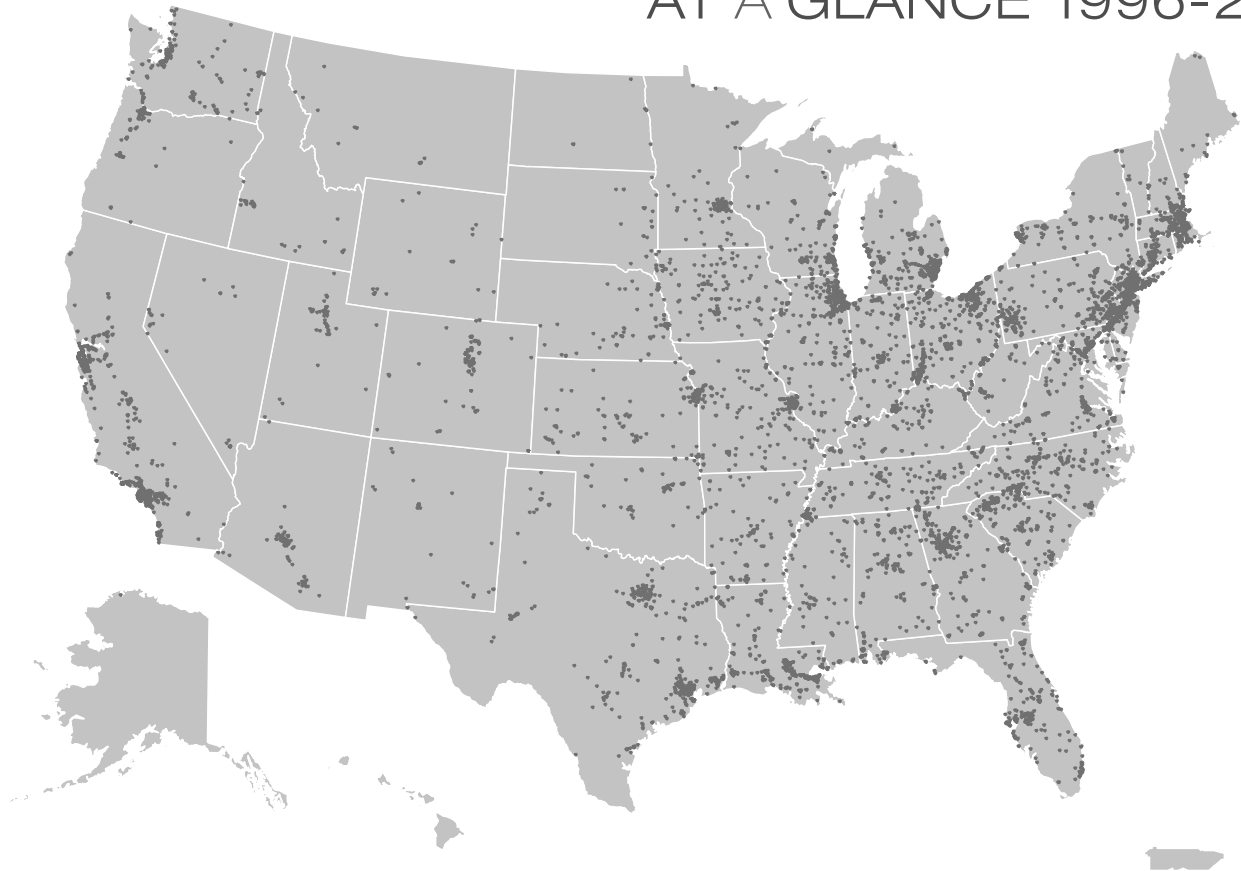




# CHEMICAL MANUFACTURING

AT A GLANCE 1996-2005<sup>1</sup>



12,377  
facilities

13,220  
▲ 7%

833,230  
employees

810,368  
▼ 3%

\$368 billion  
value of  
shipments

\$555 billion  
▲ 51%



# Latest Environmental Statistics<sup>2</sup>

**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.<sup>3</sup>

- 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).<sup>4</sup>

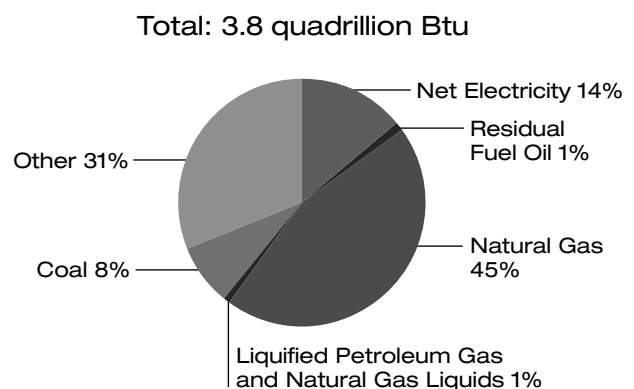
Throughout this chapter, the distinction is made between “all chemical manufacturing” and “specialty-batch manufacturing,” whenever separate data are available. “All chemical manufacturing” includes both commodity and specialty-batch processors.

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.<sup>5</sup>

