WORKING DRAFT

Quantifying Greenhouse Gas Emissions from Key Industrial Sectors in the United States

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

SectorStrategies

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1. Introduction

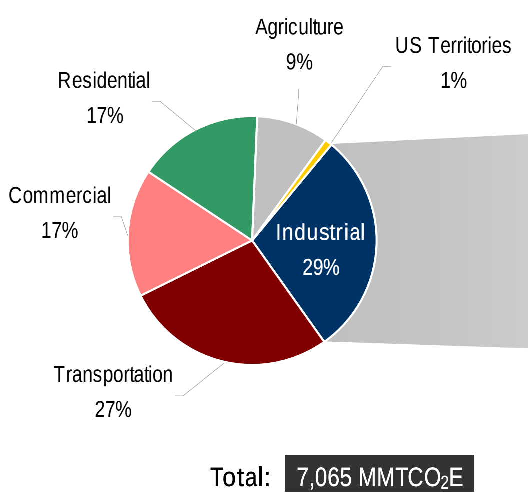
This report seeks to provide greenhouse gas (GHG) emission profiles for key sectors of U.S. industry (including indirect emissions from electricity consumption), which combined accounted for 29% of total U.S. GHG emissions in 2002,[1] more than any other economic sector (Figure 1-1). Emission profiles are provided for 14 key industrial sectors. Collectively, these sectors account for approximately 84% of industrial GHG emissions in the United States (Figure 1-2).

> This report complements—and is not intended to replace or update—the official GHG emissions inventory submission of the United States, the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*, which is prepared according to the official reporting guidelines established by the United Nations Framework Convention on Climate Change (UNFCCC) and the Intergovernmental Panel on Climate Change (IPCC).

The emission estimates included in these initial industrial sector GHG profiles may be useful to a wide array of current public and private sector GHG inventory and reduction initiatives. They also may aid in the development of new ones. Individual companies or industry groups could use this information as a reference for preparing more detailed GHG inventories and for designing effective GHG reduction strategies. To supply these companies and industries with knowledge of emissions over which they have influence, the emission profiles provided in this report include, for the first time, estimates of emissions from purchased electricity. Because many industrial sectors' energy profiles include significant electricity purchases and because national electricity generation is carbon-intensive, these profiles support holistic GHG management.

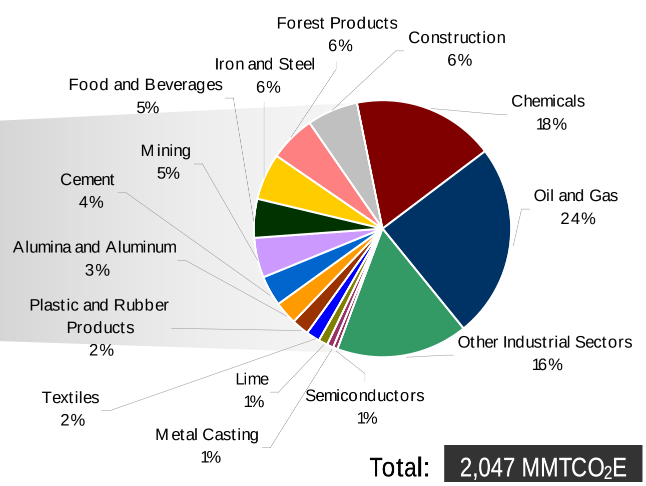
The emission estimates in this report are provided for informational purposes. Due to differences in methodologies and simplifying assumptions, emission estimates in this report may vary from EPA emission estimates for other purposes. Use of figures in this report does not connote that these estimates are preferred to EPA estimates used in another context. Further, these emission estimates may be improved upon in the future as more GHG emissions are reported, and other estimates may be developed to incorporate additional life-cycle activities such as transport of materials into and out of the sector.

Figure 1-1: Total 2002 U.S. Greenhouse Gas Emissions by Sector (MMTCO2E), Factoring in Purchased Electricity



Source: EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*. Note: MMTCO2E stands for million metric tons of carbon dioxide equivalent. Emissions from electricity have been distributed among economic sectors.

Figure 1-2: Total 2002 U.S. Greenhouse Gas Emissions from Industrial Sources, by Sector (MMTCO2E), Factoring in Purchased Electricity

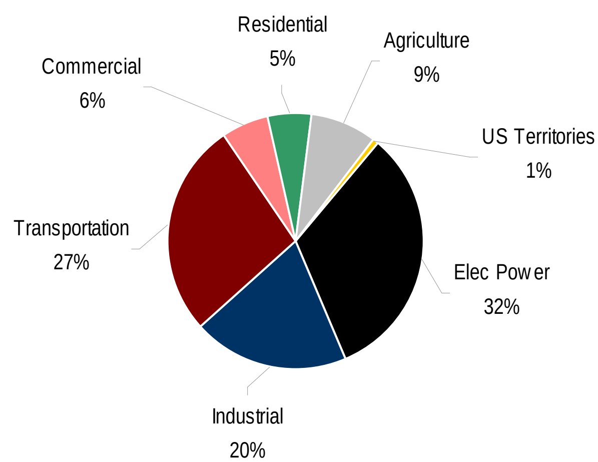


Source: Estimate based on methodology in Section 1.2. Note: "other industrial sector" emissions represent the emissions remaining within the industrial sector beyond those estimated for the 14 sectors addressed in this report.

[1] Total 2002 industrial emissions (including emissions from purchased electricity) are 2,047 million metric tons of carbon dioxide equivalent (MMTCO2E) as reported in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*, Table 2-16.

Emissions of GHGs result from all sectors of the U.S. economy.[2] With emissions from electric power distributed to the end-users, the largest percentage of GHG emissions, according to the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*, result from the industrial sector, accounting for approximately 29% of total U.S. GHG emissions. After the industrial sector, the transportation sector and—to a lesser degree—the commercial, residential, and agriculture sectors follow, in descending order by total GHG emissions. Approximately two-thirds of the industrial sector's emissions result from the combustion of fossil fuels and from the industrial processes of each sector. The remaining one-third of industrial sector GHG emissions results from the off-site generation of electricity purchased by the sector. If designated as a separate sector of the U.S. economy, the electric power sector becomes the most emissive sector (32% of total U.S. emissions), followed by transportation (27%), industrial (20%) and—to a lesser degree—the agriculture (9%), commercial (6%), and residential (5%) sectors (Figure 1-3).[3]

Figure 1-3: Total 2002 U.S. Greenhouse Gas Emissions by Sector ($MMTCO_2E$), Electric Power Presented as a Sector



Source: EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005.*
Note: $MMTCO_2E$ stands for million metric tons of carbon dioxide equivalent.
Emissions from the electric power sector are presented independent of other sectors.

1.1 Approach to Defining Sectors

As partitioning of the electric power sector indicates, clear sector definitions are critical to preparing accurate emission estimates—particularly when developing a consistent set of emission estimates for multiple sectors. Because this report examines a set of sectors side-by-side in a single document, consistency across sectors was a priority for this analysis. The sectoral definitions used for the emission estimates provided in this report include consistency among:

- Identification of the facilities or activities within the sector

[2] U.S. Territories include American Samoa, Guam, Puerto Rico, U.S. Virgin Islands, Wake Island, and other U.S. Pacific Islands. Emissions are from fossil fuel combustion. Fuels consumed by the U.S. Territories include coal, natural gas, distillate fuel oil, jet fuel, kerosene, LPG, lubricants, motor gasoline, residual fuel, and other types of petroleum (in small amounts). The consumption of these fuels in 2002 was approximately 0.7 QBtu.

[3] As reported in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*, Table 2-14.

- Delineation of the physical boundaries of the sector
- Choice of time period for the emission estimates
- Choice of GHG-emitting sources to include within each sector

A description of the broad characteristics applied to define each sector in a consistent manner, according to each of the above elements, is provided below. Emission tables throughout the report do not contain qualifiers if an emission estimate is not estimated. Emissions are not estimated if they do not occur, or if data or methodologies are not available to estimate the emissions. Assumptions associated with each sector's emission estimates are detailed in the sector chapters.

1.1.1 Identification of the Facilities/Activities within a Sector

In general, for the purposes of this analysis, the definitions of the 14 industrial sectors addressed herein have been taken from the North American Industry Classification System (NAICS).[4] Table 1-1 identifies the 14 sectors studied and their corresponding NAICS codes, where applicable. A full description of activities contained within these NAICS codes is provided in individual chapters of the report.

Table 1-1: Sectors Described in this Report, with Corresponding NAICS Codes

Sector	NAICS Code(s)
Alumina and Aluminum	3313
Cement	NA [a]
Chemicals	325
Construction	23
Food and Beverages	311, 3121
Forest Products	321, 322
Iron and Steel	331111
Lime	327410
Metal Casting	3315
Mining	212
Oil and Gas	211111, 211112, 213111, 213112, 324110, 48691, 48621, 22121
Plastic and Rubber Products	326
Semiconductors	334413
Textiles	313, 314, 315

[a] Defined by the U.S. Geological Survey's *Minerals Yearbook: Cement Annual Report 2005*.[5]

1.1.2 Delineation of the Physical Boundaries of the Sector

The emission estimates provided for each sector are not intended to represent the full life cycle emissions that could be attributed to the sector. With few exceptions, the emissions boundary begins and ends at the walls of the plant. Emissions associated with electricity generated offsite but used within the sector are also included, but presented separately from emissions resulting from the use of fuels to generate energy on-site. The exception to this boundary condition occurs when the sector is defined more broadly; for example, the

[4] NAICS was developed jointly by the U.S., Canada, and Mexico. For more information, see http://www.census.gov/epcd/www/naics.html.

[5] U.S. Geological Survey, *Minerals Yearbook: Cement Annual Report 2005*, 2006, http://minerals.usgs.gov/minerals/pubs/commodity/cement/cemenmyb05.pdf.

definition of food manufacturing includes both the growing of foods and the processing and packaging, so some transportation occurs within the sector boundary that results in GHG emissions.[6]

1.1.3 Choice of Time Period

A wide variety of external factors may impact the emissions from any sector, including changes in the U.S. economy, weather patterns, and commodity and fuel prices. In order to evaluate emissions using a common basis, emissions were estimated for all sectors for the year 2002. This year was chosen because the primary dataset from which fuel consumption can be obtained for all sectors contains data through 2002.

1.1.4 Choice of GHG-Emitting Sources within Each Sector

Sources of GHG emissions for each sector were strictly defined as CO_2 emissions from fuel consumption or electricity use, plus any process emissions that have been identified by the Intergovernmental Panel on Climate Change and calculated for the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005.*[7] No other GHG emitting sources were considered for the purposes of this report.

In a similar vein, only emission sources were estimated. Many sectors are taking actions to reduce or offset their GHG emissions. To the extent that emissions are being reduced by the sector through energy efficiency programs, for example, such actions are inherently accounted for in the emission estimates by the sector's reduced consumption of fuel. However, where sectors are taking actions to offset their emissions—e.g., by investing in projects offsite that yield GHG reductions—those actions are not accounted for in this report. Finally, carbon sinks, such as reforestation or geological carbon sequestration, are also not estimated due to the inherent complexity of carbon accounting associated with these activities.

1.2 Methodology

1.2.1 Calculation Methods for Direct and Indirect GHG Emissions

Sources of emissions in industrial sectors include **direct** GHG emissions, i.e., emissions that occur as a result of activities at the industrial establishments, and **indirect** GHG emissions, i.e., emissions that are a consequence of the activities of the establishment but that occur at sources owned by another operation. A variety of definitions exist for direct and indirect emissions; for the purposes of this report, direct and indirect emissions are defined as follows:

- Direct emissions consist of carbon dioxide (CO_2) emissions from fuels combusted by the sector, plus any GHG emissions from non-combustion activities in the sector, such as industrial process emissions, emissions from the non-energy use of fossil fuels, or emissions associated with onsite wastewater treatment.
- Indirect emissions are limited to CO_2 emissions associated with the generation of electricity purchased by the sector.

The majority of both direct and indirect emissions from these industrial sources are a result of fuel combustion. The *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*[8] does not disaggregate fuel combustion emissions by sector but, rather, presents CO_2 emissions from national fuel consumption in aggregate (under the CO_2 from Fossil Fuel Combustion source category). Therefore, a methodology was developed for this report to estimate fossil fuel combustion emissions by sector. Due to this disjuncture, the emission estimates presented here

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[6] For further information regarding the size and boundaries of sectors participating in EPA's Sector Strategies Program, please refer to *Sector Strategies Performance Report, 2nd Edition.*

[7] U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*, 15 April 2007, http://www.epa.gov/climatechange/emissions/usinventoryreport.html.

[8] U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*, 15 April 2007, http://www.epa.gov/climatechange/emissions/usinventoryreport.html.

are not directly comparable to the emissions presented in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.[8]

Direct emissions

Specific methodologies and data sources used in this report vary by sector, but, when possible and appropriate, consistency in calculation methods was the practice. Unless otherwise noted in a particular chapter, the following methodologies were universally applied to calculate **direct** GHG emission estimates for each of the 14 industrial sectors:

- Direct emissions from fossil fuel combustion were calculated by multiplying estimates of fuel consumption by fuel-specific CO_2 emission factors from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.[8] In most cases, fuel consumption estimates were taken from the U.S. Department of Energy's (DOE's) Energy Information Administration (EIA's) *2002 Manufacturing Energy Consumption Survey* (MECS).[9] Where fuel consumption data were not available, estimates of expenditures on fuel (fuel purchases) and fuel cost data were used to estimate consumption. Exceptions to this methodology are described in relevant sector chapters.

  Although combustion activities also generate emissions of methane (CH_4) and nitrous oxide (N_2O), such emissions have not been estimated. Non-CO_2 emissions typically account for only a small percentage (approximately 2%) of a sector's GHG emissions from fossil fuel combustion.

- Direct emissions from non-combustion activities (e.g., industrial processes) were taken from *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.[8] In some cases, additional analysis was required to parse out a sector's contribution to a source category. For example, this analysis disaggregates the total Wastewater Treatment source category CH_4 emissions reported in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*[8] into emissions from the treatment of pulp and paper wastewater, which was attributed to the forest products sector, and emissions from the treatment of fruit, vegetable, meat and poultry processing wastewater, which was attributed to the food and beverages sector.

Indirect Emissions

Indirect emissions associated with purchased electricity were estimated for each sector based on electricity purchases by sector, and information on the CO_2 intensity of generation from the electric power system. Where possible, the geographic distribution of the sector was taken into account to reflect the differing fuel mixes (and hence different CO_2 emissions intensities) for electricity generation in different regions of the country. Information on the geographic distribution of the sector was often not specifically available, i.e., the exact location of every facility within each sector was not known. The geographic distribution of electricity use within each sector was therefore based on the geographic distribution of the "value added" of each sector combined with a national or regional estimate of electricity purchases. This metric, "value added," was obtained from the U.S. Census Bureau's Economic Census[10] and was considered the better proxy because it negates the effect of varying input prices that would be reflected in the alternate metrics.

One of the following four methodologies was used to calculate **indirect** GHG emission estimates for each of the 14 industrial sectors. The first method (Method 1) applies a national utility CO_2 emission factor to national electricity demand data for the sector, while the remaining methods (Methods 2, 3, and 4) allocate the sector's electricity demand to regions of the country using a proxy (distribution of industrial or commercial demand, distribution of sector's value-added, or distribution of sector's production capacity, respectively), then apply regional utility CO_2 emission factors. For the latter three methods, regions were defined by the North American Electricity Reliability Council (NERC).

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[9] U.S. Department of Energy, *2002 Manufacturing Energy Consumption Survey*, Energy Information Administration, 24 Jan 2005, http://www.eia.doe.gov/emeu/mecs/mecs2002.

[10] U.S. Census Bureau, 2005, *Annual Survey of Manufactures (ASM): Statistics for Industry Groups and Industries*, 6 Nov 2007, http://www.census.gov/mcd/asm-as1.html.

The methodology chosen for each sector was dependent upon sector characteristics (e.g., homogeneity of electricity use among sub-sectors) and data availability. In no cases were direct data on regional electricity purchases by a sector available. The method used for each sector is detailed in Table 1-2. Detailed information on all of the methodologies used is contained in Appendix A.3.

In all cases:

- CO_2 emission factors (in lbs per kilowatt-hour (kWh) of generation) were taken from the *Emissions & Generation Resource Integrated Database* (eGRID), a comprehensive inventory of environmental attributes of the electric power system developed and maintained by EPA. eGRID is based on plant-specific data for U.S. electricity generating plants that provide power to the electric grid and report data to the U.S. government. eGRID provides estimated CO_2 emission factors (in lbs per kWh of generation) at the national, NERC regional, NERC sub-regional, power control area, and state levels.
- Demand estimates were corrected for losses associated with the transmission and distribution of electricity.

Table 1-2: Method Used to Estimate Emissions from Purchased Electricity by Sector

Method	Sector
Method 1 – National Level Estimates	Food and Beverages
Method 2 – Regional-Level Estimates/Customer Class Disaggregation	Plastic and Rubber Products
	Construction
Method 3 – Regional Estimates with Sector Level Disaggregation	Mining
	Oil and Gas (Production)
	Textiles
	Metal Casting
	Semiconductors
	Forest Products
	Chemicals
	Lime
Method 4 – Facility Level Estimates	Alumina and Aluminum
	Oil and Gas (Refining)
	Cement
	Iron and Steel

1.2.2 Data Sources

Estimates in this report are based upon a variety of data sources, provided in detail within each chapter. Key data sources include:

- EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*;[11]
- DOE's *2002 Manufacturing Energy Consumption Survey*;[12]
- U.S. Census Bureau's *2002 Economic Census: Industry Series Reports*;[13] and
- Source-specific activity data from organizations such as the U.S. Geological Survey (USGS) and industry associations.

[11] U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*, 15 April 2007, http://www.epa.gov/climatechange/emissions/usinventoryreport.html.

[12] U.S. Department of Energy, *2002 Manufacturing Energy Consumption Survey*, Energy Information Administration, 24 Jan 2005, http://www.eia.doe.gov/emeu/mecs/mecs2002.

[13] U.S. Census Bureau, *2002 Economic Census: Industry Series Reports*, 22 Nov 2005, http://www.census.gov/econ/census02/guide/INDRPT23.HTM.

1.3 Summary of Emission Estimates (2002)

Total combined emissions from the sectors analyzed for this report are 1,713 million metric tons of carbon dioxide equivalent ($MMTCO_2E$), representing approximately 84% of total U.S. industrial emissions. As Figure 1-2 indicates emissions from the production and refining of oil and gas are the largest contributor, with emissions of 501 $MMTCO_2E$ (24%). Emissions from the second largest contributor, chemicals, are 366 $MMTCO_2E$ (18%). Other sectors that account for more than 100 $MMTCO_2E$ include, in descending order, construction (6%), forest products (6%), iron and steel (6%), and food and beverages (5%). Figures 1-4, 1-5, and 1-6 present three different aggregations of emission estimates for all 14 sectors: for total emissions (i.e., non-combustion emissions, on-site fossil-fuel combustion emissions, and purchased electricity emissions); for just non-combustion emissions; and finally for non-combustion emissions and on-site fossil-fuel combustion emissions; respectively. Table 1-3 provides more detailed emissions information for all 14 sectors in alphabetical order.

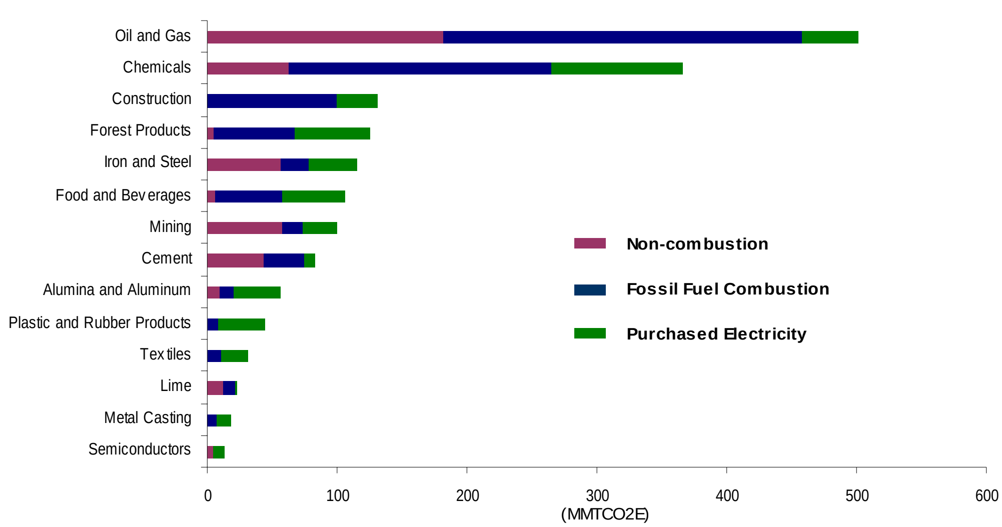
All GHG emissions in this report are estimated in units of $MMTCO_2E$, a unit of measurement that takes into account the relative potency of the gas by applying global warming potentials (GWPs) of each gas. For example, the GWP of CO_2 is 1, while the GWPs of CH_4 and N_2O are 21 and 310, respectively. For a listing of GWPs for other GHGs and a full explanation of GWPs, please see the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.[14]

For each sector, emission estimates are provided for the year 2002, which is the most recent year for which a complete dataset is available to estimate emissions for fossil fuel combustion, non-combustion activities, and electricity purchases. Data are provided for 2002 in order to provide a single consistent baseline for all sectors. Where available, more recent data are also presented in individual sector chapters.

Caution must always be applied when creating summed GHG emission estimates based on disparate sources, because the various sources may not always be able to be reconciled. For the current report, every attempt was made to ensure that a consistent definition of each sector was applied when more than one dataset was used in generating GHG emission estimates. For more information on key data sources, please see Appendix A.1.

More detailed methodologies are provided in sector chapters.

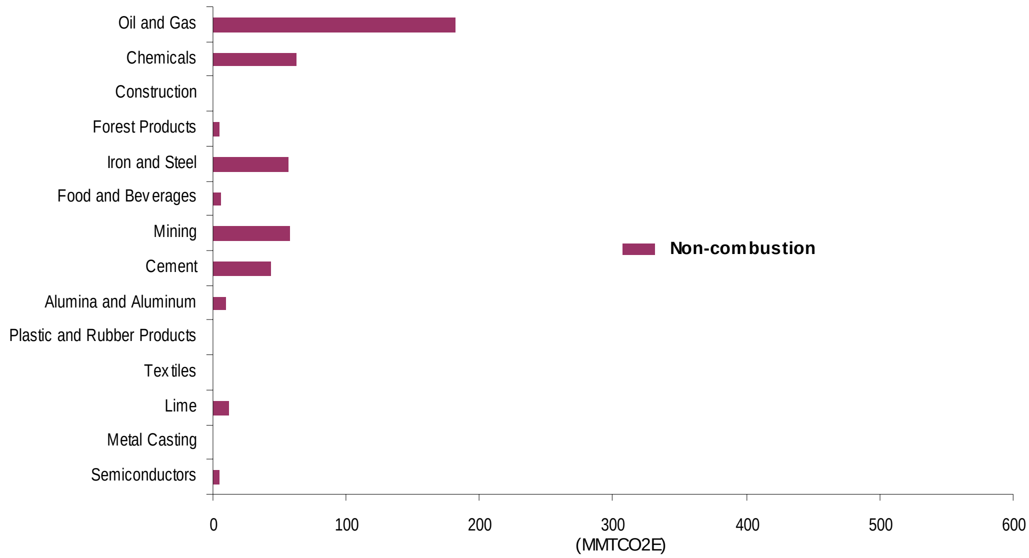
Figure 1-4: 2002 Non-combustion, On-site Fossil Fuel Combustion, and Purchased Electricity Greenhouse Gas Emissions from Key Industrial Sectors ($MMTCO_2E$)



Estimates include emissions from fossil fuel combustion, non-combustion, and the generation of purchased electricity.

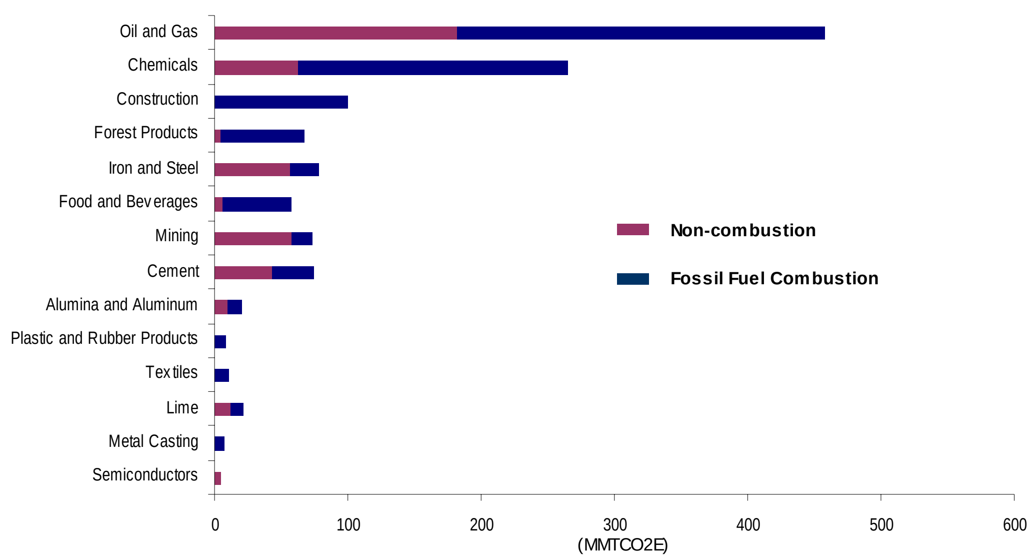
[14] U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*, 15 April 2007, http://www.epa.gov/climatechange/emissions/usinventoryreport.html.

Figure 1-5: 2002 Non-combustion Greenhouse Gas Emissions from Key Industrial Sectors ($MMTCO_2E$)



Estimates include emissions from fossil fuel combustion and non-combustion

Figure 1-6: 2002 Non-combustion and On-site Fossil Fuel Combustion Greenhouse Gas Emissions from Key Industrial Sectors ($MMTCO_2E$)



Estimates include emissions from fossil fuel combustion and non-combustion

Table 1-3: 2002 GHG Emissions from Key Industrial Sectors (MMTCO2E)

Emission Source	CO_2	CH_4	N_2O	HFCs	SF_6	PFC	Total
Alumina and Aluminum	51					5	57
Fossil Fuel Combustion	*11*						*11*
Non-Combustion	*5*					*5*	*10*
Electricity	*36*						*36*
Cement	83						83
Fossil Fuel Combustion	*32*						*32*
Non-Combustion	*43*						*43*
Electricity	*8*						*8*
Chemicals	322	1	23	20			366
Fossil Fuel Combustion	*203*						*203*
Non-Combustion	*18*	*1*	*23*	*20*			*62*
Electricity	*101*						*101*
Construction	131						131
Fossil Fuel Combustion	*100*						*100*
Non-Combustion							
Electricity	*31*						*31*
Food and Beverages	100	4		3			106
Fossil Fuel Combustion	*51*						*51*
Non-Combustion		*4*		*3*			*7*
Electricity	*49*						*49*
Forest Products	120	5					125
Fossil Fuel Combustion	*62*						*62*
Non-Combustion		*5*					*5*
Electricity	*58*						*58*
Iron and Steel	114	1					115
Fossil Fuel Combustion	*22*						*22*
Non-Combustion	*55*	*1*					*56*
Electricity	*37*						*37*
Lime	23						23
Fossil Fuel Combustion	*9*						*9*
Non-Combustion	*12*						*12*
Electricity	*1*						*1*
Metal Casting	18						18
Fossil Fuel Combustion	*7*						*7*
Non-Combustion							
Electricity	*11*						*11*
Mining	41	58					99
Fossil Fuel Combustion	*15*						*15*
Non-Combustion		*58*					*58*
Electricity	*27*						*27*
Oil and Gas	349	152					501
Fossil Fuel Combustion	*276*						*276*
Non-Combustion	*30*	*152*					*181*
Electricity	*43*						*43*
Plastic and Rubber Products	44						44
Fossil Fuel Combustion	*8*						*8*
Non-Combustion							
Electricity	*36*						*36*
Semiconductors	9			<1	3	1	13
Fossil Fuel Combustion	*1*						*1*
Non-Combustion				*<1*	*3*	*1*	*4*
Electricity	*8*						*8*
Textiles	32						32
Fossil Fuel Combustion	*10*						*10*
Non-Combustion							
Electricity	*21*						*21*
Total							1,713

Note that for the purpose of this report, a blank cell does not necessarily indicate zero emissions, and totals may not sum due to independent rounding.

1.4 Company Reporting

In addition to sector-level estimates, this report provides data from specific companies within these industrial sectors, which publicly report their GHG emissions.

In order to report their emissions, these companies often use the following protocols:

- EPA's *Climate Leaders Greenhouse Gas Inventory Protocol*, which adds on to the WBCSD/WRI *Greenhouse Gas Protocol* by requiring Climate Leader Partners to look at emissions beyond the six GHGs defined by UNFCCC/IPCC. Boundaries are set using the same equity share and control techniques as the WBCSD/WRI protocol.
- The World Business Council for Sustainable Development (WBCSD) and the World Resource Institute's (WRI) *Greenhouse Gas Protocol*, which provides guidance for the design, tracking, and reporting of the emissions associated with the six GHGs identified by the Kyoto Protocol (CO_2, CH_4, and N_2O, as well as hydrofluorocarbon (HFC), perfluorocarbon (PFC), and sulfur hexafluoride (SF_6)). Under this protocol, companies account for emissions according to their share of equity in certain operations.
- DOE/EIA's 1605(b) Reporting Guidelines for the industrial sector, *Technical Guidelines: Voluntary Reporting of Greenhouse Gases (1605(b)) Program,* which provide support to an entity that would like to inventory and report its emissions of the six Kyoto gases and, optionally, chlorofluorocarbons (CFCs) as well. The entity must report on direct and indirect emissions, not only for itself but also for all of its subsidiaries and any long-term lease sources. The protocol draws boundaries based on financial, equity share, or operational control; the entity may select which boundary type to use.

For more information on these reporting protocols, see Appendix A.7. Additional, sector-specific reporting protocols are presented in the respective, relevant chapters.

1.5 Organization of Report

This report is organized alphabetically by sector. Each sector chapter contains the following elements:

- Definition of the sector;
- Description of GHG emission sources within the sector;
- 2002 GHG emission estimates, along with a description of methodology and data sources, and key assumptions;
- 1998-2005 GHG emission estimates (where possible);
- GHG emission estimates from other sources (e.g., industry associations);
- Sector emission-reduction commitments; and
- Listing of sector-specific reporting protocols and data from reporting companies.

In addition, appendices provide more detailed information on key data sources as well as activity data and emission factors used in the emission calculations.

2. Alumina and Aluminum

Aluminum is a corrosion-resistant, light-weight, and malleable metal used in a variety of manufactured products. The transportation industry is a major buyer of aluminum, accounting for 37% of domestic shipments in 2005. Containers and packaging accounted for an additional 22% of aluminum shipments in that same year.[2]

Source	2002 Emissions ($MMTCO_2E$)
Fossil Fuel Combustion	11
Non-Combustion	10
Purchased Electricity	36
Total	57
Percent of U.S. Industrial Emissions[1]	*3%*

Other uses for aluminum include: building and construction (16%), consumer durables (7%), electrical (7%), machinery and equipment (7%), and other (4%).

The process of aluminum manufacturing (NAICS code 3313: Alumina and Aluminum) produces both primary metal, from bauxite ore, and secondary metal, from aluminum scrap. Primary aluminum manufacture is accomplished in two stages: (1) using the Bayer process of refining bauxite ore to obtain aluminum oxide (Al_2O_3); and (2) employing the Hall-Heroult process of smelting the aluminum oxide to release pure aluminum. Secondary aluminum is produced by melting scrap and recycled aluminum, primarily using natural gas as the fuel.

2.1 Sources of Greenhouse Gas Emissions

GHG emissions in the alumina (or aluminum oxide) and aluminum sector result from non-combustion activities (i.e., industrial processes), on-site fossil fuel combustion, and generation of purchased electricity.

Aluminum smelting involves the reduction of aluminum oxide into aluminum through the Hall-Heroult reduction process. This reduction occurs through electrolysis in a carbon-lined bath of molten cryolite (Na_3AlF_6). The carbon lining serves as the cathode, and the anode is a carbon mass of paste or coke. During reduction, most of this carbon is oxidized and emitted into the atmosphere as carbon dioxide (CO_2).

Perfluorocarbon (PFC) emissions occur during the production of aluminum from "anode effects", which are rapid increases in voltage due to the alumina ore content of the electrolytic bath falling below critical levels for electrolysis. As a result, carbon from the anode and fluorine from the molten cryolite combine to produce fugitive emissions of perfluoromethane (CF_4) and perfluoroethane (C_2F_6).

