

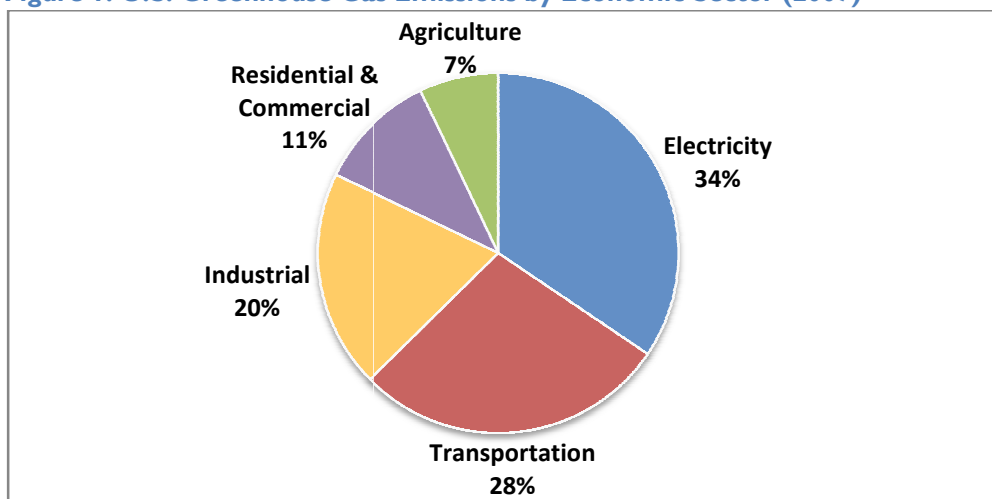
Industrial Emissions in the United States

Greenhouse gas (GHG) emissions data can be reported either by economic sector, which includes electric power generation as a separate sector, or by end-use sector, which distributes the emissions from electricity generation across the economic sectors where the electricity is used. The industrial sector encompasses a wide range of activities, including all facilities and equipment used for producing, processing, or assembling goods.¹ GHG emissions are produced from diverse processes, including the combustion of fossil fuels for heat and power, the non-energy use of fossil fuels, and numerous industrial processes. The industrial sector is a large consumer of electricity, so it is appropriate to address both emissions from direct sources and electricity end use for this sector.

- **Direct emissions**

Direct emissions from the industrial sector account for 20 percent of total GHG emissions in the United States (see Figure 1).

Figure 1: U.S. Greenhouse Gas Emissions by Economic Sector (2007)