**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.<sup>6</sup> 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.<sup>7</sup>

### 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.<sup>8</sup>

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.<sup>9</sup> 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<sub>2</sub>) emission reductions of 382,821 tons.<sup>10</sup>

### 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<sub>2</sub> emissions reductions of 10,962 tons.<sup>11</sup>

## 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.<sup>12</sup> 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.

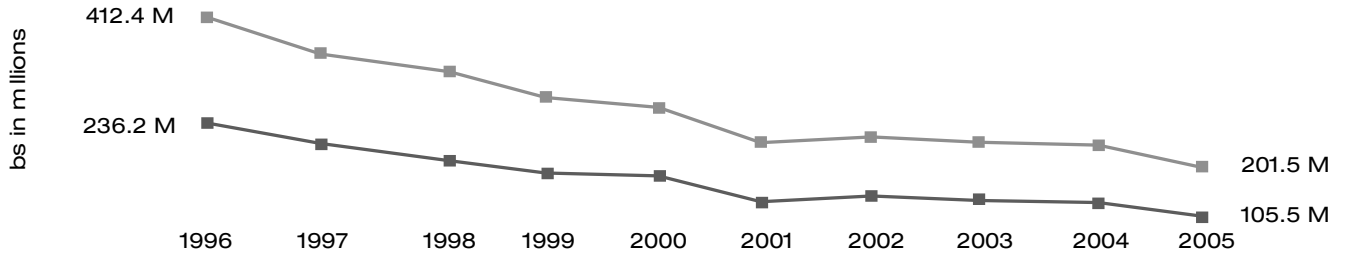
To consider toxicity of air emissions, EPA’s Risk-Screening Environmental Indicators (RSEI) model assigns every TRI chemical a relative toxicity weight, then multiplies the pounds of media-specific releases (e.g., pounds of mercury released to air) by a chemical-specific toxicity weight to calculate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