The reduction of alumina requires a substantial amount of energy, which is primarily on-site fossil fuel combustion for secondary aluminum and purchased electricity for primary aluminum; this energy use yields CO_2 emissions beyond those generated from the aluminum manufacturing process.

2.2 Summary of Emissions (2002)

This section presents a summary of the GHG emission estimates for the alumina and aluminum sector for the year 2002. The methodologies and data sources used to calculate these emission estimates, as well as the assumptions and limitations surrounding the estimates, are also described.

2.2.1 Estimates of Greenhouse Gas Emissions (2002)

GHG emissions from the alumina and aluminum sector were estimated to be 57 $MMTCO_2E$ in 2002 (as seen in Table 2-1).

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[1] Total 2002 industrial emissions are 2,047 $MMTCO_2E$ as reported in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*. See U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005,* 15 Apr 2007, http://www.epa.gov/climatechange/emissions/usinventoryreport.html, Table 2-16.

[2] U.S. Geological Survey, *Minerals Yearbook: Aluminum Annual Report 2005*, 2006, http://minerals.usgs.gov/minerals/pubs/commodity/aluminum/alumimyb05.pdf.

Table 2-1: GHG Emissions from the Alumina and Aluminum Sector (MMTCO$_2$E)

Source	CO_2	PFCs	Total
Fossil Fuel Combustion[a]	11		11
Non-Combustion[b]	5	5	10
Purchased Electricity[c]	36		36
Total	52	5	57

[a] Emissions calculated based on DOE's *2002 Manufacturing Energy Consumption Survey* and EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.

[b] EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.

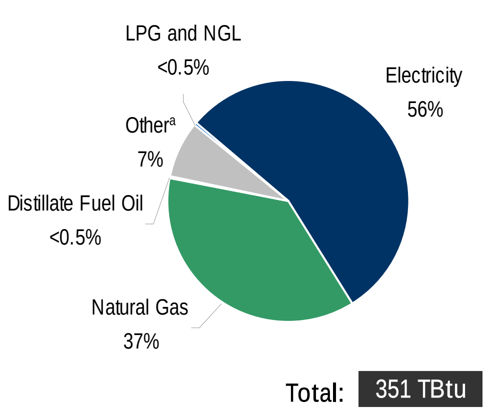
[c] Emissions calculated based on DOE's *2002 Manufacturing Energy Consumption Survey* and EPA's *Emissions and Generation Resource Integrated Database* (eGRID).

Note that for the purpose of this report, a blank cell does not necessarily indicate zero emissions; rather, it indicates that the analysis did not address that emission source, if applicable; see "Summary of Emissions (2002)" for additional information.

The overall methodology for estimating GHG emissions in this report is described in Section 1.2; more detail on the methodology used to estimate emissions from the alumina and aluminum sector can be found in Section 2.2.2. The analysis presented in this report addresses emissions related to the production processes and does not address lifecycle emissions from the use of aluminum products. Consequently, the analysis does not evaluate the environmental benefits of the produced materials. In particular, aluminum is a light-weight material that when used for automobiles may improve fuel economy and, consequently, result in reduced vehicle emissions. A more detailed lifecycle analysis would be needed to evaluate the benefits of products from this sector.

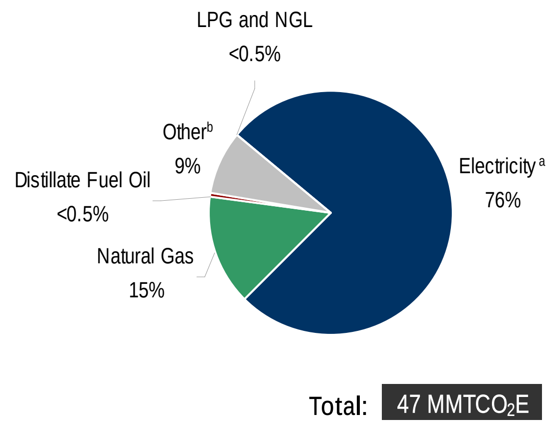
The distribution of energy consumption in this sector, by fuel type (including both on-site fossil fuel combustion and purchased electricity), is illustrated in Figure 2-1. For comparison, CO_2 emissions associated with fuel consumption are shown in Figure 2-2.

Figure 2-1: 2002 Energy Consumption in the Alumina and Aluminum Sector, by Fuel Type (TBtu)



Source: DOE, *2002 Manufacturing Energy Consumption Survey*.
[a] Composition of "other" fuel category varies among sectors.
Note: TBtu stands for trillion British thermal units.

Figure 2-2: 2002 CO_2 Emissions from Energy Consumption in the Alumina and Aluminum Sector, by Fuel Type (MMTCO$_2$E)



Source: Estimate based on methodology in Section 2.2.2.
[a] Fuel mix at utilities was taken into consideration in this calculation, per methodology described in Section 2.2.2.
[b] Composition of "other" fuel category varies among sectors.

2.2.2 Methodology and Data Sources

Fossil Fuel Combustion

Fossil fuel combustion emissions from the alumina and aluminum sector were derived from the U.S. Department of Energy's (DOE) Energy Information Administration's (EIA) *Manufacturing Energy Consumption Survey* (MECS)[3] estimates of fuel consumption for this sector. Those fuel consumption estimates were multiplied by the appropriate, fuel-specific emission factors to convert the consumption into CO_2 emitted. The emission factors for the fossil fuels used in the industry were taken from data contained in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.[4] CO_2 emissions from the "other" fuel type were taken directly from EIA's report, *Special Topic: Energy-Related Carbon Dioxide Emissions in U.S. Manufacturing*.[5]

Non-Combustion Activities

Non-combustion emission estimates, including emissions of CO_2 and PFCs, were those reported for the Aluminum Manufacturing source category within the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.[6] These estimates include the aluminum manufacturing emissions identified by the Intergovernmental Panel on Climate Change's (IPCC) *2006 IPCC Guidelines for National Greenhouse Gas Inventories*.[7]

Purchased Electricity

Electricity emissions were estimated by multiplying national-level electricity purchases (in kilowatt-hours, or kWh) provided by MECS[8] by a CO_2 emission factor (in lbs/kWh) provided by eGRID[9] at the North American Electricity Reliability Corporation (NERC)[10] region level. In order to match electricity demand to the NERC regions, facility level electricity estimates were developed based on the intensity of electricity per unit of production, provided by DOE,[11] and an estimate of production of primary aluminum. Facility-level production estimates were based on national production data (USGS)[12] and the relative capacities of the facilities. Electricity purchases were adjusted by a loss factor to reflect losses incurred in the transmission and distribution of electricity. Methods for estimating CO_2 emissions from electricity are detailed in Appendix A.3.

2.2.3 Key Assumptions and Completeness

Non-combustion emission estimates were limited to sources identified by the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* and provided in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*. Electricity and fossil fuel combustion emission estimates included only CO_2. Emissions of other GHGs (e.g., CH_4 and N_2O) that may result from combustion were not estimated.[13] Emission factors for purchased electricity provided by eGRID are for 2004, which may include different fuel mixes for electricity generation than those of the 2002 inventory year.

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[3] U.S. Department of Energy, *2002 Manufacturing Energy Consumption Survey*, Energy Information Administration, 24 Jan 2005, http://www.eia.doe.gov/emeu/mecs/mecs2002.

[4] U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005.*

[5] U.S. Department of Energy, *Special Topic: Energy-Related Carbon Dioxide Emissions in U.S. Manufacturing*, Nov 2006, http://www.eia.doe.gov/oiaf/1605/ggrpt/pdf/industry_mecs.pdf.

[6] U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005.*

[7] Intergovernmental Panel on Climate Change, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, 2007, http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.htm.

[8] U.S. Department of Energy, *2002 Manufacturing Energy Consumption Survey.*

[9] U.S. Environmental Protection Agency, *Emissions and Generation Resource Integrated Database (eGRID) v2.1*, 21 May 2007, http://www.epa.gov/cleanenergy/egrid/index.htm.

[10] NERC is the designated reliability organization that has a role in overseeing the reliability of the electric power grid. NERC regions reflect the organization structure of the regional reliability entities within with the owners of generation operate.

[11] U.S. Department of Energy, Office of Industrial Technologies, *Energy and Environmental Profile of the U.S. Aluminum Industry*, July 1997, http://www1.eere.energy.gov/industry/aluminum/pdfs/aluminum.pdf.

[12] U.S. Geological Survey, *Minerals Yearbook: Aluminum Annual Report 2005.*

[13] These non-CO_2 emissions typically account for a small percentage (approximately 2%) of a sector's GHG emissions from fossil fuel combustion.

2.3 Greenhouse Gas Emissions (1998, 2002)

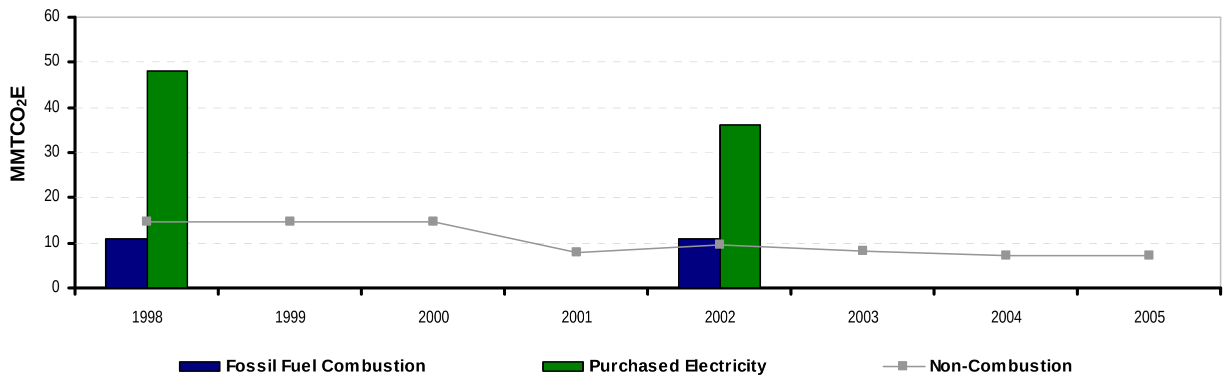
GHG emissions from select years for the alumina and aluminum sector are provided in Figure 2-3.[14]

Annual estimates of non-combustion GHG emissions from aluminum manufacturing were available from the annual *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*, which show that such emissions have decreased by 51% between 1998 and 2005, from 14.8 to 7.2 $MMTCO_2E$ in 1998 and 2005, respectively.

However, data for GHG emissions from fossil fuel combustion and purchased electricity are available only for two data points, 1998 and 2002, based on frequency of MECS reports. During this period, emissions from fossil fuel combustion remained constant at 11.0 $MMTCO_2E$, and purchased electricity emissions decreased by 26%, from 48.1 to 35.9 $MMTCO_2E$.

In aggregate, emissions from the alumina and aluminum sector decreased 24% between 1998 and 2002. Over the same period, aluminum production[15] decreased 27%.

Figure 2-3: Greenhouse Gas Emissions from the Alumina and Aluminum Sector ($MMTCO_2E$)



2.4 Other Sources of Greenhouse Gas Emission Estimates for this Sector

No reports containing complete GHG estimates for the alumina and aluminum sector were identified.

2.5 Sector Emission Reduction Commitments

The Aluminum Association (AA) and its members participating in the Voluntary Aluminum Industry Partnership (VAIP) have committed to a direct carbon intensity reduction of emissions of PFCs and of emissions of CO_2 from the consumption of the carbon anode from the primary aluminum reduction process. The target is a 53% total carbon equivalent reduction from these sources by 2010 from 1990 levels.[16]

2.6 Reporting Protocols

When calculating emissions, one of the following protocols is typically used by companies in the alumina and aluminum sector:

- EPA's *Climate Leaders Greenhouse Gas Inventory Protocol*, which is an enhanced version of the WBCSD/WRI protocol mentioned below. Climate Leaders provides extra guidance, *Draft Assessment of The Aluminum Sector*

[14] Note: in the following discussion, the percentages shown are calculated from the raw data. However, rounded data values are given in the text at an appropriate level of significance; therefore, the reader may not be able to reproduce the calculation.

[15] U.S. Geological Survey, *Minerals Yearbook: Aluminum Annual Report 2005.*

[16] See http://www.climatevision.gov/sectors/aluminum/index.html for more information on Climate VISION and the sector.

Greenhouse Gas Protocol: October 2006 for Use in Climate Leaders Reporting,[17] for the aluminum industry with regards to søderberg, prebaking, baking furnace and electrolysis reaction processes;

- DOE's *Technical Guidelines: Voluntary Reporting of Greenhouse Gases (1605(b)) Program,* which include detailed guidance for recording PFC emissions from aluminum production;
- The World Business Council for Sustainable Development (WBCSD) and the World Resource Institute's (WRI) *Greenhouse Gas Protocol*; and
- The Aluminum Sector Greenhouse Gas Protocol, which is an addendum to the WBCSD/WRI protocol and was created through the VAIP. The *Aluminum Sector Greenhouse Gas Protocol*[18] provides additional information to guide companies in the industry in estimating their emissions. The *PFC Emissions Measurement Protocol for Primary Aluminum*[19] is a standard measurement protocol that the VAIP hopes to use to advance the industry's emission reduction efforts and to disseminate to forward the adoption of a common protocol. This measurement protocol expands beyond the WBCSD/WRI protocol by including a guide to data requirements, sampling design, measurement, calculation, and quality assurance.

Table 2-2 presents a sample of companies in the sector that have publicly reported their GHG emissions.

Table 2-2: Sampling of Publicly-Reported GHG Emissions for Alumina and Aluminum Companies

Company	Protocol	Emissions ($MMTCO_2E$)	Year Reported	Geographic Scope	Goal
Alcoa	WBCSD/WRI	23.7[20]	2006	U.S.	25% by 2010 (1990 baseline)[20]

[17] See http://www.epa.gov/stateply/docs/CL_Review_of_Aluminum_Sector_Protocol.pdf.
[18] See http://www.world-aluminium.org/environment/climate/ghg_protocol.pdf.
[19] See http://www.epa.gov/highgwp/aluminum-pfc/pdf/measureprotocol.pdf.
[20] Alcoa Incorporated, "CDP 5 Companies and Response Status: Carbon Disclosure Project (CDP5) Greenhouse Gas Emissions Questionnaire," 10 Nov 2007, http://www.cdproject.net/responses/Alcoa_Inc_Corporate_GHG_Emissions_Response_CDP5_2007/public.htm.

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3. Cement

Source	2002 Emissions ($MMTCO_2E$)
Fossil Fuel Combustion	32
Non-Combustion	43
Purchased Electricity	8
Total	83
Percent of U.S. Industrial Emissions[1]	*4%*

The cement industry includes establishments primarily engaged in manufacturing straight portland, natural, masonry, pozzolanic, and other hydraulic cements. Cement facilities included in this report are those that participate in the U.S. Geological Survey's (USGS) *Minerals Yearbook: Cement Annual Report 2005*, which accounts for 100% of U.S. cement and clinker production. Cement is manufactured in 37 states and Puerto Rico, and is a key ingredient in concrete. The United States ranks as the third largest cement producer in the world and produced approximately 111 million metric tons of portland and masonry cement in 2005.[2]

3.1 Sources of Greenhouse Gas Emissions

Cement production results in CO_2 emissions from on-site fossil fuel combustion, process-related non-combustion activities, and purchased electricity consumed in manufacturing operations.

The manufacturing of cement requires energy to operate manufacturing equipment and generate and maintain high kiln temperatures. This energy use results in direct emissions of carbon dioxide (CO_2) from fossil fuel combustion and indirect CO_2 emissions from purchased electricity.

As described in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005,*[3] significant non-combustion CO_2 emissions also come from the cement production process—the high-temperature conversion of limestone (calcium carbonate, $CaCO_3$) to lime (calcium oxide, CaO), with CO_2 as a byproduct. Lime is then combined with silica-containing materials to produce clinker, which is an intermediate product combined with gypsum to produce portland cement.

3.2 Summary of Emissions (2002)

This section presents a summary of emission estimates from the cement sector. It includes a discussion of methodologies and data sources used to calculate emission estimates, as well as the assumptions and limitations surrounding the estimates.

3.2.1 Estimates of Greenhouse Gas Emissions (2002)

Table 3-1 presents emission results for the cement sector, which totaled 83 $MMTCO_2E$ and primarily result from on-site fossil fuel combustion and non-combustion processes.

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[1] Total 2002 industrial emissions are 2,047 $MMTCO_2E$ as reported in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*. See U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005,* 15 Apr 2007, http://www.epa.gov/climatechange/emissions/usinventoryreport.html, Table 2-16.

[2] U.S. Geological Survey, *Minerals Yearbook: Cement Annual Report 2005*, 2006, http://minerals.usgs.gov/minerals/pubs/commodity/cement/cemenmyb05.pdf.

[3] U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005,* Chapter 4-1.

Table 3-1: 2002 GHG Emissions from the Cement Sector (MMTCO2E)

Source	CO_2	Total
Fossil Fuel Combustion[a]	32	32
Non-Combustion[b]	43	43
Purchased Electricity[c]	8	8
Total	83	83

[a] Emissions calculated based on USGS *Minerals Yearbook: Cement Annual Report 2005* and EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*. Some fuels data do not include Puerto Rico, please see USGS Minerals Yearbook.

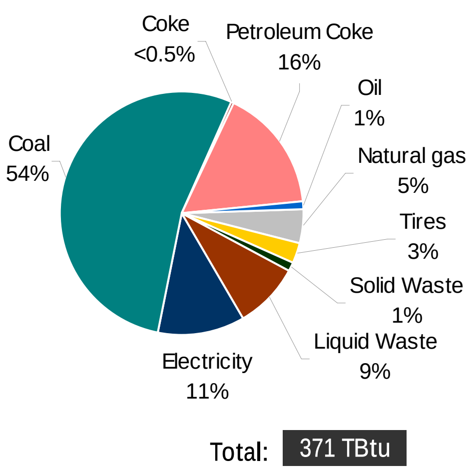
[b] EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*. Includes Puerto Rico

[c] Emissions calculated based on USGS *Minerals Yearbook: Cement Annual Report 2005* and EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*. Some fuels data do not include Puerto Rico, please see USGS Minerals Yearbook.

The overall methodology for estimating GHG emissions in this report is described in Section 1.2; more detail on the methodology used to estimate emissions from the cement sector can be found in Section 3.2.2. The analysis presented in this report addresses emissions related to the production processes and does not address lifecycle emissions from the use of cement. Consequently, the analysis does not evaluate the environmental benefits of the produced materials, such as the use of cement as a thermally efficient building material.

Figure 3-1 shows the distribution of energy consumption in this sector by fuel type (including both on-site fossil fuel combustion and purchased electricity). For comparison, CO_2 emissions associated with fuel consumption are shown in Figure 3-2.

Figure 3-1: 2002 Energy Consumption in the Cement Sector, by Fuel Type (TBtu)



Source: USGS *Minerals Yearbook: Cement Annual Report 2005.*

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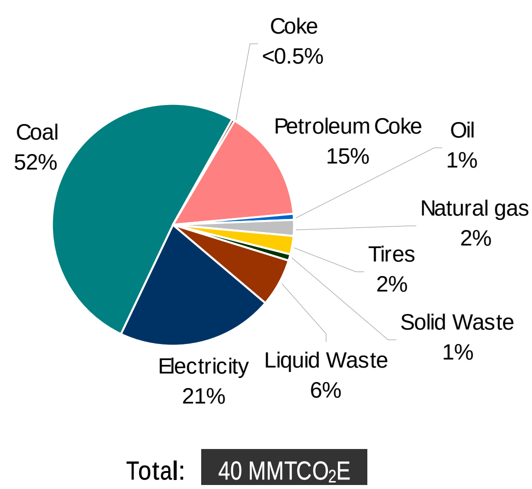
Figure 3-2: 2002 CO_2 Emissions from Energy Consumption in the Cement Sector, by Fuel Type (MMTCO2E)



Source: Estimate based on methodology in Section 3.2.2.

3.2.2 Methodology and Data Sources

Fossil Fuel Combustion

Fossil fuel combustion emissions from the cement sector were estimated using USGS *Minerals Yearbook: Cement Annual Report 2005*[4] estimates of fuel consumption for this sector. Those fuel consumption estimates were multiplied by the appropriate, fuel-specific emission factors to convert the consumption into CO_2 emitted. The emission factors for the fossil fuels used in the cement industry were taken from data contained in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*[5] and the Intergovernmental Panel on Climate Change's (IPCC) *2006 IPCC Guidelines for National Greenhouse Gas Inventories*.[6]

Non-Combustion Activities

Non-combustion emission estimates for the cement industry were obtained directly from the Cement Manufacture source category of the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.[7] The emission factor assumed is approximately 0.51 $MTCO_2$/metric ton clinker produced, plus an additional 2% of the CO_2 estimated.[8] The additional 2% is attributed to calcined raw materials contained in cement kiln dust, which is a general term for particulates that form during the clinker production process. These particulates are often captured by dust control technologies and recycled to the kiln. Cement kiln dust that is not recycled to the kiln is assumed to be emitted.

Purchased Electricity

Electricity emissions were estimated by multiplying national-level electricity purchases (in kilowatt-hours, or kWh) provided by USGS,[9] by CO_2 emission factors (in lbs/kWh) provided by eGRID[10] at the North American Electricity Reliability Corporation (NERC) region level.[11] Electricity purchases at the NERC region level were based on facility-level estimates of electricity consumption. Electricity consumed by each facility was estimated based on the electricity intensity per unit of production (tons of clinker) and an estimate of each facility's output. Total output was estimated based on each facility's capacity (tons of clinker per year) and a state-appropriate utilization factor—a measure of how much the facility's equipment is run. Different electricity intensities were used for wet and dry clinker production processes and for grinding-only facilities. In all cases, the estimated total electricity consumption was scaled to reflect actual national electricity purchases provided by USGS, and a loss factor was applied to reflect losses incurred in the transmission and distribution of electricity. Methods for estimating CO_2 emissions from electricity are detailed in Appendix A.3

3.2.3 Key Assumptions and Completeness

The boundaries of this sector correspond to facilities that reported to the USGS *Minerals Yearbook: Cement Annual Report 2005*, which accounts for 100% of U.S. cement and clinker production.[12] Electricity and fossil fuel combustion emission estimates include only CO_2. Emissions factors for purchased electricity provided by eGRID

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[4] U.S. Geological Survey, Minerals Yearbook: Cement Annual Report 2005.

[5] U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.

[6] Intergovernmental Panel on Climate Change, *2006 IPCC Guidelines for National Greenhouse Gas Inventories, 2007*, http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.htm. These guidelines detail the internationally agreed upon best available methods for national GHG emission inventories based on current technical and scientific knowledge.

[7] U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005,* Table 4-3, CO_2 Emissions from Cement Production.

[8] Factors used in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005* are taken directly from the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, pp. 2-13. These factors assume that all CaO stems from carbonate sources, which is likely not true since non-carbonates (e.g., fly ash, slag) are likely contained in the clinker. This factor and the addition of 2% for cement kiln dust may result in a slight overestimate of emissions.

[9] U.S. Geological Survey, *Minerals Yearbook: Cement Annual Report 2005*, Table 8.

[10] U.S. Environmental Protection Agency, *Emissions and Generation Resource Integrated Database (eGRID) v2.1*, 21 May 2007, http://www.epa.gov/cleanenergy/egrid/index.htm.

[11] The National Reliability Electricity Corporation (NERC) is the designated reliability organization that has a role in overseeing the reliability of the electric power grid. NERC regions reflect the organization structure of the regional reliability entities within with the owners of generation operate.

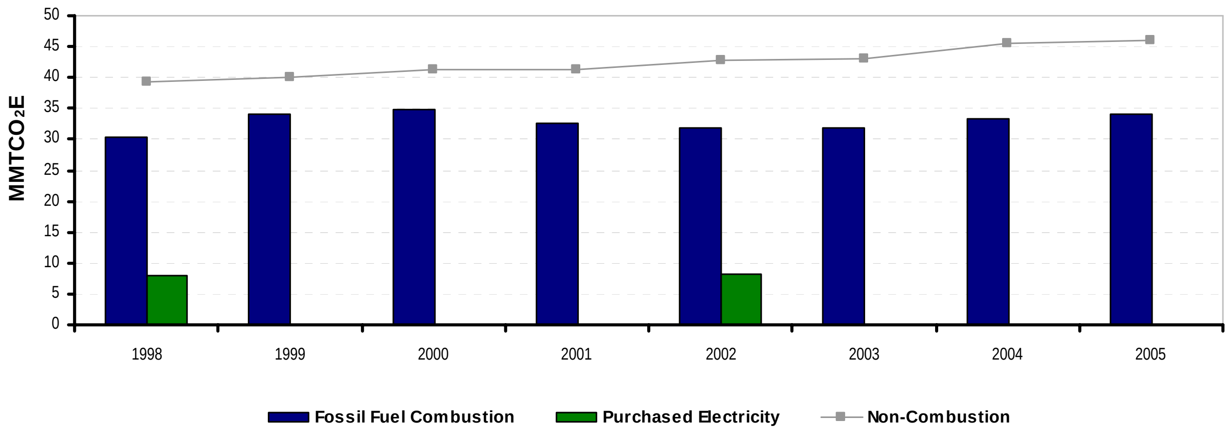
[12] U.S. Geological Survey, *Minerals Yearbook: Cement Annual Report 2005.*

are for 2004, which may include different fuel mixes for electricity generation than those of the 2002 inventory year. Emissions of other GHGs such as CH_4 and N_2O that may result from combustion were not estimated.[13]

3.3 Greenhouse Gas Emissions (1998, 2002)

GHG emissions for select years from fossil fuel combustion and non-combustion emissions are available for years 1998 to 2005 and are shown in Figure 3-1.[14] GHG emissions from purchased electricity are available for 1998 and 2002. Emission estimates were developed using the methodologies described above. From 1998 to 2005, emissions from on-site fossil fuel combustion and non-combustion processes increased by 15%. Electricity emissions increased by 5% from 1998 to 2002. Emissions from the cement sector as a whole increased by 9% between 1998 and 2002. Cement production increased by 9% during the same period.[15]

Figure 3-1: Greenhouse Gas Emissions for the Cement Sector



3.4 Other Sources of Greenhouse Gas Emission Estimates for this Sector

CO_2 Emissions Profile of the U.S. Cement Industry[16] is a conference paper prepared to geographically disaggregate CO_2 emissions from the cement industry. It provides an overview of national process emissions and energy use, as well as a detailed analysis of facility level capacity data. The report provides an emission estimate of 41.4 MMTCO$_2$E from process emissions in 2001. In addition, the analysis estimates 2001 fuels used for fossil fuel consumption for coal (71%), petroleum coke (12%), liquid and solid waste fuels (9%), natural gas (4%), and the remainder from oil and coke.[17] Emission totals from fossil fuel combustion were estimated at 35.5 MMTCO$_2$E in 2001, for a total industry estimate of 76.9 MMTCO$_2$E.[18]

3.5 Sector Emission Reduction Commitments

In 2003, the Portland Cement Association committed to a 10% reduction in CO_2 emissions per ton of cementitious product produced or sold from a 1990 baseline by 2020. PCA will be using metrics under DOE's

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[13] These non-CO_2 emissions typically account for only a small percentage (approximately 2%) of a sector's GHG emissions from fossil fuel combustion.

[14] Note: in the following discussion, the percentages shown are calculated from the raw data. However, rounded data values are given in the text at an appropriate level of significance; therefore, the reader may not be able to reproduce the calculation.

[15] U.S. Geological Survey, *Minerals Yearbook: Cement Annual Report 2005.*

[16] Hanle, L. and K. Jayaraman (2004). CO_2 Emissions Profile of the U.S. Cement Industry. Submitted to 13th International Emission Inventory Conference: "Working for Clean Air in Clearwater." Clearwater, FL, June 8-10, 2004. http://www.epa.gov/ttn/chief/conference/ei13/ghg/hanle.pdf.

[17] Coke (i.e., metallurgical coke) may be misreported petroleum coke (van Oss 2008)

[18] Also see the Portland Cement Association's *U.S. and Canadian Labor-Energy Input Survey 2006, a* proprietary annual survey detailing the U.S. and Canadian cement industry's labor and energy usage. The report focuses on energy consumption by fuel type (including waste fuels) and contains aggregated historical labor and energy efficiency trends summarized by type of process, size of kiln, and age of plant. Individual plant detail is not presented. Available at http://www.cement.org/bookstore/profile.asp?store=&pagenum=1&pos=0&catID=&id=15216.

Technical Guidelines: Voluntary Reporting of Greenhouse Gases (1605(b)) Program and the World Business Council for Sustainable Development (WBCSD) and the World Resource Institute's (WRI) *Greenhouse Gas Protocol* to report its results.[19]

3.6 Reporting Protocols

When calculating emissions, one of the following protocols is typically used by companies in the cement sector:

- EPA's *Climate Leaders Greenhouse Gas Inventory Protocol*, which is an enhanced version of the WBCSD/WRI protocol mentioned below. The cement industry's protocol, *Draft Assessment of CO_2 Accounting and Reporting Standard for the Cement Industry: Version 2.0 for Use in Climate Leaders Reporting*, for Climate Leaders exempts companies from reporting purchased electricity, owned or leased off-site mobile combustion, and CH_4 and N_2O emissions from kiln fuel combustion.[20]
- DOE's *Technical Guidelines: Voluntary Reporting of Greenhouse Gases (1605(b)) Program*; and
- WBCSD/WRI *Greenhouse Gas Protocol* (note: WBCSD also coordinates a voluntary Cement Sustainability Initiative (CSI), a member-sponsored program to find new ways to meet the sustainability challenge of: reducing the industry's ecological footprint, increasing stakeholder engagement, and understanding the industry's social contributions).[21]

Table 3-2 presents a sample of cement companies that have publicly reported their GHG emissions.

Table 3-2: Sampling of Publicly-Reported GHG Emissions for Cement Companies

Company	Protocol	Emissions (kg/t)	Year Reported	Geographic Scope	Goal
Holcim	NI	658[22]	2005	World	12% below 2000 levels per ton cement by 2008[23]
Lafarge[24]	NI	670	2006	World	20% below 1990 levels per metric ton cement by 2010
St. Lawrence Cement[25]	NI	668	2005	World	15% below 2000 levels per ton cement by 2010

NI = Not Indicated

[19] See http://www.climatevision.gov/sectors/cement/index.html.
[20] See http://www.epa.gov/stateply/docs/CLReview_of_Cement_Sector_Protocol.pdf.
[21] See http://www.wbcsd.org/templates/TemplateWBCSD1/layout.asp?type=p&MenuId=MTI2&doOpen=1&ClickMenu=LeftMenu.
[22] Holcim Ltd, "Corporate Sustainable Development Report 2005," Global Reporting Initiative, June 2006, http://www.corporateregister.com/search/report.cgi?num=15774-Osb.ki8YtnY 24.
[23] U.S. Environmental Protection Agency, "Partner Profile: Holcim (U.S.) Inc.," Climate Leaders, 12 Nov 2007, http://www.epa.gov/stateply/partners/partners/holcimusinc.html.
[24] LaFarge, "Sustainability Report 2006," Global Reporting Initiative, May 2007, http://www.corporateregister.com/search/report.cgi?num=18921-2w8aZcpFvC2 20 – 21.
[25] St. Lawrence Cement Group, "Sustainable Development Report," February 2006, http://www.stlawrencecement.com/gc/CA/uploads/SLC%20SD%20Report%20February%202006%20FINAL.pdf 9.

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4. Chemicals

The chemical sector, as defined by NAICS code 325, produces products by transforming organic and inorganic raw materials by a chemical process.[1] Over 96% of all manufactured goods are directly impacted by chemistry, either as a material, in processing, or in some other value-added means.[2] The United States is the top chemical-producing country.[2]

Source	2002 Emissions ($MMTCO_2E$)
Fossil Fuel Combustion	203
Non-Combustion	62
Purchased Electricity	101
Total	366
Percent of U.S. Industrial Emissions[1]	*18%*

The chemical sector contains the following segments: basic chemicals, specialties, agricultural chemicals, pharmaceuticals, and consumer products. Basic, or commodity chemicals, such as industrial chemicals and fertilizers, are produced in large volumes to homogenous chemical composition specifications. Specialty chemicals are used for specific purposes such as a functional ingredient or as processing aids in the manufacture of a wide variety of products. Examples of specialty chemicals include adhesives, catalysts, coatings, and water management chemicals. Agricultural, pharmaceutical, and consumer product chemicals include crop protection chemicals, prescription and over-the-counter drugs, in-vitro and other diagnostic substances, vaccines, soaps, detergents, bleaches, and toothpaste.[2]

4.1 Sources of Greenhouse Gas Emissions

The chemical sector depends on fuel inputs for energy and for raw materials (feedstocks).[2] As such, GHG emissions from chemicals result from both the energy used by the industry as well as from the chemical processes themselves.