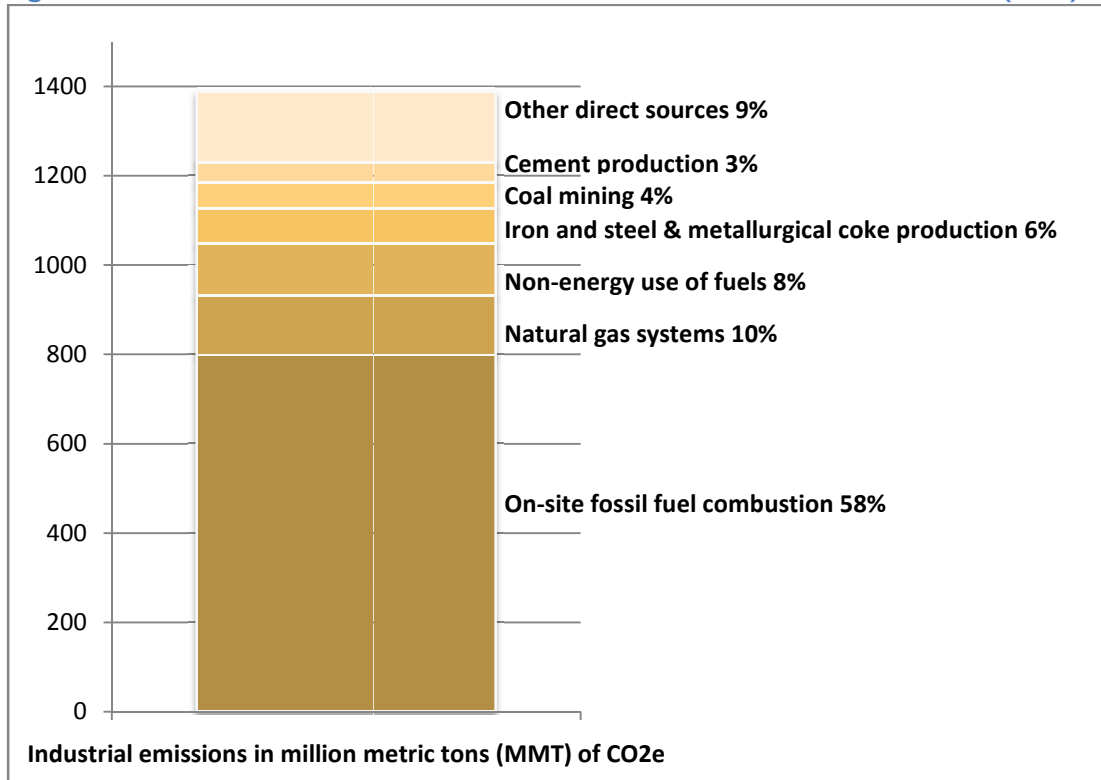


Source: Environmental Protection Agency (EPA), *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007*, Table ES-7, 2009. <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>

Direct emissions from the industrial sector come from both the on-site combustion of fossil fuels (56 percent of direct emissions) and from certain non-energy-related industrial production processes (44 percent of direct emissions). For example, heating iron ore to produce iron directly releases carbon dioxide (CO₂). Similarly, the cement manufacturing process requires heating limestone, which also results in the release of CO₂.

Figure 2 shows the main sources of direct industrial emissions in the United States, including the following sources of process emissions: natural gas production and refining (10 percent), the non-energy use of fuels (8 percent), iron and steel production and metallurgical coke production (6 percent), coal mining (4 percent), cement production (3 percent), and a variety of sources (9 percent).² Industrial process emissions, which include all direct emissions except on-site fossil fuel combustion, account for 5 percent of total U.S. GHG emissions.

Figure 2: Direct Emissions of Greenhouse Gases from the U.S. Industrial Sector (2007)³



Source: EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007*, Table 2-14, 2009. <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>

Industrial process emissions include numerous GHGs, including several gases with high global warming potentials, like hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF₆). Global warming potential (GWP) is a metric used to compare the warming effects of different gases. Over a 100-year time horizon, carbon dioxide (CO₂) is assumed to have a GWP of one. In comparison, SF₆ has a GWP of 23,900, which means that over 100 years one ton of SF₆ will have the same effect as 23,900 tons of CO₂ (see Table 1).⁴

The industrial sector emits more non-CO₂ gases than any other end-use sector and is responsible for 71 percent of U.S. methane (CH₄) emissions and 63 percent of non-CO₂ and non-CH₄ emissions.⁵

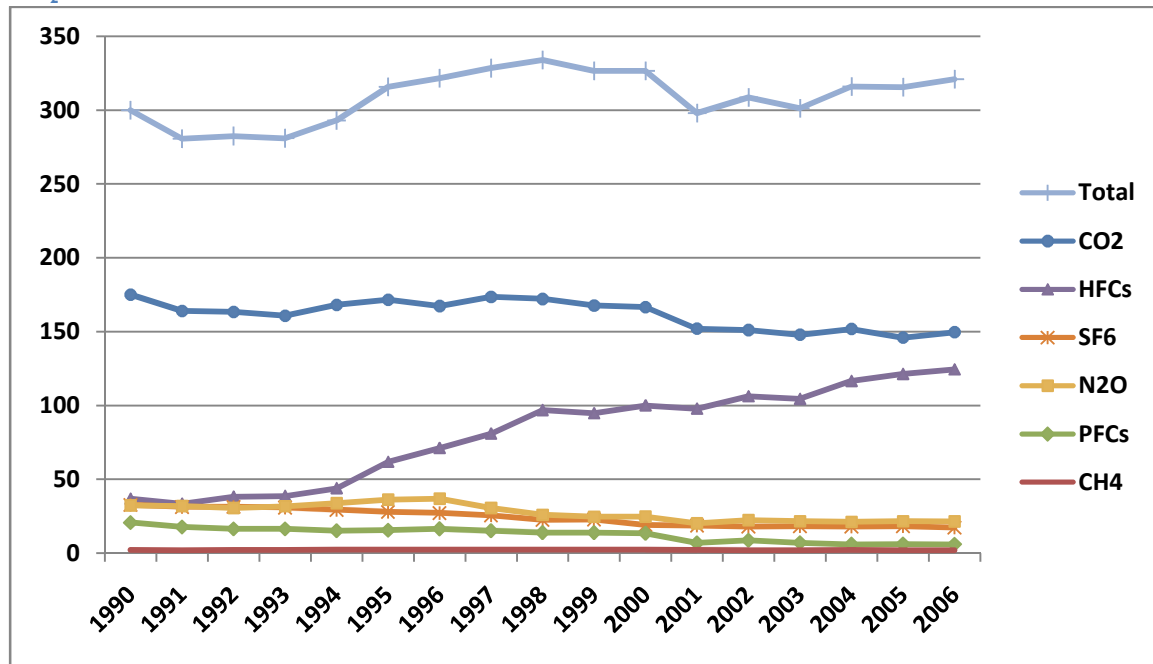
Table 1: Global Warming Potentials for 100-year Time Horizon