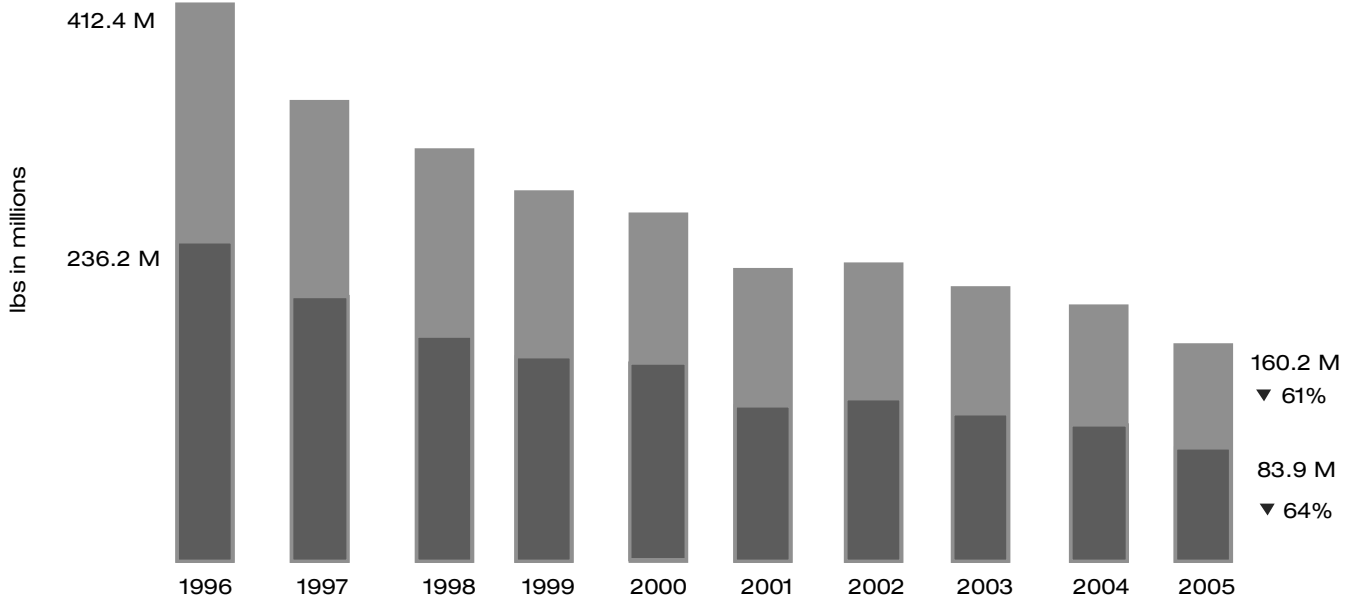
**FIGURE 2**  
Air Emissions Reported to TRI 1996-2005

■ All TRI Chemicals, including HAPs  
■ HAPs

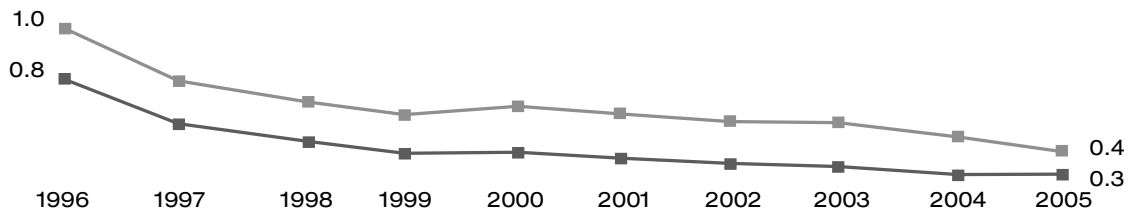
**a. Absolute lbs**



**b. Normalized lbs**



**c. Normalized Toxicity Score Trend**



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.<sup>13</sup> 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.<sup>14</sup>

Over the same period, air emissions from the specialty-batch subsector declined by 49%.<sup>15</sup> 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.<sup>16</sup>

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 <sup>1</sup>	Percentage of Toxicity Score	Number of Facilities Reporting <sup>2</sup>
<i>Acrolein</i> <sup>3</sup>	49,000	8% <sup>4</sup>	37
Ammonia	50,421,000	2%	589
<i>Carbon Disulfide</i>	10,111,000	<1%	54
<i>Carbonyl Sulfide</i>	12,852,000	4%	33
<i>Certain Glycol Ethers</i>	600,000	<1%	484
Chlorine	1,048,000	18%	285
Chromium	32,000	5% <sup>5</sup>	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
<i>Xylene (Mixed Isomers)</i>	2,793,000	<1%	585
<b>Percentage of Sector Total</b>	<b>62%<sup>6</sup></b>	<b>60%<sup>7</sup></b>	<b>65%<sup>8</sup></b>

**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.).<sup>17</sup>

## 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.<sup>18</sup> 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 <sub>2</sub>	482,000
NO <sub>x</sub>	309,000
PM <sub>10</sub>	57,000
PM <sub>2.5</sub>	39,000
CO	476,000
VOCs	175,000

**Note:**

PM<sub>10</sub> includes PM<sub>2.5</sub> emissions.