Manufacturing in the chemical sector involves complex chemical reactions, often requiring large amounts of heat, pressure and/or electricity. Energy-related emissions result from on-site fossil fuel combustion and from purchased electricity. As described in the American Chemistry Council's (ACC) *Guide to the Business of Chemistry*, fossil fuel combustion serves to supply heat and power for plant operations. The largest use of fuel for heat and power is in boilers used to produce steam to drive chemical reactions and perform product separation and finishing operations.[3] Electricity is used to power equipment, drive electrochemical processes, and heat, light, and cool facilities.[3]

Emissions resulting from feedstocks are referred to as process-related, or non-combustion, GHG emissions. Oil and natural gas are both feedstocks in the manufacturing of organic chemicals. As described in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*,[4] chemical manufacturing processes that result in significant non-combustion GHG emissions include (GHGs emitted by each process are provided in parentheses):

- Petrochemicals Production (CO_2, CH_4): Petrochemicals are chemicals isolated or derived from petroleum or natural gas. Methane (CH_4) emissions result from the production of carbon black, ethylene, ethylene dichloride, and methanol, while carbon dioxide (CO_2) emissions result solely from carbon black production. Carbon black is an intensely black powder generated by the incomplete combustion of an aromatic petroleum or coal-based feedstock.
- Phosphoric Acid Production (CO_2): Phosphoric acid production from natural phosphate rock emits CO_2 due to the chemical reaction of the inorganic carbon (calcium carbonate) component of the phosphate rock.

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[1] Total 2002 industrial emissions are 2,047 $MMTCO_2E$ as reported in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*. See U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005,* 15 Apr 2007, http://www.epa.gov/climatechange/emissions/usinventoryreport.html, Table 2-16.

[2] American Chemistry Council, *Guide to the Business of Chemistry*, 2006, pp. 1, 16-40, 43, 103.

[3] U.S. Department of Energy, *1998 Chemicals Industry Analysis Brief: Energy Consumption*, Energy Information Administration, 7 Jan 2004, http://www.eia.doe.gov/emeu/mecs/iab98/chemicals/index.html.

[4] U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.

- Titanium Dioxide Production (CO_2): There are two processes used for making titanium dioxide: the chloride process and the sulfate process. Only the chloride process emits process-related CO_2 as a result of using petroleum coke and chlorine as raw materials.
- Adipic Acid Production (N_2O): Adipic acid is produced by oxidizing cyclohexane to form a cyclohexanone/cyclohexanol mixture, which is then oxidized with nitric acid to produce adipic acid. N_2O is generated as a by-product of the nitric acid oxidation stage and is emitted in the waste gas stream.
- Nitric Acid Production (N_2O): N_2O is formed as a by-product of the catalytic oxidation of ammonia, the process by which virtually all of the nitric acid produced in the U.S. is manufactured.
- HCFC-22 Production (HFC-23): HCFC-22 is produced by the reaction of chloroform and hydrogen fluoride in the presence of a catalyst, $SbCl_5$. The production process involves a continuous flow reactor, condensation of chemicals, and fluorination. The final vapors of these processes consist primarily of HCFC-22, HFC-23, HCl and residual HF. Of the remaining vapors, the HCl is recovered, the HF is removed, and once it is separated from HCFC-22, the HFC-23 is vented into the atmosphere.
- Soda Ash Manufacturing (CO_2): There are two types of soda ash produced internationally: natural and synthetic. The production of natural soda ash involves the treatment of trona ore which generates CO_2 as a by-product.
- Ammonia Manufacturing (CO_2): CO_2 is emitted through the use of natural gas, naphtha, and in some cases petroleum coke, as a feedstock. The carbon from these feedstocks is removed to produce CO_2, leaving hydrogen (H_2), which is used in the production of ammonia (NH_3).

4.2 Summary of Emissions (2002)

This section presents a summary of the GHG emission estimates for the chemical sector for the year 2002. The methodologies and data sources used to calculate these emission estimates, as well as the assumptions and limitations surrounding the estimates, are also described.

4.2.1 Estimates of Greenhouse Gas Emissions (2002)

Total GHG emissions from the chemical sector were estimated to be 366 $MMTCO_2E$ in 2002 (as seen in Table 4-1).

Table 4-1: 2002 GHG Emissions from the Chemical Sector ($MMTCO_2E$)

Source	CO_2	CH_4	N_2O	HFCs	Total
Fossil Fuel Combustion[a]	203				203
Non-Combustion[5]	18	1	23	20	62
Petrochemicals Production	*3*	*1*			*4*
Phosphoric Acid Production	*1*				*1*
Titanium Dioxide Production	*2*				*2*
Adipic Acid Production			*6*		*6*
Nitric Acid Production			*17*		*17*
HCFC-22 Production				*20*	*20*
Soda Ash Manufacture	*2*				*2*
Ammonia Manufacture	*11*				*11*
Purchased Electricity[b]	101				101
Total	322	1	23	20	366

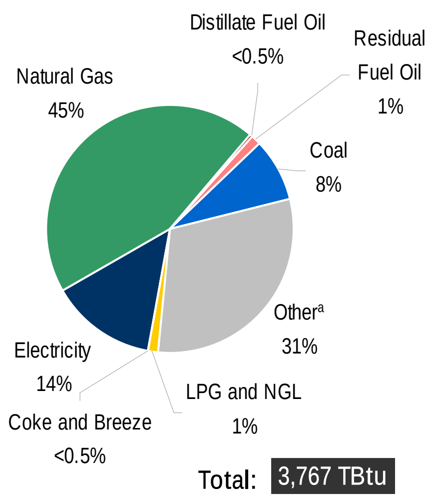
[a] Emissions calculated based on DOE's *2002 Manufacturing Energy Consumption Survey* and EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.
[b] Emissions calculated based on DOE's *2002 Manufacturing Energy Consumption Survey* and EPA's *Emissions and Generation Resource Integrated Database* (eGRID).
Note that for the purpose of this report, a blank cell does not necessarily indicate zero emissions; rather, it indicates that the analysis did not address that emission source, if applicable; see "Summary of Emissions (2002)" for additional information.

[5] U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.

The overall methodology for estimating GHG emissions in this report is described in Section 1.2; more detail on the methodology used to estimate emissions from the chemical sector can be found in Section 4.2.2.

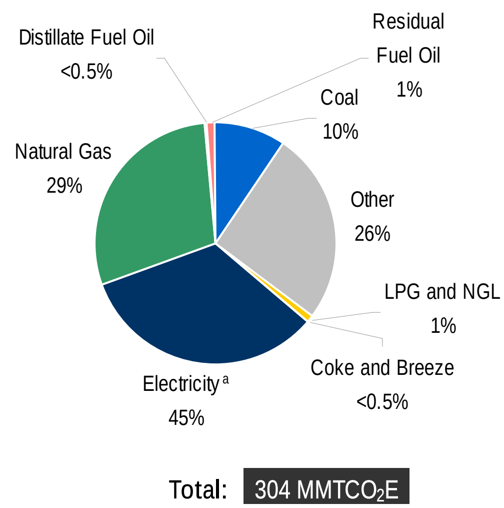
Figure 4-1 shows the distribution of energy consumption in this sector by fuel type (including both on-site fossil fuel combustion and purchased electricity). For comparison, CO_2 emissions associated with fuel consumption are shown in Figure 4-2.

Figure 4-1: 2002 Energy Consumption in the Chemical Sector, by Fuel Type (TBtu)



Source: DOE, *2002 Manufacturing Energy Consumption Survey*.
[a] Composition of "other" fuel category varies among sectors. In the chemicals sector, "other" fuels include petroleum-derived byproduct gases and solids, woody materials, hydrogen, and waste materials.
Note: TBtu stands for trillion British thermal units.

Figure 4-2: 2002 CO_2 Emissions from Energy Consumption in the Chemical Sector, by Fuel Type ($MMTCO_2E$)



Source: Estimate based on methodology in Section 4.2.2.
[a] Fuel mix at utilities was taken into consideration in this calculation, per methodology described in Section 4.2.2.

4.2.2 Methodology and Data Sources

Fossil Fuel Combustion

Fossil fuel combustion emissions from the chemical sector were derived from the U.S. Department of Energy's (DOE) Energy Information Administration's (EIA) *Manufacturing Energy Consumption Survey* (MECS)[6] estimates of fuel consumption for this sector. Those fuel consumption estimates were multiplied by the appropriate, fuel-specific emission factors to convert the consumption into CO_2 emitted. The emission factors for the fossil fuels used in the chemical industry were taken from data contained in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.[7]

Non-Combustion Activities

Non-combustion emission estimates, including emissions of CO_2, CH_4, N_2O, and HFCs, from chemicals were obtained from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.[7] These estimates include the

[6] U.S. Department of Energy, *2002 Manufacturing Energy Consumption Survey*, Energy Information Administration, 24 Jan 2005, http://www.eia.doe.gov/emeu/mecs/mecs2002.
[7] U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.

chemical sector emission sources identified by the Intergovernmental Panel on Climate Change's (IPCC) *2006 IPCC Guidelines for National Greenhouse Gas Inventories*.[8] As described above, for the United States, the nine sources are petrochemical production, phosphoric acid production, titanium dioxide production, adipic acid production, nitric acid production, HCFC-22 production, soda ash manufacturing, and ammonia manufacturing. These are source categories 4.13, 4.9, 4.7, 4.16, 4.15, 4.18, 4.6, and 4.3, respectively, in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005.*

Purchased Electricity

Electricity emissions were estimated by mapping national electricity purchases (in kilowatt-hours, or kWh) provided by MECS to North American Electricity Reliability Corporation (NERC) regions,[9] then applying NERC regional utility CO_2 emission factor (in lbs/kWh) provided by eGRID. Sector electricity purchases were adjusted by a loss factor to reflect losses incurred in the transmission and distribution of electricity.

Since electricity purchase data were not available at the NERC regional level, distribution of the sector's value added was used to distribute the sector's national electricity purchases to the state-level, then state data were rolled up to the NERC regions. Where a state lay in two or more NERC regions, electricity purchases were distributed to the appropriate NERC region using sales data for the industrial customer class from EIA Report 861. This approach assumes that the electricity-intensity of production activities are correlated with the value added. Methods for estimating CO_2 emissions from electricity are described in more detail in Appendix A.3.

4.2.3 Key Assumptions and Completeness

Non-combustion emission estimates were limited to sources identified by the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Electricity and fossil fuel combustion emission estimates include only CO_2. Emissions of other GHGs (e.g., CH_4 and N_2O) that may result from combustion were not estimated.[10] Emission factors for purchased electricity provided by eGRID are for 2004, which may include different fuel mixes for electricity generation than those of the 2002 inventory year.

4.3 Greenhouse Gas Emissions (1998, 2002)

GHG emissions for select years from the chemical sector are provided in Figure 4-3.[11]

Data for non-combustion GHG emissions are available for the years 1998 to 2005 from the annual *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*. These process-related emissions have decreased by approximately 38% over the time-series, from 90 to 56 $MMTCO_2E$.

Data for GHG emissions from fossil fuel combustion and purchased electricity are available only for two data points, 1998 and 2002, based on frequency of MECS reports. Fossil fuel combustion emissions increased by approximately 10%, from 185 to 203 $MMTCO_2E$, and emissions from purchased electricity declined by approximately 13%, from 117 to 101 $MMTCO_2E$.

Total emissions from the chemical sector decreased by approximately 7% between 1998 and 2002. Over the same period, value added[12] in the chemical sector increased 3%.

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[8] Intergovernmental Panel on Climate Change, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, 2007, http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.htm. These guidelines detail the internationally agreed upon best available methods for national GHG emission inventories based on current technical and scientific knowledge.

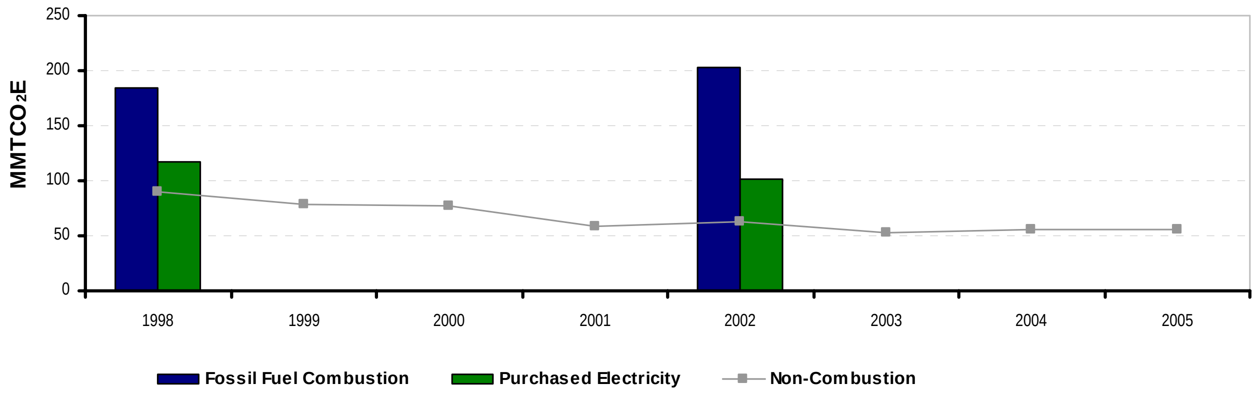
[9] The North American Electricity Reliability Corporation (NERC) is the designated reliability organization that has a role in overseeing the reliability of the electric power grid. NERC regions reflect the organization structure of the regional reliability entities within with the owners of generation operate.

[10] These non-CO_2 emissions typically account for a small percentage (approximately 2%) of a sector's GHG emissions from fossil fuel combustion.

[11] Note: in the following discussion, the percentages shown are calculated from the raw data. However, rounded data values are given in the text at an appropriate level of significance; therefore, the reader may not be able to reproduce the calculation.

[12] Value added is a measure of the enhancement a company gives its product or service before offering the product to customers. It is used here as a surrogate for production. Value added is considered to be the best value measure available for comparing the relative economic importance of manufacturing among industries and geographic areas (source: U.S. Census Bureau, *Annual Survey of Manufactures (ASM): Statistics for Industry Groups and Industries*, 2005, http://www.census.gov/mcd/asm-as1.html). The data were normalized to account for fluctuation in industry size or production over time; dollars were adjusted for inflation using a gross domestic product price deflator.

Figure 4-3: Greenhouse Gas Emissions for the Chemical Sector



4.4 Other Sources of Greenhouse Gas Emission Estimates for this Sector

ACC's *Guide to the Business of Chemistry* is an annual publication that describes the industry's performance and trends. The guide includes GHG emission estimates for CO_2, CH_4, N_2O, and "others," which may include HFCs, SF_6, and other gases generated during the manufacturing process. Similar to estimates presented here, ACC's estimates include fossil fuel combustion, non-combustion activities, and purchased electricity. For the year 2002, ACC estimated total GHG emissions to be 278.6 $MMTCO_2E$ (Table 4-2), an estimate that is approximately 87 $MMTCO_2E$ less than the estimate presented here. The difference results from the different energy consumption numbers used by MECS and ACC for the "other" fossil fuel category. For the year 2002, MECS data indicates 1,158 TBtu for this category whereas ACC estimates 583 TBtus for this category. In addition, estimates for CO_2 process-related emissions differ. Process CO_2 emissions are estimated to be 18 $MMTCO_2E$, whereas ACC estimates these emissions to be 3.5 $MMTCO_2E$. ACC's estimates account only for non-combustion emissions from soda ash manufacture and titanium dioxide production, whereas estimates presented here account for non-combustion emissions from these two sources in addition to ammonia manufacture, petrochemical production and phosphoric acid manufacture. ACC will evaluate the processes undertaken by its members and consider whether it is appropriate to include these in future estimates.[13]

Table 4-2: GHG Emission Estimates from the American Chemistry Council's Guide to the Business of Chemistry ($MMTCO_2E$)

	2002	2003	2004	2005
Fossil Fuel Combustion and Purchased Electricity CO_2	*231*	*235*	*226*	*227*
Non-Combustion CO_2	*4*	*4*	*4*	*4*
N_2O	*23*	*23*	*22*	*22*
CH_4	*2*	*2*	*2*	*1*
Others	*20*	*12*	*16*	*16*
Total	279	276	269	270

Source: ACC, *Guide to the Business of Chemistry*.

[13] Personal communication, ACC and ICF International, 2 Nov 2007.

4.5 Sector Commitments

ACC has committed to reduce overall GHG emission intensity by 18% by 2012 (from a 1990 baseline). ACC is using metrics under DOE's *Technical Guidelines: Voluntary Reporting of Greenhouse Gases (1605(b)) Program* for its annual member-wide reports.[14]

4.6 Reporting Protocols

When calculating emissions, one of the following protocols may be used by companies in the chemical sector:

- EPA's *Climate Leaders Greenhouse Gas Inventory Protocol*, which is an enhanced version of the WBCSD/WRI protocol mentioned below;
- DOE's *Technical Guidelines: Voluntary Reporting of Greenhouse Gases (1605(b)) Program*, which include specific guidance on calculating N_2O emissions from adipic and nitric acid production (*Sector-Specific Issues 51*);[14] and
- The World Business Council for Sustainable Development (WBCSD) and the World Resource Institute's (WRI) *Greenhouse Gas Protocol*.

Table 4-3 presents a sample of companies in the sector that have publicly reported their GHG emissions.

Table 4-3: Sampling of Publicly-Reported GHG Emissions for Chemical Companies

Company	Protocol	Emissions ($MMTCO_2E$)	Year Reported	Geographic Scope	Goal
Air Products & Chemicals[15]	WBCSD/WRI	2.0	2006	Annex B[a]	NI
Dow Chemical[16]	WBCSD/WRI	20.2	2006	U.S.	2.5% per year reduction per pound of produced product till 2015 (2005 baseline)
DuPont[17]	WBCSD/WRI	10.3	2005	U.S.	15% below 2004 levels by 2015[18]
Johnson & Johnson[19]	WBCSD/WRI	0.6	2006	U.S.	14% below 2001 levels by 2010[20]
Rohm and Haas[21]	WBCSD/WRI	3.2	2006	Global	NI

NI = Not Indicated

[a] Countries included in Annex B of the Kyoto Protocol

[14] See http://www.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/gg-v1-3-indust.pdf.

[15] Air Products & Chemicals, "CDP 5 Companies and Response Status: Carbon Disclosure Project (CDP5) Greenhouse Gas Emissions Questionnaire," 29 Feb 2008, http://www.cdproject.net/responses/Air_Products___Chemicals_Corporate_GHG_Emissions_Response_CDP5_2007/public.htm.

[16] The Dow Chemical Company, "CDP 5 Companies and Response Status: Carbon Disclosure Project (CDP5) Greenhouse Gas Emissions Questionnaire," 29 Feb 2008, http://www.cdproject.net/responses/Dow_Chemical_Company_The_Corporate_GHG_Emissions_Response_CDP5_2007/public.htm.

[17] E.I. du Pont de Nemours & Company, "CDP 5 Companies and Response Status: Carbon Disclosure Project (CDP5) Greenhouse Gas Emissions Questionnaire," 29 Feb 2008, http://www.cdproject.net/responses/EI_du_Pont_de_Nemours___Company_Corporate_GHG_Emissions_Response_CDP5_2007/public.htm.

[18] U.S. Environmental Protection Agency, "Partner Profile: DuPont Company," Climate Leaders, 29 Feb 2008, http://www.epa.gov/stateply/partners/partners/johnsonjohnson.html.

[19] Johnson & Johnson, "CDP 5 Companies and Response Status: Carbon Disclosure Project (CDP5) Greenhouse Gas Emissions Questionnaire," 29 Feb 2008, http://www.cdproject.net/responses/Johnson___Johnson_Corporate_GHG_Emissions_Response_CDP5_2007/public.htm.

[20] U.S. Environmental Protection Agency, "Partner Profile: Johnson & Johnson," Climate Leaders, 29 Feb 2008, http://www.epa.gov/stateply/partners/partners/dupontcompany.html.

[21] Rohm & Haas, "2006 EHS and Sustainability Report," September 2007, http://www.rohmhaas.com/assets/attachments/about_us/ehs/pdfs/2006ehs.pdf.

5. Construction

Source	2002 Emissions ($MMTCO_2E$)
Fossil Fuel Combustion	100
Non-Combustion	
Purchased Electricity	31
Total	131
Percent of U.S. Industrial Emissions[1]	*6%*

The construction sector comprises establishments engaged in the construction of buildings and engineering projects.The work performed includes new work, additions, alterations, maintenance and repairs, and demolitions. With spending set at $873.1 billion in 2003, the U.S. construction sector is one of the world's largest, and it is the seventh-largest employer in the U.S.[2] The activities included in the construction sector may be found under the following NAICS codes: Construction Buildings (NAICS code: 236), Heavy and Civil Engineering Construction (NAICS code 237), and Specialty Trade Contractors (NAICS code: 238).

NAICS code 236, Construction Buildings, is defined as those establishments primarily responsible for the construction of buildings.[3]

NAICS code 237, Heavy and Civil Engineering Construction, is defined as those establishments whose primary activity is the construction of entire engineering projects (e.g., highways and dams), and specialty trade contractors, whose primary activity is the production of a specific component for such projects.[3]

NAICS code 238, Specialty Trade Contractors, is defined as establishments whose primary activity is performing specific activities (e.g., pouring concrete, site preparation, plumbing, painting, and electrical work) involved in building construction or other activities that are similar for all types of construction but that are not responsible for the entire project.[3]

5.1 Sources of Greenhouse Gas Emissions

GHG emissions from the construction sector result from fuel consumed by on- and off-road construction equipment and from electricity consumed to provide power to construction tools and offices. Off-road diesel engines used by construction companies include a wide variety of loaders, dozers, excavators, graders, and other specialized equipment.[4] Emissions from this sector are associated with energy use from construction, and do not include the post-construction performance of buildings.

5.2 Summary of Emissions (2002)

This section presents a summary of the GHG emission estimates from construction activities for the year 2002. The methodologies and data sources used to calculate emission estimates, as well as the assumptions and limitations surrounding the estimates, are also described.

5.2.1 Estimates of Greenhouse Gas Emissions (2002)

GHG emissions from the construction sector were estimated to be 131 $MMTCO_2E$ in 2002 (as seen in Table 5-1).

Note that for the purpose of this report, a blank cell does not necessarily indicate zero emissions; rather, it indicates that the analysis did not address that emission source, if applicable; see "Summary of Emissions (2002)" for additional information.

[1] Total 2002 industrial emissions are 2,047 $MMTCO_2E$ as reported in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*. See U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005,* 15 Apr 2007, http://www.epa.gov/climatechange/emissions/usinventoryreport.html, Table 2-16.

[2] U.S. Department of Commerce, *Construction Services Sector*, International Trade Administration, 2007, http://trade.gov/investamerica/construction.asp.

[3] U.S. Census Bureau, *2002 NAICS Codes and Titles*, 23 Mar 2004, http://www.census.gov/epcd/naics02/naicod02.htm.

[4] ICF Consulting, *Emission Reduction Incentives for Off-Road Diesel Equipment Used in the Port and Construction Sectors,* 2005, http://www.epa.gov/sustainableindustry/pdf/emission_20050519.pdf, p. 1.

Table 5-1: GHG Emissions from Construction ($MMTCO_2E$)

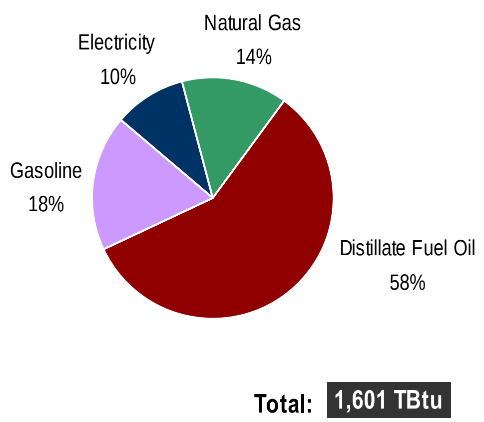
Source	CO_2	CH_4	N_2O	HFCs	Total
Fossil Fuel Combustion[a]	100				100
Non-Combustion					
Purchased Electricity[b]	31				31
Total[5]	131				131

[a] Emissions calculated based on DOE's *2002 Manufacturing Energy Consumption Survey* and EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.
[b] Emissions calculated based on DOE's *2002 Manufacturing Energy Consumption Survey* and EPA's *Emissions and Generation Resource Integrated Database* (eGRID).
Note that for the purpose of this report, a blank cell does not necessarily indicate zero emissions; rather, it indicates that the analysis did not address that emission source, if applicable; see "Summary of Emissions (2002)" for additional information.

The overall methodology for estimating GHG emissions in this report is described in Section 1.2; more detail on the methodology used to estimate emissions from construction can be found in Section 5.2.2.

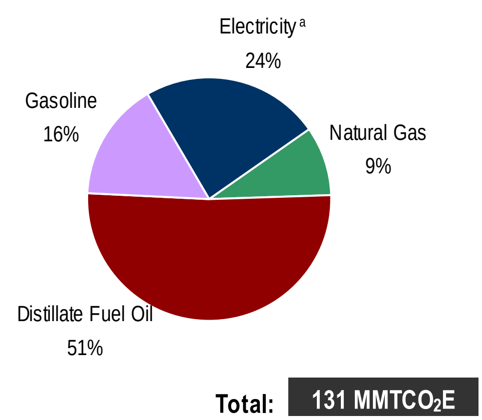
The distribution of energy consumption in this sector, by fuel type (including both on-site fossil fuel combustion and purchased electricity), is illustrated in Figure 5-1. For comparison, CO_2 emissions associated with fuel consumption are shown in Figure 5-2.

Figure 5-1: 2002 Energy Consumption in the Construction Sector, by Fuel Type (TBtu)



Source: U.S. Census Bureau, *2002 Economic Census Industry Series Reports Construction*.
Note: TBtu stands for trillion British thermal units.

Figure 5-2: 2002 CO_2 Emissions from Energy Consumption in the Construction Sector, by Fuel Type ($MMTCO_2E$)



Source: Estimate based on methodology in Section 5.2.2.
[a] Fuel mix at utilities was taken into consideration in this calculation, per methodology described in Section 5.2.2.

[5] A report developed by EPA's Sector Strategies Division, *Measuring Construction Industry Environmental Performance* (September 2007) tracks various environmental performance indicators of U.S. construction activities, including energy use and GHG emissions. Carbon dioxide emissions from construction activities were estimated to be approximately 85 $MMTCO_2E$ from fossil fuel combustion and 29 $MMTCO_2E$ from electricity in this report. Due to new data and information, the numbers presented here – 100 $MMTCO_2E$ from fossil fuel combustion and 31 $MMTCO_2E$ from electricity – differ. The emission estimate presented in the previous report assumes 100 percent of fuel consumed by on-highway vehicles is gasoline. This report assumes a 50/50 split between diesel and gasoline fuel types for on-highway vehicles.

5.2.2 Methodology and Data Sources

Fossil Fuel Combustion

Fossil fuel consumption was estimated based on reported dollars spent on distillate fuel, natural gas, and gasoline for construction activities, provided by the U.S. Census Bureau's *Industry Series Report for Construction.*[6] Those fuel consumption estimates were divided by the cost of fuel, provided by EIA's *State Energy Data Report*, as shown in Table 5-2. Because the U.S. Census data provides dollars spent on on- and off-highway fuel use as an aggregated sum of diesel and gasoline, the emission estimates were based on the assumption that all off-highway use was diesel, and that 50% of on-highway use was motor gasoline and the other 50% diesel.[7] The fossil fuel combustion emission estimate utilized an emission factor of 0.073 $MMTCO_2E$/TBtu for distillate fuel, 0.071 $MMTCO_2E$/TBtu for motor gasoline, and 0.053 $MMTCO_2E$/TBtu for natural gas, as provided by EIA's *Annual Electric Power Industry Report.*

Table 5-2: Cost of Fuel Provided by EIA's State Energy Data Report ($/TBtu)

Industrial Fuel Type	Price
Distillate Fuel	*$ 6,324,590*
Natural Gas	*$ 4,365,110*
Motor Gasoline	*$ 10,658,510*

Source: DOE, *State Energy Data Report, Fuel Prices.*

Non-Combustion Activities

Non-combustion emissions would include GHG emissions that occur from activities within construction that are not related to energy use. Non-combustion emissions from this sector are not identified by the Intergovernmental Panel on Climate Change's (IPCC) *2006 IPCC Guidelines for National Greenhouse Gas Inventories*[8] and, hence, are not included in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005* or this report.

Purchased Electricity

Electricity consumption was determined by dividing dollars spent on purchased electricity provided by the U.S. Census Bureau's *Industry Series Report for Construction*, by the cost of electricity ($0.049/kWh), provided by EIA's *State Energy Data Report.*[9] Electricity emissions were estimated by multiplying electricity consumption (in kilowatt-hours, or kWh) by CO_2 emission factor (in lbs/kWh) provided by eGRID[10] at the North American Electricity Reliability Corporation (NERC) region level.[11] Sector electricity purchases were adjusted by a loss factor to reflect losses incurred in the transmission and distribution of electricity. The geographic distribution of electricity purchases was assumed to be the same as that of the commercial class. This customer class distribution was based on data collected by EIA on sales, by customer class, on all electricity providers (from EIA Form 861). [12] Methods for estimating CO_2 emissions from electricity are detailed in Appendix A.3.

[6] U.S. Census Bureau, *2002 Economic Census Industry Series Reports Construction*, 22 Nov 2005.

[7] Personal communication from Peter Truitt of EPA's Sector Strategies Division to ICF International, 8 Nov 2007.

[8] Intergovernmental Panel on Climate Change, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, 2007, http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.htm. These guidelines detail the internationally agreed upon best available methods for national GHG emission inventories based on current technical and scientific knowledge.

[9] U.S. Department of Energy, *State Energy Data Report, Fuel Prices*, Energy Information Administration, 1 Jun 2007, http://www.eia.doe.gov/emeu/states/_seds.html.

[10] U.S. Environmental Protection Agency, *Emissions and Generation Resource Integrated Database (eGRID) v2.1*, May 2007, http://www.epa.gov/cleanenergy/egrid/index.htm.

[11] The North American Electricity Reliability Corporation (NERC) is the designated reliability organization that has a role in overseeing the reliability of the electric power grid. NERC regions reflect the organization structure of the regional reliability entities within with the owners of generation operate.

[12] U.S. Department of Energy, *Annual Electric Power Industry Report: Form EIA-861*, Energy Information Administration, http://www.eia.doe.gov/cneaf/electricity/page/eia861.html.

5.2.3 Key Assumptions and Completeness

Electricity and fossil fuel combustion emission estimates included only CO_2. Emissions of other greenhouse gases (e.g., CH_4 and N_2O) that may result from combustion were not estimated.[13] Emission factors for purchased electricity provided by eGRID are for 2004, which may include different fuel mixes for electricity generation than those of the 2002 inventory year.

Information from the U.S. Census Bureau's *2002 NAICS Codes and Titles* was obtained for fuel use according to the NAICS codes that define the construction sector. Further research is needed to determine whether data provided by the U.S. Census Bureau on total dollars spent on gasoline and diesel fuel can be disaggregated into dollars spent on gasoline and dollars spent on diesel fuel. Additional research is also needed regarding the assumption that all off-highway fuel use is diesel and that 50% of on-highway use is motor gasoline and the other 50% diesel.

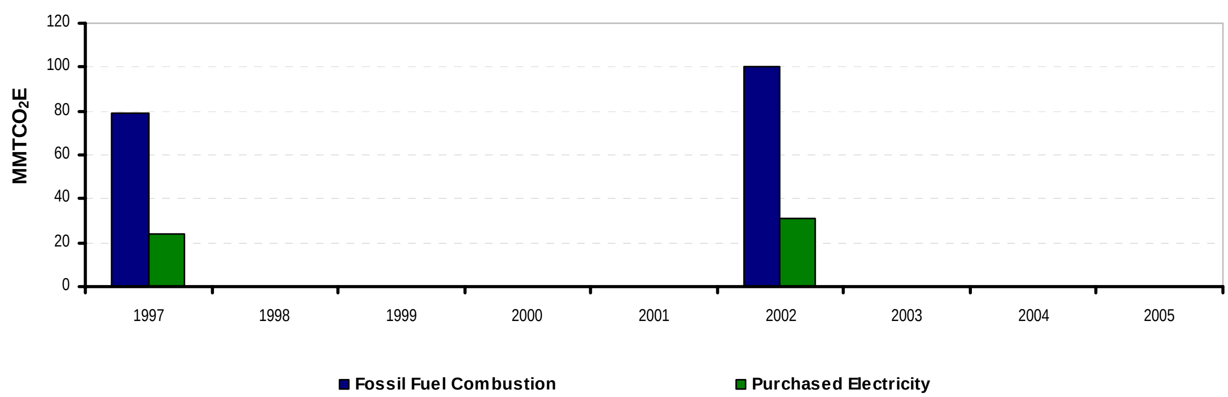
5.3 Greenhouse Gas Emissions (1997, 2002)

GHG emissions for select years from construction activities are provided in Figure 5-3.[14]

Data for GHG emissions from purchased electricity and fossil fuel combustion are available only for two data points, 1997 and 2002, based on the frequency of the U.S. Census Bureau's *Industry Series Report for Construction*.[15] During this period, emissions from fossil fuel combustion increased by approximately 26%, from 79.4 to 100.1 $MMTCO_2E$, and emissions from purchased electricity increased by approximately 31%, from 23.8 to 31.1 $MMTCO_2E$.