Gas		GWP
Carbon dioxide	CO ₂	1
Methane	CH ₄	21
Nitrous oxide	N ₂ O	310
Hydrofluorocarbons (HFCs)	HFC-23	11,700
	HFC-32	650
	HFC-125	2,800
	HFC-134a	1,300
	HFC-143a	3,800
	HFC-152a	140
	HFC-227ea	2,900
	HFC-236fa	6,300
Perfluorocarbons (PFCs)	HFC-4310mee	1,300
	CF ₄	6,500
	C ₂ F ₆	9,200
	C ₄ F ₁₀	7,000
Sulfur hexafluoride	C ₆ F ₁₄	7,400
	SF ₆	23,900

Source: EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007*, Table ES-1, 2009.
<http://www.epa.gov/climatechange/emissions/usinventoryreport.html>

Between 1990 and 2007, total industrial process emissions increased nearly 9 percent even though several individual GHGs decreased during this time period (see Figure 3).⁶

Figure 3: Industrial Process Emissions by Greenhouse Gas Type in Million Metric Tons (MMT) of CO₂e⁷



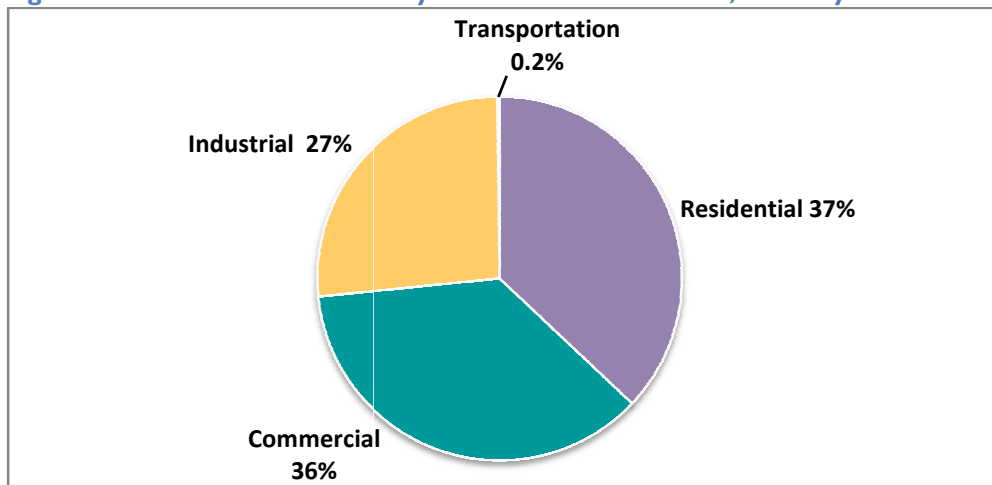
Source: EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006*, Table 2-6, 2008.
<http://www.epa.gov/climatechange/emissions/usinventoryreport.html>

Two trends in the industrial sector account for most of the rise in industrial process emissions: increased emissions from the cement industry and the emission of HFCs as substitutes for substances that deplete the ozone layer, such as chlorofluorocarbons (CFCs).

- **End-use emissions**

U.S. electricity sales are roughly evenly split among the residential, commercial, and industrial sectors, with the industrial sector accounting for 27 percent of sales (see Figure 4).

