# VOLUNTARY $CO_2$ TARGET FOR THE U.S. CEMENT INDUSTRY

APCA Board of Directors Approved on July 19, 2001 the following Goal:

The cement industry endorses a voluntary goal to reduce $CO_2$ emissions by ten percent per ton [from a baseline of 1990] of cementitious product produced—and/or sold for use in concrete applications—by the year 2020.

2012

# U.S. Cement Industry: Perspectives on Climate Change

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# U.S. Cement Industry: Perspectives on Climate Change

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# U.S. Cement Industry: Perspectives on Climate Change

## Executive Summary

Cement manufacturing requires the combustion of large amounts of fossil fuels; as a consequence, the industry emits greenhouse gases, particularly carbon dioxide ($CO_2$). The U.S. portland cement industry has made great strides over the last few decades to improve energy efficiency, and, as a result, has reduced markedly the amount of $CO_2$ emitted per ton of cement produced. Nevertheless, the process remains energy intensive, and international policies to reduce atmospheric concentrations of greenhouse gases could have a deleterious effect on U.S. production. The industry is, therefore, very interested in the development and outcome of international negotiations addressing greenhouse gas emission reductions.

Portland cement is produced by grinding limestone and other materials to a fine powder, which is then heated to around 2700°F. The resulting clinker is ground again with gypsum to produce cement. Cement is mixed with stone, sand, and water to produce concrete, a major building material.

Because of the high temperatures required to make cement, the manufacturing process is energy intensive. In recent decades, however, the cement industry has increased energy efficiency considerably through the installation of very efficient "dry" process manufacturing technology and other efforts. Moreover, because cement comprises a relatively small portion of concrete, the energy used per ton of concrete still compares favorably to other building materials.

In addition to the greenhouse gas emissions resulting from fossil fuel combustion, cement manufacturing produces carbon dioxide directly when the raw materials are heated to produce clinker. This process, called calcination, liberates the $CO_2$ from limestone -- which is composed primarily of calcium carbonate ($CaCO_3$) -- to produce calcium oxide ($CaO$).

There are a number of opportunities that the U.S. cement industry may take to reduce $CO_2$ emissions, including: further improvements in energy efficiency, the use of alternative fuels and raw materials, and other efforts. By taking advantage of these opportunities, the portland cement industry can help the United States meet its $CO_2$ reduction targets. Individual cement companies and the American Portland Cement Alliance are working closely with EPA and DOE as participants in the Climate Wise program to voluntarily reduce greenhouse gas emissions.

# U.S. CEMENT INDUSTRY: PERSPECTIVES ON CLIMATE CHANGE

## INTRODUCTION

Climate change is an issue of global concern. Though it has not been universally accepted that climate change is in fact occurring, a body of evidence suggests that the rising levels of greenhouse gases in the atmosphere are linked to climate change. These gases, primarily carbon dioxide ($CO_2$), nitrous oxide ($N_2O$), and methane ($CH_4$), trap heat in the atmosphere, perhaps resulting in increased global temperatures. Despite the lack of conclusive evidence or unanimity, there is broad international consensus that the potential risks associated with climate change are sufficiently great that action should be taken to reduce, or at least stabilize, greenhouse gas emissions.

The formation of the Intergovernmental Panel on Climate Change (IPCC) in 1988 marked the first time that governments throughout the world gave broad attention to the issues of greenhouse gas emissions and the possibility of climate change. The IPCC was responsible for assessing the scientific information on climate change, potential environmental and socio-economic impacts, and possible response strategies. The IPCC issued its First Assessment Report in 1990. This report provided a scientific basis for negotiators to draft a treaty on climate change that was introduced at the United Nations Conference on Environment and Development (the Rio Earth Summit) in June 1992.

The treaty referred to as the Framework Convention on Climate Change (FCCC) became effective in 1994. The objective of the FCCC is to stabilize atmospheric concentrations of greenhouse gases at levels that would prevent dangerous interference with the global climate. Developed countries agreed to take the lead in reducing emissions and, as a non-binding target, hold their emissions in the year 2000 to 1990 levels or below.