Total emissions increased by approximately 27% over this time period, from 103 to 131 $MMTCO_2E$. Over the same period, the value of construction put in place increased 23%.[16]

Figure 5-3: Greenhouse Gas Emissions for the Construction Sector ($MMTCO_2E$)



5.4 Other Sources of Greenhouse Gas Emission Estimates for this Sector

No reports containing complete GHG emissions estimates for the construction sector were identified.

[13] These non-CO_2 emissions typically account for a small percentage (approximately 2%) of a sector's GHG emissions from fossil fuel combustion.

[14] Note: in the following discussion, the percentages shown are calculated from the raw data. However, rounded data values are given in the text at an appropriate level of significance; therefore, the reader may not be able to reproduce the calculation.

[15] Because only one data point was available between the years 1998 and 2002, data from 1997 was included in this chapter.

[16] U.S. Census Bureau, *Construction Spending: October 2007 Construction at a Glance*, 30 Nov 2007, http://www.census.gov/const/C30index.html.

5.5 Sector Emission Reduction Commitments

No sector commitments to reducing GHG emissions were identified.

5.6 Reporting Protocols

When calculating emissions, one of the following protocols may be used by companies in the construction sector:

- EPA's *Climate Leaders Greenhouse Gas Inventory Protocol*, which is an enhanced version of the WBCSD/WRI protocol mentioned below; and
- The World Business Council for Sustainable Development (WBCSD) and the World Resource Institute's (WRI) *Greenhouse Gas Protocol*.

No public reports of GHG emissions from companies in the construction sector were identified.

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6. Food and Beverages

Source	2002 Emissions ($MMTCO_2E$)
Fossil Fuel Combustion	51
Non-Combustion	6
Purchased Electricity	49
Total	106
Percent of U.S. Industrial Emissions[1]	*5%*

The food and beverage sector represents a wide range of processes by which food products are manufactured and both alcoholic and non-alcoholic beverages are made.

For the purposes of this report, the food and beverage sector includes facilities that manufacture food products by transforming livestock or agricultural products into products for intermediate (or final) consumption by humans (NAICS code 311: Food Manufacturing); and facilities that produce non-alcoholic beverages (including water and ice), alcoholic beverages via fermentation, or distilled alcoholic beverages (NAICS code 3121: Beverage Manufacturing).[2]

6.1 Sources of Greenhouse Gas Emissions

GHG emissions from the food and beverage sector result from energy use and non-combustion activities. Food and beverage manufacturing involves energy use for heating, cooking, drying, cooling, freezing, and other common processes. Most of these energy inputs come from fossil fuel combustion and purchased electricity. The processes that consume the most energy in the sector are grain milling, fruit and vegetable processing, meat processing, and beverage production.

Non-combustion emissions from the sector include hydrofluorocarbon (HFC) emissions from refrigeration and air conditioning equipment and emissions from on-site wastewater treatment. Note that emissions from off-site (municipal) wastewater treatment were not included in this analysis.

6.2 Summary of Emissions (2002)

This section presents a summary of the GHG emission estimates for the food and beverage sector for the year 2002. The methodologies and data sources used to calculate these emission estimates, as well as the assumptions and limitations surrounding the estimates, are also described.

6.2.1 Estimates of Greenhouse Gas Emissions (2002)

GHG emissions from the food and beverage sector were estimated to be 106 $MMTCO_2E$ in 2002 (as shown in Table 6-1).

[1] Total 2002 industrial emissions are 2,047 $MMTCO_2E$ as reported in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*. See U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005,* 15 Apr 2007, http://www.epa.gov/climatechange/emissions/usinventoryreport.html, Table 2-16.

[2] The GHG emissions due to farming, food wholesaling, and retailing were considered outside of the scope of this sector.

Table 6-1: 2002 GHG Emissions from the Food and Beverages Sector ($MMTCO_2E$)

Source	CO_2	CH_4	N_2O	HFCs	Total
Fossil Fuel Combustion[a]	51				51
Non-Combustion[b]		3		3	6
On-Site Wastewater Treatment		*3*			*3*
Refrigeration				*3*	*3*
Purchased Electricity[c]	49				49
Total	100	3		3	106

[a] Emissions calculated based on DOE's *2002 Manufacturing Energy Consumption Survey* and EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005.*

[b] EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.

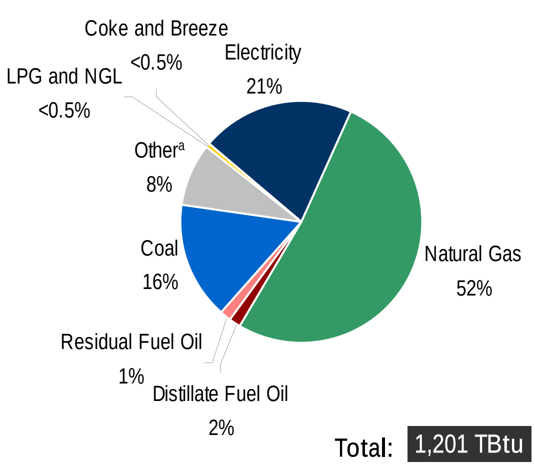
[c] Emissions calculated based on DOE's *2002 Manufacturing Energy Consumption Survey* and EPA's *Emissions and Generation Resource Integrated Database* (eGRID).

Note that for the purpose of this report, a blank cell does not necessarily indicate zero emissions; rather, it indicates that the analysis did not address that emission source, if applicable; see "Summary of Emissions (2002)" for additional information. Totals may not sum due to independent rounding.

The overall methodology for estimating GHG emissions in this report is described in Section 1.2; more detail on the methodology used to estimate emissions from the food and beverages sector can be found in Section 6.2.2.

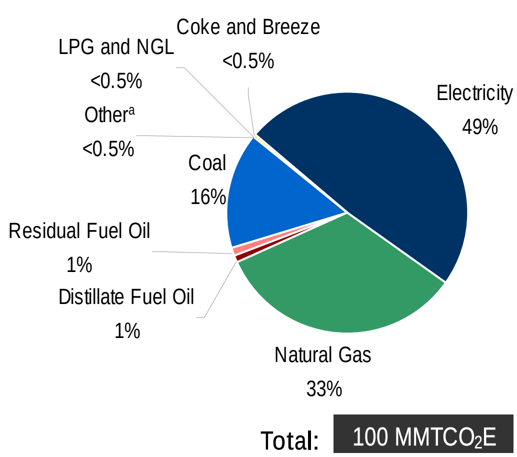
The distribution of energy consumption in this sector by fuel type (including both on-site fossil fuel combustion and purchased electricity) is illustrated in Figure 6-1. For comparison, CO_2 emissions associated with fuel consumption are shown in Figure 6-2.

Figure 6-1: 2002 Energy Consumption in the Food and Beverages Sector, by Fuel Type (TBtu)



Source: DOE, *2002 Manufacturing Energy Consumption Survey*.
[a] Composition of "other" fuel category varies among sectors.
Note: TBtu stands for trillion British thermal units.

Figure 6-2: 2002 CO_2 Emissions from Energy Consumption in the Food and Beverages Sector, by Fuel Type ($MMTCO_2E$)



Source: Estimate based on methodology in Section 6.2.2.
[a] Composition of "other" fuel category varies among sectors.
[b] Fuel mix at utilities was taken into consideration in this calculation, per methodology described in Section 6.2.2.

6.2.2 Methodology and Data Sources

Fossil Fuel Combustion

The methodology developed for this report to estimate fossil fuel combustion emissions from the food and beverages sector utilizes the U.S. Department of Energy's (DOE) Energy Information Administration's (EIA) *Manufacturing Energy Consumption Survey* (MECS)[3] estimates of fuel consumption for the sector. Fuel consumption estimates were multiplied by appropriate fuel-specific emission factors to convert the consumption into CO_2 emitted. The emission factors for the fossil fuels used in the food and beverages industry were taken from data contained in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.[4] CO_2 emissions from the "other" fuel type were taken directly from EIA's report, *Special Topic: Energy-Related Carbon Dioxide Emissions in U.S. Manufacturing*.

Non-Combustion Activities

The *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005* provides information on total emissions from ozone depleting substances substitutes (Section 4.17 of the *Inventory*, Substitution of Ozone Depleting Substances). The United States provides more detailed information in its companion dataset, the Common Reporting Format (CRF) tables, which contain information on total emissions from refrigeration and air-conditioning end-use applications. Of these applications, emissions from cold storage and industrial process refrigeration (IPR) were relevant to the food processing sector. Information on the percent of total refrigeration and air-conditioning emissions that were the result of these two end-use applications was found in the report, *Global Mitigation of Non CO_2 Greenhouse Gases*,[5] which indicated that 1 and 5 percent of total refrigeration and air-conditioning HFC emissions result from cold storage and IPR, respectively. No information was available on the amount of emissions from each of these end-use applications that was from use in the food production sector. Therefore, for this analysis it was estimated that most of the emissions (95%) from cold storage would be from food production uses, and that IPR would be more diverse, such that half (50%) could be assumed to be associated with food and beverage production in applications such as bakeries, dairy products, meat processing, and ice manufacturing.[6]

Non-combustion CH_4 emissions from onsite wastewater treatment were estimated based on production data and methodology detailed in the Wastewater Treatment source category of the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.[7] Specifically, the industrial wastewater emission estimate in the *Inventory* includes emissions from pulp and paper production and meat, poultry, fruit, and vegetable processing facilities. The activity data to calculate emissions from meat, poultry, fruit, and vegetable processing were not available in the *Inventory*; however, the activity data for pulp and paper production were. Therefore, the CH_4 emissions for pulp and paper production were calculated using the activity data, constants, and equations provided; this number was then subtracted from the total industrial wastewater CH_4 emissions number, to yield the CH_4 emissions associated with wastewater treatment from meat, poultry, fruit, and vegetable processing facilities.

Purchased Electricity

Electricity emissions were estimated by multiplying national-level electricity purchases (in kilowatt-hours, or kWh) provided by MECS,[8] by a national-level CO_2 emission factor (in lbs/kWh) provided by eGRID.[9] Sector electricity purchases were multiplied by a loss factor to reflect losses incurred in the transmission and distribution of electricity.

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[3] U.S. Department of Energy, *2002 Manufacturing Energy Consumption Survey*, Energy Information Administration, 24 Jan 2005, http://www.eia.doe.gov/emeu/mecs/mecs2002.

[4] U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.

[5] U.S. Environmental Protection Agency, *Global Mitigation of Non CO_2 Greenhouse Gases*, 2006, http://www.epa.gov/nonco2/econ-inv/international.html.

[6] The other 50% of IPR use includes the chemical, pharmaceutical, petrochemical, manufacturing, and construction industries.

[7] U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.

[8] U.S. Department of Energy, *2002 Manufacturing Energy Consumption Survey*.

[9] U.S. Environmental Protection Agency, *Emissions and Generation Resource Integrated Database (eGRID) v2.1*, 21 May 2007, http://www.epa.gov/cleanenergy/egrid/index.htm.

6.2.3 Key Assumptions and Completeness

Emissions associated with N_2O used in pressure-packaged foods and CO_2 used in carbonated beverages were assumed to occur at the point of consumption and were consequently outside of the boundary of this sector. Those emissions were, therefore, not counted in the emission estimates presented here. CO_2 emissions associated with fermentation were assumed to be biogenic in origin and, therefore, not applicable (as indicated in the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*). Electricity and fossil fuel combustion emission estimates included only CO_2. Emissions of other GHGs (e.g., CH_4 and N_2O) that may result from combustion were not estimated.[10] Emission factors for purchased electricity provided by eGRID are for 2004, which may include different fuel mixes for electricity generation than those of the 2002 inventory year.

6.3 Greenhouse Gas Emissions (1998, 2002)

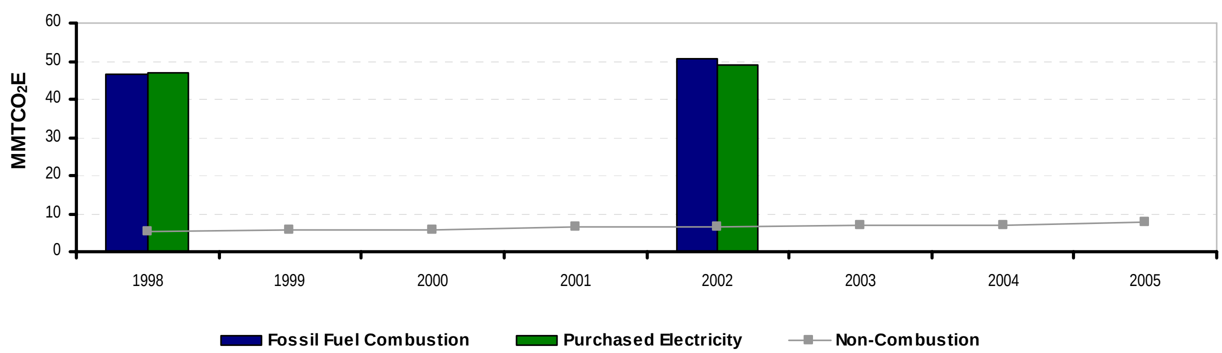
GHG emissions for select years from the food and beverage sector are provided in Figure 6-3.[11]

Data for HFC emissions from refrigeration were available for the years 1998 to 2005 from the CRF tables of the annual *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*. Data for CH_4 emissions from wastewater treatment were available for years 2000 to 2005; the datum for 2000 was then used as a proxy from 1998 to 1999 (since the wastewater emissions number remains essentially constant over the time series, no time projection was deemed necessary). These non-combustion process-related emissions have increased by approximately 38% between 1998 and 2005, from 5.3 to 7.3 MMTCO$_2$E.

Data for GHG emissions from fossil fuel combustion and purchased electricity were available only for two data points, 1998 and 2002, based on the frequency of MECS reports. Fossil fuel combustion emissions increased by 9% over this time period, while electricity emissions increased by 4 percent.

Overall, emissions from the food and beverage sector increased 8% between 1998 and 2002. Over the same period, value added[12] in the food and beverage sector increased 26%.

Figure 6-3: Greenhouse Gas Emissions from the Food and Beverages Sector (MMTCO$_2$E)



[10] These non-CO_2 emissions typically account for a small percentage (approximately 2%) of a sector's GHG emissions from fossil fuel combustion.

[11] Note: in the following discussion, the percentages shown are calculated from the raw data. However, rounded data values are given in the text at an appropriate level of significance; therefore, the reader may not be able to reproduce the calculation.

[12] Value added is a measure of the enhancement a company gives its product or service before offering the product to customers. It is used here as a surrogate for production. Value added is considered to be the best value measure available for comparing the relative economic importance of manufacturing among industries and geographic areas (source: U.S. Census Bureau, *Annual Survey of Manufactures (ASM): Statistics for Industry Groups and Industries*, 2005, http://www.census.gov/mcd/asm-as1.html). The data were normalized to account for fluctuation in industry size or production over time; dollars were adjusted for inflation using a gross domestic product price deflator.

6.4 Other Sources of Greenhouse Gas Emission Estimates for this Sector

No reports containing complete GHG emissions estimates for the food and beverages sector were identified.

6.5 Sector Emission Reduction Commitments

No sector commitments to reducing GHG emissions were identified.

6.6 Reporting Protocols

When calculating emissions, one of the following protocols is typically used by companies in the food and beverages sector:

- EPA's *Climate Leaders Greenhouse Gas Inventory Protocol*, which is an enhanced version of the WBCSD/WRI protocol mentioned below;
- DOE's *Technical Guidelines: Voluntary Reporting of Greenhouse Gases (1605(b)) Program*; and
- The World Business Council for Sustainable Development (WBCSD) and the World Resource Institute's (WRI) *Greenhouse Gas Protocol*.

Table 6-2 presents a sample of companies which have publicly reported their GHG emissions.

Table 6-2: Sampling of Publicly-Reported GHG Emissions for Food and Beverages Companies

Company	Protocol	Emissions ($MMTCO_2E^a$)	Year Reported	Geographic Scope	Goal
Molson Coors Brewing[13]	WBCSD/WRI	0.96	2006	U.S.	NI
Anheuser-Busch[14]	WBCSD/WRI	3.03	2006	Annex B[b]	5% by 2010 (2005 baseline)
General Mills[15]	WBCSD/WRI	1.02	2006	Annex B[b]	NI
Heinz[16]	EPA fuel emission factors	0.81	2006	Annex B[b]	NI
Green Mountain Coffee Roasters[17]	NI	9,823 short tons	2005	Global	Zero net emissions from 2005-2009
Kellogg Company[18]	WBCSD/WRI	1.1	2006	Global	NI
Kraft Foods[19]	WBCSD/WRI	2.67	2006	Global	NI

NI = Not Indicated
a Unless otherwise noted
b Countries included in Annex B of the Kyoto Protocol

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[13] Molson Coors Brewing Company, "CDP 5 Companies and Response Status: Carbon Disclosure Project (CDP5) Greenhouse Gas Emissions Questionnaire," 12 Nov 2007, http://www.cdproject.net/responses/Molson_Coors_Brewing_Company_Corporate_GHG_Emissions_Response_CDP5_2007/public.htm.
[14] Anheuser-Busch Companies Incorporated, "CDP 5 Companies and Response Status: Carbon Disclosure Project (CDP5) Greenhouse Gas Emissions Questionnaire," 10 Nov 2007, http://www.cdproject.net/responses/AnheuserBusch_Companies_Inc_Corporate_GHG_Emissions_Response_CDP5_2007/public.htm.
[15] General Mills Incorporated, "CDP 5 Companies and Response Status: Carbon Disclosure Project (CDP5) Greenhouse Gas Emissions Questionnaire," 10 Nov 2007, http://www.cdproject.net/responses/General_Mills_Inc_Corporate_GHG_Emissions_Response_CDP5_2007/public.htm.
[16] HJ Heinz Company, "CDP 5 Companies and Response Status: Carbon Disclosure Project (CDP5) Greenhouse Gas Emissions Questionnaire," 25 Oct 2007, http://www.cdproject.net/responses/HJ_Heinz_Company_Corporate_GHG_Emissions_Response_CDP5_2007/public.htm.
[17] Green Mountain Coffee Roasters, "Corporate Social Responsibility Report," July 2006, http://www.greenmountaincoffee.com/GMCRContent/HTMLFiles/gmcr_csr_full.pdf 97.
[18] Kellogg Company, "CDP 5 Companies and Response Status: Carbon Disclosure Project (CDP5) Greenhouse Gas Emissions Questionnaire," 10 Nov 2007, http://www.cdproject.net/responses/Kellogg_Company_Corporate_GHG_Emissions_Response_CDP5_2007/public.htm.
[19] Kraft Foods, "CDP 5 Companies and Response Status: Carbon Disclosure Project (CDP5) Greenhouse Gas Emissions Questionnaire," 10 Nov 2007, http://www.cdproject.net/responses/Kraft_Foods_Corporate_GHG_Emissions_Response_CDP5_2007/public.htm.

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7. Forest Products

Source	2002 Emissions ($MMTCO_2E$)
Fossil Fuel Combustion	62
Non-Combustion	5
Purchased Electricity	58
Total	125
Percent of U.S. Industrial Emissions[1]	*6%*

The forest products sector is defined as companies that process wood and wood fiber; manufacture pulp, paper and paperboard products from both virgin and recycled fiber; and produce engineered and traditional wood products.

For the purposes of this analysis, the forest products sector includes facilities that make wood products by sawing and shaping logs, and establishments that purchase sawed lumber to make wood products (NAICS code 321: Wood Product Manufacturing); and facilities that process and create pulp, paper, and converted paper products (NAICS code 322: Paper Manufacturing).

The wood products manufacturing subsector includes the manufacture of lumber, plywood, veneers, wood containers, wood flooring, wood trusses, mobile homes, and prefabricated wood buildings. Common processes include sawing, planning, shaping, laminating, and assembly. The paper manufacturing subsector includes manufacture of pulp, paper, and converted paper products (e.g., making paper bags from paper). The main process in pulping is separating usable cellulose fibers from other materials in wood or recycled paper. Papermaking involves matting fibers into a sheet. Converted paper products are made by cutting, shaping, coating, and laminating paper products. Photosensitive papers are excluded.

7.1 Sources of Greenhouse Gas Emissions

The forest product sector encompasses a variety of processes, including sawing, wood product fabrication, pulping, and papermaking. Fossil fuel combustion provides power and heat for these operations, both through direct burning of fossil fuels and through the consumption of purchased electricity. Fossil fuels are burned directly for heated processes in lumber processing and pulp and papermaking. Electricity is used to operate equipment. To a greater extent than other sectors, much of the electricity and process heat used by this sector comes from onsite, largely biomass-based, efficient co-generation plants.[2] To the extent that these burn biomass, the GHG emissions were not counted in our estimates, in accordance with the Intergovernmental Panel on Climate Change's (IPCC) *2006 IPCC Guidelines for National Greenhouse Gas Inventories*.[3] Approximately 52% of the energy used in the forest product sector was derived from biomass.[4] To the extent that any fossil fuels are burned, they were included in totals cited in this chapter. GHG emissions also result from the treatment of wastewater onsite at facilities in this sector.

7.2 Summary of Emissions (2002)

This section presents a summary of the emission estimates from the forest products sector for the year 2002. The methodologies and data sources used to calculate these emission estimates, as well as the assumptions and limitations surrounding the estimates, are also described.

7.2.1 Estimates of Greenhouse Gas Emissions (2002)

Total emissions from the forest product sector were estimated to be 125 $MMTCO_2E$ in 2002 (as shown in Table 7-1).

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[1] Total 2002 industrial emissions are 2,047 $MMTCO_2E$ as reported in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks:1990-2005*. See U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005,* 17 Oct 2007, http://www.epa.gov/climatechange/emissions/usinventoryreport.html, Table 2-16.

[2] National Council for Air and Stream Improvement (NCASI), *Monitoring Progress Toward the AF&PA Climate VISION Commitment*, 2007, p. 2.

[3] According to IPCC Guidelines, CO_2 released from the burning of biogenic materials, such as wood, is not counted toward anthropogenic emissions of GHGs because that CO_2 was only recently sequestered from the atmosphere into the wood.

[4] U.S. Department of Energy, *Energy Use, Loss and Opportunities Analysis: U.S. Manufacturing and Mining*, Energy Efficiency and Renewable Energy Industrial Technologies Program, Dec 2004.

Table 7-1: 2002 GHG Emissions from the Forest Product Sector (MMTCO2E)

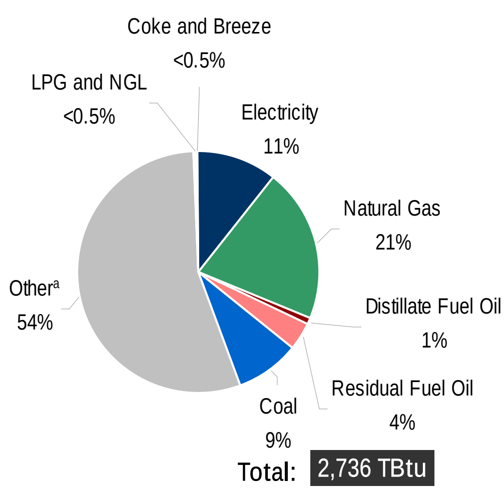
Source	CO_2	CH_4	Total
Fossil Fuel Combustion[a]	62		62
Paper	*58*		*58*
Wood Products	*4*		*4*
Non-Combustion[b]		5	5
Purchased Electricity[c]	58		58
Paper	*44*		*44*
Wood Products	*14*		*14*
Total	120	5	125

[a] Emissions calculated based on DOE's *2002 Manufacturing Energy Consumption Survey* and EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005.*
[b] EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005.*
[c] Emissions calculated based on DOE's *2002 Manufacturing Energy Consumption Survey* and EPA's *Emissions and Generation Resource Integrated Database* (eGRID).
Note that for the purpose of this report, a blank cell does not necessarily indicate zero emissions; rather, it indicates that the analysis did not address that emission source, if applicable; see "Summary of Emissions (2002)" for additional information.

The overall methodology for estimating GHG emissions in this report is described in Section 1.2; more detail on the methodology used to estimate emissions from the forest products sector can be found in Section 7.2.2.

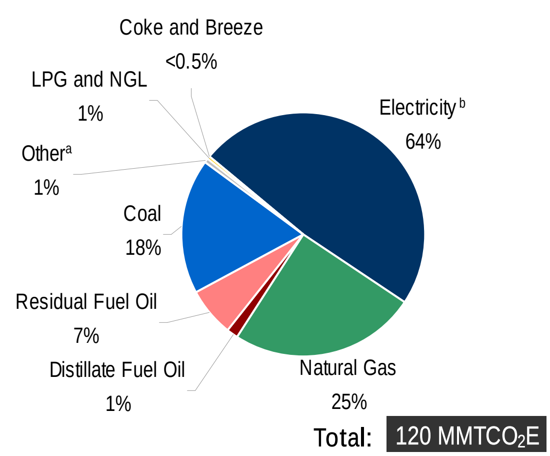
The distribution of energy consumption in this sector by fuel type (including both on-site fossil fuel combustion and purchased electricity) is illustrated in Figure 7-1. For comparison, CO_2 emissions associated with fuel consumption are shown in Figure 7-2.

Figure 7-1: 2002 Energy Consumption in the Forest Products Sector, by Fuel Type (TBtu)



Source: DOE, *2002 Manufacturing Energy Consumption Survey*.
[a] Composition of "other" fuel category varies among sectors. In the forest products sector, "other" fuels include primarily black liquor and other biomass.
Note: TBtu stands for trillion British thermal units.

Figure 7-2: 2002 CO_2 Emissions from Energy Consumption in the Forest Products Sector, by Fuel Type (MMTCO2E)



Source: Estimate based on methodology in Section 7.2.2.
[a] Note that biomass-related emissions are not included in the estimates for "other" fuel types.
[b] Fuel mix at utilities was taken into consideration in this calculation, per methodology described in Section 7.2.2.

Note that the emission estimates presented in this report do not account for emissions or benefits (e.g., carbon sequestration) associated with the raw materials used by this industry or products produced by this industry. The analysis presented in this report addresses emissions related to the production processes and does not address lifecycle emissions or sequestration from the use or disposal of forest products. Consequently, the analysis does not evaluate the environmental benefits of the produced materials. For further discussion of sequestration, see Section 7.2.3.

7.2.2 Methodology and Data Sources

Fossil Fuel Combustion

The methodology developed for this report to estimate fossil fuel combustion emissions from the forest products sector utilizes the U.S. Department of Energy's (DOE) Energy Information Administration's (EIA) Manufacturing Energy Consumption Survey (MECS) [5] estimates of fuel consumption for the sector. Fuel consumption estimates were multiplied by appropriate fuel-specific emission factors to convert the consumption into CO_2 emitted. The emission factors for the fossil fuels used in the forest products industry were derived from data contained in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005.*[6] CO_2 emissions from the "other" fuel type were taken directly from EIA's report, *Special Topic: Energy-Related Carbon Dioxide Emissions in U.S. Manufacturing.*

Non-Combustion Activities

Non-combustion CH_4 emissions from onsite wastewater treatment were estimated based on production data for this sector and methodology detailed in the Wastewater Treatment source category of the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005.*[6] Specifically, the CH_4 emissions for pulp and paper production were calculated using the emission calculation equation, pulp and paper production data, wastewater generation rate, chemical oxygen demand, CH_4 production potential, correction factor, and wastewater treatment rate, all of which are provided in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.

Purchased Electricity

Electricity emissions were estimated by mapping national electricity purchases (in kilowatt-hours, or kWh) provided by MECS to North American Electricity Reliability Corporation (NERC) regions,[7] then applying NERC regional utility CO_2 emission factor (in lbs/kWh) provided by eGRID. Sector electricity purchases were adjusted by a loss factor to reflect losses incurred in the transmission and distribution of electricity.

Since electricity purchase data were not available at the NERC regional level, distribution of the sector's value added was used to distribute the sector's national electricity purchases to the state-level, then state data were rolled up to the NERC regions. Where a state lay in two or more NERC regions, electricity purchases were distributed to the appropriate NERC region using sales data for the industrial customer class from EIA Report 861. This approach assumes that the electricity-intensity of production activities are correlated with the value added. Methods for estimating CO_2 emissions from electricity are described in more detail in Appendix A.3.

7.2.3 Key Assumptions and Completeness

Electricity and fossil fuel combustion emission estimates include only CO_2. Emissions of other GHGs such as CH_4 and N_2O that may result from combustion were not estimated due to data and methodological constraints.[8] Emission factors for purchased electricity provided by eGRID are for 2004, which may include different fuel mixes for electricity generation than those of the 2002 inventory year. In addition, CO_2 emissions

[5] U.S. Department of Energy, *2002 Manufacturing Energy Consumption Survey*, Energy Information Administration, 24 Jan 2005, http://www.eia.doe.gov/emeu/mecs/mecs2002.

[6] U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005.*

[7] The North American Electricity Reliability Corporation (NERC) is the designated reliability organization that has a role in overseeing the reliability of the electric power grid. NERC regions reflect the organization structure of the regional reliability entities within with the owners of generation operate.

[8] These non-CO_2 emissions account for less than 2% of GHG emissions from fossil fuel combustion.

from make-up carbonates during pulp and paper manufacturing and CO_2 emissions from wood byproduct (biomass) combustion were not included. These sources were excluded because the associated emissions were biogenic in origin; in accordance with *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, emissions of CO_2 from biogenic sources were not counted as contributing to emissions.

Emission estimates presented here do not include emissions from logging or transportation of logs, nor do they include carbon sequestration by forests, as these processes were considered outside the boundary of the sector as it is defined in this report.

Annual change (net flux) in carbon stocks within forests, in harvested wood products, and in landfilled wood and paper have been calculated in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005* and *Monitoring Progress Toward the AF&PA Climate VISION Commitment* (published by the National Council for Air and Stream Improvement [NCASI][9]), but there remain significant obstacles to allocating net flux estimates to the forest product sector. In short, three issues remain unclear:

1. The origin of the carbon. Whether carbon from forests grown on land not owned by the forest product sector should be attributed to the forest product sector was unclear.
2. The fate of the carbon. Similarly, it was not clear whether the accumulation of carbon in the harvested wood products pool (in the form of ever-increasing amounts of furniture or structural lumber) or the accumulation of un-degraded carbon in landfills (from disposal of wood and paper) should be attributed to the forest product sector. From a life cycle perspective, the farther from the industrial activity (harvest/ milling), the more tenuous the case for attributing carbon accumulation to the forest product sector.
3. The location of the carbon. There were enormous cross-boundary flows of inputs, products, and recyclables. Estimates developed by the U.S. Department of Agriculture, Forest Service (USDA-FS) account for carbon in exported wood and paper as if it remained in the United States, and carbon in imported wood was not counted.

For these reasons, carbon sequestration from the forest products sector was not included in emission totals. However, sequestration in harvested wood products was estimated by NCASI at 28.2 $MMTCO_2E$ in 2002.[10] For comparison purposes, the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005* reported an estimate of 34.1 $MMTCO_2E$ sequestered in harvested wood products in use in 2002.

7.3 Greenhouse Gas Emissions (1998, 2002)

GHG emissions for select years from the forest product sector are provided in Figure 7-3.

Data for CH_4 emissions from wastewater treatment were available for years 2000 to 2005; the datum for 2000 was then used as a proxy from 1998 to 1999 (since the wastewater emission estimate remains essentially constant over the time series, no time projection was deemed necessary). These non-combustion process-related emissions have fluctuated over the time series, but overall have decreased by approximately 8% between in 2000 and 2005.

Data for GHG emissions from fossil fuel combustion and purchased electricity were available only for two data points, 1998 and 2002, based on the frequency of MECS reports. Fossil fuel combustion emissions decreased 15% over this time period, while electricity emissions decreased by 6%.

