Cement

PROFILE The cement sector[4] comprises 114 plants in 37 states that produce portland cement, which is used as a binding agent in virtually all concrete. Concrete, in turn, is used in a wide variety of construction projects and applications. In 2004, California, Texas, Pennsylvania, Michigan, Missouri, and Alabama were the six leading cement-producing states, accounting for approximately one-half of U.S. production.[5]

Sector At-a-Glance

Number of Facilities:	114[1]
Value of Shipments:	$8 billion[2]
Number of Employees:	17,500[3]

TRENDS Buoyed by a strong residential construction market, the U.S. cement industry has grown in recent years. Higher prices for other construction materials such as steel and lumber also contributed to greater reliance on cement and, therefore, increased the demand for cement.

- Between 2003 and 2004, U.S. cement consumption increased by nearly 7% to a record 115 million metric tons. Forecasters expected a 5% increase in consumption in 2005.[6]
- Most of the U.S. demand for cement in 2004 was met by domestic production. Operating at maximum capacity, U.S. facilities produced 95 million metric tons of cement (including portland and masonry cement), an increase of 2% over 2003.[7]
- To meet increasing demand, U.S. cement manufacturers have announced plans to increase production capacity by 15% (nearly 15 million tons) by 2010.[8]

In addition, the effort to rebuild New Orleans and the Gulf Coast area after Hurricanes Katrina and Rita, which struck the region in August and September of 2005, is expected to increase demand for cement over the next four to five years.[9]

KEY ENVIRONMENTAL OPPORTUNITIES

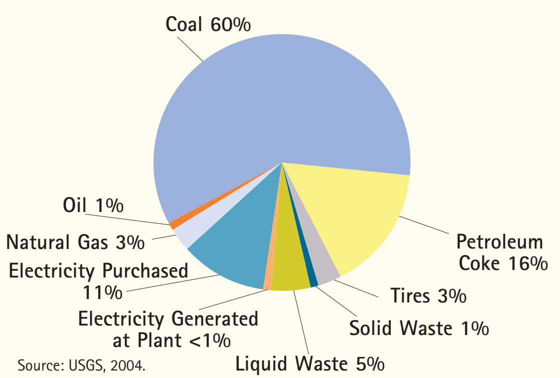
For the cement sector, the greatest opportunities for environmental improvement are in increasing energy efficiency, reducing air emissions, and managing and minimizing toxics and waste.

The cement sector voluntarily tracks its environmental performance. In recent years, the Portland Cement Association (PCA) has expanded its data collection efforts to obtain information on environmental indicators such as air emissions, implementation of environmental management systems, and handling of cement kiln dust (CKD). PCA reported on these results and other issues in its inaugural *Report on Sustainable Manufacturing* in 2005.[10]

INCREASING ENERGY EFFICIENCY Cement is composed of four elements – calcium, silica, aluminum, and iron – which are commonly found in limestone, clay, and sand. Cement manufacturing requires the thermochemical processing (i.e., pyroprocessing) of substantial quantities of these raw materials in huge kilns at very high and sustained temperatures to produce an intermediate product called clinker. Cement kilns use an average of nearly 5 million Btus per ton of clinker.[11] Clinker is then ground up with a small quantity of gypsum to create portland cement.

As illustrated in the *Distribution of Cement Energy Consumption* pie chart, cement manufacturing processes are fueled by coal and petroleum coke, electricity, wastes, and natural gas.

Distribution of Cement Energy Consumption



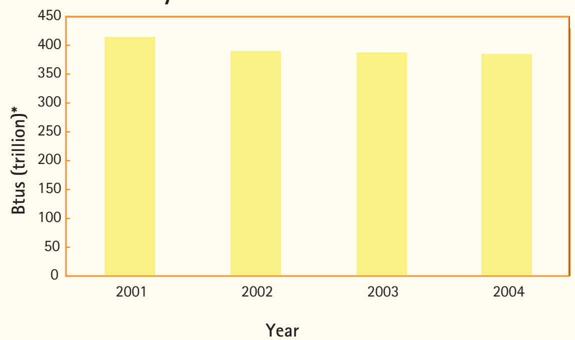
Source: USGS, 2004.