President Clinton, in April 1993, confirmed the U.S. intention of meeting this target and, in October 1993, the Administration issued the Climate Change Action Plan (CCAP) which consists of primarily voluntary measures aimed at achieving the emission goal. A number of factors combined to weaken the effectiveness of the CCAP and it is now apparent that U.S. greenhouse gas emissions in 2000 will probably be significantly above 1990 levels.

In the summer of 1996, the second Conference of the Parties (COP-2) agreed that the existing FCCC commitments were not sufficient to address the issue of climate change and that new <u>binding</u> commitments were needed. The parties agreed that these commitments would be negotiated with the understanding that they would apply only to industrialized countries. These commitments are to be ready for adoption at the third Conference of the Parties (COP-3) in December 1997.

The cement manufacturing process produces relatively minor amounts of $N_2O$ and $CH_4$, but emits $CO_2$ from combustion of fossil fuel and from chemical reactions that occur when raw materials are heated during the manufacturing process. The focus of this paper -- and of the cement industry's efforts to reduce greenhouse gas emissions -- is on $CO_2$ emissions. By decreasing carbon dioxide emissions through enhanced energy efficiency or alternative raw materials, cement manufacturers can make significant contributions to global efforts to avert climate change.

The U.S. cement industry is concerned about the type of commitments that may emerge from COP-3, the principal concern being the potential for upsetting the global balance in a widely traded product such as cement. The U.S. cement industry stance is that binding targets should be prescribed only in a more realistic timeframe, such as achieving 1990 levels by 2020, rather than by 2000 or 2005.

## BACKGROUND ON CEMENT AND CONCRETE

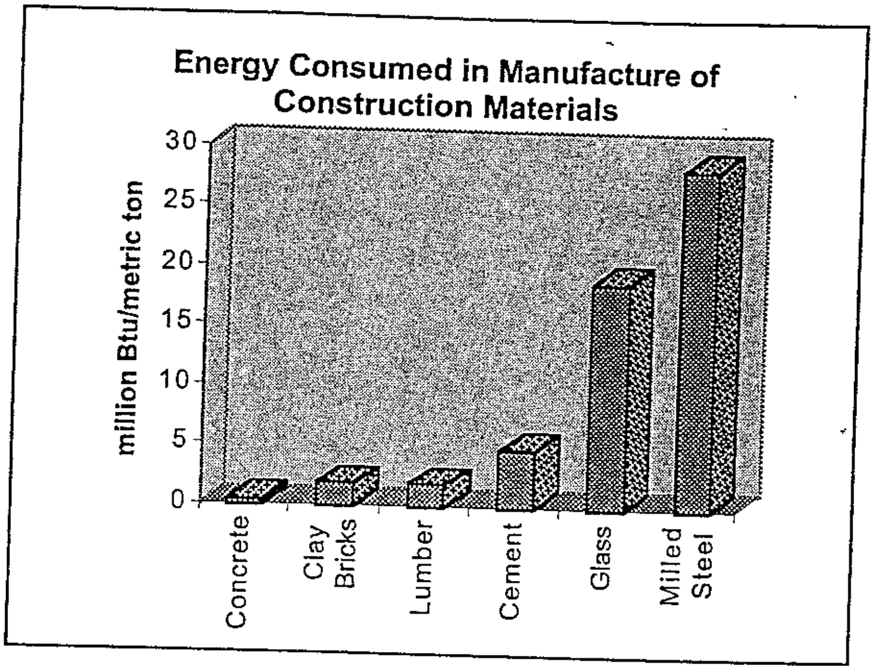
Portland cement is a finely-ground manufactured mineral product that, when mixed with water, sand, gravel and other materials, forms concrete, the most widely used construction material in the world. The raw materials used to produce cement are primarily limestone, shale, clay, and silica sand.

These materials, usually quarried within a few miles of the cement plant, are crushed, proportioned to give the required chemical composition, and ground to a fine powder. Small quantities of iron oxide and alumina may be added to adjust the chemistry of the raw material mixture. The mixture is heated to about 2700°F (1500°C) in large rotary kilns. The resulting intermediate product is clinker, a hard granular substance, that is discharged from the kiln and ground with approximately 5 percent gypsum to produce cement.

