm?Section=PDFs&CONTENTFILEID=937&TEMPLATE=/CM/ContentDisplay.cfm.

20. EPA, *Profile of the Iron and Steel Industry*, September 1995, http://www.epa.gov/compliance/resources/publications/assistance/sectors/notebooks/iron.html.

21. USGS, Manganese; *Statistics and Information*, http://minerals.usgs.gov/minerals/pubs/commodity/manganese.

22. Federal Register, September 20, 2007 (Volume 72, Number 182) p. 53814.

23. Information current as of June 26, 2008; see End of Life Vehicle Solutions Corporation, http://www.elvsolutions.org.

24. EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*, p. 4-7.

25. According to the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*, GHG emissions from all coking coal used to produce metallurgical coke are attributed to the Iron & Steel sector. However, this includes emissions from coke ovens that are not located at iron and steel facilities, the coke from which is predominantly used by steel mills.

26. EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*, p. 4-7.

27. EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*, p. 4-6.

28. For more information, see EPA, *Energy Trends in Selected Manufacturing Sectors: Opportunities and Challenges for Environmentally Preferable Energy Outcomes*, March 2007, p. 3-53.

29. AISI letter to Honorable Spencer Abraham, Secretary of Energy, http://www.climatevision.gov/sectors/steel/pdfs/aisi_letter.pdf.

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32. Testimony of Jim Slattery, Climate Change: Competitiveness Concerns for Engaging Developing Countries, before the Energy and Air Quality Subcommittee, Energy and Commerce Committee, U.S. House of Representatives, March 5, 2008.

33. 2006 Annual Statistical Report, American Iron and Steel Institute, Washington, DC, p. 3.

34. DOE, Industrial Water Use and Its Energy Implications, http://www1.eere.energy.gov/industry/steel/printable_versions/news_detail.html?news_id=7885, citing AISI, *Public Policy Statements—1999-2000, 106th Congress*, Washington, DC: AISI, 1999, p. 21.

35. AISI, *Public Policy Statements—1999-2000, 106th Congress*, p. 21.

36. DOE, Office of Energy Efficiency and Renewable Energy, Industrial Technologies Program, *Water Use in Industries of the Future*, 2003, http://www.ana.gov.br/Destaque/d179-docs/PublicacoesEspecificas/Metalurgia/Steel_water_use.pdf.

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38. DOE, Industrial Technologies Program, *Steel Industry of the Future Report on Water Use in the Industries of the Future: Steel Industry*, July 2003 (citing: Wakelin, David H. ed. 1999. *The Making, Shaping and Treating of Steel: Ironmaking Volume, 11th ed.* Pittsburgh, PA, p. 386-93; and Yamada, Louise. 1998. *Market Magic: Riding the Greatest Bull Market of the Century.* New York: John Wiley & Sons, Inc., at 160); AISI, communication with Tom Tyler, EPA, February 4, 2008.

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40. Includes direct discharges to waterways of any TRI chemical and discharges of metals to POTWs.

41. EPA, TRI, 2005 PDR.

42. EPA, "Profile of the Iron and Steel Industry," September 1995, p. 17.

43. EPA, "Profile of the Iron and Steel Industry," September 1995. Wet scrubbers/venturi scrubbers use about 1,000 gallons of water per ton of steel processed. Water treatment plant sludge from the scrubbers is processed by sintering to be fed back into the blast furnace or is disposed of as waste.

44. Steel Recycling Institute, "Steel Recycling in the U.S. Continues Its Record Pace In 2005" (press release), April 26, 2006, http://www.recycle-steel.org/PDFs/2005Release.pdf.

45. Jennifer R. Kaduck, Georgia Environmental Protection Division, *Innovative Solutions Towards the Elimination of Land Disposal of Electric Arc Furnace Emission Control Dust (Hazardous Waste K061)*, http://www.p2pays.org/ref/21/20282.pdf.

46. EPA, 2005 RCRA Hazardous Waste Report.

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48. Mini Steel Mills, Pollution Prevention and Abatement Handbook, WORLD BANK GROUP, July 1998, p. 341, http://www.ifc.org/ifcext/sustainability.nsf/AttachmentsByTitle/gui_ministeel_WB/$FILE/ministeel_PPAH.pdf.