In 2004, the industry derived 60% of its energy from coal. Another 16% of the sector's energy was from petroleum coke, 5% from solid and liquid wastes, and the balance from natural gas, fuel oils, and used tires.[12]

As shown in the *Energy Consumption* bar chart, the cement sector consumed 422 trillion Btus of energy in 2004,[13] which represented almost 2% of total energy consumption by U.S. manufacturing that year.[14] When normalized for production, the sector's 2004 energy consumption was 7% lower than in 2001.

The following case study illustrates measures taken at one cement plant to save energy and reduce accompanying emissions.

Energy Consumption by the Cement Sector



* Normalized by annual clinker production.
Source: USGS.

Case Study: California Portland Cement Company's Energy Management Program *The California Portland Cement Company worked with EPA's ENERGY STAR program to develop a formal corporate energy management program and an energy management team at its Colton, CA, plant. The energy savings measures identified and implemented at the Colton plant included improvements in the manufacturing process, equipment upgrades or replacement, and new policies for equipment procurement. Through these efforts, the plant has significantly reduced its energy use and accompanying emissions. Between 2003 and 2004, the Colton plant reduced its energy consumption per unit of production by nearly 5%, which translated into more than $800,000 in savings and the prevention of nearly 30,000 metric tons of carbon dioxide (CO_2) emissions.*

The California Portland Cement Company's energy management program is designed to achieve continuing improvements in energy efficiency through the following actions:

- *Establishing baseline energy use through metering and other reporting methods;*
- *Setting goals based on benchmarking and industry best practices;*
- *Performing audits to identify opportunities for energy savings;*
- *Implementing energy savings measures through capital spending, operations and maintenance practices, purchasing policies, and inventory controls; and*
- *Measuring improvements.*[15]

REDUCING AIR EMISSIONS Cement manufacturing operations emit criteria air pollutants and greenhouse gases (GHG).

Criteria Air Pollutants Three criteria air pollutants are released to the air during cement manufacturing: nitrogen oxides (NO_X), sulfur dioxide (SO_2), and particulate matter (PM).

The combustion of fuels at high temperatures in cement kilns results in the release of NO_X emissions. EPA's National Emissions Inventory (NEI) estimates that, in 2002, the sector released 214,000 tons of NO_X emissions. As shown in the *Nitrogen Oxide and Sulfur Dioxide Emissions* bar chart, between 1996 and 2002 the normalized quantity of NO_X emissions fell by 6% through the use of various process controls. In 2002, NO_X emissions from the cement sector accounted for approximately 1% of total U.S non-agricultural NO_X emissions.[16]

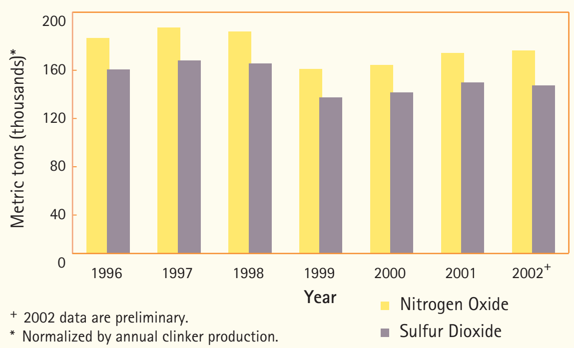
SO_2 emissions from cement plants result from the combustion of sulfur-bearing compounds in coal, oil, and petroleum coke, and from the processing of pyrite and sulfur in raw materials. To mitigate these emissions, cement plants typically install air pollution control technologies called "scrubbers" to trap such pollutants in their exhaust gases. In addition, the limestone used to produce cement has "self-scrubbing" properties, which enable the industry to handle high-sulfur fuels. NEI estimates that, in 2002, the sector released 177,000 tons of SO_2 emissions. As shown in the *Nitrogen Oxide and Sulfur Dioxide Emissions* bar chart, between 1996 and 2002 the normalized quantity of SO_2 emissions decreased by 9%.[17]