Source: U.S. Environmental Protection Agency

## Reduced Energy Use and CO<sub>2</sub> 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<sub>2</sub> emissions avoided.<sup>19</sup>

## Greenhouse Gases

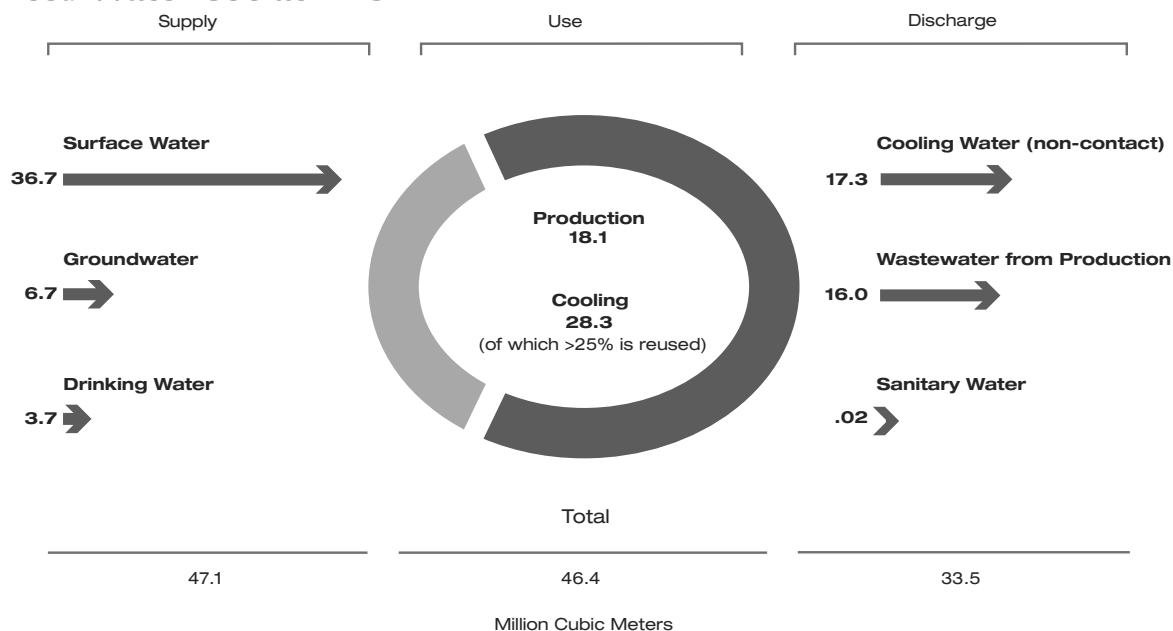
Chemical manufacturers directly emit GHGs from the combustion of fossil fuels and from production processes. Non-combustion emissions occur from the use of fossil fuels as feedstocks and the use of other raw materials. Such emissions include nitrous oxide (N<sub>2</sub>O), fluoroform (HFC-23), CO<sub>2</sub>, and methane (CH<sub>4</sub>). The largest process-related sources of GHG emissions include production of hydrochlorofluorocarbons (HCFCs), ammonia, and acids such as nitric and adipic acid.<sup>20</sup> 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.<sup>21</sup> 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.<sup>22</sup> The companies reduced their GHG intensity by more than 30% since 1992; GHG intensity fell 5% between 2003 and 2005.<sup>23</sup>

## 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.<sup>24</sup> 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.<sup>25</sup> Throughout the sector, more than 80% of the water used for cooling and steam is recycled; process water recycling varies widely.<sup>26</sup> 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.<sup>27</sup>

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.<sup>28</sup> 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.<sup>29</sup>