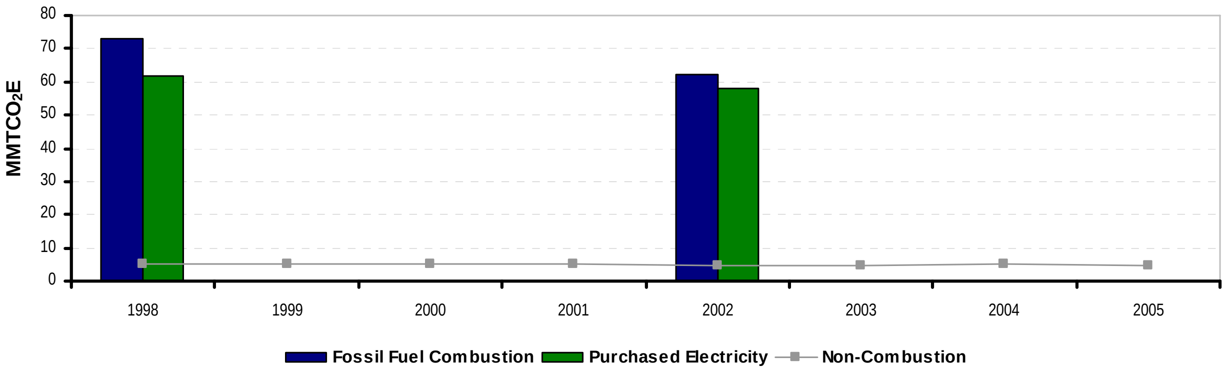
Overall, emissions from the forest products sector decreased 11 % between 1998 and 2002. Over the same period, value added[11] in the forest products sector decreased 3%.

[9] NCASI, *Monitoring Progress Toward the AF&PA Climate VISION Commitment*, p. 5.

[10] NCASI, *Monitoring Progress Toward the AF&PA Climate VISION Commitment*, p. 5.

[11] Value added is a measure of the enhancement a company gives its product or service before offering the product to customers. It is used here as a surrogate for production. Value added is considered to be the best value measure available for comparing the relative economic importance of manufacturing among industries and geographic areas (source: U.S. Census Bureau, *Annual Survey of Manufactures (ASM): Statistics for Industry Groups and Industries*, 2005,

Figure 7-3: Greenhouse Gas Emissions from the Forest Products Sector (MMTCO2E)



7.4 Other Sources of Greenhouse Gas Emission Estimates for this Sector

An alternate source of emission estimates for fossil fuel combustion and purchased electricity was the report *Monitoring Progress Toward the AF&PA Climate VISION Commitment*,[12] produced by NCASI based on a survey of American Forest and Paper Association (AF&PA) members. AF&PA members account for over 75% of the paper, wood, and forest products produced in the United States.

- Fossil fuel combustion estimates from this report were based on fuel use data collected by the AF&PA from their members. NCASI used emission factors from the World Resources Institute/World Business Council for Sustainable Development (WRI/WBCSD) *Greenhouse Gas Protocol* when calculating estimates for this report.
- Emission estimates from purchased electricity consumption were based on energy use data collected by the AF&PA from their member companies. NCASI used a national electricity emission factor to calculate emissions based on purchased electricity consumption data collected in the biannual AF&PA fuel and energy survey. The purchased electricity data collected in the survey were adjusted upward by NCASI to account for the fact that not all AF&PA members reported purchased electricity consumption. The emission factor represents a three-year weighted average of U.S. utilities and was taken from DOE's *Updated State-Level Greenhouse Gas Emission Coefficients for Electricity Generation 1998-2000* report.[13]

The two methods (MECS and NCASI) result in similar fossil fuel emissions, as shown in Table 7-1 and Table 7-2, respectively; however, electricity emissions estimated by NCASI are lower than those estimated with the MECS data. One explanation may be that AF&PA accounts for only about 75% of the industry, and that survey data were incomplete and had to be extrapolated based on completed surveys.

http://www.census.gov/mcd/asm-as1.html). The data were normalized to account for fluctuation in industry size or production over time; dollars were adjusted for inflation using a gross domestic product price deflator.

[12] NCASI, *Monitoring Progress Toward the AF&PA Climate VISION Commitment*, p. 2.

[13] U.S. Department of Energy, *Updated State-Level Greenhouse Gas Emission Coefficients for Electricity Generation 1998-2000*, Energy Information Administration, 2002, http://tonto.eia.doe.gov/FTPROOT/environment/e-supdoc-u.pdf.

Table 7-2: Emissions from the National Council for Air & Stream Improvement's Monitoring Progress Toward the AF&PA Climate VISION Commitment ($MMTCO_2E$)

Source	CO_2	Total
Fossil Fuel Combustion[a]	54	54
Pulp and Paper	*53*	*53*
Wood Products	*1*	*1*
Purchased Electricity[a]	28	28
Pulp and Paper	*22*	*22*
Wood Products	*5*	*5*
Total	81	81

[a] Fossil fuel and purchased electricity emissions taken directly from NCASI, p. 5.
Note: totals may not sum due to independent rounding.

7.5 Sector Emission Reduction Commitments

AF&PA has an initiative to reduce GHG intensity by 12% by 2012 relative to a 2000 baseline.[14] The industry is using a combination of WBCSD/WRI and NCASI protocols. To calculate emissions, industries use two tools, one for pulp and paper mills, and the other for wood product facilities. There is also a sequestration tool provided by NCASI for companies requesting to inventory their stored carbon quantities.

7.6 Reporting Protocols

When calculating emissions, one of the following protocols is typically used by companies in the forest products sector:

- EPA's *Climate Leaders Greenhouse Gas Inventory Protocol*, which is an enhanced version of the WBCSD/WRI protocol mentioned below, has a special protocol for pulp and paper mills known as the *Draft Assessment of Calculation Tools for Estimating Greenhouse Gas Emissions from Pulp and Paper Mills: v 1.1 for Use in Climate Leaders Reporting*.[15] The mills are to use international factors for stationary combustion and purchased electricity. Mills are to use emissions factors for Kraft Mill Lime Kilns and Calciners, detailed CH_4 and N_2O factors for biomass combustion and methodologies to calculate emissions from anaerobic treatment of sludge and use of carbonate-based make-up chemicals;
- DOE's *Technical Guidelines: Voluntary Reporting of Greenhouse Gases (1605(b)) Program*;
- The previously-mentioned WBCSD and WRI *Greenhouse Gas Protocol* and NCASI protocol; and
- The California Climate Action Registry, which has added a protocol for the forest products industry in order to account for forest carbon stocks as well as biological emissions.[16]

Table 7-3 presents a sample of companies that have publicly reported their GHG emissions.

[14] See http://www.climatevision.gov/sectors/forest/index.html.
[15] See http://www.epa.gov/stateply/docs/CLReview_of_PulpnPaper_Sector_Protocol.pdf.
[16] See http://www.climateregistry.org/PROTOCOLS/FP/.

Table 7-3: Sampling of Publicly-Reported GHG Emissions for Forest Products Companies

Company	Protocol	Emissions ($MMTCO_2E$)	Year Reported	Geographic Scope	Goal
Kimberly Clark[17]	WBCSD/WRI	3.8	2006	U.S.	NI
International Paper[18]	WBCSD/WRI	11.7	2006	U.S.	15% by 2010 (2000 baseline)
Mead Westvaco[19]	WBCSD/WRI	3.4	2006	Annex B[a]	6% by 2010 (average of 1998-2000 baseline)
Boise Cascade[20]	NI	3.1	2006	U.S. and Canada	10% by 2014 (2004 baseline)
StoraEnso[21]	NI	12.0	2006	Global	NI
Weyerhaeuser[22]	WBCSD/WRI	10.7	2006	Global	40% by 2020 (2000 baseline)

NI = Not Indicated
[a] Countries included in Annex B of the Kyoto Protocol

[17] Kimberly-Clark Corporation, "CDP 5 Companies and Response Status: Carbon Disclosure Project (CDP5) Greenhouse Gas Emissions Questionnaire," 23 Oct 2007, http://www.cdproject.net/responses/KimberlyClark_Corporation_Corporate_GHG_Emissions_Response_CDP5_2007/public.htm.
[18] International Paper Company, "CDP 5 Companies and Response Status: Carbon Disclosure Project (CDP5) Greenhouse Gas Emissions Questionnaire," 23 Oct 2007, http://www.cdproject.net/responses/International_Paper_Company_Corporate_GHG_Emissions_Response_CDP5_2007/public.htm.
[19] MeadWestVaco, "CDP 5 Companies and Response Status: Carbon Disclosure Project (CDP5) Greenhouse Gas Emissions Questionnaire," 23 Oct 2007, http://www.cdproject.net/responses/MeadWestVaco_Corporate_GHG_Emissions_Response_CDP5_2007/public.htm.
[20] U.S. Environmental Protection Agency, "Partner Profile: Boise Cascade," Climate Leaders, 12 Nov 2007, http://www.epa.gov/stateply/partners/partners/boisecascade.html.
[21] Stora Enso, "Annual Report 2006 – Sustainability Booklet," March 2007, http://www.storaenso.com/CDAvgn/main/0,,1_EN-1861-1059-,00.html 23.
[22] Weyerhaeuser Company, "2006 Sustainability Performance Report," Global Reporting Initiative, June 2007, http://www.corporateregister.com/search/report.cgi?num=18895-IxSMdtpMFO2 12.

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8. Iron and Steel

Iron and steel are durable, strong metals used for many purposes including as building and bridge skeletons and supports, vehicle bodies, and as parts of appliances, tools, and heavy equipment. The iron and steel sector consists of establishments that produce pig iron from iron ore, produce metallurgical coke from coking coal, and produce steel through the use of one of two primary technologies— from iron in basic oxygen furnaces (BOFs) and from recycled steel in electric arc furnaces (EAFs). In 2002, 51% of raw steel production stemmed from EAFs with the remainder produced by BOFs at integrated steel mills.[2]

Source	2002 Emissions ($MMTCO_2E$)
Fossil Fuel Combustion	22
Non-Combustion	56
Purchased Electricity	37
Total	**115**
Percent of U.S. Industrial Emissions[1]	*6%*

In an integrated steel mill, a blast furnace produces molten iron from iron ore, coal, coke, and fluxing agents (e.g., limestone, dolomite). A BOF is then used to convert the molten iron, along with scrap steel and alloying metals, into steel and steel alloys. EAFs use scrap steel and other iron-bearing materials to produce carbon, alloy, and specialty steels. While both processes are energy intensive, their emission profiles differ due to differences in energy consumption. Integrated steel mills have more on-site fossil fuel consumption and use more raw materials than EAF mills, which primarily consume electricity. For the purposes of this report, emissions from the production and use of metallurgical coke at integrated steel mills are classified as non-combustion (process) emissions, rather than as emissions from energy use.

Though the energy intensity of steel production in the U.S. has been steadily declining, the production of iron and steel remains an energy intensive process.

8.1 Sources of Greenhouse Gas Emissions

GHG emissions in the iron and steel sector result from on-site fossil fuel combustion, generation of purchased electricity, and non-combustion activities (i.e., industrial processes). On-site use of fossil fuels for energy purposes largely occurs at integrated steel mills to supply energy to the blast furnace, process heaters, and generate electricity through cogeneration,[3] while purchased electricity consumption largely occurs at EAFs to melt the scrap steel and other iron-bearing materials.[4]

Emissions associated with the industrial process of producing iron and steel stem from a variety of sources, which can be broadly categorized into the production of metallurgical coke from coking coal,[5] pig iron production, and steel making (GHGs emitted by each process are provided in parentheses):

- Metallurgical Coke Production (CO_2, CH_4): To produce metallurgical coke, coking coal is heated in a low-oxygen, high temperature environment within a coke oven. This process can occur on-site at integrated steel mills or off-site at merchant coke plants.[6] At an integrated steel mill, the metallurgical coke produced is used in the blast furnace charge during iron production. Some carbon contained in the coking coal is released during this process as CO_2 and CH_4 emissions. Coke-oven gas, which is produced as a by-product of metallurgical coke production, is often used for energy purposes within the integrated steel mill.

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[1] Total 2002 industrial emissions are 2,047 $MMTCO_2E$ as reported in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks:1990-2005*. See U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005,* 15 Apr 2007, http://www.epa.gov/climatechange/emissions/usinventoryreport.html, Table 2-16.

[2] American Iron and Steel Institute (AISI), *2005 Annual Statistical Report*, 2006, Washington, D.C., pp. 9.

[3] AISI, "How a Blast Furnace Works."

[4] AISI, "Electric Arc Furnace Steelmaking."

[5] The non-combustion emission estimate is based on the industrial process emission estimate provided by the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*, which accounts for both the carbon emissions from the use of metallurgical coke as a reducing in the blast furnace and the carbon stored in raw steel produced. For the purposes of this report, emissions from the production and use of metallurgical coke are classified as non-combustion emissions.

[6] According to the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*—upon which non-combustion GHG emissions for this report are based—GHG emissions from all coking coal used to produce metallurgical coke are attributed to the iron and steel sector. However, it should be noted that this includes emissions from coke ovens that are not located on iron and steel facilities, the coke from which is predominantly used by steel mills.

- Sintering (CO_2): At integrated steel mills, CO_2 emissions also result from sintering, a process used to convert iron-bearing materials into a higher-grade ore (or sinter) for use as a raw material in the blast furnace.
- Pig Iron Production (CO_2, CH_4): At integrated steel mills, metallurgical coke is used as a reducing agent in the blast furnace to chemically reduce iron ore to pig iron, which is used as a raw material in the production of steel. The carbon contained in the metallurgical coke also provides heat to the blast furnace, and produces CO_2 through both the heating and reduction process. For the purposes of this report, emissions from the production and use of metallurgical coke are classified as non-combustion (process) emissions, rather than as emissions from energy use.
- Steelmaking (CO_2): At an integrated steel mill, molten iron produced by a blast furnace enters a BOF where the iron is combined with high-purity oxygen to oxidize the carbon and reduce the carbon content of the metal—producing steel. Carbon contained in both the scrap steel and molten iron is released as CO_2. In EAFs, CO_2 emissions occur from the use of carbon anodes that produce the electric arc used in the melting of scrap steel.[7] EAFs also use injected carbon in the form of coal and other raw materials. Both integrated mills and EAFs use natural gas for reheat furnaces and other processes. CO_2 emissions also result from the use of limestone and other carbonate raw materials as fluxing agents.

8.2 Summary of Emissions (2002)

This section presents a summary of emission estimates from the iron and steel sector. It includes a discussion of methodologies and data sources used to estimate emissions, as well as the assumptions and limitations surrounding the estimates.

8.2.1 Estimates of Greenhouse Gas Emissions (2002)

As shown in Table 8-1, total 2002 GHG emissions from the iron and steel sector were 115 $MMTCO_2E$. More than half of the sector's GHG emissions were from non-combustion (process) emissions, rather than from energy use.

Table 8-1: 2002 GHG Emissions from the Iron and Steel Sector ($MMTCO_2E$)

Source	CO_2	CH_4	Total
Fossil Fuel Combustion[a]	22		22
Non-Combustion[b]	55	1	56
Purchased Electricity[c]	37		37
Total	114	1	115

[a] Emissions calculated based on AISI's *2005 Annual Statistical Report* and EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005.*

[b] EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005,* pp. 4-6.

[c] Emissions calculated based on DOE's *2002 Manufacturing Energy Consumption Survey* and EPA's *Emissions and Generation Resource Integrated Database* (eGRID).

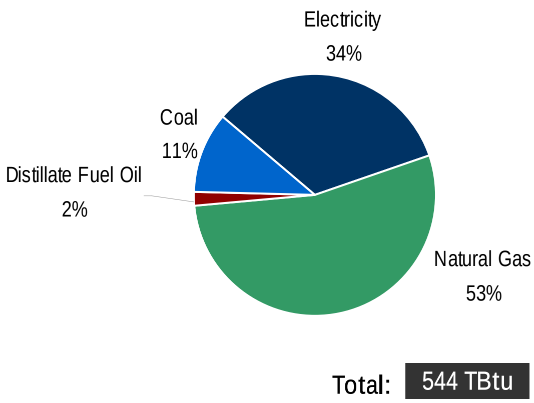
Note that for the purpose of this report, a blank cell does not necessarily indicate zero emissions; rather, it indicates that the analysis did not address that emission source, if applicable; see "Summary of Emissions (2002)" for additional information.

The overall methodology for estimating GHG emissions in this report is described in Section 1.2; more detail on the methodology used to estimate emissions from the iron and steel sector can be found in Section 8.2.2.

The distribution of energy consumption in this sector, by fuel type (including both on-site fossil fuel combustion and purchased electricity), is illustrated in Figure 8-1. For comparison, CO_2 emissions associated with fuel consumption are shown in Figure 8-2.

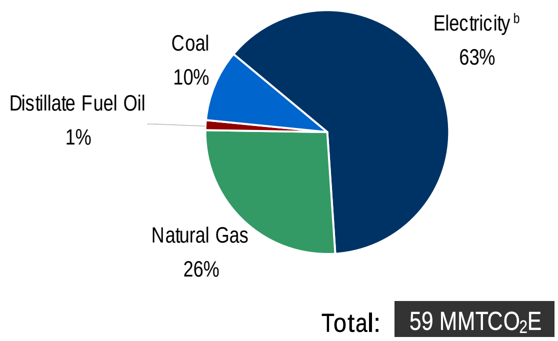
[7] U.S .Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks,* pp. 4-6.

Figure 8-1: 2002 Energy Consumption in the Iron and Steel Sector, by Fuel Type (TBtu)[a]



Source: Fossil Fuel Combustion, AISI, *2005 Annual Statistical Report*; Electricity, DOE, *2002 Manufacturing Energy Consumption Survey*.
[a] Excludes metallurgical coke, blast furnace, and coke oven gas used for energy purposes. See Section 8.2.3 for further details.
Note: TBtu stands for trillion British thermal units.

Figure 8-2: 2002 CO_2 Emissions from Energy Consumption in the Iron and Steel Sector, by Fuel Type ($MMTCO_2E$)[a]



Source: Estimate based on methodology in Section 8.2.2.
[a] Excludes metallurgical coke, blast furnace, and coke oven gas used for energy purposes. See Section 8.2.3 for further details.
[b] Fuel mix at utilities was taken into consideration in this calculation, per methodology described in Section 8.2.2.

8.2.2 Methodology and Data Sources

Fossil Fuel Combustion

CO_2 emissions due to fossil fuel consumption for iron and steel manufacturing were based on on-site fuel consumption data from the American Iron and Steel Institute's (AISI) *2005 Annual Statistical Report*.[8] These fuel consumption estimates were multiplied by the appropriate, fuel-specific emission factors to convert the consumption into CO_2 emitted. The emission factors were taken from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.[9]

Non-Combustion Activities

Non-combustion CO_2 and CH_4 emission estimates for iron and steel manufacturing were obtained directly from the iron and steel production source category of the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*. CO_2 emission estimates from the consumption of fluxes (e.g., limestone, dolomite), which are not included in the iron and steel chapter of the *Inventory of U.S. Greenhouse Gas Emissions Inventory and Sinks: 1990-2005,* were estimated based on consumption data from AISI's *2005 Annual Statistical Report* and emission factors presented by the Intergovernmental Panel on Climate Change's (IPCC) *2006 IPCC Guidelines for National Greenhouse Gas Inventories*.[10]

[8] AISI , *2005 Annual Statistical Report*, Table 37.
[9] U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.
[10] Intergovernmental Panel on Climate Change, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, 2007, http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.htm, Table 4.3.

Purchased Electricity

Electricity emissions were estimated by multiplying national-level electricity purchases (in kilowatt-hours, or kWh) provided by MECS[11] by CO_2 emission factors (in lbs/kWh) provided by eGRID[12] at the North American Electricity Reliability Corporation (NERC) region level.[13] NERC regional electricity purchases were developed based on estimates of facility-level electricity consumption. Facility level electricity purchases were estimated for each facility based on the facility's furnace type (EAF or BOF) and the furnace's electricity intensity per ton of raw steel produced. Purchase estimates were scaled to match national level purchase estimates. Electricity purchases were adjusted by a loss factor to reflect losses incurred in the transmission and distribution of electricity. Methods for estimating CO_2 emissions from electricity are detailed in Appendix A.3.

8.2.3 Key Assumptions and Completeness

The non-combustion emission estimate, taken directly from the industrial process emission estimate presented by the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*, includes emissions associated with producing metallurgical coke from coking coal and consuming metallurgical coke during the production of pig iron. Because metallurgical coke is used both as a reducing agent and to produce heat, the resultant emissions are both process and energy based. Both emission types (process and energy) are included in the non-combustion emission estimate because, in accordance with the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*,[14] the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* does not make this distinction. This estimate also includes emissions associated with metallurgical coke production in coke ovens that are not located in iron and steel mills. Some consumption of the metallurgical coke occurs during metal casting processes; however, data are unavailable to disaggregate emissions associated with this consumption from those presented for iron and steel.

Blast furnace gas and coke oven gas consumption are not included in the on-site fossil fuel combustion emission estimate, because the carbon contained in these gases stems from carbon contained in coking coal and metallurgical coke that, based on the methodologies described in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005,* has already been accounted for in the non-combustion emission estimates.

Electricity and fossil fuel combustion emission estimates include only CO_2. Energy consumption data are taken from AISI's *Annual Statistical Report* with the exception of purchased electricity data, which is taken from MECS. Purchased electricity data are taken from MECS, because AISI data likely underestimates electricity consumed by EAFs during the 2002 inventory year due to limitations in data collection. Emission factors for purchased electricity provided by eGRID are for 2004, which may include different fuel mixes for electricity generation than those of the 2002 inventory year. Emissions of other GHGs that may result from combustion, such as CH_4 and N_2O, were not estimated.[15]

8.3 Greenhouse Gas Emissions (1998, 2002)

GHG emissions for select years from the iron and steel sector are provided in Figure 8-3.[16]

Data for GHG emissions from non-combustion and on-site fossil fuel combustion in the iron and steel sector are available from 1998 through 2005, while purchased electricity estimates are available only for 1998 and 2002 using the data sources and methodologies described above. From 1998 to 2005, emissions from fossil fuel

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[11] U.S. Department of Energy, *2002 Manufacturing Energy Consumption Survey*, Energy Information Administration, 24 Jan 2005, http://www.eia.doe.gov/emeu/mecs/mecs2002.

[12] U.S. Environmental Protection Agency, *Emissions and Generation Resource Integrated Database (eGRID) v2.1*, 21 May 2007, http://www.epa.gov/cleanenergy/egrid/index.htm.

[13] The National Reliability Electricity Corporation (NERC) is the designated reliability organization that has a role in overseeing the reliability of the electric power grid. NERC regions reflect the organization structure of the regional reliability entities within with the owners of generation operate.

[14] Intergovernmental Panel on Climate Change, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*.

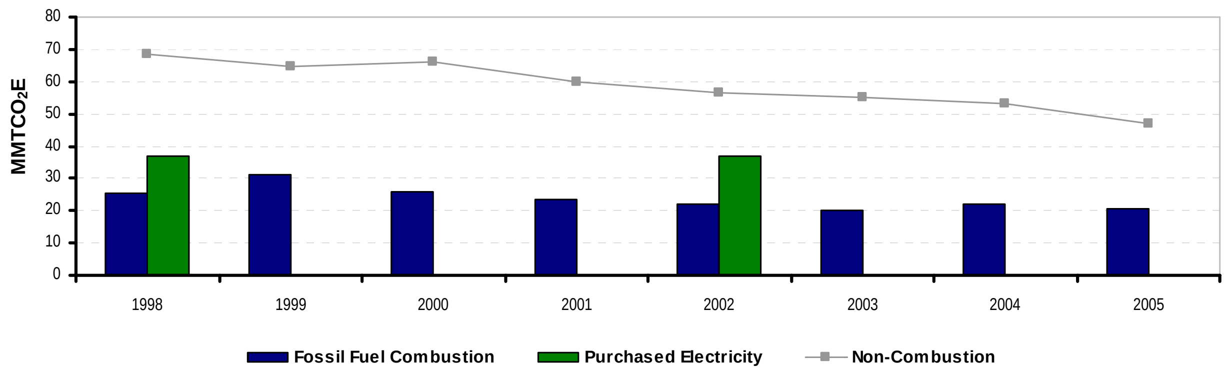
[15] These non-CO_2 emissions typically account for a small percentage (approximately 2%) of a sector's GHG emissions from fossil fuel combustion.

[16] Note: in the following discussion, the percentages shown are calculated from the raw data. However, rounded data values are given in the text at an appropriate level of significance; therefore, the reader may not be able to reproduce the calculation.

combustion decreased 20%, and non-combustion emissions decreased by 32%. From 1998 to 2002, emissions from purchased electricity increased by 1%.

Overall, from 1998 to 2002, emissions decreased by approximately 12%, from 131 to 115 $MMTCO_2E$. Raw steel production, from both integrated steel mills and EAFs, increased by 4% over the same time period.[17]

Figure 8-3: Greenhouse Gas Emissions for the Iron and Steel Sector



8.4 Other Sources of Greenhouse Gas Emission Estimates for this Sector

No reports containing complete GHG emissions estimates for the iron and steel sector were identified.

8.5 Sector Emission Reduction Commitments

AISI has committed to a goal of achieving by 2012 a 10% increase in sector-wide average energy efficiency using a 1998 baseline of 18.1 million Btu (MMBtu) per ton of steel produced.[18]

8.6 Reporting Protocols

When calculating emissions, one of the following protocols is typically used by companies in the iron and steel sector:

- EPA's *Climate Leaders Greenhouse Gas Inventory Protocol*, which is an enhanced version of the WBCSD/WRI protocol mentioned below, provides sector specific guidance, *Direct Emissions from Iron & Steel Production,* for the iron and steel industry through support for calculating coke, coke oven gas, blast furnace gas, EAF, and carbon-bearing product emissions;[19]
- DOE's *Technical Guidelines: Voluntary Reporting of Greenhouse Gases (1605(b)) Program;*
- The World Business Council for Sustainable Development (WBCSD) and the World Resource Institute's (WRI) *Greenhouse Gas Protocol*; and

[17] AISI, *2005 Annual Statistical Report*, Table 23.
[18] See http://www.climatevision.gov/sectors/steel/index.html.
[19] See http://www.epa.gov/stateply/docs/ironsteel.pdf.

The International Iron and Steel Institute (IISI), which has established an emissions calculation protocol and is establishing a common system of CO_2 emission accounting and reporting to collect data on a site-wide, rather than company-wide, basis. The system will include both direct and indirect emissions and will have a standard set of boundaries that will be common among all sites.[20]

Table 8-2 presents a sample of companies that have publicly reported their GHG emissions.

Table 8-2: Sampling of Publicly-Reported GHG Emissions for Iron and Steel Companies

Company	Protocol	Emissions ($MMTCO_2E$)	Year Reported	Geographic Scope	Goal
Gerdau Ameristeel Corporation[21]	IISI	0.8	2006	U.S.	NI

NI = Not Indicated

[20] International Iron and Steel Institute, *Fact Sheets on Climate Change*, 2007.

[21] Gerdau Ameristeel, "CDP 5 Companies and Response Status: Carbon Disclosure Project (CDP5) Greenhouse Gas Emissions Questionnaire," 10 Nov 2007.

9. Lime

Lime is a manufactured product with major applications in steel production, flue gas desulphurization systems at coal-fired power plants, construction, and water purification.

Source	2002 Emissions ($MMTCO_2E$)
Fossil Fuel Combustion	9
Non-Combustion	12
Purchased Electricity	1
Total	23
Percent of U.S. Industrial Emissions[1]	*1%*

In 2006, lime was used for the following purposes: metallurgical uses (36%), environmental uses (29%), chemical and industrial uses (21%), construction uses (13%), and to make dolomite refractories (1%).[2] In terms of manufacturing distribution throughout the U.S., 35 states (and Puerto Rico) produce lime.[2]

In U.S. operations, the term "lime" in lime manufacturing (NAICS code 327410: Lime Manufacturing), refers to several chemical compounds. These compounds include high-calcium quicklime (calcium oxide, CaO), hydrated lime (calcium hydroxide, $Ca(OH)_2$), dolomitic quicklime ($CaO{\cdot}MgO$), and dolomitic hydrate ($[CA(OH)_2{\cdot}MgO]$ or $[Ca(OH)_2{\cdot}Mg(OH)_2]$).

9.1 Sources of Greenhouse Gas Emissions

GHG emissions in the lime sector result from non-combustion activities (i.e., industrial processes), on-site fossil fuel combustion, and generation of purchased electricity.

As described in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*,[3] lime manufacture results in non-combustion CO_2 emissions. There are three main processes in lime production: stone preparation, calcination, and hydration. CO_2 is emitted during the calcination stage, in which limestone – mostly calcium carbonate ($CaCO_3$) – is roasted in a kiln at high temperatures to produce CaO and CO_2.

The manufacturing of lime requires energy to operate manufacturing equipment and maintain high kiln temperatures. This energy use results in direct emissions of CO_2 from fossil fuel combustion and indirect CO_2 emissions from purchased electricity.

9.2 Summary of Emissions (2002)

This section presents a summary of the GHG emission estimates for the lime sector as estimated for the year 2002. The methodologies and data sources used to calculate these emission estimates, as well as the assumptions and limitations surrounding the estimates, are also described.

9.2.1 Estimates of Greenhouse Gas Emissions (2002)

The total GHG emissions from the lime sector are estimated to be 23 $MMTCO_2E$ in 2002 (as seen in Table 9-1).

[1] Total 2002 industrial emissions are 2,047 $MMTCO_2E$ as reported in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*. See U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005,* 15 Apr 2007, http://www.epa.gov/climatechange/emissions/usinventoryreport.html, Table 2-16.

[2] U.S. Geological Survey, *Minerals Yearbook: Lime Annual Report 2005,* 2006, http://minerals.usgs.gov/minerals/pubs/commodity/lime/lime_myb05.pdf.

[3] U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005.*

Table 9-1: 2002 GHG Emissions from the Lime Sector ($MMTCO_2E$)

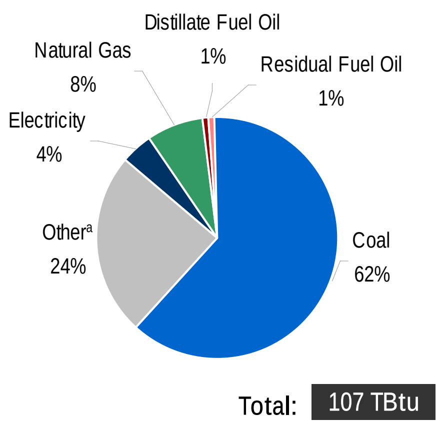
Source	CO_2	Total
Fossil Fuel Combustion[a]	9	9
Non-Combustion[b]	12	12
Purchased Electricity[c]	1	1
Total	23	23

[a] Emissions calculated based on DOE's *2002 Manufacturing Energy Consumption Survey* and EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005.*
[b] EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005.*
[c] Emissions calculated based on DOE's *2002 Manufacturing Energy Consumption Survey* and EPA's *Emissions and Generation Resource Integrated Database* (eGRID).

The overall methodology for estimating the GHG emissions for this report was described in Section 1.2; more detail on the methodology used to estimate emissions from the lime sector can be found in Section 9.2.2.

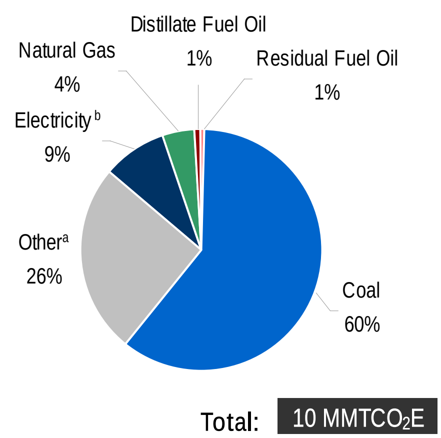
The distribution of energy consumption in this sector, by fuel type (including both on-site fossil fuel combustion and purchased electricity), is illustrated in Figure 9-1. For comparison, CO_2 emissions associated with fuel consumption are shown in Figure 9-2.

Figure 9-1: 2002 Energy Consumption in the Lime Sector, by Fuel Type (TBtu)



Source: DOE', *2002 Manufacturing Energy Consumption Survey*.
[a] Composition of "other" fuel category varies among sectors and is not defined in source.
Note: TBtu stands for trillion British thermal units.

Figure 9-2: 2002 CO_2 Emissions from Energy Consumption in the Lime Sector, by Fuel Type ($MMTCO_2E$)



Source: Estimate based on methodology in Section 9.2.2.
[a] Fuel mix at utilities was taken into consideration in this calculation, per methodology described in Section 9.2.2.
[b] Composition of "other" fuel category varies among sectors.

9.2.2 Methodology and Data Sources

Fossil Fuel Combustion

Fossil fuel combustion emissions from the lime sector were derived from the U.S. Department of Energy's (DOE) Energy Information Administration's (EIA) *Manufacturing Energy Consumption Survey* (MECS)[4] estimates

[4] U.S. Department of Energy, *2002 Manufacturing Energy Consumption Survey*, Energy Information Administration, 24 Jan 2005, http://www.eia.doe.gov/emeu/mecs/mecs2002.

of fuel consumption for this sector. Those fuel consumption estimates were then multiplied by the appropriate, fuel-specific emission factors to convert the consumption into CO_2 emitted. The emission factors for the fossil fuels used in the lime manufacturing industry were taken from data contained in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.