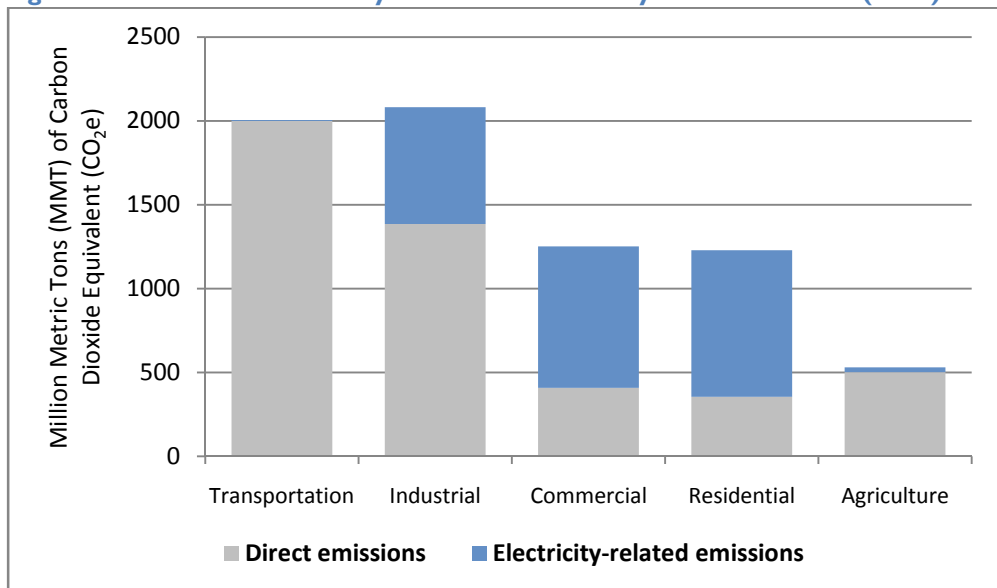
Figure 4: Retail Sales of Electricity to Ultimate Customers, Total by End-Use Sector (2007)⁸



Source: U.S. Energy Information Administration (EIA), *Electric Power Monthly*, Table 5.1, 22 April 2009. http://www.eia.doe.gov/cneaf/electricity/epm/table5_1.html

When GHG emissions from electricity generation are distributed across the end-use sectors, the industrial sector is the largest source of GHG emissions, responsible for 29 percent of total U.S. emissions (see Figure 5). Emissions from the use of electricity generated off-site are also called *indirect emissions* to distinguish them from the direct emissions released on site.

Figure 5: Direct and Electricity-related Emissions by End-Use Sector (2007)



Source: EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007*, Table 2-14, 2009. <http://epa.gov/climatechange/emissions/usinventoryreport.html>

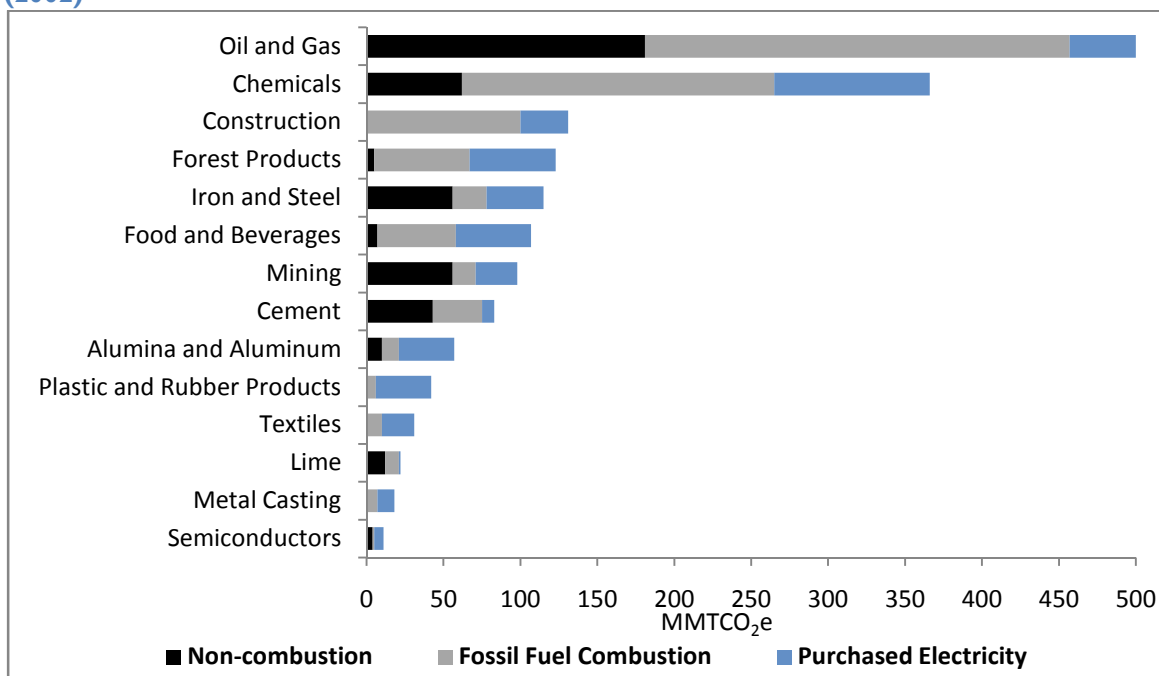
Relative to the residential and commercial sectors, a smaller percentage of the industrial sector's GHG emissions come from electricity use. The industrial sector relies less on purchased electricity in