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51. Tom Tyler, EPA Sector Strategies Division.

52. Eric Stuart, SMA, personal communication to Tom Tyler, EPA, May 9, 2007.

Metal Casting

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2. *Energy Use:* DOE, EIA, Manufacturing Energy Consumption Survey (MECS), 2002; *Emissions of Criteria Air Pollutants:* EPA, National Emission Inventory (NEI) for Point Sources: Final v3 2002. *Chemicals Reported to TRI:* EPA, TRI, 2005 Public Data Release (PDR), freeze date: December 19, 2006; *Hazardous Waste Generated and Managed:* EPA, *National Biennial RCRA Hazardous Waste Report*, 2005, http://www.epa.gov/epaoswer/hazwaste/data/biennialreport.

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5. DOE, EIA, MECS, 2002 Data Tables, Table 1.2, Consumption of Energy for All Purposes (First Use), http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/shelltables.html.

6. DOE, *Theoretical/Best Practice Energy Use In Metalcasting Operations*, Analysis prepared by KERAMIDA Environmental, Inc., Schifo, J.F., and Radia, J.T., May 2004, p. 13.

7. DOE, EIA, MECS, 2002 Data Tables, Table 1.2, Consumption of Energy for All Purposes (First Use), http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/shelltables.html.

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10. EPA, TRI, 2005 PDR.

11. Steve Lewallen, Gregg Industries, a subsidiary of Neenah Enterprises Inc., personal communication with Jeffrey Kohn, EPA, January 31, 2008.

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13. Includes direct discharges to waterways of any TRI chemical and discharges of metals to POTWs.

14. EPA, TRI, 2005 PDR.

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17. EPA, TRI, 2005 PDR.

18. EPA, TRI, 2005 PDR.

19. Diane Kurtzman, Kurtz Bros., Inc., communication with Jeffrey Kohn, EPA, January 18, 2008.

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21. Daniel Twarog, NADCA, communication with Jeffrey Kohn, EPA, August 14, 2007.

Oil & Gas

1. *Wells:* World Oil Magazine, Producing Oil Wells, February 2007 (Total 2005), at http://www.worldoil.com/WO_MAG/Feb-2007/07-02_US_Oil_Wells_tab1.htm; *Employment:* Department of Labor, Bureau of Labor Statistics, NAICS codes 211111, 211112, 213111, and 213112; *Production:* Department of Energy, Energy Information Administration, Production in Btu derived from Crude Oil Field Production (Barrels) and Natural Gas Gross Withdrawals and Production (MMcf), http://tonto.eia.doe.gov/dnav/pet/pet_crd_crpdn_adc_mbbl_m.htm; and http://tonto.eia.doe.gov/dnav/ng/ng_prod_sum_dcu_NUS_m.htm.

2. *Refineries:* DOE, EIA, Refinery Capacity Report, Table 1, http://www.eia.doe.gov/oil_gas/petroleum/data_publications/refinery_capacity_data/refcapacity.html, trend data for 1996 and 1998 were not available; *Employment:* Department of Labor, Bureau of Labor Statistics; *Crude Oil Inputs into Refineries:* DOE, EIA, Petroleum Refining & Processing, Weekly Inputs, Utilization & Production http://tonto.eia.doe.gov/dnav/pet/pet_pnp_wiup_dcu_nus_w.htm. Although EIA data indicate 148 refineries, the number of facilities in SIC 2911 (Petroleum Refineries) including the TRI and BR databases exceed this count. This could be the result of numerous factors, such as: (1) there are differences in how EIA defines the sector and how the sector is defined by SIC code 2911, and (2) database counts reflect the number of IDs in the data system; some facilities may inadvertently report under multiple IDs within a data system. 2005 barrels of crude oil inputs into refineries were estimated by multiplying the average weekly inputs (barrels/day) by seven (days/week), and summing all weeks in the calendar year.

3. The relevant NAICS categories (and codes) are Petroleum and Natural Gas Extraction (211111), Natural Gas Liquid Extraction (211112), Drilling Oil and Gas Wells (213111), Oil and Gas Operations Support Activities (213112), and Petroleum Refineries (32411).