Non-Combustion Activities

Non-combustion emissions of CO_2 from lime manufacturing were those reported for the Lime Manufacturing source category within the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.[5] These estimates include the lime manufacturing emission sources identified by the Intergovernmental Panel on Climate Change's (IPCC) *2006 IPCC Guidelines for National Greenhouse Gas Inventories*.[6]

Purchased Electricity

Electricity emissions were estimated by mapping national electricity purchases (in kilowatt-hours, or kWh) provided by MECS to North American Electricity Reliability Corporation (NERC) regions,[7] then applying NERC regional utility CO_2 emission factor (in lbs/kWh) provided by eGRID. Sector electricity purchases were adjusted by a loss factor to reflect losses incurred in the transmission and distribution of electricity.

Since electricity purchase data were not available at the NERC regional level, distribution of the sector's value added was used to distribute the sector's national electricity purchases to the state-level, then state data were rolled up to the NERC regions. Where a state lay in two or more NERC regions, electricity purchases were distributed to the appropriate NERC region using sales data for the industrial customer class from EIA Report 861. This approach assumes that the electricity-intensity of production activities are correlated with the value added. Methods for estimating CO_2 emissions from electricity are described in more detail in Appendix A.3.

9.2.3 Key Assumptions and Completeness

Non-combustion emission estimates were limited to sources identified by the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* and provided in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*. Electricity and fossil fuel combustion emission estimates include only CO_2. Emissions of other GHGs (e.g., CH_4 and N_2O) that may result from combustion were not estimated.[8] Emission factors for purchased electricity provided by eGRID are for 2004, which may include different fuel mixes for electricity generation than those of the 2002 inventory year.

9.3 Greenhouse Gas Emissions (2002)

GHG emissions for select years from the lime sector are shown in Figure 9-3.[9]

Annual estimates of non-combustion GHG emissions from the sector were available from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*, which show that such emissions have decreased by 2% between 1998 and 2005, from 14.0 to 13.7 $MMTCO_2E$. Over the same period, lime production remained relatively unchanged (decreasing 0.5%)[10], while value added[11] in lime manufacturing decreased 4%.

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[5] U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005.*

[6] Intergovernmental Panel on Climate Change, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, 2007, http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.htm.

[7] The North American Electricity Reliability Corporation (NERC) is the designated reliability organization that has a role in overseeing the reliability of the electric power grid. NERC regions reflect the organization structure of the regional reliability entities within with the owners of generation operate.

[8] Non-CO_2 emissions typically account for only a small percentage (approximately 2%) of a sector's GHG emissions from fossil fuel combustion.

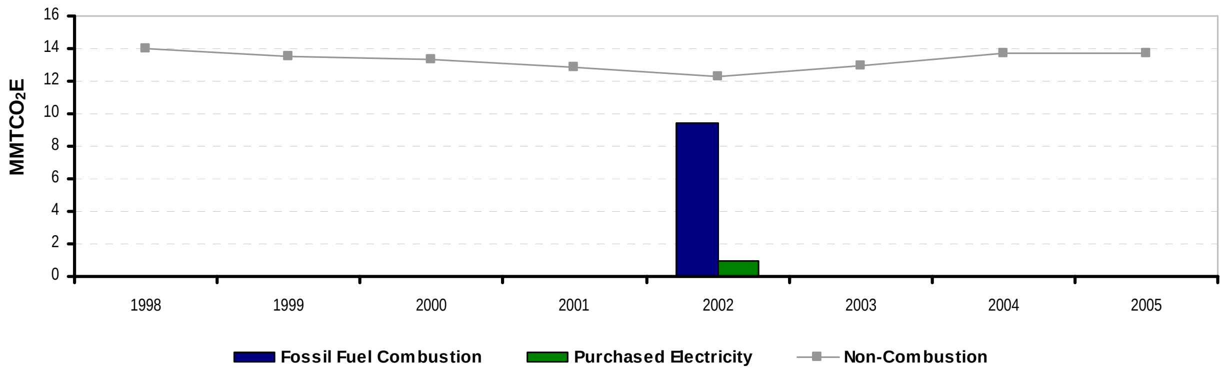
[9] Note: in the following discussion, the percentages shown are calculated from the raw data. However, rounded data values are given in the text at an appropriate level of significance; therefore, the reader may not be able to reproduce the calculation.

[10] U.S. Geological Survey, Minerals Yearbook: Lime Annual Report 2005.

[11] Value added is a measure of the enhancement a company gives its product or service before offering the product to customers. It is used here as a surrogate for production. Value added is considered to be the best value measure available for comparing the relative economic importance of manufacturing among industries and geographic areas (source: U.S. Census Bureau, Annual Survey of Manufactures (ASM): Statistics for Industry Groups and Industries, 2005, http://www.census.gov/mcd/asm-as1.html). The data were normalized to account for fluctuation in industry size or production over time; dollars were adjusted for inflation using a gross domestic product price deflator.

However, data for GHG emissions from fossil fuel combustion and purchased electricity in 1998 were not available, since the 1998 MECS report does not separately report energy used for lime manufacturing.

Figure 9-3: Greenhouse Gas Emissions from the Lime Sector (MMTCO$_2$E)



9.4 Other Sources of Greenhouse Gas Emission Estimates for this Sector

The National Lime Association (NLA), under the Department of Energy's Climate VISION program, prepares GHG emission estimates using a protocol developed by the NLA and approved by the Department of Energy, and survey data provided by NLA members.[12] The NLA's GHG emission estimate includes CO_2 emissions that result from fossil fuel combustion, non-combustion activities, and purchased electricity. For the year 2002, NLA estimated total GHG emissions to be 26 MMTCO$_2$E (Table 9-2), an estimate that is approximately 3 MMTCO$_2$E higher than the estimate presented in Table 9-1. The emission estimate provided by NLA is higher for both fossil fuel combustion and non-combustion emissions. The NLA suggests that the higher fossil fuel combustion estimate occurs because survey respondents use more coal than natural gas relative to the estimate presented here, and that the higher non-combustion estimate occurs because the NLA protocol includes emissions from carbonaceous byproducts.[13]

Table 9-2: 2002 GHG Emission Estimates from the National Lime Association (MMTCO$_2$E)

Source	CO_2	Total
Fossil Fuel Combustion	11	11
Non-Combustion	14	14
Purchased Electricity	1	1
Total	**26**	**26**

Source: National Lime Association 2007.

9.5 Sector Emission Reduction Commitments

The National Lime Association (NLA) has committed that NLA members will, on an aggregate basis, reduce GHG emissions from fuel combustion per ton of production by 8% between 2002 and 2012.[14]

[12] National Lime Association 2005.
[13] National Lime Association 2007.
[14] See http://www.climatevision.gov/sectors/lime/index.html.

9.6 Reporting Protocols

When calculating emissions, one of the following protocols may be used by companies in the lime sector:

- EPA's *Climate Leaders Greenhouse Gas Inventory Protocol*, which is an enhanced version of the WBCSD/WRI protocol mentioned below;
- DOE's *Technical Guidelines: Voluntary Reporting of Greenhouse Gases (1605(b)) Program*;
- The World Business Council for Sustainable Development (WBCSD) and the World Resource Institute's (WRI) *Greenhouse Gas Protocol*; and
- The specific protocol developed by the NLA for the lime industry, which includes guidance for estimating CO_2 emissions associated with quicklime, calcined byproducts/wastes, and kiln, quarry, mine and other miscellaneous fuels.

No public reports of GHG emissions from companies in the lime sector were identified.

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10. Metal Casting

Metal casting is prevalent in the U.S. economy, as over 90% of goods manufactured in the United States contain cast metal components.[2] The automotive and transportation sectors are the largest users of castings, consuming 50-60% of all castings produced.[3]

Source	2002 Emissions ($MMTCO_2E$)
Fossil Fuel Combustion	7
Non-Combustion	
Purchased Electricity	11
Total	18
Percent of U.S. Industrial Emissions[1]	*1%*

The industry includes over 2,300 facilities, among which the metals used, the capacity of the plants, the casting processes, and other characteristics vary greatly. These 2,300 facilities are primarily small, independent foundries, though some facilities are vertically integrated within larger manufacturing operations. Although the industry is geographically widespread, 80% of the industry's shipments originate in ten states—Alabama, California, Illinois, Indiana, Michigan, Ohio, Pennsylvania, Tennessee, Texas, and Wisconsin.[4]

The metal casting sector (NAICS code 3315: Foundries) consists of operations that pour or inject molten metal into molds or dies to form castings. Establishments that use metal castings as a primary input—such as machining or assembling—are classified according to the nature of the finished product. Thus, more involved processes that transform castings into secondary products are classified elsewhere in the manufacturing sector, according to the product being made. For example, an automobile manufacturing plant may cast engines, but it would not be classified under this NAICS code.

10.1 Sources of Greenhouse Gas Emissions

Metal casting requires a significant amount of heat and electricity to achieve high furnace temperatures. Indirect GHG emissions from metal casting result from electricity consumption by electric arc furnaces and electric induction furnaces. Direct emissions result from onsite fossil fuel combustion. Almost half of these direct sources of combustion-related emissions are from the combustion of natural gas and coke for the firing of holding and cupola melting furnaces, with the remainder coming primarily from combustion of coal, liquefied petroleum gas (LPG), and distillate fuel.

10.2 Summary of Emissions (2002)

This section presents a summary of the GHG emission estimates for the metal casting sector as estimated for the year 2002. The methodologies and data sources used to calculate these emission estimates, as well as the assumptions and limitations surrounding the estimates, are also described.

10.2.1 Estimates of Greenhouse Gas Emissions (2002)

The total GHG emissions from the metal casting sector are estimated to be 18 $MMTCO_2E$ (as seen in Table 10-1).

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[1] Total 2002 industrial emissions are 2,047 $MMTCO_2E$ as reported in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*. See U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005,* 15 Apr 2007, http://www.epa.gov/climatechange/emissions/usinventoryreport.html, Table 2-16. Note that for the purpose of this report, a blank cell does not necessarily indicate zero emissions; rather, it indicates that the analysis did not address that emission source, if applicable; see "Summary of Emissions (2002)" for additional information.

[2] U.S. Environmental Protection Agency, *Energy Trends in Selected Manufacturing Sectors: Opportunities and Challenges for Environmentally Preferable Energy Outcome,* 2007, http://www.epa.gov/sectors/pdf/energy/report.pdf.

[3] U.S. Environmental Protection Agency, *Profile of the Metal Casting Industry,* 1998, http://www.epa.gov/compliance/resources/publications/assistance/sectors/notebooks/metcstsnapt1.pdf.

[4] U.S. Environmental Protection Agency, *Energy Trends in Selected Manufacturing Sectors.*

Table 10-1: 2002 GHG Emissions from the Metal Casting Sector ($MMTCO_2E$)

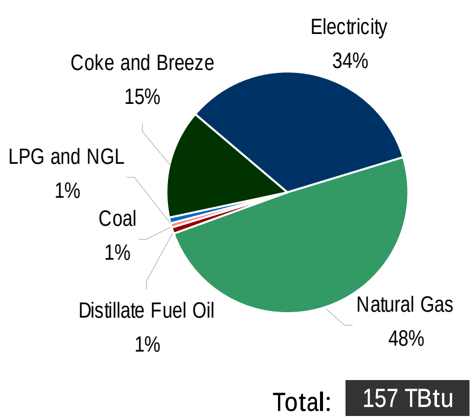
Source	CO_2	Total
Fossil Fuel Combustion[a]	7	7
Non-Combustion[b]		
Purchased Electricity[c]	11	11
Total [d]	18	18

[a] Emissions calculated based on DOE's *2002 Manufacturing Energy Consumption Survey* and EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.
[b] EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005.*
[c] Emissions calculated based on DOE's *2002 Manufacturing Energy Consumption Survey* and EPA's *Emissions and Generation Resource Integrated Database* (eGRID).
[d] Emission estimates do not include captive foundries.
Note that for the purpose of this report, a blank cell does not necessarily indicate zero emissions; rather it indicates that the analysis did not address that emission source, if applicable; see "Summary of Emissions (2002)" for additional information.

The overall methodology for estimating the GHG emissions for this report is described in Section 1.2; more detail on the methodology used to estimate emissions from the metal casting sector can be found in Section 10.2.2.

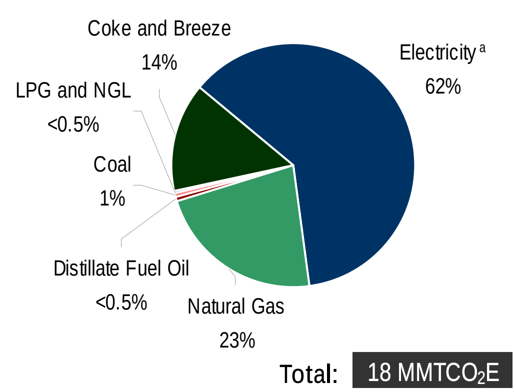
The distribution of energy consumption in this sector, by fuel type (including both on-site fossil fuel combustion and purchased electricity), is illustrated in Figure 10-1. For comparison, CO_2 emissions associated with fuel consumption are shown in Figure 10-2.

Figure 10-1: 2002 Energy Consumption in the Metal Casting Sector, by Fuel Type (TBtu)



Source: DOE, *2002 Manufacturing Energy Consumption Survey*.
Note: TBtu stands for trillion British thermal units.

Figure 10-2: 2002 CO_2 Emissions from Energy Consumption in the Metal Casting Sector, by Fuel Type ($MMTCO_2E$)



Source: Estimate based on methodology in Section 10.2.2.
[a] Fuel mix at utilities was taken into consideration in this calculation, per methodology described in Section 10.2.2.

10.2.2 Methodology and Data Sources

Fossil Fuel Combustion

Fossil fuel combustion emissions from the metal casting sector were derived from U.S. Department of Energy's (DOE) Energy Information Administration's (EIA) *Manufacturing Energy Consumption Survey* (MECS)[5] estimates of fuel consumption for this sector. Those fuel consumption estimates were then multiplied by the appropriate, fuel-specific emission factors to convert the consumption into CO_2 emitted.

The emission factors for the fossil fuels used in the metal casting industry were taken from data contained in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.

Non-Combustion Activities

Emissions from non-combustion sources were not estimated for this sector due to methodological and data constraints, though some emissions may result from the use of SF_6 as a cover gas for magnesium casting. (Cover gases are used during the metal casting process to prevent burning at the molten metal surface.) However, the use of magnesium is uncommon in the metal casting sector, as it is forecasted to account for only 1% of the sector's casting capacity in 2007.[6]

Purchased Electricity

Electricity emissions were estimated by mapping national electricity purchases (in kilowatt-hours, or kWh) provided by MECS to North American Electricity Reliability Corporation (NERC) regions,[7] then applying NERC regional utility CO_2 emission factor (in lbs/kWh) provided by eGRID. Sector electricity purchases were adjusted by a loss factor to reflect losses incurred in the transmission and distribution of electricity.

Since electricity purchase data were not available at the NERC regional level, distribution of the sector's value added was used to distribute the sector's national electricity purchases to the state-level, then state data were rolled up to the NERC regions. Where a state lay in two or more NERC regions, electricity purchases were distributed to the appropriate NERC region using sales data for the industrial customer class from EIA Report 861. This approach assumes that the electricity-intensity of production activities are correlated with the value added. Methods for estimating CO_2 emissions from electricity are described in more detail in Appendix A.3.

10.2.3 Key Assumptions and Completeness

Non-combustion emissions of SF_6 as a result of the manufacturing process were not included in this report. Emission estimates do not include captive foundries because these foundries are not included in the MECS data used to define the sector boundary. Electricity and fossil fuel combustion emission estimates include only CO_2. Emissions of other GHGs (e.g., CH_4 and N_2O) that may result from combustion were not estimated.[8] Emission factors for purchased electricity provided by eGRID are for 2004, which may include different fuel mixes for electricity generation than those of the 2002 inventory year.

10.3 Greenhouse Gas Emissions (1998, 2002)

GHG emissions for select years from the metal casting sector are shown in Figure 10-3.[9]

Data for GHG emissions from fossil fuel combustion and purchased electricity were available only for two data points, 1998 and 2002, based on frequency of MECS reports. During this period, fossil fuel combustion

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[5] U.S. Department of Energy, *2002 Manufacturing Energy Consumption Survey*, Energy Information Administration, 24 Jan 2005, http://www.eia.doe.gov/emeu/mecs/mecs2002.

[6] Kirgin, Ken, "U.S. Casting Sales to Maintain Course with 3.7% Rise," Nov 2007, http://www.afsinc.org/images/stories/aboutmetalcasting/27jan07.pdf.

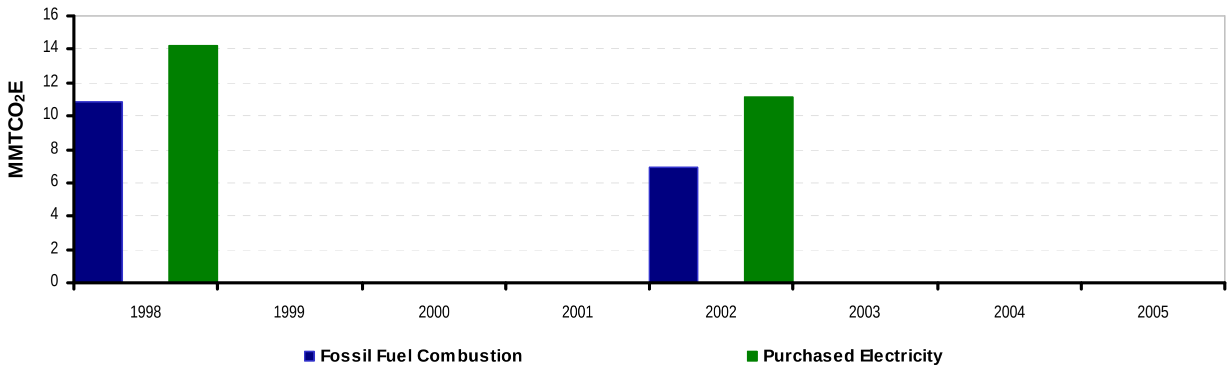
[7] The North American Electricity Reliability Corporation (NERC) is the designated reliability organization that has a role in overseeing the reliability of the electric power grid. NERC regions reflect the organization structure of the regional reliability entities within with the owners of generation operate.

[8] These non-CO_2 emissions typically account for only a small percentage (approximately) 2% of a sector's GHG emissions from fossil fuel combustion.

[9] Note: in the following discussion, the percentages shown are calculated from the raw data. However, rounded data values are given in the text at an appropriate level of significance; therefore, the reader may not be able to reproduce the calculation.

emissions declined by 36%, from 10.9 to 6.9 $MMTCO_2E$, and emissions from purchased electricity declined by 22%, from 14.2 to 11.1 $MMTCO_2E$. Over the same period, shipments of ferrous and nonferrous metals[10] decreased 11%.

Figure 10-3: Greenhouse Gas Emissions from the Metal Casting Sector ($MMTCO_2E$)



10.4 Other Sources of Greenhouse Gas Emission Estimates for this Sector

A report prepared for DOE, *Theoretical/Best Management Energy Use in Metal Casting Operations,*[11] describes a study conducted to determine the theoretical and practical potential for minimizing energy requirements (and associated CO_2 emissions) to produce one ton of molten metal in metal casting operations.

This report includes cast iron, steel, aluminum, copper, zinc, magnesium, and other non-ferrous metals in its CO_2 emission estimates. As shown in Table 10-2, for the year 2003, the report estimates total CO_2 emissions to be 27.5 $MMTCO_2E$. This estimate is approximately 10 $MMTCO_2E$ more than the estimate presented here. The difference in emission estimates is likely due to the fact that the DOE report accounts for captive foundries, which are not included in this report's emission estimates.[12]

[10] American Foundry Society, "Metal Casting Forecast & Trends: Demand & Supply Forecast," Stratecasts, Inc.

[11] Schifo, J.F. and J.T. Radia, KERAMIDA Environmental, Inc. *Theoretical/Best Practice Energy Use in Metalcasting Operations*. Prepared for the U.S. Department of Energy Industrial Technologies Program, May 2004.

[12] "Data Reconciliation for the Metal Casting Sector," BCS 2008.

Table 10-2: CO_2 Emission Estimates from the U.S. Department of Energy's *Theoretical/Best Management Energy Use in Metal Casting Operations*

Metal Casting Operation	2003 CO_2 Emission Estimate ($MMTCO_2E$)[a]
Grey Iron	10.1
Ductile (Other than pipe)	3.2
Ductile Iron Pipe	1.1
Steel	2.7
Al High Pressure Die Casting	5.6
Al Permanent Mold/Sand	1.2
Al Lost Foam	1.5
Mg Die Casting	0.4
Zinc Die Casting	0.5
Copper-Base; Sand	0.7
Titanium: Investment; Induction; Hot Isostatic Pressing (HIP)	0.2
Other Non-Ferrous	0.3
Total	27.5

[a] Emission estimates were converted from thousand short tons CO_2, as reported by DOE, into $MMTCO_2E$. 1,000 short ton = 0.0009072 MMT.

10.5 Sector Emission Reduction Commitments

No sector commitments to reducing GHG emissions were identified.

10.6 Reporting Protocols

When calculating emissions, one of the following protocols may be used by companies in the metal casting sector:

- EPA's *Climate Leaders Greenhouse Gas Inventory Protocol*, which is an enhanced version of the WBCSD/WRI protocol mentioned below;
- DOE's *Technical Guidelines: Voluntary Reporting of Greenhouse Gases (1605(b)) Program*; and
- The World Business Council for Sustainable Development (WBCSD) and the World Resource Institute's (WRI) *Greenhouse Gas Protocol*.

No public reports of GHG emissions from companies in the metal casting sector were identified.

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11. Mining

Mining operations provide the mineral commodities that are essential to numerous indispensable goods and services. Mined materials are necessary to construct roads and buildings, to make computers and satellites, to generate electricity, and to build other common commodities.

Source	2002 Emissions ($MMTCO_2E$)
Fossil Fuel Combustion	15
Non-Combustion	58
Purchased Electricity	27
Total	99
Percent of U.S. Industrial Emissions[1]	*5%*

The mining sector (NAICS code 212: Mining), contains facilities that primarily engage in mining, mine site development, and preparing metallic minerals and nonmetallic minerals. Mining activities broadly include ore extraction, quarrying, and beneficiating (e.g., reducing extracted materials to particles for separation into mineral for processing or use and waste). Mining establishments include those that have complete responsibility for operating mines and quarries, as well as those establishments that operate mines and quarries on a contract or fee basis. This sector includes mining of all materials (e.g., coal, metal, and nonmetallic minerals) except oil and gas (NAICS code 211: Oil and Gas Extraction), which is included in the Oil and Gas chapter of this report.

11.1 Sources of Greenhouse Gas Emissions

As described in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005,*[2] significant direct, non-combustion emissions result from coal mining operations. In particular, CH_4 is liberated during normal coal mining operations, as CH_4 that resides in coal ("*in situ*") is released during underground mining, surface mining, and post-mining (i.e., coal handling) activities. The in-situ CH_4 content of coal depends upon the amount of CH_4 created during the coal formation process, as well as the geological characteristics of the coal seam. Coal mines without ongoing mining operations continue to emit CH_4, albeit at a much slower rate than active mines.

Mining operations require energy to operate quarrying and beneficiating machinery. This energy use results in direct emissions of CO_2 from fossil fuel combustion and indirect CO_2 emissions from purchased electricity.

11.2 Summary of Emissions (2002)

This section presents a summary of the GHG emission estimates for the mining sector as estimated for the year 2002. The methodologies and data sources used to calculate these emission estimates, as well as the assumptions and limitations surrounding the estimates, are also described.

11.2.1 Estimates of Greenhouse Gas Emissions (2002)

The total GHG emissions from the mining sector are estimated to be 99 $MMTCO_2E$ (as seen in Table 11-1).

[1] Total 2002 industrial emissions are 2,047 $MMTCO_2E$ as reported in the Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005. See U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*, 15 Apr 2007, http://www.epa.gov/climatechange/emissions/usinventoryreport.html, Table 2-16. Note that for the purpose of this report, totals may not sum due to independent rounding.
[2] U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005.*

Table 11-1: 2002 GHG Emissions from the Mining Sector ($MMTCO_2E$)

Source	CO_2	CH_4	Total
Fossil Fuel Combustion[a]	15		15
Non-Combustion[b]		58	58
Coal Mining		*52*	*52*
Abandoned Coal Mines		*6*	*6*
Purchased Electricity[c]	27		27
Total	41	58	99

[a] Emissions calculated based on U.S. Census Bureau's *2002 Mining Statistics Sampler* and EPA's *Inventory of U.S . Greenhouse Gas Emissions and Sinks: 1990-2005*.

[b] EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005.*

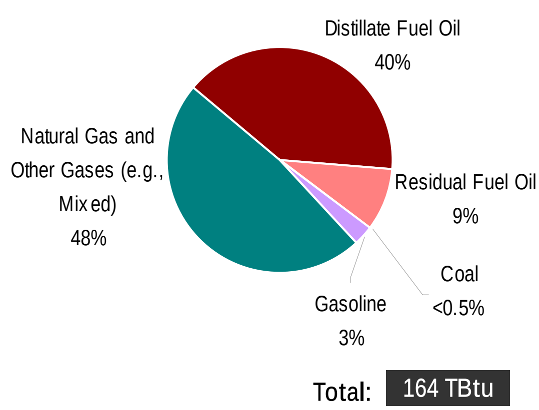
[c] Emissions calculated based on DOE's *2002 Manufacturing Energy Consumption Survey* and EPA's *Emissions and Generation Resource Integrated Database* (eGRID).

Note that for the purpose of this report, a blank cell does not necessarily indicate zero emissions; rather, it indicates that the analysis did not address that emission source, if applicable; see "Summary of Emissions (2002)" for additional information.

The overall methodology for estimating GHG emissions for this report is described in Section 1.2; more detail on the methodology used to estimate emissions from the mining sector can be found in Section 11.2.2.

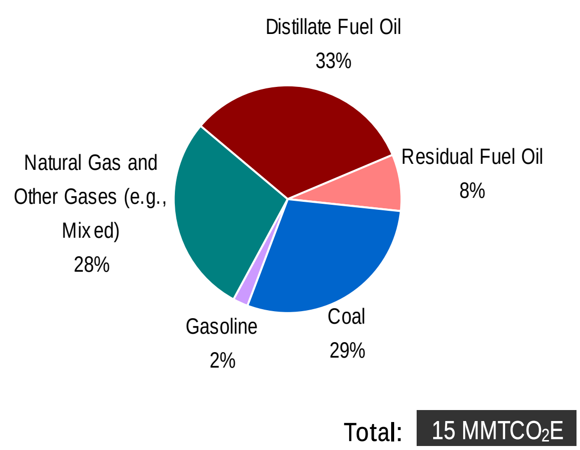
The distribution of energy consumption in this sector, by fuel type (including both on-site fossil fuel combustion and purchased electricity), is illustrated in Figure 11-1. For comparison, CO_2 emissions associated with fuel consumption are shown in Figure 11-2.

Figure 11-1: 2002 Energy Consumption in the Mining Sector, by Fuel Type (TBtu)



Source: U.S. Census Bureau, *2002 Mining Statistics Sampler.*
Note: TBtu stands for trillion British thermal units.

Figure 11-2: 2002 CO_2 Emissions from Energy Consumption in the Mining Sector, by Fuel Type ($MMTCO_2E$)



Source: Estimate based on methodology in Section 11.2.2.

11.2.2 Methodology and Data Sources

Fossil Fuel Combustion

Fossil fuel combustion emissions from the mining sector were derived from the U.S. Census Bureau's 2002 *Economic Census Industry Series Reports: Mining*[3] estimates of fuel consumption for this sector, as the U.S. Department of Energy's (DOE) Energy Information Administration's (EIA) *Manufacturing Energy Consumption Survey* (MECS) does not contain fuel use estimates for this sector. These estimates include fuel consumed for both on-road and off-road mining equipment. Those fuel consumption estimates were then multiplied by the appropriate, fuel-specific emission factors to convert the consumption into CO_2 emitted. The emission factors for the fossil fuels used in the mining sector were derived from data contained in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.

Non-Combustion Activities

Non-combustion emissions of CH_4 from coal mining operations were those reported for the coal mining and abandoned underground coal mines source categories within the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.[4] These estimates also include the mining emission sources identified by the Intergovernmental Panel on Climate Change's (IPCC) *2006 IPCC Guidelines for National Greenhouse Gas Inventories*.[5]

Purchased Electricity

Electricity emissions were estimated by mapping national electricity purchases (in kilowatt-hours, or kWh) provided by MECS to North American Electricity Reliability Corporation (NERC) regions,[6] then applying NERC regional utility CO_2 emission factor (in lbs/kWh) provided by eGRID. Sector electricity purchases were adjusted by a loss factor to reflect losses incurred in the transmission and distribution of electricity.

Since electricity purchase data were not available at the NERC regional level, distribution of the sector's value added was used to distribute the sector's national electricity purchases to the state-level, then state data were rolled up to the NERC regions. Where a state lay in two or more NERC regions, electricity purchases were distributed to the appropriate NERC region using sales data for the industrial customer class from EIA Report 861. This approach assumes that the electricity-intensity of production activities are correlated with the value added. Methods for estimating CO_2 emissions from electricity are described in more detail in Appendix A.3.

11.2.3 Key Assumptions and Completeness

Non-combustion emission estimates were limited to sources identified by the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* and provided in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*. Electricity and fossil fuel combustion emission estimates include only CO_2. Emissions of other GHGs (e.g., CH_4 and N_2O) that may result from combustion were not estimated.[7] Emission factors for purchased electricity provided by eGRID are for 2004, which may include different fuel mixes for electricity generation than those of the 2002 inventory year.

11.3 Greenhouse Gas Emissions (1997, 2002)

GHG emissions for select years from the mining sector are shown in Figure 11-3.[8]

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[3] U.S. Census Bureau, *2002 Economic Census of Mining Industry Series Data*, Economics and Statistics Administration, 2005, http://www.census.gov/econ/census02/guide/INDRPT21.HTM.

[4] U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005.*

[5] Intergovernmental Panel on Climate Change, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, 2007, http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.htm.

[6] The North American Electricity Reliability Corporation (NERC) is the designated reliability organization that has a role in overseeing the reliability of the electric power grid. NERC regions reflect the organization structure of the regional reliability entities within with the owners of generation operate.

[7] These non-CO_2 emissions typically account for a small percentage (approximately 2%) of a sector's GHG emissions from fossil fuel combustion.

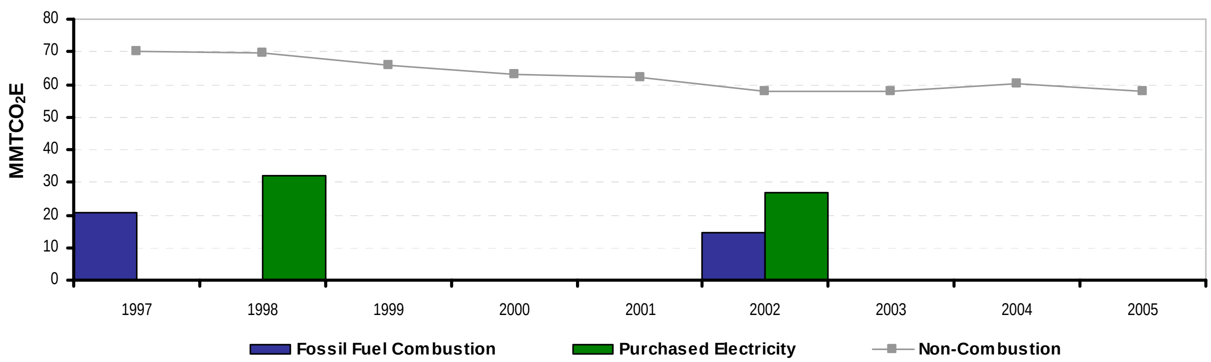
[8] Note: in the following discussion, the percentages shown are calculated from the raw data. However, rounded data values are given in the text at an appropriate level of significance; therefore, the reader may not be able to reproduce the calculation.

Annual estimates of non-combustion GHG emissions from mining were available from the annual *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*, which show that such emissions have decreased by 18% between 1997[9] and 2005, from 70.3 to 57.9 $MMTCO_2E$.

However, the data for GHG emissions from fossil fuel combustion were available only for two data points, 1997 and 2002, based on frequency of U.S. Census reports. Data for GHG emissions from purchased electricity were available for 1998 and 2002. The 1998 value was assumed for 1997. During the period, 1997-2002, these energy-related emissions declined by 22%, from 52.9 to 41.4 $MMTCO_2E$.

In aggregate, emissions from the mining sector decreased 19% between 1997 and 2002. Over the same period, mining production[10] increased 4%.

Figure 11-3: Greenhouse Gas Emissions from the Mining Sector ($MMTCO_2E$)



11.4 Other Sources of Greenhouse Gas Emission Estimates for this Sector

No reports containing complete GHG emissions estimates for the mining sector were identified.