part because of the on-site production of heat and power, also known as cogeneration or combined heat and power (CHP).

Industrial Emission Sources and Types

The industrial sector encompasses a diverse collection of industries that have very different energy and feedstock needs to produce products that range from paper to gasoline to pharmaceuticals. While GHG emissions from the electricity sector depend largely on the type of fuel used and emissions from the residential and commercial sectors come largely from buildings, similar generalizations cannot be made about the industrial sector. Examining industrial emissions on an industry-by-industry basis shows that the magnitude of emissions associated with different industries varies significantly (see Figure 6).

Figure 6: GHG Emissions for Key Industrial Sub-sectors in Million Metric Tons (MMT) of CO₂e (2002)



Source: EPA, *Quantifying Greenhouse Gas Emissions from Key Industrial Sectors in the United States*, Working Draft, Table 1-3, 2008. <http://www.epa.gov/ispd/>

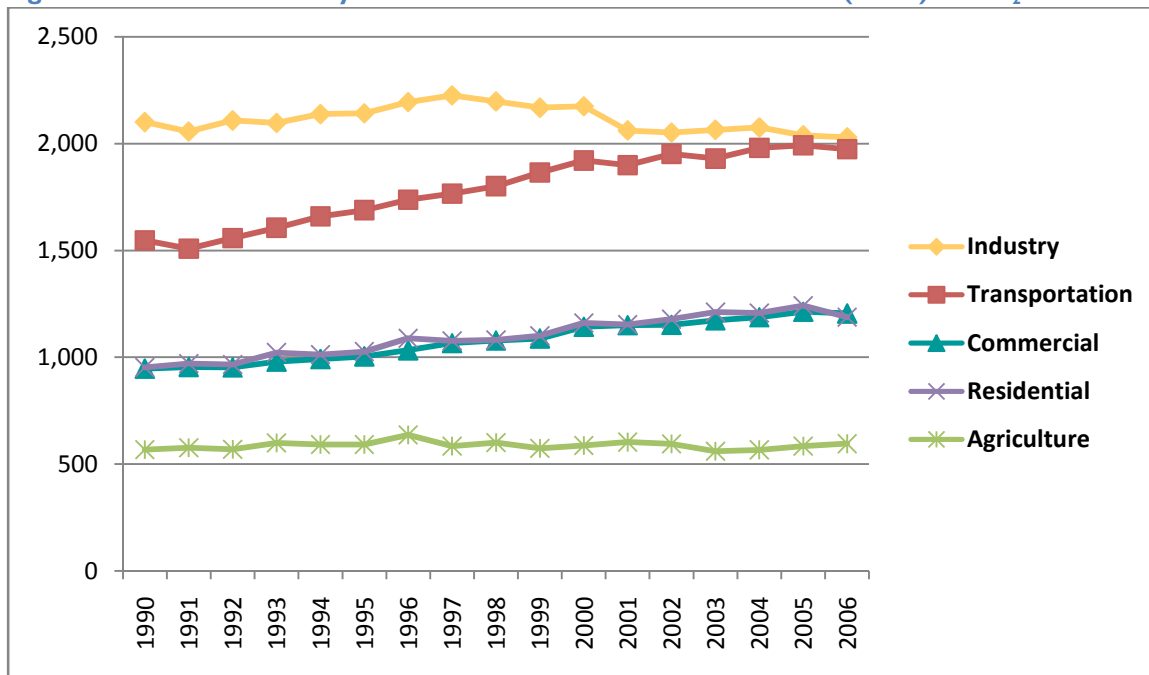
Figure 6 also shows the relative importance of different types of emissions to individual industries. For example, five industries (oil and gas, chemicals, iron and steel, mining, and cement) produce the majority of non-combustion-related direct emissions. Similarly, oil and gas, chemicals, construction, forest products, and food and beverages produce large amounts of GHG emissions from on-site fossil fuel combustion.