4. World Oil Magazine, Producing Oil Wells, February 2007 (Total 2005), http://www.worldoil.com/WO_MAG/Feb-2007/07-02_US_Oil_Wells_tab1.htm; World Oil Magazine, Producing Gas Wells, February 2007 (Total 2005), http://www.worldoil.com/magazine/MAGAZINE_DETAIL.asp?ART_ID=3115&MONTH_YEAR=Feb-2007;

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DOE, EIA, *U.S. Crude Oil and Natural Gas Rotary Rigs in Operation (Count)*, 2005, available at http://tonto.eia.doe.gov/dnav/pet/pet_crd_drill_s1_a.htm.

5. The EIA website contains further information on global production, http://www.eia.doe.gov/emeu/cabs/topworldtables1_2.htm and http://www.eia.doe.gov/emeu/international/RecentNaturalGasProductionTCF.xls.

6. The Exploration and Production overview of this chapter was written based upon the EPA sector lead's knowledge base that was informed by various governmental, industry, and non-governmental information sources including the following: EPA Office of Policy, Economics and Innovation (OPEI) Sector Strategies Program Report Review Draft: *Environmental Impacts from Oil and Gas Production in EPA Region 8*, May 2008; DOE report to Congress, *Energy Demands on Water Resources: Report to Congress on the Interdependency of Energy and Water*, December 2006; and EPA Office of Enforcement and Compliance Assurance (OECA), *Industry Sector Compliance Assistance Notebook: Profile of the Oil and Gas Extraction Industry*, 1999.

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8. WRAP is a collaborative effort and voluntary organization of tribal governments, state governments, and various federal agencies. Formed in 1997, WRAP works to improve visibility in western areas by providing the technical expertise and policy tools needed by states and tribes to implement the federal Regional Haze Rule (RHR).

9. EPA, Technical Support Document for the 2004 Effluent Guidelines Program Plan, EPA-821-R-04-014, August 2004.

10. Devon, Natural Gas STAR Partner Newsletter, http://www.epa.gov/gasstar/pdf/devon_newsletter_1005.pdf.

11. DOE, National Energy Technology Laboratory (NETL) by Argonne National Laboratory, *A White Paper Describing Produced Water from Production of Crude Oil, Natural Gas, and Coal Bed Methane.* January 2004; See also: DOE, report to Congress, *Energy Demands on Water Resources: Report to Congress on the Interdependency of Energy and Water*, p. 47, December 2006.

12. The main sources of water data are from Lasser and HIS, privately managed databases containing data reported by industry to the states for taxation and royalty purposes. They are widely used by industry and government to help characterize oil and gas exploration and production activity. The Lasser data provide information on the number of wells drilled and amount of oil, gas, and water produced. These data were used to estimate the amount of produced water resulting from oil and gas operations as well as well-count and oil and gas production. The HIS database was used to identify the CBM wells and to help disaggregate the well data, including produced water, by well type.

13. DOE, report to Congress, *Energy Demands on Water Resources: Report to Congress on the Interdependency of Energy and Water*, December 2006.

14. International Finance Corporation, World Bank Group, *Environmental, Health and Safety Guidelines: Onshore Oil and Gas Development*, April 30, 2007.

15. Devon, Corporate Responsibility Achievements, www.devonenergy.com/CorpResp/Pages/achievements.aspx.

16. Drilling waste estimates are based on the API report, *Overview of Exploration and Production Waste Volumes and Waste Management Practices in the United States.* This API report provides emission factors for drilling wastes based on production. The Draft EPA Sector Strategies report used those emission factors with operating data from the year of estimate. These emission factors have been used by API for many years and are believed to be the best available.

17. *Energy Use:* DOE, EIA, Manufacturing Energy Consumption Survey (MECS), 2002, Table 3.1, http://www.eia.doe.gov/emeu/mecs/contents.html. *Emissions of Criteria Air Pollutants:* EPA's National Emission Inventory (NEI) for Point Sources: Final v3 2002. *Releases of Chemicals Reported to TRI:* EPA, TRI, Public Data Release (PDR), 2005, freeze date: December 19, 2006; *Hazardous Waste Generated and Managed:* EPA, National Biennial RCRA Hazardous Waste Report, 2005, http://www.epa.gov/epaoswer/hazwaste/data/biennialreport.