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%.<sup>30</sup>



## 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.<sup>31</sup>

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.<sup>32</sup>

# 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.<sup>33</sup>

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.<sup>34</sup>





## Waste Management Reported to TRI

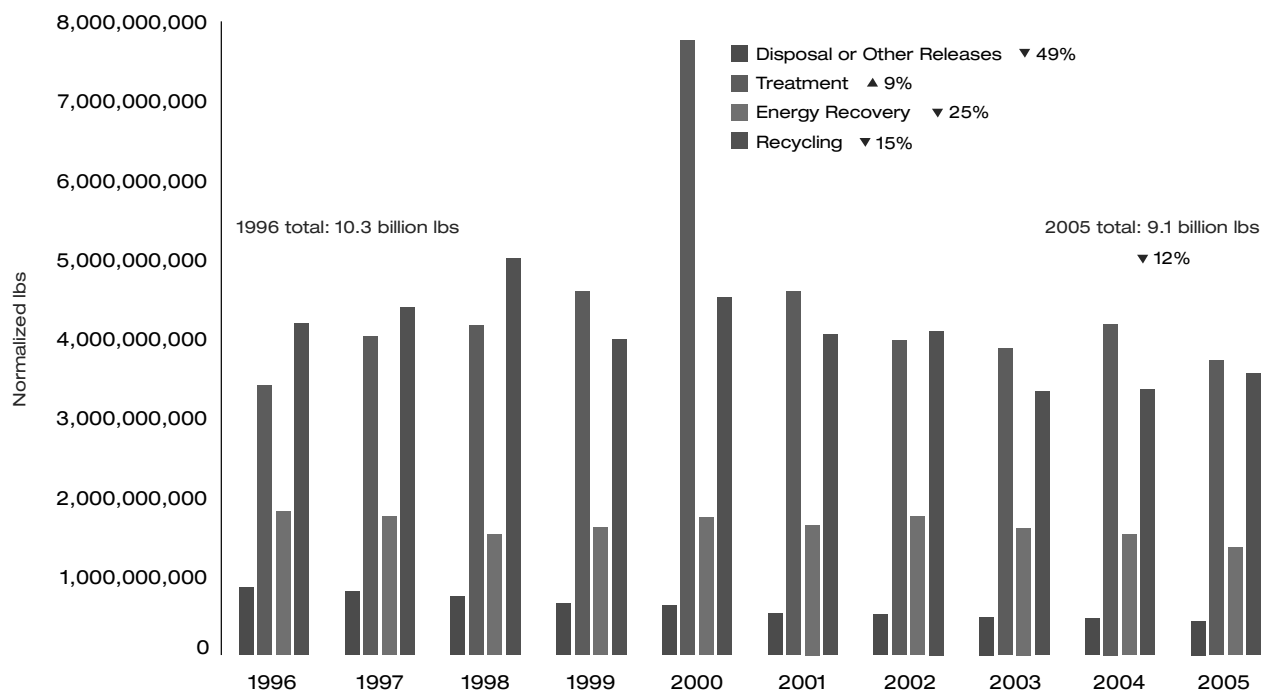
In 2005, chemical manufacturers reported managing 11.4 billion absolute lbs. of TRI chemicals in waste. When normalized by the sector's VOS, this was 12% less than 1996. Figure 3 shows how the sector managed this waste. In 2005, 5% of TRI-reported waste was released or disposed. Most of the waste disposed 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.<sup>35</sup> 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.<sup>36</sup>

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 <sup>1</sup>	Number of Facilities Reporting <sup>2</sup>
Acetonitrile	16,700,000 <sup>3</sup>	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% <sup>4</sup>	27% <sup>5</sup>

**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<sub>2</sub> emissions. Nitrogen reductions brought significant supplier energy savings and CO<sub>2</sub> 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<sub>2</sub> 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.<sup>37</sup> In 2006 the distillation equipment realized an annual total waste reduction of 609 tons.<sup>38</sup>

## 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.<sup>39</sup> 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.<sup>40</sup>