Certain industries are termed *energy-intensive* because they require large energy inputs per unit of output or activity. The largest energy-consuming industries in the United States are bulk chemicals, oil and gas, steel, paper, and food products; these five industries account for 60 percent of industrial energy use, but only 20 percent of the value of the products. Other energy-intensive industries include glass, cement, and aluminum. In general, energy-intensive industries are growing more slowly in the United States than industries with lower energy intensities.⁹

Historical Trends

Total industrial emissions in the United States have gradually declined over the past decade in both absolute and relative terms (see Figure 7). Several factors have contributed to this reduction, including fuel switching, increased efficiency, and changes to the U.S. economy from a more manufacturing-based to a more service-based economy and from more energy-intensive industries to less energy-intensive industries. Over time, the proportion of industrial GHG emissions from electricity use has increased, while the proportion of GHGs from direct emissions has decreased.¹⁰

Figure 7: GHG Emissions by End-Use Sector in Million Metric Tons (MMT) of CO₂e



Source: EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006*, Table 2-14, 2008.
<http://www.epa.gov/climatechange/emissions/usinventoryreport.html>

The industrial sector is the largest end-user of energy in the United States. Since 1970, total energy consumption has increased across all end-use sectors, but the growth rate has been slowest in the industrial sector. The industrial sector has also been more responsive to energy price fluctuations.

Global Context

At the global level, the industrial sector is a key energy consumer and GHG producer. Manufacturing industries account for nearly a third of total energy consumption and 36 percent of CO₂ emissions.¹¹ At the global level, data on non-CO₂ gases and non-combustion CO₂ emissions have higher levels of uncertainty.¹² A small number of industries account for a large percentage of global industrial emissions. In 2004, five industries (chemicals and petrochemicals, iron and steel, non-metallic minerals, pulp and paper, and non-ferrous metals) accounted for 67 percent of total industrial energy use.¹³

Trends in global industrial energy use and emissions include:

- Overall industrial energy use increased between 1971 and 2004, with demand growing especially rapidly in emerging economies.
- Energy efficiency in energy-intensive manufacturing industries has increased, with Japan and Korea generally achieving the highest levels of energy efficiency.
- Cost-effective GHG mitigation opportunities exist for the industrial sector but are currently under-utilized in both developed and developing countries. The adoption of best practice commercial technologies by manufacturing industries could reduce industrial sector CO₂ emissions by 19-32 percent annually by, for example, improving the efficiency of motor systems.¹⁴
- Since 1970, several energy-intensive industries have seen significant growth. For example, production of steel increased 84 percent; paper, 180 percent; ammonia, 200 percent; aluminum 223 percent; and cement, 271 percent.¹⁵
- Energy-intensive manufacturing industries are growing in many developing countries. Industrial energy use frequently accounts for a larger portion of total energy consumption in these countries; for example, an estimated 77 percent of delivered energy in China is used by the industrial sector.¹⁶

Industrial Sector Mitigation Opportunities

The diverse opportunities for reducing GHG emissions from the industrial sector can be broken down into three broad categories:¹⁷

- **Sector-wide options**

Some mitigation options can be used across many different industries, for example energy efficiency improvements for cross-cutting technologies, such as electric motor systems, can yield benefits across diverse sub-sectors. Other sector-wide mitigation options include the use of fuel switching, combined heat and power, renewable energy sources, more efficient electricity use, more efficient use of materials and materials recycling, and carbon capture and storage.

- **Process-specific options**

Certain mitigation opportunities come from improvements to specific processes and are not applicable across the entire sector. For energy-intensive industries, process improvements can reduce energy demand and, therefore, GHG emissions and energy costs. Other improvements can reduce emissions of non-CO₂ gases with high global warming potentials.

Case studies can help illuminate the effectiveness of these process-specific options. For example, Alcoa's aluminum smelters collectively reduced their emissions of perfluorocarbons (PFCs) from anode effects, which occur when a particular step in the smelting process is interrupted, by more than 1.1 million tons in 2008.¹⁸

- **Operating procedures**

A variety of mitigation opportunities can be achieved through improvements to standard operating procedures. These options can include making optimal use of currently available technologies, such as improving insulation and reducing air leaks in furnaces.