Quarrying operations, the crushing and grinding of raw materials and clinker, and the kiln line also result in PM emissions during cement manufacturing. Most of the PM in the exhaust gases from cement plants is removed by fabric filters (known as "baghouses") or by electrostatic precipitation. As described later in this section, this PM (know as CKD) is often reused in the cement manufacturing process. NEI estimates that, in 2002, the sector released 31,000 tons of PM_{10} emissions and 13,000 tons of $PM_{2.5}$ emissions. As shown in the *Particulate Matter Emissions* bar chart, between 1996 and 2002 the normalized quantity of PM_{10} emissions from the cement sector remained fairly constant, following marked improvements begun in the early years of implementing the Clean Air Act.[18]

Greenhouse Gases In the cement sector, CO_2 emissions result from the burning of fossil fuels (predominantly coal) during pyroprocessing and from the chemical reactions (calcination) that convert limestone into clinker.

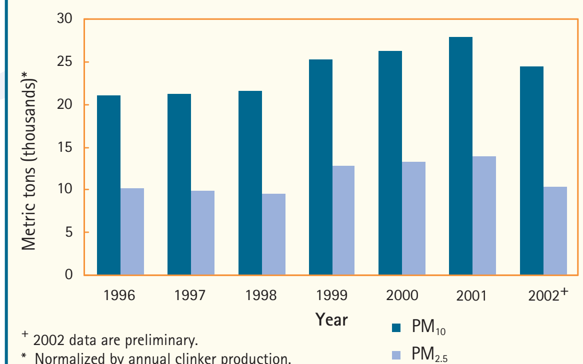
In 2003, fuel combustion accounted for about 97% of total CO_2 emissions in the U.S. – with more than 60% of that coming from power plants and motor vehicles. CO_2 emissions from all industrial processes accounted for about 2.5% of national CO_2 emissions. Within that industrial percentage, iron and steel production accounted for about 37%, while cement manufacturing contributed 29%. Although this sector is the second largest industrial source of CO_2 emissions in the U.S., it accounts for less than 1% of total U.S. CO_2 emissions.[19]

Nitrogen Oxide and Sulfur Dioxide Emissions from the Cement Sector



+ 2002 data are preliminary.
* Normalized by annual clinker production.
Sources: U.S. EPA, USGS.

Particulate Matter Emissions from the Cement Sector



+ 2002 data are preliminary.
* Normalized by annual clinker production.
Sources: U.S. EPA, USGS.

In 2003, PCA formalized its commitment to reduce CO_2 emissions from the cement sector by joining Climate VISION, a voluntary program administered by DOE. PCA committed to a 10% reduction in CO_2 emissions per ton of product by 2020 (from a 1990 baseline). The sector hopes to reach this goal through changes in the cement manufacturing process and in product formulation.[20] In addition, four cement companies have joined EPA's Climate Leaders program, which helps partners to develop long-term comprehensive climate change strategies, set corporate-level GHG reduction goals, and inventory emissions to measure progress. Partner companies include California Portland Cement Company, Holcim (US) Inc., St. Lawrence Cement, and LaFarge North America Inc.[21]

Managing and Minimizing Toxics

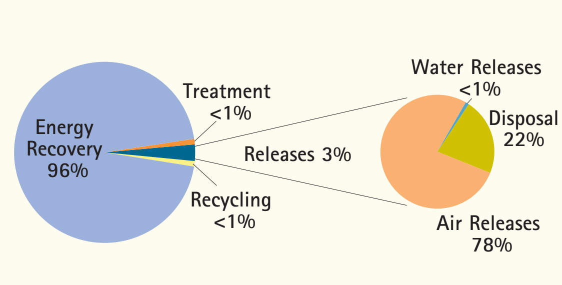
Cement manufacturing facilities use a variety of chemicals and report on the release and management of many of those materials through EPA's Toxics Release Inventory (TRI).

In 2003, 102 facilities in the sector reported 450 million pounds of chemicals released (including disposal) or otherwise managed through treatment, energy recovery, or recycling. Of this quantity, 96% was managed through energy recovery, while 3% was disposed or released to the environment, as shown in the *TRI Waste Management* pie chart. Of those chemicals disposed or released to the environment, 22% were disposed and 78% were released into air or water.