Cement manufacturing is energy intensive, requiring an average of 5.26 million Btu per metric ton of product in U.S. plants. The energy consumption data provided in this paper include both fuel and power use. All masses are reported in metric tons. The average efficiency for different types of cement plants ranges from 4.4 to 6.5 million Btu per ton of product.

Concrete contains 10 - 15 percent cement, the remainder being crushed stone or gravel, sand, and water. The cement reacts with the water to bind the mixture into a hard, durable mass. Because of the relatively small cement content, concrete is not energy intensive when compared to other construction materials. For example, manufacture of one ton of concrete requires 0.46 million Btu. In contrast, milling one ton of steel requires 28.44 million Btu, while producing one ton of aluminum consumes 255.91 million Btu.

The following table compares the energy consumed in the manufacture of primary construction materials. Concrete is by far the least energy intensive material, despite the energy required to manufacture cement. Therefore, using more concrete in construction is one way of reducing greenhouse gas emissions.




Source: U.K. Cement Manufacture and the Environment, Institute of Concrete Technology, April 1993

## PROFILE OF THE U.S. CEMENT INDUSTRY

**U.S. Cement Industry 1995 Summary**

| | | | |
|---|---|---|---|
| Clinker Capacity: | 76.3 million tons | Shipments: | 75.1 million tons |
| Imports: | 13.8 million tons | Exports: | 0.48 million tons |
| Avg. Energy Efficiency: | 5.26 mmBtu/ton | Capacity Utilization: | 90.6% |
| Employment: | 17,800 | Productivity: | 2.29 tons/manhr |

Energy as a Percent of Manufacturing Cost: 30 - 40%

The U.S. cement industry consists of 47 companies operating 118 plants in 38 states. Ranked on the basis of cement grinding capacity, the 10 major producing states account for 65 percent of capacity. U.S. cement plants are large in scale. Average plant capacity in 1995 was about 647,000 annual tons. The largest plant has grinding capacity of 2.1 million tons per year. The manufacturing process is continuous, with the kilns operating 24 hours per day for approximately 330 days per year. Except for occasional process upsets or equipment failure, the downtime is scheduled and is used for major maintenance.

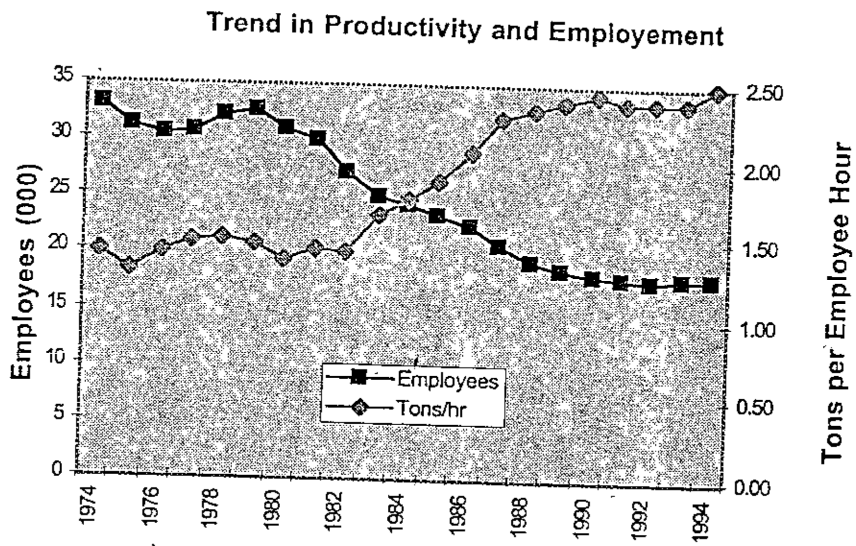
U.S. annual cement production capacity (roughly, clinker capacity plus 5 percent) is about 80 million tons, making it the third largest cement manufacturer in the world. U.S. production accounts for 5.8 percent of the total world production of 1.4 billion tons. China is the largest producer, with 390 million tons of capacity or 27.3 percent of world production. As a point of comparison, about 80 percent of Chinese production is from relatively inefficient mini-plants of less than 100,000 tons per year capacity.