18. EPA, Sector Strategies Program (SSP), *Energy Trends in Selected Manufacturing Sectors: Opportunities and Challenges for Environmentally Preferable Energy Outcomes*, 2007, p. 2-10 and 3-11.

19. DOE, *Office of Energy Efficiency and Renewable Energy*, Industrial Technologies Program. *Energy Use, Loss, and Opportunities Analysis: U.S. Manufacturing and Mining*, December 2004.

20. API, *Fuel Choices for Advanced Vehicles*, p. 14, September 2006.

21. EPA, SSP, E*nergy Trends in Selected Manufacturing Sectors: Opportunities and Challenges for Environmentally Preferable Energy Outcomes*, p. 3-11, Petroleum Refining Section, Table 52.

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23. DOE, Office of Energy Efficiency and Renewable Energy, Energy and Environmental Profile of the U.S. Petroleum Refining Industry, November 2007, http://www1.eere.energy.gov/industry/petroleum_refining/analysis.html.

24. EPA, ENERGY STAR, News Room Content, http://yosemite.epa.gov/opa/admpress.nsf/.

25. See Endnote 2, above, discussing number of facilities reporting various releases to TRI.

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27. EPA, TRI, 2005 PDR.

28. EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005.*

29. EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*, p. 3-45.

30. DOE, report to Congress, *Energy Demands on Water Resources: Report to Congress on the Interdependency of Energy and Water*, December 2006.

31. EPA, TRI, 2005 PDR.

32. EPA, TRI, 2005 PDR.

33. EPA, Natural Gas STAR, *Partner Update*, fall 2005.

34. Performance Track recognizes and drives environmental excellence by encouraging facilities with strong environmental records to go beyond their legal requirements.

35. EPA, Performance Track, Feature Stories, http://www.epa.gov/perftrac/members/news/mar08/feature.htm.

Paint & Coatings

1. *Facilities:* Census Bureau, CBP, 2005; available at http://www.census.gov/epcd/cbp/view/cbpview.html, defined by NAICS code 32551 or SIC code 2851; *Employment:* Census Bureau, CBP, 2005; *Production*: Census Bureau, Current Industrial Reports (CIR), 2006; http://www.census.gov/industry/1/ma325f06.pdf; *Value of Shipments:* DOC, BEA: Industry Economic Accounts; http://bea.gov/Industry/Index.htm.

2. *Emissions of Criteria Air Pollutants:* EPA's NEI for Point Sources: Final v3 2002 (includes facilities with NAICS code 32551 or SIC code 2851, data compiled from EPA's facility-summary datasets); *Chemicals Reported to TRI*: EPA Toxics Release Inventory (TRI) 2006

Public Data Release (PDR) (includes facilities that report primary SIC code 2851 on their Form R); *Hazardous Waste Generated and Managed:* EPA, *National Biennial RCRA Hazardous Waste Report*, 2005, http://www.epa.gov/epaoswer/hazwaste/data/biennialreport.

3. The sector is defined by SIC code 2851 or NAICS code 32551.

4. Census Bureau, Economic Census, Paint and Coating Manufacturing: 2002, issued June 2005, Table 3, http://www.census.gov/prod/ec02/ec0231i325510.pdf. Census Bureau, Economic Census, General Summary: 2002, issued October 2005, Table 4, http://www.census.gov/econ/census02/guide.

5. EPA TRI, 2006 PDR, modeled through EPA's Risk-Screening Environmental Indicators (RSEI).

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7. EPA NEI for Point Sources: Final v3 2002.

8. EPA NEI for Point Sources: Final v3 2002.

9. Includes direct discharges to waterways of any TRI chemical and discharges of metals to POTWs.

10. EPA TRI, 2006 PDR.

11. Federal Register, February 13, 2001, p. 10060; the survey covered manufacturers of architectural, original equipment manufacturers, and special purpose paints/coatings, but did not include the other categories, such as miscellaneous allied products and artist paint.

12. In responding to public comment in the final rule (Federal Register, April 4, 2002, p. 16262) EPA examined the impact of revising its statistical analysis somewhat, which had the effect of reducing the total wastewater volume slightly to about 14.5 million gallons.