11.5 Sector Emission Reduction Commitments

In 2003, the National Mining Association (NMA) and its members that are in the coal and metals and minerals industry, committed to increasing the energy efficiency of production (and where applicable) processing operations, with the goal of obtaining a 10 percent increase in efficiency in systems that can be optimized with the processes and techniques developed by the Department of Energy (DOE) and made available to the industry through a series of jointly sponsored government industry workshops. NMA members also committed to maintain and improve progress made in reduction of CH_4 emissions from coalmines, wherever economically and technically possible.

11.6 Reporting Protocols

When calculating emissions, one of the following protocols is typically used by companies in the mining sector:

- EPA's *Climate Leaders Greenhouse Gas Inventory Protocol*, which is an enhanced version of the WBCSD/WRI protocol mentioned below;

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[9] Trends in GHG emissions from the mining sector start in 1997 since only one data point for emissions from energy consumption was available for this sector.

[10] U.S. Department of Energy, "Coal Production in the United States," 5 Oct 2006, http://www.eia.doe.gov/cneaf/coal/page/fig1_us_historical_production_bar_chart.xls; U.S. Geological Survey, *Minerals Yearbook: Mining and Quarrying Report 2000*, 2001, http://minerals.usgs.gov/minerals/pubs/commodity/m&q/, Table 1; U.S. Geological Survey, *Minerals Yearbook: Mining and Quarrying Report 2005*, 2006, http://minerals.usgs.gov/minerals/pubs/commodity/m&q/, Table 1.

- DOE's *Technical Guidelines: Voluntary Reporting of Greenhouse Gases (1605(b)) Program*; and
- The World Business Council for Sustainable Development (WBCSD) and the World Resource Institute's (WRI) *Greenhouse Gas Protocol*.

Table 11-2 presents a sample of mining companies that have publicly reported their GHG emissions.

Table 11-2: Sampling of Publicly-Reported GHG Emissions for Mining Companies

Company	Protocol	Emissions ($MMTCO_2E$)	Year Reported	Geographic Scope	Goal
Newmont Mining	WBCSD/WRI	1.2[11]	2006	U.S.	NI

NI = Not Indicated

[11] Newmont Mining Corporation, "CDP 5 Companies and Response Status: Carbon Disclosure Project (CDP5) Greenhouse Gas Emissions Questionnaire," 10 Nov 2007 http://www.cdproject.net/responses/Newmont_Mining_Corporation_Corporate_GHG_Emissions_Response_CDP5_2007/public.htm.

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12. Oil and Gas

The oil and gas sector, as defined in this report, includes the exploration and production of petroleum and natural gas, processing of natural gas, the refining of petroleum and the non-combustion emissions from the transportation and distribution of oil and gas. The processes included in these sub-sectors may be found under the following NAICS codes: Crude Petroleum and Natural Gas Extraction (211111), Natural Gas Liquid Extraction (211112), Drilling Oil and Gas Wells (213111), Support Activities for Oil and Gas Operations (213112), Petroleum Refineries (324110), Pipeline Transportation of Refined Petroleum Products (48691), Pipeline Transportation of Natural Gas (48621) and Natural Gas Distribution (22121).

Source	2002 Emissions ($MMTCO_2E$)[1]
Fossil Fuel Combustion	276
Non-Combustion	181
Purchased Electricity	43
Total	**501**
Percent of U.S. Industrial Emissions[1]	*24%*

The sector can be divided into two parts in two ways: the first is to split oil and gas production (i.e., the exploration and production of oil and gas from the ground or off-shore sources) from petroleum refining (i.e., processing of crude oil that has been extracted or imported) and processing of natural gas (i.e., the removal of impurities and natural gas liquids from wellhead natural gas); the second is to split petroleum systems from natural gas systems – with systems defined in each case to include the exploration, production, transportation, and refining of petroleum and the exploration, production, processing, transmission and storage, and distribution of natural gas.

The oil and gas exploration and production sub-sector includes the upstream operations engaged in locating and extracting oil and natural gas resources that may undertake activities such as seismic and geological data acquisition and interpretation, leasing and permitting, exploration drilling, development drilling, work-overs and re-completions, and production operations. Geographically, this industry extracts oil and natural gas from more than 30 states, including offshore sources. In 2005, the U.S. produced almost two billion barrels of crude oil with the largest sources being the Gulf of Mexico, Texas (onshore), Alaska and California. In total, these wells accounted for 77% of all U.S. oil production.[2] In natural gas production, the U.S. produced nearly 24 trillion cubic feet of raw gas from onshore and offshore sources in 2005, with the largest producers being Texas, the Gulf of Mexico, Wyoming, New Mexico, Oklahoma, Colorado, and Louisiana. Together, these sources accounted for 83% of all U.S. gross gas withdrawals that year.[3] After processing, this production yielded about 18 trillion cubic feet of marketable dry natural gas.[3]

The petroleum refining sub-sector includes establishments engaged in refining crude petroleum into refined petroleum products through multiple distinct processes that may include distillation, hydrotreating, alkylation, and reforming. In addition to fuel production, this sub-sector produces raw materials for the petrochemical industry. Currently there are 149 petroleum refineries in the U.S. located in 33 states, with approximately 75% of the total refining capacity held in just 7 states (Texas, Louisiana, California, New Jersey, Pennsylvania, Ohio and Oklahoma). In 2006, U.S. refineries had processed more than 5.5 billion barrels of crude oil.[4]

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[1] Total 2002 industrial emissions are 2,047 $MMTCO_2E$ as reported in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005.* See U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*, 15 Apr 2007, http://www.epa.gov/climatechange/emissions/usinventoryreport.html, Table 2-16. Note: totals may not sum due to independent rounding.

[2] U.S. Department of Energy, *EIA Distribution and Production of Oil and Gas Well*s, 1990-2004, Energy Information Administration, 2006. Data for 2005 were developed by using EIA's state oil production growth from 2004 to 2005.

[3] U.S. Department of Energy, EIA Natural Gas Gross Withdrawals and Production, February 2008, http://tonto.eia.doe.gov/dnav/ng/ng_prod_sum_dcu_NUS_a.htm.

[4] U.S. Department of Energy, *EIA Refinery Capacity and Utilization, 2007,* Energy Information Administration, June 2007, http://tonto.eia.doe.gov/dnav/pet/pet_pnp_unc_dcu_nus_a.htm.

12.1 Sources of Greenhouse Gas Emissions

12.1.1 Oil and Gas Exploration, Production and Delivery Sub-Sector

There are two direct sources of GHG emissions (in the form of CO_2) in the oil and gas production and delivery sub-sector: processes (considered non-combustion emissions) and fossil fuel combustion. Natural gas and distillates (i.e., diesel and fuel oils) are the primary fuels used in oil and gas exploration and production, and they are used to operate internal combustion engines, process heaters, and to produce steam. Additionally, diesel fuel is used for off-road transportation. The majority of the natural gas consumed by this sub-sector is produced and used locally in the production areas or in gas processing plants (called natural gas lease and plant fuel), although some gas may also be purchased. Where gas is not available, diesel fuel is the preferred internal combustion engine fuel due to its transportability.

In natural gas processing plants, the direct sources of GHG emissions are primarily the acid-gas removal units that rid raw natural gas of CO_2. Other direct sources of non-combustion CO_2 emissions are the flaring of gas in field production[5], leaks from transmission and storage, and fugitive emissions in the distribution systems.

The indirect sources of GHG emissions (in the form of CH_4) are leaks, venting and fugitive emissions. In field production, a substantial portion of the total CH_4 emissions come from pneumatic devices, while in natural gas processing plants, the primary source of CH_4 emissions is fugitive emissions from compressors. In transmission and storage facilities, CH_4 emissions may come from the compressors at metering and regulating stations or storage facilities, or CH_4 may be emitted from the dehydrators at storage facilities. Fugitive CH_4 emissions are also emitted from distribution systems for natural gas.

12.1.2 Petroleum Refining Sub-Sector

The direct source of GHG emissions in the petroleum refining sub-sector is fossil-fuel combustion. The two largest fossil-fuel consuming processes in the petroleum refining industry are fluid heating and steam production. Fluid heaters are used in a variety of important refining steps such as distillation and pre-heating feedstock to induce reactions. Steam production is also considered to be a major refinery activity since substantial amounts of steam are used throughout a refinery.

Refinery fuel gas (also called still gas), catalyst coke and natural gas are the primary fossil fuels consumed by this sub-sector. Refinery fuel gases are the by-products of various petroleum refinery processes (such as crude oil distillation, cracking, reforming and treating). These gases are collected and then processed (to recover the propane, or other light hydrocarbons), and then the sulfur and nitrogen compounds are removed. This cleaner gas is basically a mixture of methane, ethane, and lesser amounts of hydrogen and light hydrocarbons with trace amounts of ammonia and hydrogen sulfide. Refinery gas is the primary fuel used in fluid heaters, with natural gas being the preferred purchased fuel.

For steam production, petroleum coke (a by-product of the coking process) is the fuel of choice since it provides a free source of fuel. 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. The petroleum refining industry is considered to be a major co-generator of steam and electricity. As a result of co-generation, purchased electricity (primarily used for machine drives) in petroleum refineries is not as significant a source of indirect emissions as it is in other major energy-intensive industries that do not produce their own electricity.

[5] Flaring is a combustion activity; however, the IPCC reporting requirements are designed such that natural gas flaring is reported within the process emissions from Natural Gas Systems rather than from CO_2 emissions from fossil fuel combustion within the U.S. Inventory (See U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*, 15 Apr 2007). Thus, flaring is reported here as a "non-combustion" activity.

12.2 Summary of Emissions (2002)

This section presents a summary of the GHG emission estimates for the oil and gas sector for the year 2002. The methodologies and data sources used to calculate these emission estimates, as well as the assumptions and limitations surrounding the estimates, are also described.

12.2.1 Estimates of Greenhouse Gas Emissions (2002)

As shown in Table 12-1, 2002 GHG emissions from the oil and gas sector totaled 501 MMTCO$_2$E and resulted primarily from the combustion of fossil fuels (276 MMTCO$_2$E) and non-combustion emissions (181 MMTCO$_2$E) were also a significant contributor.

Figure 12-1 and Figure 12-2 illustrate the distribution of energy consumption (including both on-site fossil fuel combustion and purchased electricity) and CO_2 emissions by fuel type, respectively. Figure 12-1 shows that natural gas (including natural gas used at the wellhead and in the gas processing plants) and other fuels (primarily comprised of by-product fuels, like refinery gas and petroleum coke) are the main energy types used in the oil and gas sector. These two fuels account for 93% of total energy consumption by the sector.

Table 12-1: 2002 GHG Emissions from the Oil and Gas Sector (MMTCO$_2$E)

Source	CO_2	CH_4	Total
Fossil Fuel Combustion[a]	276		276
Petroleum Refining	*199*		*199*
Oil and Gas Exploration and Production	*77*		*77*
Non-Combustion[b]	30	152	181
Petroleum Systems		27	27
Exploration and Production		*26*	*26*
Transportation		*<1*	*<1*
Refining		*1*	*1*
Natural Gas Systems	30	125	155
Exploration and Production	*7*	*42*	*49*
Processing	*23*	*14*	*37*
Transmission and Storage	*<1*	*43*	*43*
Distribution	*<1*	*26*	*26*
Purchased Electricity[c]	43		43
Petroleum Refining	*22*		*22*
Oil and Gas Production	*21*		*21*
Total	349	152	501

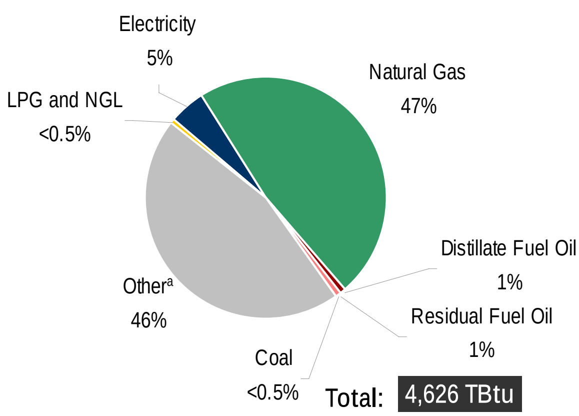
[a] Emissions calculated based on DOE's *2002 Manufacturing Energy Consumption Survey*, EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*, and U.S. Census *2002 Economic Census of Mining.*

[b] EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005.*

[c] Emissions calculated based on EPA's *Emissions and Generation Resource Integrated Database* (eGRID).

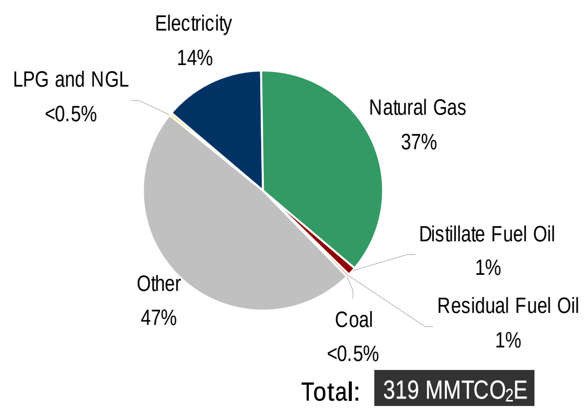
Note that for the purpose of this report, a blank cell does not necessarily indicate zero emissions; rather, it indicates that the analysis did not address that emission source, if applicable; see "Summary of Emissions (2002)" for additional information. Totals may not sum due to independent rounding.

Figure 12-1: 2002 Energy Consumption in the Oil and Gas Sector, by Fuel Type (TBtu)



Source: DOE, *2002 Manufacturing Energy Consumption Survey* and U.S. Census, *2002 Economic Census of Mining.*
[a] Composition of "other" fuel category varies among sectors. In the oil and gas sector, "other" fuels include crude oil, petroleum coke, and refinery gas.
Note: TBtu stands for trillion British thermal units.

Figure 12-2: 2002 CO_2 Emissions from Energy Consumption in the Oil and Gas Sector, by Fuel Type ($MMTCO_2E$)



Source: Estimate based on methodology in Section 12.2.2.
[a] Composition of "other" fuel category varies among sectors. In the oil and gas sector, "other" fuels include crude oil, petroleum coke, and refinery gas.

12.2.2 Methodology and Data Sources

Fossil Fuel Combustion

The estimated GHG emissions due to on-site fossil fuel combustion by the exploration and production sub-sector and petroleum refining sub-sector of the oil and gas sector were developed using two distinct methodologies.

- *Exploration and Production Sub-Sector:* The methodology developed to estimate fossil fuel combustion emissions from crude oil and natural gas extraction, drilling oil and gas wells, and support activities for oil and gas operations utilizes the U.S Census Bureau's *2002 Economic Census of Mining*[6] (2005) estimates of fuel consumption. However, the fuel consumption estimates for two fuel types in the Census pertaining to byproduct natural gas—"natural gas produced and used in the same plant as fuel" (commonly called lease fuel), and "residue gas produced and used in the same plant as fuel" (commonly called plant fuel)—were replaced by EIA natural gas lease and plant estimates. This was done for consistency with other studies and estimates done by industry groups and other organizations. EIA has the most consistent source of lease and plant data since they survey plants annually.

  Fuel consumption estimates were multiplied by appropriate, fuel-specific emission factors to convert the consumption into CO_2 emitted. The emission factors for the fossil fuels were derived from data contained in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks*: 1990-2005.[7]

- *Petroleum Refining Sub-Sector:* The methodology developed to estimate fossil fuel combustion emissions from petroleum refining utilizes the U.S. Department of Energy's Energy Information Administration's

[6] U.S. Department of Commerce, *2002 Economic Census: Crude Petroleum and Natural Gas Extraction: 2002*, December 2004, http://www.census.gov/prod/ec02/ec0221i211111.pdf.
[7] U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005.*

Manufacturing Energy Consumption Survey (MECS)[8] estimates of fuel consumption, found in Tables 3.1 and 3.2 of MECS. Estimates of fuel consumption by fuel type were obtained for NAICS code 324110 (petroleum refineries). Fuel consumption estimates were multiplied by appropriate, fuel-specific emission factors to convert the consumption into CO_2 emitted. The emission factors for the fossil fuels used in petroleum refining were derived from data contained in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.

Non-Combustion Activities

Estimates for non-combustion emissions from the petroleum systems and natural gas systems sub-sectors of this sector were both derived from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.

Non-combustion emissions for petroleum systems (source category 1B2a, which includes petroleum production, transportation, and refining) were obtained directly from Table 3-38 of the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*, which only includes CH_4 emissions. These emissions were calculated from activity data on the production, transportation, and refining for petroleum systems in accordance with the Intergovernmental Panel on Climate Change's (IPCC) *2006 IPCC Guidelines for National Greenhouse Gas Inventories,* the internationally agreed upon best available methods for national GHG emission inventories based on current technical and scientific knowledge.

Non-combustion emissions for natural gas systems (source category 1B2b, which includes natural gas production, processing, transmission and storage, and distribution) were obtained directly from Table 3-33 of the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*, which includes CO_2 and CH_4 emissions. These emissions were calculated from activity data on the production, processing, transmission and storage, and distribution for natural gas systems in accordance with the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*.

Purchased Electricity

Estimated emissions from purchased electricity from the exploration and production and petroleum refining sub-sectors of the oil and gas sector were developed using two separate methodologies. Methods for estimating CO_2 emissions from electricity are detailed in Appendix A.3.

- *Oil and Gas Production Sub-Sector:* Electricity emissions were estimated by mapping national electricity purchases (in kilowatt-hours, or kWh) provided by the U.S. Census Bureau's *2002 Economic Census of Mining* to North American Electricity Reliability Corporation (NERC) regions,[9] then applying NERC regional utility CO_2 emission factor (in lbs/kWh) provided by eGRID. Sector electricity purchases were adjusted by a loss factor to reflect losses incurred in the transmission and distribution of electricity.

  Since electricity purchase data were not available at the NERC regional level, distribution of the sector's value added was used to distribute the sector's national electricity purchases to the state-level, then state data were rolled up to the NERC regions.[10] Where a state lay in two or more NERC regions, electricity purchases were distributed to the appropriate NERC region using sales data for the industrial customer class from EIA Report 861. This approach assumes that the electricity-intensity of production activities are correlated with the value added.

- *Petroleum Refining Sub-Sector:* Electricity emissions were estimated by multiplying electricity purchases by refineries provided by EIA's Petroleum Supply Annual, by CO_2 emission factors (in lbs/kWh) provided by eGRID at the NERC region level. The electricity purchases by refinery were based on total electricity

[8] U.S. Department of Energy, *2002 Manufacturing Energy Consumption Survey*, Energy Information Administration, 24 Jan 2005, http://www.eia.doe.gov/emeu/mecs/mecs2002.

[9] The North American Electricity Reliability Corporation (NERC) is the designated reliability organization that has a role in overseeing the reliability of the electric power grid. NERC regions reflect the organization structure of the regional reliability entities within with the owners of generation operate.

[10] Value added is a measure of the enhancement a company gives its product or service before offering the product to customers. It is used here as a surrogate for production. Value added is considered to be the best value measure available for comparing the relative economic importance of manufacturing among industries and geographic areas (source: U.S. Census Bureau, *Annual Survey of Manufactures (ASM): Statistics for Industry Groups and Industries*, 2005, http://www.census.gov/mcd/asm-as1.html). The data were normalized to account for fluctuation in industry size or production over time; dollars were adjusted for inflation using a gross domestic product price deflator.

purchased by each Petroleum Administration for Defense District (PADD), and adjusted to the refinery-level using the "equivalent distillation capacity" (EDC) of each refinery. This value was calculated because it more accurately reflects the electricity purchasing needs of a refinery than the pure atmospheric distillation capacity alone. The EDC of each refinery was multiplied by its utilization for the given year, as provided by EIA's *Petroleum Supply Annual*, in order to determine electricity purchases.[11, 12]

12.2.3 Key Assumptions and Completeness

Non-combustion emission estimates were limited to sources identified by the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Electricity and fossil fuel combustion emission estimates include only CO_2. Emissions of other GHGs (e.g., N_2O) were not estimated due to data and methodological constraints.[13]

12.3 Greenhouse Gas Emissions (1998, 2002)

GHG emissions for select years from the oil and gas sector are provided in Figure 12-3:.

Data for non-combustion GHG emissions were available for the years 1998 to 2005 from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005.*

Fuel combustion and purchased electricity emission estimates were provided only for two years, 1998 and 2002. As mentioned above, emissions from oil and gas production and petroleum refining were estimated separately; the data sources used were both available for the year 2002. However, the dataset used for the exploration and production sub-sector (*Economic Census of Mining*) provided fuel consumption for the years 1997 and 2002, while the dataset used for the petroleum refining sub-sector (MECS) was available for the years 1998 and 2002. To estimate emissions from fossil fuel combustion in oil and gas production, emission estimates were created for 1997 and then the rate of growth in industrial production from 1997 to 1998 published by the Federal Reserve Board was applied to these estimates.

Figure 12-3 shows GHG emission estimates for the oil and gas sector. Overall emissions from the oil and gas sector decreased 4% between 1998 and 2002. Emissions from fossil fuel combustion have fallen by 5% from 1998 to 2002, while emissions from purchased electricity have remained constant. Non-combustion emissions decreased by 2%, and oil & gas production[14] decreased 3% over the same timeframe. From 1998 to 2005, non-combustion emissions decreased by 9%, while oil & gas production decreased by 6% over that same timeframe.

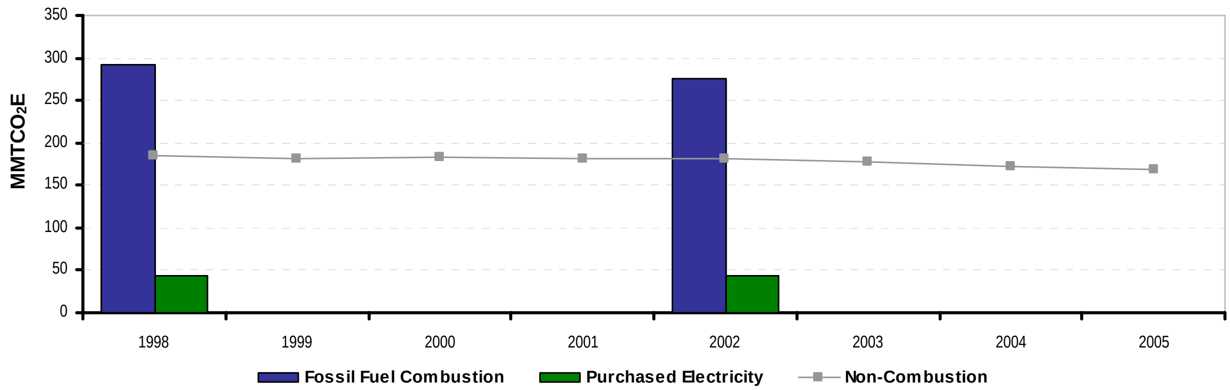
[11] U.S. Department of Energy, *Petroleum Supply Annual 1998*, Volume 1. Table 16. Energy Information Administration, June 1999, http://www.eia.doe.gov/pub/oil_gas/petroleum/data_publications/petroleum_supply_annual/psa_volume1/historical/1998/pdf/table_16.pdf.

[12] U.S. Department of Energy, *Petroleum Supply Annual 2002*, Volume 1. Table 16. Energy Information Administration, June 2003, http://www.eia.doe.gov/pub/oil_gas/petroleum/data_publications/petroleum_supply_annual/psa_volume1/historical/2002/pdf/table_16.pdf.

[13] These non-CO_2 emissions typically account for only a small percentage (approximately 2%) of a sector's GHG emissions from fossil fuel combustion.

[14] U.S. Department of Energy, *Production in Btu derived from Crude Oil Field Production (Barrels) and Natural Gas Gross Withdrawals and Production (MMcf)*; Energy Information Administration, 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.

Figure 12-3: Greenhouse Gas Emissions from the Oil and Gas Sector (MMTCO2E)



12.4 Other Sources of Greenhouse Gas Emission Estimates for this Sector

No reports containing complete GHG emissions estimates for the oil and gas sector were identified.

12.5 Sector Emission Reduction Commitments

The American Petroleum Institute (API) has instituted three programs for the industry.[15] The *API Climate Action Challenge* focuses on reducing, sequestering, offsetting or avoiding GHG emissions. API-member refining companies have committed to improve energy efficiency by 10% by 2012. The *API Climate R&D Challenge* focuses on research and development into improved technologies to reduce or sequester GHG emissions. The *API Climate Greenhouse Gas Estimation & Reporting Challenge* focuses on improving calculation and reporting techniques, and adopting a world-wide compendium for consistent estimation throughout the world.

12.6 Reporting Protocols

When calculating emissions, one of the following protocols is typically used by companies in the oil and gas sector:

- EPA's *Climate Leaders Greenhouse Gas Inventory Protocol*, which is an enhanced version of the WBCSD/WRI protocol mentioned below;
- DOE's *Technical Guidelines: Voluntary Reporting of Greenhouse Gases (1605(b)) Program*, which has a protocol on estimating methane emissions from natural gas operations in *Sector-Specific Issues and Reporting Methodologies: Supporting the General Guidelines for the Voluntary Reporting of Greenhouse Gases under Section 1605(b) of the Energy Policy Act of 1992.*[16] The protocol provides guidance specifically on methane emissions due to normal operations, routine maintenance and system upsets;
- The World Business Council for Sustainable Development (WBCSD) and the World Resource Institute's (WRI) *Greenhouse Gas Protocol*; and
- The *Petroleum Industry Guidelines for Reporting Greenhouse Gas Emissions* protocol developed by API and the International Association of Oil and Gas Producers, which provides sector specific guidance for oil and gas companies in reporting their emissions.

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[15] See http://www.climatevision.gov/sectors/oil_gas/index.html.

[16] See http://www.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/gg-v1-3-indust.pdf.

Table 12-2 presents a sample of oil and gas companies that have publicly reported their emissions.

Table 12-2: Sampling of Publicly-Reported GHG Emissions for Oil and Gas Companies

Company	Protocol	Emissions ($MMTCO_2E$)	Year Reported	Geographic Scope	Goal
ConocoPhilips	Mass balance and process flow	45.8	2006	North America	NI
ExxonMobil	WBCSD/WRI	64.4	2006	North America	NI
		101.5	2006	Annex B[a]	NI
Anadarko Petroleum	WBCSD/WRI	5.3	2006	Annex B[a]	NI
Chevron	WBCSD/WRI	33.1	2006	Annex B[a]	NI
Marathon	API	18.4	2006	Annex B[a]	NI
Halliburton	WBCSD/WRI	3.2*	2006	Global	NI
XTO Energy	API	3.7	2006	Global	NI

NI = Not Indicated
* Direct Emissions Only
[a] Countries included in Annex B of the Kyoto Protocol

13. Plastic and Rubber Products

In the U.S., the plastic and rubber products sector is comprised of more than 16,000 companies producing goods that range from plastic bottles to rubber hoses

For the purposes of this analysis, the plastic and rubber products sector (NAICS code 326: Plastic and Rubber Product Manufacturing) is defined as creating goods by processing plastic and raw rubber[2] into industrial or consumer goods that are generally made of just one material (i.e., rubber or plastic) with the major exception of tires (which is included in this sector). Where a product uses more than one material for their manufacture (e.g., footwear or furniture), those activities are not included, as the core technologies are diverse and involve multiple materials. Given this definition, there are two main sub-sectors studied in this analysis.

Source	2002 Emissions ($MMTCO_2E$)
Fossil Fuel Combustion	8
Non-Combustion	
Purchased Electricity	36
Total	44
Percent of U.S. Industrial Emissions[1]	*2%*

The first is the plastic manufacturing sub-sector (NAICS code 3261: Plastic Product Manufacturing), which is primarily engaged in processing new or spent (i.e., recycled) plastic resins into intermediate or final products by means of compression, extrusion, injection, or blow molding, or else by casting. The second sub-sector analyzed was the rubber manufacturing sub-sector (NAICS code 3262: Rubber Product Manufacturing), which is comprised of companies that mainly process natural and synthetic (or reclaimed) rubber materials into intermediate or final products using processes like vulcanizing, cementing, molding, extruding, and lathe-cutting. (This is the sub-sector under which tire manufacturing and other related composite products fall.)

13.1 Sources of Greenhouse Gas Emissions

Direct GHG emissions from the plastic and rubber product manufacturing sector result from on-site fossil fuel combustion. Natural gas is the primary fuel used for creating plastic and rubber products. Electricity (either generated on-site or purchased) may be used to power equipment that operates injection or compression molding machines or other processes.

Manufacturing products from either rubber (whether natural or synthetic) or plastic (whether new or recycled) requires electricity for both the manufacturing and handling equipment, as well as for various processes like heating, drying, cooling, molding, sheeting, forming, and other common processing techniques. One process that is changing the energy use in these factories is reaction injection molding, which requires little heating and, therefore, uses considerably less energy. Still, the on-site energy use by this sector represents a direct source of GHG emissions.

Indirect sources of GHG emissions in this sector result from the purchased electricity needed to supplement any on-site combustion of fossil fuels.

13.2 Summary of Emissions (2002)

This section presents a summary of emissions estimates from the plastic and rubber products sector for the year 2002. The methodologies and data sources used to calculate these emissions estimates, as well as the assumptions and limitations surrounding the estimates, are also described.

[1] Total 2002 industrial emissions are 2,047 $MMTCO_2E$ as reported in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*. See U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*, 15 Apr 2007, http://www.epa.gov/climatechange/emissions/usinventoryreport.html, Table 2-16. Note that for the purpose of this report, a blank cell does not necessarily indicate zero emissions; rather, it indicates that the analysis did not address that emission source, if applicable; see "Summary of Emissions (2002)" for additional information.

[2] Plastic and rubber are combined in the same NAICS code, because plastic is increasingly being used as a substitute for rubber.

13.2.1 Estimates of Greenhouse Gas Emissions (2002)

GHG emissions from the plastic and rubber products sector were estimated to be 44 MMTCO$_2$E in 2002 (as seen in Table 13-1).

Table 13-1: GHG Emissions from the Plastic and Rubber Product Sector (MMTCO$_2$E)

Source	CO_2	CH_4	N_2O	HFCs	Total
Fossil Fuel Combustion[a]	8				8
Non-Combustion					
Purchased Electricity[b]	36				36
Total	44				44

[a] Emissions calculated based on DOE's *2002 Manufacturing Energy Consumption Survey* and EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005.*

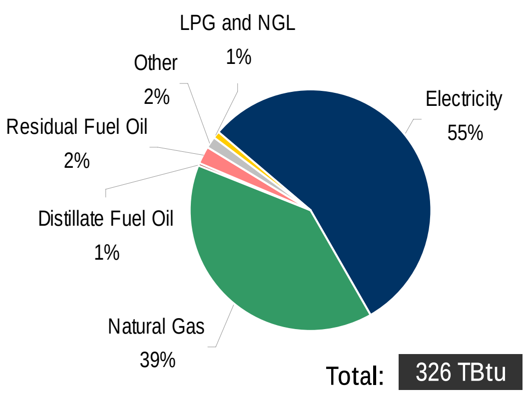
[b] Emissions calculated based on data from DOE's *2002 Manufacturing Energy Consumption Survey* and EPA's *Emissions and Generation Resource Integrated Database* (eGRID).

Note that for the purpose of this report, a blank cell does not necessarily indicate zero emissions; rather, it indicates that the analysis did not address that emission source, if applicable; see "Summary of Emissions (2002)" for additional information.

The overall methodology for estimating GHG emissions in this report is described in Section 1.2; more detail on the methodology used to estimate emissions from the plastic and rubber products sector can be found in Section 13.2.2.

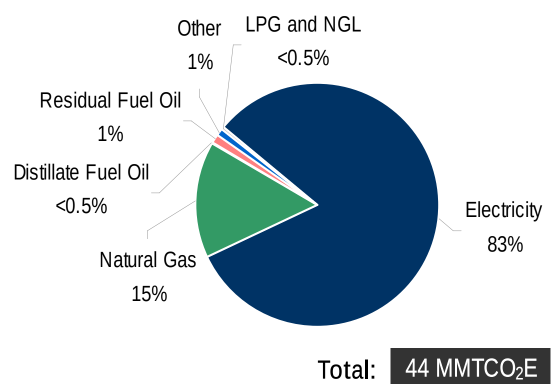
The distribution of energy consumption in this sector, by fuel type (including both on-site fossil fuel combustion and purchased electricity), is illustrated in Figure 13-1. For comparison, CO_2 emissions associated with fuel consumption are shown in Figure 13-2.

Figure 13-1: 2002 Energy Consumption in the Plastic and Rubber Products Manufacturing Sector by Fuel Type (TBtu)[a]



Source: U.S. DOE, *2002 Manufacturing Energy Consumption Survey*.
[a] Excludes coal because data are withheld by MECS.
Note that composition of "other" fuel category varies among sectors.

Figure 13-2: 2002 CO_2 Emissions from Energy Consumption in the Plastic and Rubber Products Sector, by Fuel Type (MMTCO$_2$E)[a]



Source: Estimate based on methodology in Section 13.2.2.
[a] Excludes coal because data are withheld by MECS.
[b] Fuel mix at utilities was taken into consideration in this calculation, per methodology described in Section 13.2.2.