The U.S. cement industry is regional, with about 60 percent of shipments being sent to destinations within 150 miles of the plants. There is, however, considerable competition within the numerous regional cement markets. Plants are located to minimize transportation of raw materials and finished products. Virtually all plants are adjacent to their limestone source and as close as possible to major markets. However, if sited on navigable waters, raw materials may be received by water from remote quarries. Finished products may also be shipped to more distant markets from plants on navigable waters.

There are five main categories of cement products that are used in different applications. The two most common types of cement, general use and moderate heat of hydration, account for 87.5 percent of the market. All the products are made in rotary kilns with the different properties resulting primarily from changes in the chemical composition of the raw material mixture and the fineness of the finished cement. With the exception of masonry cement, which consists of up to 50 percent interground limestone and other cementitious materials, all have similar energy requirements.

The primary cement customer, accounting for 60 percent of shipments, is the ready-mix concrete industry, which supplies concrete to construction sites. Other major customers are concrete products manufacturers, building material dealers, government agencies and contractors. About 70 percent of cement is shipped directly from the plant to the customer. The remainder is distributed though terminals that are supplied from cement plants primarily by rail, or barge and boat.

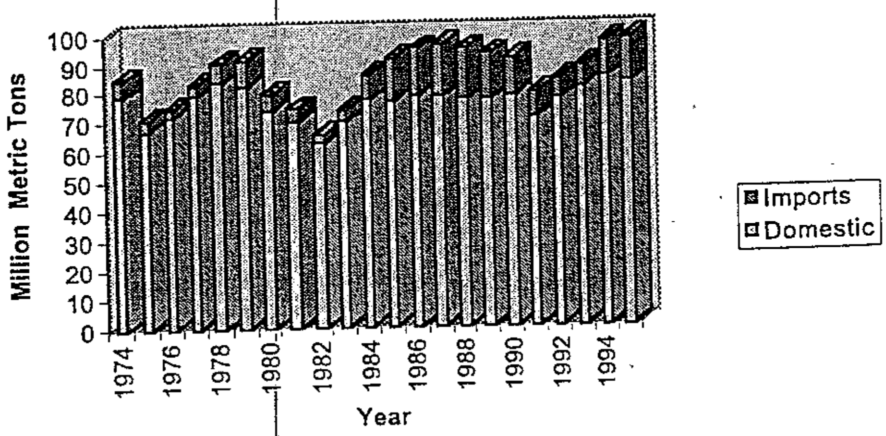
Clinker production capacity in 1995 was 76.3 million tons, which is 8 percent below the 1974 level. Between 1974 and 1995 the number of operating kilns dropped from 432 to 208, an indicator of the trend toward larger, more efficient units. Increasing unit size has increased labor productivity from 1.30 tons per man hour in 1974 to 2.29 tons in 1995, a 76 percent improvement. Because production capacity has not increased, employment has dropped from 32,000 in 1974 to its current level of just under 18,000.




Source: PCA Economic Research Dept. U.S. Cement Industry Fact Sheet, Fourteenth Ed.

U.S. cement consumption, estimated to be 85.8 million tons in 1995, has grown modestly over the last 20 years, with an average annual growth rate below 1 percent per year. Consumption shows a strong cyclical pattern concurrent with the business cycle. Imports of clinker and cement, primarily from Canada, Latin America and Europe, were 13.8 million tons in 1995, approximately 16 percent of U.S. consumption. Import volumes follow a clear pattern, increasing in periods of strong demand and dropping when demand weakens. The accessibility of the U.S. market to offshore cement makes the U.S. cement producers vulnerable to any type of unilateral regulatory or tax burden that would increase their costs, but not the costs of offshore producers.

## Trend In U.S. Domestic Shipments and Imports




Source: PCA Economic Research Dept. U.S. Cement Industry Fact Sheet, Fourteenth Ed.