13. Due to an apparent reporting error, a non-paint and coatings facility is included in the hazardous waste generation total of 146,000 tons and constitutes 12% of this total. If removed, the industry's total hazardous waste generation would be reduced to 129,000 tons. Industry classification for Haros Anodizing Specialists Inc. from Dun & Bradstreet, accessed via EPA's Integrated Data for Enforcement Analysis (IDEA), April 2008.

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15. EPA, *National Biennial RCRA Hazardous Waste Report*, 2005,: http://www.epa.gov/epaoswer/hazwaste/data/biennialreport/.
This sector is defined by NAICS code 32551.

16. EPA TRI, 2006 PDR.

17. EPA TRI, 2006 PDR.

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19. Product Stewardship Institute, "Paint Product Stewardship Initiative Background Summary," October 29, 2004 (revised April 1, 2005), http://www.productstewardship.us/associations/6596/files/PaintMOUBkgrdSummary.doc.

20. EPA, "Quantifying the Disposal of Post-Consumer Architectural Paint," final report prepared for EPA's Sector Strategies Division by Abt Associates, Inc., April 2007.

21. Product Stewardship Institute, "PSI Paint Project-National Dialogue," http://www.productstewardship.us/displaycommon.cfm?an=1&subarticlenbr=117.

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1. *Number of Ports:* AAPA, U.S. Public Port Facts, http://www.aapa-ports.org; *Direct Jobs*: AAPA, The Local and Regional Economic Impacts of the U.S. Deepwater Port System, 2006, p.7, prepared by Martin Associates, September 5, 2007, http://www.aapa-ports.org/Press/PRdetail.cfm?itemnumber3485; *Revenue*: Census Bureau, 1997 and 2002 Economic Census, http://www.census.gov/econ/census02, North American Industry Classification System (NAICS) codes 48831 and 48832.

2. In the 2005 survey, 48 ports responded, representing a 57% response rate.

3. Meredith Martino, AAPA, personal correspondence with Kathleen Bailey, EPA, regarding unpublished surveys conducted in 2005 and 2007.

4. *Number of Ports*, U.S. Public Port Facts, AAPA, http://www.aapa-ports.org; *Contribution of port activity to GDP*: Trade & Economic Growth - Port Industry Information, http://www.aapa-ports.org; *Customs Revenue*: U.S. Customs and Border Protection, http://www.nemo.cbp.gov/of/customs_report.pdf.

5. AAPA, "U.S. Port Industry," http://www.aapa-ports.org/Industry/content.cfm?ItemNumber=1022&navItemNumber=901.

6. Department of Transportation, Bureau of Transportation Statistics, *Pocket Guide to Transportation 2007*, Tables 5-5 and 5-6, http://www.bts.gov/publications/pocket_guide_to_transportation/2007.

7. Cruise Lines International Association, *The Cruise Industry: A $35.7 Billion Partner in U.S. Economic Growth*, undated, http://www.cruising.org/press/research/2006.CLIA.EconomicSummary.pdf.

8. Testimony of Jean Godwin, AAPA, before the National Surface Transportation Policy and Revenue Study Commission, March 19, 2007, http://www.transportationfortomorrow.org/pdfs/commission_meetings/0307_field_hearing_washington/031907_fh_aapa_testimony.pdf.

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17. Port of Oakland, "Port of Oakland and SunEdison Flip the Switch" (press release), November 8, 2007, http://www.oaklandairport.com/press_releases_detail.cfm?ID=500.

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Shipbuilding & Ship Repair

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3. See Article 4(1)(a) of the United Nations Framework Convention on Climate Change http://www.unfccc.int. Under decision 3/CP.5 of the UNFCCC Conference of the Parties, national inventories for UNFCCC Annex I parties should be provided to the UNFCCC Secretariat each year by April 15. Parties to the Convention, by ratifying, "shall develop, periodically update, publish and make available...national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the *Montreal Protocol*, using comparable methodologies..." Article 4(1)(a) of the United Nations Framework Convention on Climate Change (also identified in Article 12). Subsequent decisions by the Conference of the Parties elaborated the role of Annex I Parties in preparing national inventories. See http://unfccc.int.

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United States Environmental Protection Agency
Sector Strategies Division
Office of Cross Media Programs (1807T)
EPA 100-R-08-002
September 2008

Recycled/Recyclable
Printed on paper that contains
at least 50% post consumer fiber.