As shown in the *Total TRI Disposal or Other Releases* line graph, the annual normalized quantity of chemicals disposed or released by the cement sector increased by 196% between 1994 and 2003. This increase primarily occurred prior to 1998, and reported disposal and release quantities have remained fairly stable since then. Quantities released to air and water followed a similar trend.

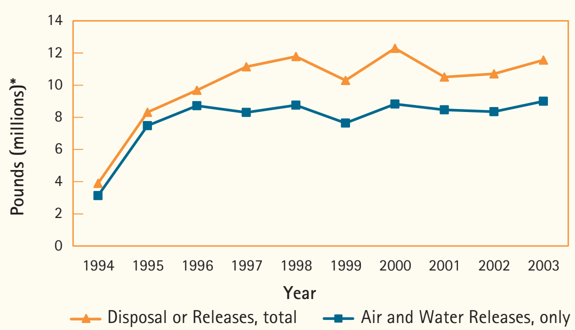
In 2003, hydrochloric and sulfuric acids accounted for 51% of the amount released or disposed, while ammonia, manganese, and zinc accounted for another 24%. Along with ethylene, benzene, and lead, these chemicals accounted for 89% of all pounds reported to TRI as disposed or released by the cement sector.[22]

TRI Waste Management by the Cement Sector



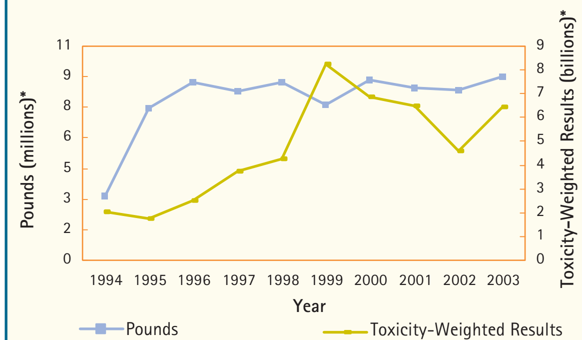
Source: U.S. EPA, 2003.

Total TRI Disposal or Other Releases by the Cement Sector

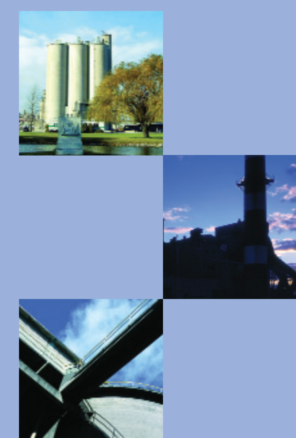


* Normalized by annual clinker production.
Sources: U.S. EPA, USGS.

TRI Air and Water Releases by the Cement Sector



* Normalized by annual clinker production.
Sources: U.S. EPA, USGS.



Data from TRI allow comparisons of the total quantities of a sector's reported chemical releases across years, as presented earlier in this chapter. However, this comparison does not take into account the relative toxicity of each chemical. Chemicals vary greatly in toxicity, meaning they differ in how harmful they can be to human health. To account for differences in toxicities, each chemical can be weighted by a relative toxicity weight using EPA's Risk-Screening Environmental Indicators (RSEI) model.

The *TRI Air and Water Releases* line graph on the previous page presents trends for the sector's air and water releases in both reported pounds and toxicity-weighted results. When weighted for toxicity, the sector's normalized air and water releases increased by 218% from 1994 to 2003. Between 2000 and 2003, toxicity-weighted results remained fairly steady, despite some fluctuations. Increases in reported releases of sulfuric acid, manganese, and lead were the primary drivers in the overall toxicity-weighted increase in 2003.

The table below presents a list of the chemicals released that accounted for 90% of the sector's total toxicity-weighted releases to air and water in 2003. More than 99% of the sector's toxicity-weighted results were attributable to air releases, while discharges to water accounted for less than 1%. Therefore, reducing air emissions of these chemicals represents the greatest opportunity for the sector to make progress in reducing the toxicity of its releases.