## The Cement Manufacturing Process

The cement manufacturing process consists of four main steps.

| Quarry & Crush → | Raw Grinding → | Pyroprocess → | Finish Grind |
|---|---|---|---|
| Raw material extraction. Crushing to 2" pieces. Conveying and stockpiling. | Recovery of materials from stockpiles. Proportioning materials to the correct chemical composition. Grinding and blending to produce raw "meal." | Processing the raw meal to remove water. Calcining the limestone and reacting the mix components to form clinker. Clinker cooling and storage. | Reclaiming the clinker from storage. Adding gypsum and grinding to a fine powder. Conveying to storage and shipping in bulk or bags. |

There are four main process types. One is "wet," where the finely divided raw materials are blended with water before being inserted into the kiln. The remaining three are "dry," in which the kiln feed material is in powder form. All four use similar raw materials and can produce the same products. They differ in energy efficiency because of the method of grinding the raw meal, or in the configuration of the pyroprocessing step. The modern, more energy efficient plants are equipped with preheater and precalciner systems that heat and partially calcine the raw meal before it enters the kiln.

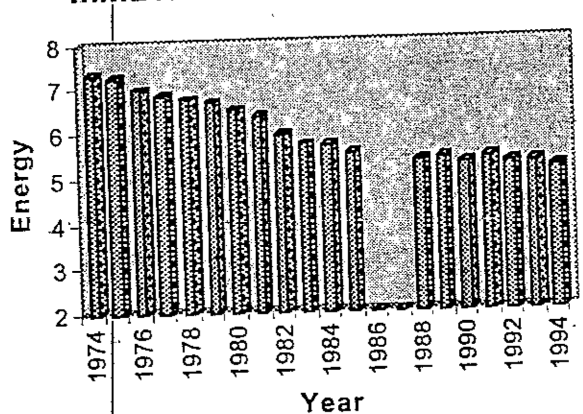
| | |
|---|---|
| **Wet** | Raw materials are ground with 30 to 40 percent water and pyroprocessed in a long kiln. Average energy consumption is 6.46 million Btu per ton of cement. |
| **Long Dry** | Raw materials are dry ground and pyroprocessed in a long kiln. Average energy consumption is 5.78 million Btu per ton of cement. |
| **Preheater** | Raw materials are dry ground, preheated in cyclones, and pyroprocessed in a shorter kiln. Average energy consumption is 4.62 million Btu per ton of cement. |
| **Precalciner** | Raw materials are dry ground, preheated in cyclones, precalcined, and pyroprocessed in a shorter kiln. Average energy consumption is 4.44 million Btu per ton of cement. |

## Energy Use by the Cement Industry

The energy price increases resulting from the Arab oil embargo in the early 1970s triggered a drive by the cement industry to reduce fuel costs by becoming more energy efficient and by switching away from petroleum products and natural gas. This move was supported by federal energy policy as well. The focus of the time was on conservation of "scarce" fossil fuels such as natural gas. Coal, not considered scarce, was the fuel of choice.

The gains in energy efficiency were achieved by shutting down older, primarily wet process kilns and replacing them with modern dry process units. Wet process kilns accounted for 58 percent of capacity in 1974 but only 29 percent in 1994. Further improvements in energy efficiency were realized from upgrades to other major steps in the cement manufacturing process, such as grinding and crushing of raw materials and products. The result has been to reduce average energy input per ton of cement from 7.44 mmBtu in 1972 to 5.26 mmBtu in 1995, a reduction of 29 percent.

**Trend In Energy Consumption mmBtu/metric ton of Cement**

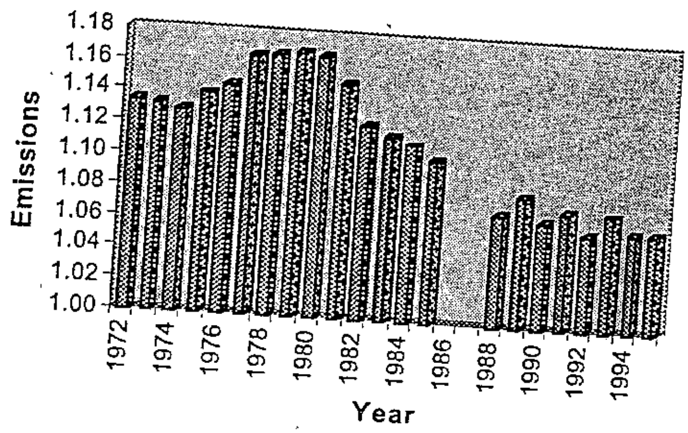



Source: PCA Economic Research Dept. U.S. Cement Industry Fact Sheet, Fourteenth Ed

Note: No energy survey was conducted in 1986 and 1987.