A variety of public and private efforts have been developed to help reduce industrial GHG emissions, energy use, or energy intensity. Some of these programs include:

- Climate Leaders – U.S. Environmental Protection Agency (EPA)

Partnership between industry and government to develop comprehensive climate change strategies. <http://www.epa.gov/stateply/>

- Climate VISION – Interagency program, including U.S. Department of Energy (DOE), U.S. EPA, U.S. Department of Transportation, and U.S. Department of Agriculture
Voluntary program to reduce U.S. GHG emissions intensity. <http://climatevision.gov/>
- ENERGY STAR® for Industry – U.S. EPA
Program to improve corporate energy management. http://www.energystar.gov/index.cfm?c=industry.bus_industry
- Save Energy Now – U.S. DOE, Industrial Technologies Program
Program to achieve the goal of reducing industrial energy intensity 25 percent by 2017, per the *Energy Policy Act of 2005*. <http://www1.eere.energy.gov/industry/saveenergynow/>
- Voluntary Programs to Reduce High Global Warming Potential Gases – U.S. EPA
A variety of programs to reduce gases with high global warming potentials, including perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), and sulfur hexafluoride (SF₆). <http://www.epa.gov/highgwp/voluntary.html>

¹ U.S. Energy Information Administration (EIA). *Glossary*. http://www.eia.doe.gov/glossary/glossary_i.htm. Accessed 4 May 2007.

² U.S. Environmental Protection Agency (EPA), *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007*. 2009. <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>

³ One million metric ton is equal to one teragram. For reference, one million metric ton of CO₂e is equal to 280,000 new cars each being driven 12,500 miles or 90 minutes of U.S. energy consumption or 1 day of U.S. energy emissions from lighting buildings, see U.S. Department of Energy (DOE), *2008 Buildings Energy Data Book*. Prepared for U.S. Department of Energy Office of Energy Efficiency and Renewable Energy by D&R International, Ltd. Silver Spring, MD. September 2008. <http://buildingsdatabook.eren.doe.gov/>

⁴ Global warming potential is a system of multipliers devised to enable warming effects of different gases to be compared. The cumulative warming effect, over a specified time period, of an emission of a mass unit of CO₂ is assigned the value of 1. Effects of emissions of a mass unit of non-CO₂ greenhouse gases are estimated as multiples. For example, over the next 100 years, a gram of methane (CH₄) in the atmosphere is currently estimated as having 23 times the warming effect as a gram of carbon dioxide; methane's 100-year GWP is thus 23. Estimates of GWP vary depending on the time-scale considered (e.g., 20-, 50-, or 100-year GWP) because the effects of some GHGs are more persistent than others.

⁵ EIA, *Distribution of Total U.S. Greenhouse Gas Emissions by End-Use Sector, 2007*. December 2008. http://www.eia.doe.gov/oiaf/1605/ggrpt/pdf/enduse_tbl.pdf

⁶ EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007*. 2009. <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>

⁷ Carbon dioxide equivalent (CO₂e) is a unit used to measure the emissions of a gas, by weight, multiplied by its global warming potential.

⁸ This figure excludes commercial and industrial facility use of onsite net electricity generation, which was roughly 4 percent of net electricity generation in 2007.

⁹ EIA, *Annual Energy Outlook 2009*. 2009. <http://www.eia.doe.gov/oiaf/aeo/demand.html>

¹⁰ EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007*. 2009. <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>

¹¹ Ibid.

¹² Ibid.

¹³ Ibid.

¹⁴ Ibid.

¹⁵ Intergovernmental Panel on Climate Change (IPCC), "Industry." In *Climate Change 2007: Mitigation*. Contribution of Working Group III to the Fourth Assessment Report. Cambridge: Cambridge University Press, 2007. <http://www.ipcc.ch/ipccreports/ar4-wg3.htm>

¹⁶ EIA. *International Energy Outlook 2008*, June 2008. <http://www.eia.doe.gov/oiaf/ieo/world.html>

¹⁷ IPCC, 2007.

¹⁸ Alcoa, "Alcoa Smelters Meet Challenge to Reduce Greenhouse Gas Emissions by One Million Tons Annually," http://www.alcoa.com/global/en/about_alcoa/sustainability/case_studies/2009/case_ghg_million_ton.asp. Accessed 6 May 2009.