Top TRI Chemicals Based on Toxicity-Weighted Results

AIR RELEASES (99%)	WATER RELEASES (<1%)
Sulfuric Acid	Lead
Manganese	Mercury
Lead	
Chromium	
Hydrochloric Acid	

Source: U.S. EPA

From 2000 to 2003, the normalized air releases of the chemicals driving the sector's toxicity-weighted results changed as follows: sulfuric acid and lead both fluctuated from year-to-year, manganese releases increased by 65%, and chromium releases decreased by 72%.

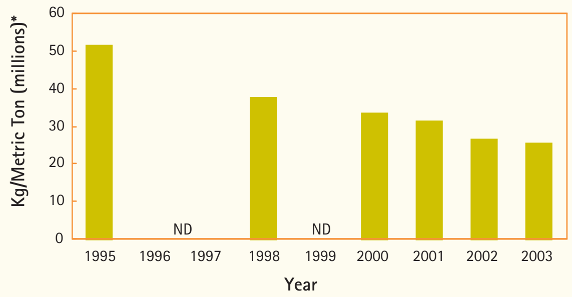
EPA's RSEI model conservatively assumes that chemicals are released in the form associated with the highest toxicity weight. With respect to chromium releases to air and water, therefore, the model assumes that 100% of these emissions are hexavalent chromium (the most toxic form, with significantly higher oral and inhalation toxicity weights than trivalent chromium).[23] Research indicates that the hexavalent form of chromium does not constitute a majority of total chromium releases in the sector.[24] Thus, RSEI analyses overestimate the relative harmfulness of chromium in the sector.

Managing and Minimizing Waste The cement sector reuses CKD generated during the cement production process and utilizes waste products from other industry sectors both as material inputs and as fuel. The cement sector also generates hazardous waste.

Cement Kiln Dust CKD consists of the particles released from the pyroprocessing line at cement plants. It includes partially burned raw materials, clinker, and eroded fragments from the refractory brick lining of the kilns. Recycling CKD reduces the amount of raw materials needed for cement production, and because CKD is already partially processed, recycling it also reduces energy consumption. The industry recycles more than 75% of its CKD, nearly eight million tons, each year.[25] When normalized by annual clinker production, the amount of CKD sent to landfills has declined by 49% since 1995, as shown in the *Cement Kiln Dust Disposed in Landfills* bar chart.[26] Newer plants (typically dry-kiln operations with pre-heater and pre-calciner technologies) are more effective at recovering CKD and reusing it in the manufacturing process.

There are limits, however, to recycling CKD in the manufacturing process, because contaminants can build up in the CKD and compromise the quality of the clinker. The CKD that is not recycled is either disposed at a landfill or sold to other sectors for beneficial reuse applications, such as road fill, liming agent for soil, or as a stabilizer for sludges and other wastes.

Cement Kiln Dust Disposed in Landfills by the Cement Sector



ND=No Data
* Normalized by annual clinker production.
Source: PCA.

Waste Products as an Energy Source The cement sector relies primarily on a combination of coal and petroleum coke for fuel. However, the sector also uses waste products such as tires and used motor oil as fuel sources. In a 2001 survey, PCA found that 53 of the 95 member plants that responded were using some type of waste fuel, with tire-derived fuel being the most common waste fuel used. The survey also found that waste fuels provided almost 8% of the Btus consumed by the sector in 2001.[27]

Hazardous Waste EPA hazardous waste data on large quantity generators, as reported in the *National Biennial RCRA Hazardous Waste Report*, indicate that the waste generated by the cement sector accounted for less than 1% of the hazardous waste generated nationally in 2003.

In 2003, 15 cement facilities reported 14,900 tons of hazardous waste generated. Nearly 86% of this waste was generated from managing wastes and production or service-related processes. The waste management method most utilized by this sector was onsite energy recovery for use as fuel.

When reporting hazardous wastes to EPA, quantities can be reported as a single waste code (e.g., lead) or as a commingled waste composed of multiple types of wastes. Quantities of a specific waste within the commingled waste are not reported. In the cement sector, individually reported wastes accounted for less than 1% of the wastes reported. With such limited data, no meaningful conclusions can be drawn about the most predominant types of waste generated by the sector.[28]