Coincident with reductions in energy consumption, the cement industry also reduced energy costs by burning more coal and petroleum coke. From 1972 to 1994, coal and coke rose as a percentage of the gross fuel mixture from 36 percent to 74 percent. In contrast, natural gas represented 45 percent of the mixture in 1972 and 7.2 percent in 1994. The result of the switch from natural gas to coal and coke -- which have a higher carbon content than natural gas -- is that the reduction of $CO_2$ emissions per ton of cement resulting from improved energy efficiency has been offset to some extent by greater emissions per unit of energy consumed.

Trend in Carbon Dioxide Emissions
(Tons/ton of Cement)




Note: No energy survey was conducted in 1986 and 1987.

An additional trend, beginning in the early 1980s, has been the use of selected waste materials with high energy contents, such as spent solvents, paint residues, used oil and scrap tires, as kiln fuels. The high temperatures in cement kilns assure effective combustion of these fuel alternatives, while at the same time recover the energy value of these materials, which otherwise might have been landfilled or incinerated without energy recovery. Alternative fuels in 1994 accounted for 7.4 percent of the industry's energy requirements. This percentage has not changed appreciably since 1990.

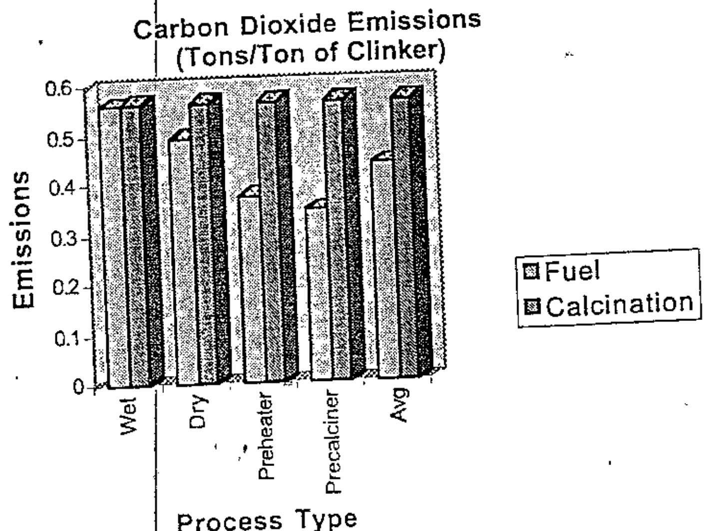
**Energy Mix**
**Percent Based on Btus Consumed**

| Fuel | 1972 | 1994 |
|---|---|---|
| Natural Gas | 45.1 | 7.2 |
| Coal & Coke | 36.1 | 74.2 |
| Petroleum Products | 12.2 | 1.1 |
| Alternative Fuels | 0 | 7.4 |
| Electricity | 6.6 | 10.1 |

Source: PCA Economic Research Dept. U.S. Energy and Labor Survey 1995.

# Greenhouse Gas Emissions from U.S. Cement Manufacturing

Most of the greenhouse gas emissions from cement production occur during the pyroprocess stage. The primary greenhouse gases of concern are carbon dioxide ($CO_2$), nitrous oxide ($N_2O$) and methane. Cement manufacturing produces relatively minor amounts of $N_2O$ and $CH_4$ but emits $CO_2$ from combustion of fossil fuel and from calcination of limestone in the raw material during the pyroprocess stage. Emissions from calcination are constant at about 0.54 tons of $CO_2$ per ton of cement while emissions from fuel depend on the type of fuel being burned and fuel efficiency of the process. The less efficient wet process emitted an average of 0.56 tons of $CO_2$ from fuel per ton of cement in 1994; the most efficient technology, precalciners, emitted an average of 0.35 tons of $CO_2$ from fuel per ton of cement. Total $CO_2$ emissions, therefore, range from about 0.89 to 1.1 tons of $CO_2$ per ton of cement.




## U.S. Carbon Dioxide Emissions, Current Cement Industry Contribution

The following table presents carbon dioxide emissions in the United States by broad sector. The industrial and transportation sectors each account for about one third of carbon dioxide emissions from fuel. The residential and commercial sectors combined make up virtually all the remainder. Included in the totals are electric utility emissions that have been distributed across the sectors based on their power consumption.

## Energy End-Use Sector Sources of Carbon Dioxide Emissions from 1995

| Sector | Million Metric Tons of Carbon | Million Metric Tons of Carbon Dioxide | Percent of Total |
|---|---|---|---|
| Residential | 272.9 | 1,000.7 | 19.6 |
| Commercial | 217.7 | 798.3 | 15.7 |
| Industrial | 466.2 | 1,709.5 | 33.5 |
| Transportation | 423.6 | 1,553.2 | 30.5 |
| U.S. Territories | 9.8 | 36.0 | 0.7 |
| **Total** | **1,390.3** | **5,097.7** | **100.0** |

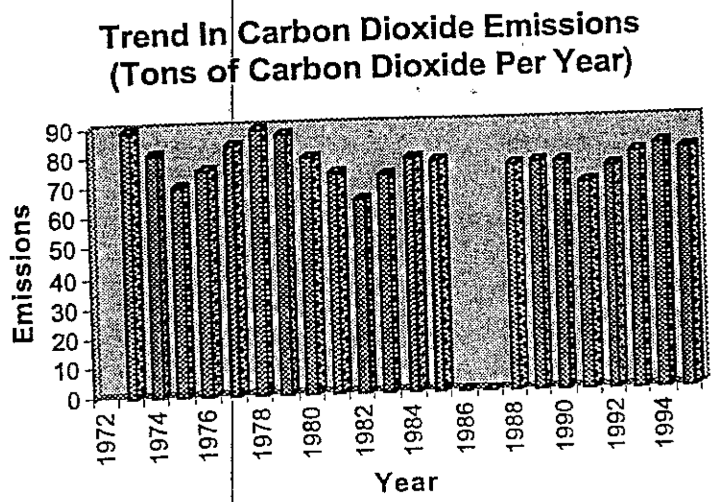
Source: Emissions of Greenhouse Gases in the United States for 1995, Energy Information Administration, U.S. Dept. of Energy, Washington, DC 20585, Oct. 1996.

In 1995, U.S. cement industry $CO_2$ emissions from energy consumption were estimated at 38.8 million tons. Emissions from calcination -- the process of heating the limestone to convert calcium carbonate into calcium oxide -- were approximately 41.2 million tons. Total $CO_2$ emissions from cement manufacturing in 1995, therefore, were 80 million tons or 1.5 percent of total U.S. emissions.

Trends in Carbon Dioxide Emissions by the Cement Industry

The FCCC set 1990 as the base year by which to measure future greenhouse gas emissions. The original treaty called for a reduction of emissions to at or below 1990 levels by 2000. Cement consumption is cyclical, thus selection of any single year as a base poses difficulties. Therefore, cement industry $CO_2$ emissions may exceed targets at the peak of the business cycle, but this will be offset during the troughs when emissions are below target levels.

The 20-year trend in $CO_2$ emissions per ton of cement shows a drop from an average of 1.10 tons in 1974 to 1.03 tons in 1990, an improvement of 6.3 percent. The decrease in $CO_2$ emissions would have been considerably greater if the cement industry had not, for economic and government policy reasons, converted most of its kilns from natural gas to coal, a higher carbon fuel.




Note: No energy survey was conducted in 1986 and 1987.

The single greatest factor in determining the amount of $CO_2$ emitted by the industry is the level of cement shipments by domestic producers. Total industry $CO_2$ emissions since 1974 have fluctuated from a high of 89 million tons in 1978 at the peak of the business cycle to a low of 65 million tons during poor business conditions in 1982. Emissions in 1990, the base year, were 76 million tons.

## Conclusions

The U.S. cement industry has taken many steps to increase fuel efficiency over the past 20 years. These efforts have resulted in significant reductions in greenhouse gas emissions per ton of cement produced.

The industry will continue to pursue energy efficiency improvements and other opportunities for further reductions in carbon dioxide emissions through greater use of alternative fuels and raw materials. Many U.S. manufacturers have formalized such efforts by joining the U.S. EPA and DOE Climate Wise program. The program promotes the reduction of greenhouse gas emissions by industry, primarily through enhancing energy efficiency.