13.2.2 Methodology and Data Sources

Fossil Fuel Combustion

The methodology developed for this report to estimate fossil fuel combustion emissions from the plastic and rubber products sector utilized the U.S. Department of Energy's Energy Information Administration's (EIA) *Manufacturing Energy Consumption Survey* [3] (MECS) estimates of fuel consumption for the sector. Fuel consumption estimates were multiplied by appropriate, fuel-specific emission factors to convert the consumption into CO_2 emitted. The emission factors for the fossil fuels used in the plastic and rubber product sector were taken from data contained in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.[4] The "other" fuel type includes all other types of fuel that MECS respondents indicated could have been consumed and were not otherwise listed.

Non-Combustion Activities

Non-combustion emissions would include GHG emissions that occur from activities within the sector that were not related to on-site fossil fuel consumption or purchased energy. Non-combustion emissions were not specifically identified for this sector by the Intergovernmental Panel on Climate Change's (IPCC) *2006 IPCC Guidelines for National Greenhouse Gas Inventories*[5] and, hence, were not included in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005* or this report.

Purchased Electricity

Electricity emissions were estimated by multiplying national- or regional-level electricity purchases (in kilowatt-hours, or kWh) provided by MECS[6] by CO_2 emission factor (in lbs/kWh) provided by eGRID[7] at the North American Electricity Reliability Corporation (NERC) region level.[8] Sector electricity purchases were adjusted by a loss factor to reflect losses incurred in the transmission and distribution of electricity. The geographic distribution of electricity purchases were assumed to be the same as those of the industrial class. This customer class distribution was based on data collected by EIA on sales, by customer class, on all electricity providers (from EIA Form 861).[9]

13.2.3 Key Assumptions and Completeness

Electricity and fossil fuel combustion emission estimates include only CO_2. Emissions of other greenhouse gases such as CH_4 and N_2O that may result from combustion were not estimated.[10] Emission factors for purchased electricity provided by eGRID are for 2004, which may include different fuel mixes for electricity generation than those of the 2002 inventory year.

13.3 Greenhouse Gas Emissions (1998, 2002)

GHG emissions for select years from purchased electricity and fossil fuel combustion consist of two data points based on data availability from MECS for the years 1998 and 2002.[11] Overall process-related emissions

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[3] U.S. Department of Energy, *2002 Manufacturing Energy Consumption Survey*, Energy Information Administration, 24 Jan 2005, http://www.eia.doe.gov/emeu/mecs/mecs2002.

[4] U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.

[5] Intergovernmental Panel on Climate Change, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, 2007, http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.htm.

[6] U.S. Department of Energy, *2002 Manufacturing Energy Consumption Survey.*

[7] U.S. Environmental Protection Agency, *Emissions and Generation Resource Integrated Database (eGRID) v2.1*, May 2007, http://www.epa.gov/cleanenergy/egrid/index.htm.

[8] The National Reliability Electricity Corporation (NERC) is the designated reliability organization that has a role in overseeing the reliability of the electric power grid. NERC regions reflect the organization structure of the regional reliability entities within with the owners of generation operate.

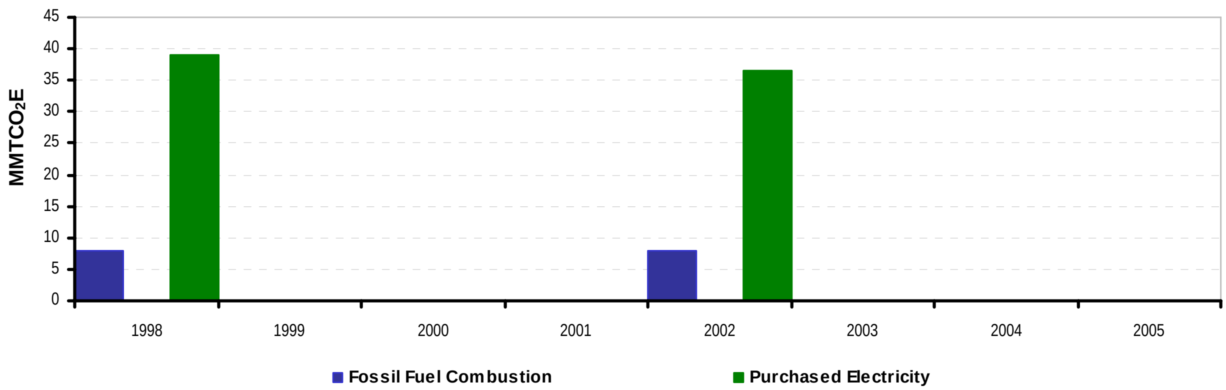
[9] U.S. Department of Energy, *Annual Electric Power Industry Report: Form EIA-861*, Energy Information Administration, http://www.eia.doe.gov/cneaf/electricity/page/eia861.html.

[10] These non-CO_2 emissions typically account for only a small percentage (approximately 2%) of a sector's GHG emissions from fossil fuel combustion.

[11] Note: in the following discussion, the percentages shown are calculated from the raw data. However, rounded data values are given in the text at an appropriate level of significance; therefore, the reader may not be able to reproduce the calculation.

have decreased by approximately 6% over the time-series, from 47.2 to 44.5 MMTCO_2E. Over the same period, value added[12] in plastic and rubber products remained relatively unchanged – increasing 0.2%.

Figure 13-3: Greenhouse Gas Emissions for the Plastic and Rubber Products Sector



13.4 Other Sources of Greenhouse Gas Emission Estimates for this Sector

No reports containing complete GHG emissions estimates for the plastic and rubber products sector were identified.

13.5 Sector Emission Reduction Commitments

No sector commitments to reducing GHG emissions were identified.

13.6 Reporting Protocols

When calculating emissions, one of the following protocols may be used by companies in the plastic and rubber products sector:

- EPA's *Climate Leaders Greenhouse Gas Inventory Protocol*, which is an enhanced version of the WBCSD/WRI protocol mentioned below;
- DOE's *Technical Guidelines: Voluntary Reporting of Greenhouse Gases (1605(b)) Program*; and
- The World Business Council for Sustainable Development (WBCSD) and the World Resource Institute's (WRI) *Greenhouse Gas Protocol*.

No public reports of GHG emissions from companies in the plastic and rubber products sector were identified.

[12] Value added is a measure of the enhancement a company gives its product or service before offering the product to customers. It is used here as a surrogate for production. Value added is considered to be the best value measure available for comparing the relative economic importance of manufacturing among industries and geographic areas (source: U.S. Census Bureau, *Annual Survey of Manufactures (ASM): Statistics for Industry Groups and Industries*, 2005, http://www.census.gov/mcd/asm-as1.html). The data were normalized to account for fluctuation in industry size or production over time; dollars were adjusted for inflation using a gross domestic product price deflator.

14. Semiconductors

Semiconductors form the heart of many modern technologies. A semiconductor is a solid that has electrical conductivity between that of a conductor and that of an insulator. Semiconductors operate many electronic devices ranging from cell phones to computers. Other examples of semiconductor products include microprocessors, memory chips, integrated circuits, diodes, transistors, and solar cells.

The process of semiconductor manufacturing (NAICS code 334413: Semiconductor and Related Device Manufacturing) produces semiconductors and related solid state devices.

Source	2002 Emissions ($MMTCO_2E$)
Fossil Fuel Combustion	1
Non-Combustion	4
Purchased Electricity	8
Total	**13**
Percent of U.S. Industrial Emissions[1]	*1%*

14.1 Sources of Greenhouse Gas Emissions

The direct sources of GHG emissions due to semiconductor manufacturing result from industrial processes (i.e., non-combustion activities) and on-site fossil fuel combustion. The indirect sources of GHG emissions due to semiconductor manufacturing result from the purchased electricity consumed in manufacturing operations.

As described in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*,[2] direct non-combustion emissions from semiconductor manufacturing result from the use of a variety of high global warming potential (GWP) gases to etch patterns onto dielectric films to provide pathways for conducting material to connect circuitry, as well as to rapidly clean chemical vapor deposition (CVD) tool chambers. The perfluorocarbons (PFCs) used in these processes (CF_4, C_2F_6, and C_3F_8, as well as HFC-23, SF_6, and NF_3) are vital for the development of significantly more complex semiconductor products.[3] The materials removed during the production process and cleaning of CVD chambers, as well as the undissociated gases, are emitted into the atmosphere unless abatement systems are employed. Under normal operating conditions, anywhere from 10% to 80% of these gases are emitted.[3]

The manufacture of semiconductors requires energy for both the manufacturing and the semiconductor handling equipment, as well as for the heating, ventilation, and air conditioning equipment required to maintain sanitary production conditions. This energy use results in direct emissions of CO_2 from fossil fuel combustion and indirect CO_2 emissions from purchased electricity.

14.2 Summary of Emissions (2002)

This section presents a summary of the GHG emission estimates for the semiconductor sector as estimated for the year 2002. The methodologies and data sources used to calculate these emission estimates, as well as the assumptions and limitations surrounding the estimates, are also described.

14.2.1 Estimates of Greenhouse Gas Emissions (2002)

The total GHG emissions from the semiconductor sector are estimated to be 13 $MMTCO_2E$ in 2002 (as seen in Table 14-1).

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[1] Total 2002 industrial emissions are 2,047 $MMTCO_2E$ as reported in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*. See U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*, 15 Apr 2007, http://www.epa.gov/climatechange/emissions/usinventoryreport.html, Table 2-16.

[2] U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.

[3] U.S. Environmental Protection Agency, "PFC Reduction/Climate Partnership for the Semiconductor Industry," 15 Mar 2007, http://www.epa.gov/semiconductor-pfc/index.html.

Table 14-1: 2002 GHG Emissions from the Semiconductor Sector ($MMTCO_2E$)

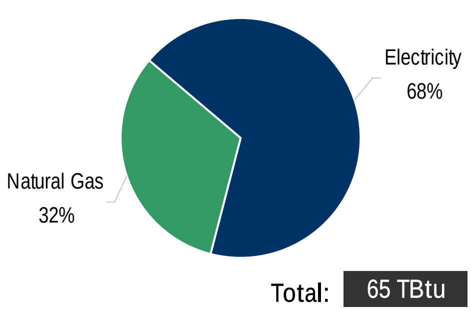
Source	CO_2	HFCs	PFCs	SF_6	Total
Fossil Fuel Combustion[a]	1				1
Non-Combustion[b]		<1	3	1	4
Semiconductor Manufacturing		*<1*	*3*	*1*	*4*
Purchased Electricity[c]	8				8
Total	9	<1	3	1	13

[a] Emissions calculated based on DOE's *2002 Manufacturing Energy Consumption Survey* and EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.
[b] EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.
[c] Emissions calculated based on DOE's *2002 Manufacturing Energy Consumption Survey* and EPA's *Emissions and Generation Resource Integrated Database* (eGRID).
Note that for the purpose of this report, a blank cell does not necessarily indicate zero emissions; rather, it indicates that the analysis did not address that emission source, if applicable; see "Summary of Emissions (2002)" for additional information.

The overall methodology for estimating the GHG emissions for this report was described in Section 1.2; more detail on the methodology used to estimate emissions from the semiconductor sector can be found in Section 14.2.2.

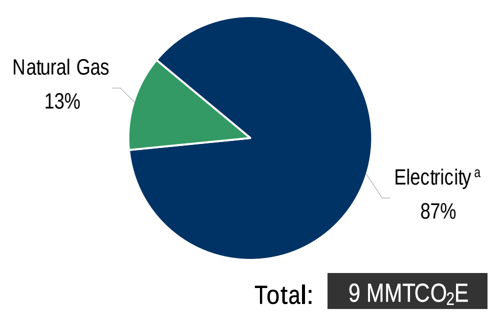
The distribution of energy consumption in this sector, by fuel type (including both on-site fossil fuel combustion and purchased electricity), is illustrated in Figure 14-1. For comparison, CO_2 emissions associated with fuel consumption are shown in Figure 14-2.

Figure 14-1: 2002 Energy Consumption in the Semiconductor Sector, by Fuel Type (TBtu)



Source: DOE, *2002 Manufacturing Energy Consumption Survey*.
Note: TBtu stands for trillion British thermal units.

Figure 14-2: 2002 CO_2 Emissions from Energy Consumption in the Semiconductor Sector, by Fuel Type ($MMTCO_2E$)



Source: Estimate based on methodology in Section 14.2.2.
[a] Fuel mix at utilities was taken into consideration in this calculation, per methodology described in Section 14.2.2.

14.2.2 Methodology and Data Sources

Fossil Fuel Combustion

Fossil fuel combustion emissions from the semiconductor sector were derived from the U.S. Department of Energy's (DOE) Energy Information Administration's (EIA) *Manufacturing Energy Consumption Survey* (MECS)[4]

[4] U.S. Department of Energy, *2002 Manufacturing Energy Consumption Survey*, Energy Information Administration, 24 Jan 2005, http://www.eia.doe.gov/emeu/mecs/mecs2002.

estimates of fuel consumption for this sector. Those fuel consumption estimates were then multiplied by the appropriate, fuel-specific emission factors to convert the consumption into CO_2 emitted.

The emission factors for the fossil fuels used in the semiconductor manufacturing industry were taken from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.

Non-Combustion Activities

Non-combustion emissions of PFCs from semiconductor manufacturing were those reported for the Semiconductor Manufacturing source category within the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.[5] These estimates include the semiconductor manufacturing emissions identified by the Intergovernmental Panel on Climate Change's (IPCC) *2006 IPCC Guidelines for National Greenhouse Gas Inventories*.[6]

Purchased Electricity

Electricity emissions were estimated by mapping national electricity purchases (in kilowatt-hours, or kWh) provided by MECS to North American Electricity Reliability Corporation (NERC) regions,[7] then applying NERC regional utility CO_2 emission factor (in lbs/kWh) provided by eGRID. Sector electricity purchases were adjusted by a loss factor to reflect losses incurred in the transmission and distribution of electricity.

Since electricity purchase data were not available at the NERC regional level, distribution of the sector's value added was used to distribute the sector's national electricity purchases to the state-level, then state data were rolled up to the NERC regions. Where a state lay in two or more NERC regions, electricity purchases were distributed to the appropriate NERC region using sales data for the industrial customer class from EIA Report 861. This approach assumes that the electricity-intensity of production activities are correlated with the value added. Methods for estimating CO_2 emissions from electricity are described in more detail in Appendix A.3.

14.2.3 Key Assumptions and Completeness

Non-combustion emission estimates were limited to sources identified by the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* and provided in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*. Electricity and fossil fuel combustion emission estimates include only CO_2. Emissions of other GHGs (e.g., CH_4 and N_2O) that may result from combustion were not estimated.[8] Emission factors for purchased electricity provided by eGRID are for 2004, which may include different fuel mixes for electricity generation than those of the 2002 inventory year.

14.3 Greenhouse Gas Emissions (1998, 2002)

GHG emissions for select years from the semiconductor sector are shown in Figure 14-3.[9]

Annual estimates of non-combustion GHG emissions from semiconductor manufacturing were available from the annual *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*, which show that such emissions have decreased by 39% between 1998 and 2005, from 7.1 to 4.3 $MMTCO_2E$.

However, the data for GHG emissions from fossil fuel combustion and purchased electricity were available only for two data points, 1998 and 2002, based on frequency of MECS reports. During this period, emissions from fossil fuel combustion increased by 5%, and emissions from purchased electricity declined by 6%, from 8.0 to 7.5 $MMTCO_2E$.

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[5] U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005.*

[6] Intergovernmental Panel on Climate Change, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, 2007, http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.htm.

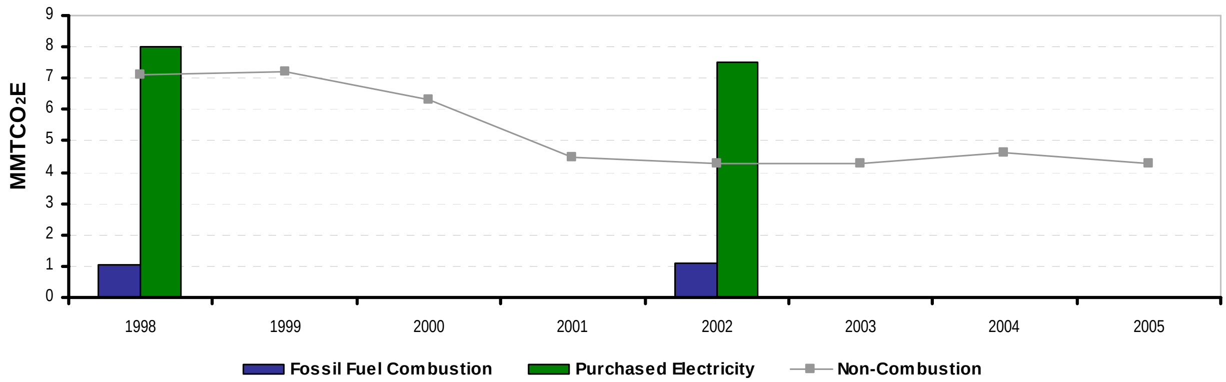
[7] The North American Electricity Reliability Corporation (NERC) is the designated reliability organization that has a role in overseeing the reliability of the electric power grid. NERC regions reflect the organization structure of the regional reliability entities within with the owners of generation operate.

[8] These non-CO_2 emissions typically account for only a small percentage (approximately 2%) of a sector's GHG emissions from fossil fuel combustion.

[9] Note: in the following discussion, the percentages shown are calculated from the raw data. However, rounded data values are given in the text at an appropriate level of significance; therefore, the reader may not be able to reproduce the calculation.

In aggregate, emissions from the semiconductor sector decreased 20% between 1998 and 2002. Over the same period, value added[10] in semiconductor manufacturing decreased 31%.

Figure 14-3: Greenhouse Gas Emissions for the Semiconductor Sector



14.4 Other Sources of Greenhouse Gas Emission Estimates for this Sector

No reports containing complete GHG emissions estimates for the semiconductor sector were identified.

14.5 Sector Emission Reduction Commitments

The members of the PFC Reduction/Climate Partnership for the Semiconductor Industry have committed to reduce their absolute PFC emissions to 10% below 1995 levels by 2010.[11]

14.6 Reporting Protocols

When calculating emissions, one of the following protocols is typically used by companies in the semiconductor sector:

- EPA's *Climate Leaders Greenhouse Gas Inventory Protocol*, which is an enhanced version of the WBCSD/WRI protocol mentioned below;
- DOE's *Technical Guidelines: Voluntary Reporting of Greenhouse Gases (1605(b)) Program*;
- The World Business Council for Sustainable Development (WBCSD) and the World Resource Institute's (WRI) *Greenhouse Gas Protocol*; and
- *Intergovernmental Panel on Climate Change Good Practice Inventory Tier 2 Methods for the Semiconductor Industry* for PFC reduction reporting.

[10] Value added is a measure of the enhancement a company gives its product or service before offering the product to customers. It is used here as a surrogate for production. Value added is considered to be the best value measure available for comparing the relative economic importance of manufacturing among industries and geographic areas (source: U.S. Census Bureau, *Annual Survey of Manufactures (ASM): Statistics for Industry Groups and Industries*, 2005, http://www.census.gov/mcd/asm-as1.html). The data were normalized to account for fluctuation in industry size or production over time; dollars were adjusted for inflation using a gross domestic product price deflator.

[11] See http://www.climatevision.gov/sectors/semiconductors/index.html.

Table 14-2 presents a sample of companies that have publicly reported their GHG emissions.

Table 14-2: Sampling of Publicly-Reported GHG Emissions for Semiconductor Companies

Company	Protocol	Emissions ($MMTCO_2E$)	Year reported	Geographic Scope	Goal
National Semiconductor	WBCSD/WRI	0.33[12]	2006	Annex B[a]	10% PFC (1995 baseline)[b]

[a] Countries included in Annex B of the Kyoto Protocol
[b] National Semiconductor Corp.

[12] National Semiconductor Corporation, "CDP 5 Companies and Response Status: Carbon Disclosure Project (CDP5) Greenhouse Gas Emissions Questionnaire," 12 Nov 2007, http://www.cdproject.net/responses/National_Semiconductor_Corporation_Corporate_GHG_Emissions_Response_CDP5_2007/public.htm.

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15. Textiles

Textiles are materials consisting of synthetic or natural fibers that are sewn together to produce apparel (e.g., shirts, pants) and non-apparel items—such as sheets or blankets. For the purposes of this report, the textile sector is defined by NAICS codes 313, 314, and 315, which consist of textile mills, textile product mills, and apparel manufacturers, respectively. These sub-sectors form products by transforming basic natural or synthetic fibers into a manufactured good, but do generate the synthetic fibers.

Source	2002 Emissions ($MMTCO_2E$)
Fossil Fuel Combustion	10
Non-Combustion	
Purchased Electricity	21
Total	32
Percent of U.S. Industrial Emissions[1]	*2%*

Textile mills transform a basic fiber (natural or synthetic) into a product, such as yarn or fabric that is further manufactured into usable items, such as apparel, sheets, towels, and textile bags for individual or industrial consumption. Further manufacturing may occur in the same establishment or it may be performed at a separate establishment such as a textile product mill. The main processes in this subsector include preparation and spinning of fiber, knitting or weaving of fabric, and the finishing of the textile.

Textile product mills make textile products other than apparels, which are made at an apparel manufacturer. Generally, textile product mills cut and sew textiles to produce non-apparel items such as towels.

Apparel manufacturers make ready-to-wear custom apparel from the textile usually through a cut and sew process or by first knitting the fabric and then cutting and sewing the fabric into a garment. Only when knitting is combined with garment production is the process classified as apparel manufacturing; knitting fabric for later manufacturing into apparel is classified under textile mills.

15.1 Sources of Greenhouse Gas Emissions

GHG emissions from the textile sector result from on-site fossil fuel combustion and, indirectly, through the purchase of electricity. The primary fossil fuel consumed is natural gas, which is largely used to heat boilers that provide steam and or dry fabric. Manufacturing textiles (both at the mill level or the factory level) requires electricity for both the manufacturing and handling equipment, as well as for various processes like heating, drying, cooling, finishing, dying, and other common processing techniques. Processes that consume the most energy in this sector are drying and application of various finishes.

15.2 Summary of Emissions (2002)

This section presents a summary of the GHG emission estimates for the textile sector for the year 2002. The methodologies and data sources used to calculate these emission estimates, as well as the assumptions and limitations surrounding the estimates, are also described.

15.2.1 Estimates of Greenhouse Gas Emissions (2002)

The total GHG emissions from the textiles sector are estimated to be 32 $MMTCO_2E$ in 2002 (as seen in Table 15-1).

---

[1] Total 2002 industrial emissions are 2,047 $MMTCO_2E$ as reported in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*. See U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*, 15 Apr 2007, http://www.epa.gov/climatechange/emissions/usinventoryreport.html, Table 2-16. Note that for the purpose of this report, a blank cell does not necessarily indicate zero emissions; rather, it indicates that the analysis did not address that emission source, if applicable; see "Summary of Emissions (2002)" for additional information. Totals may not sum due to independent rounding.

Table 15-1: 2002 GHG Emissions from the Textile Sector ($MMTCO_2E$)

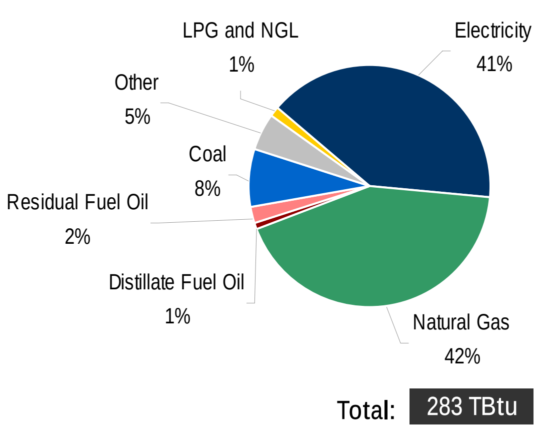
Source	CO_2	CH_4	N_2O	HFCs	Total
Fossil Fuel Combustion[a]	10				10
Non-Combustion					
Purchased Electricity[b]	21				21
Total	32				32

[a] Emissions calculated based on DOE's *2002 Manufacturing Energy Consumption Survey* and EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.
[b] Emissions calculated based on DOE's *2002 Manufacturing Energy Consumption Survey* and EPA's *Emissions and Generation Resource Integrated Database* (eGRID).
Note that for the purpose of this report, a blank cell does not necessarily indicate zero emissions; rather, it indicates that the analysis did not address that emission source, if applicable; see "Summary of Emissions (2002)" for additional information. Totals may not sum due to independent rounding.

The overall methodology for estimating GHG emissions in this report is described in Section 1.2; more detail on the methodology used to estimate emissions from the textile sector can be found in Section 15.2.2.

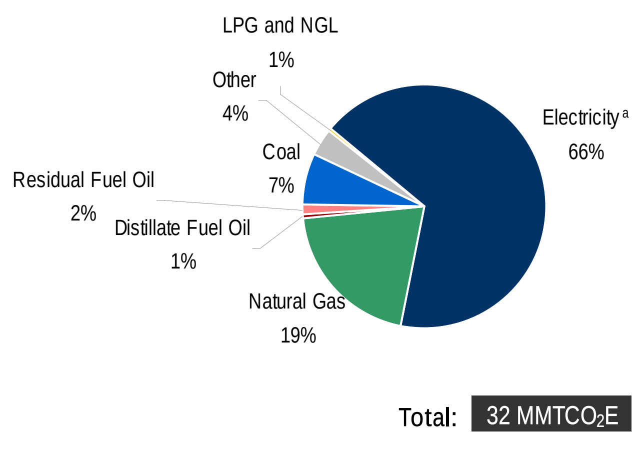
The distribution of energy consumption in this sector, by fuel type (including both on-site fossil fuel combustion and purchased electricity), is illustrated in Figure 15-1. For comparison, CO_2 emissions associated with fuel consumption are shown in Figure 15-2.

Figure 15-1: 2002 Energy Consumption in the Textiles Sector by Fuel Type (TBtu)



Source: DOE, *2002 Manufacturing Energy Consumption Survey.*
Note that composition of "other" fuel category varies among sectors.
Note: TBtu stands for trillion British thermal units.

Figure 15-2: 2002 CO_2 Emissions from Energy Consumption in the Textiles Sector, by Fuel Type ($MMTCO_2E$)



Source: Estimate based on methodology in Section 15.2.2.
[a] Fuel mix at utilities was taken into consideration in this calculation, per methodology described in Section 15.2.2.

15.2.2 Methodology and Data Sources

Fossil Fuel Combustion

The fossil fuel combustion estimate for textile manufacturing is derived using the U.S. Department of Energy's (DOE) Energy Information Administration's (EIA) *Manufacturing Energy Consumption Survey* [2] (MECS) estimates of fuel consumption for textile manufacturing. Fuel consumption estimates were multiplied by appropriate, fuel-specific emission factors to convert the consumption into CO_2 emitted. The emission factors for the fossil fuels used in the textile sector were taken from data contained in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005.*[3] "Other" CO_2 emissions were calculated by applying an emission factor for "miscellaneous products" based on carbon contents from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005.*

Non-Combustion Activities

Non-combustion emissions would include GHG emissions that occur from activities within the sector that are not related to on-site fossil fuel consumption or purchased energy. Non-combustion emissions were not specifically identified for this sector by the Intergovernmental Panel on Climate Change's (IPCC) *2006 IPCC Guidelines for National Greenhouse Gas Inventories*[4] and, hence, were not included in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005* or this report.

Purchased Electricity

Electricity emissions were estimated by mapping national electricity purchases (in kilowatt-hours, or kWh) provided by MECS to North American Electricity Reliability Corporation (NERC) regions,[5] then applying NERC regional utility CO_2 emission factor (in lbs/kWh) provided by eGRID. Sector electricity purchases were adjusted by a loss factor to reflect losses incurred in the transmission and distribution of electricity.

Since electricity purchase data were not available at the NERC regional level, distribution of the sector's value added was used to distribute the sector's national electricity purchases to the state-level, then state data were rolled up to the NERC regions. Where a state lay in two or more NERC regions, electricity purchases were distributed to the appropriate NERC region using sales data for the industrial customer class from EIA Report 861. This approach assumes that the electricity-intensity of production activities are correlated with the value added. Methods for estimating CO_2 emissions from electricity are described in more detail in Appendix A.3.

15.2.3 Key Assumptions and Completeness

Electricity and fossil fuel combustion emission estimates include only CO_2. Emissions of other greenhouse gases such as CH_4 and N_2O that may result from combustion were not estimated.[6] Emission factors for purchased electricity provided by eGRID are for 2004, which may include different fuel mixes for electricity generation than those of the 2002 inventory year.

15.3 Greenhouse Gas Emissions (1998, 2002)

GHG emissions for select years from the textiles sector are shown in Figure 15-3.[7]

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[2] U.S. Department of Energy, *2002 Manufacturing Energy Consumption Survey*, Energy Information Administration, 24 Jan 2005, http://www.eia.doe.gov/emeu/mecs/mecs2002.

[3] U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005.*

[4] Intergovernmental Panel on Climate Change, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, 2007, http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.htm.

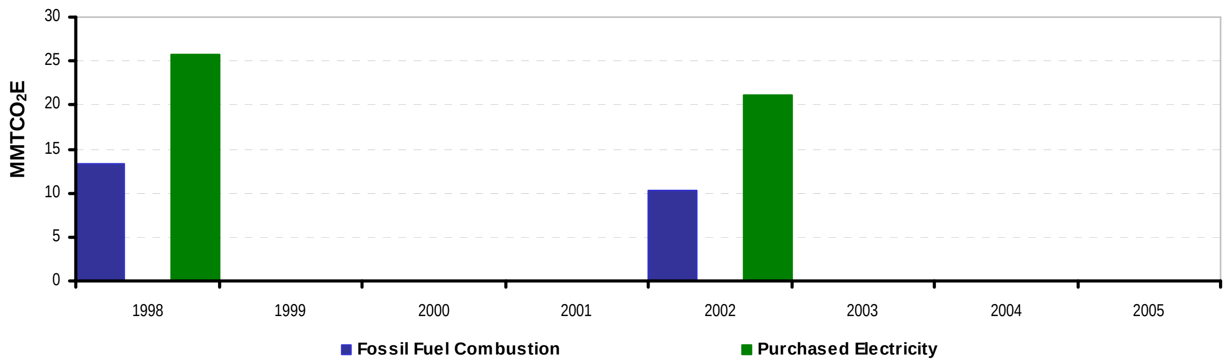
[5] The North American Electricity Reliability Corporation (NERC) is the designated reliability organization that has a role in overseeing the reliability of the electric power grid. NERC regions reflect the organization structure of the regional reliability entities within with the owners of generation operate.

[6] These non-CO_2 emissions typically account for only a small percentage (approximately 2%) of a sector's GHG emissions from fossil fuel combustion.

[7] Note: in the following discussion, the percentages shown are calculated from the raw data. However, rounded data values are given in the text at an appropriate level of significance; therefore, the reader may not be able to reproduce the calculation.

GHG emissions from purchased electricity and fossil fuel combustion consist of two data points based on data availability from MECS for the years 1998 and 2002. These process-related emissions have decreased by 19% over the time-series, from 39.1 to 31.5 MMTCO$_2$E in 1998 and 2002, respectively. Over the same period, value added[8] in textiles manufacturing decreased 29%.

Figure 15-3: Greenhouse Gas Emissions for the Textile Sector



15.4 Other Sources of Greenhouse Gas Emission Estimates for this Sector

No reports containing complete GHG emissions estimates for the textiles sector were identified.

15.5 Sector Emission Reduction Commitments

No sector commitments to reducing GHG emissions were identified.

15.6 Reporting Protocols

When calculating emissions, one of the following three protocols may be used by companies in the textile sector:

- EPA's *Climate Leaders Greenhouse Gas Inventory Protocol*, which is an enhanced version of the WBCSD/WRI protocol mentioned below;
- DOE's *Technical Guidelines: Voluntary Reporting of Greenhouse Gases (1605(b)) Program*; and
- The World Business Council for Sustainable Development (WBCSD) and the World Resource Institute's (WRI) *Greenhouse Gas Protocol.*

No public reports of GHG emissions from companies in the textile sector were identified.

[8] Value added is a measure of the enhancement a company gives its product or service before offering the product to customers. It is used here as a surrogate for production. Value added is considered to be the best value measure available for comparing the relative economic importance of manufacturing among industries and geographic areas (source: U.S. Census Bureau, *Annual Survey of Manufactures (ASM): Statistics for Industry Groups and Industries*, 2005, http://www.census.gov/mcd/asm-as1.html). The data were normalized to account for fluctuation in industry size or production over time; dollars were adjusted for inflation using a gross domestic product price deflator.

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Appendices

The following appendices contain additional information on data sources and factors used to calculate emission estimates presented in the main body of this report.

A.1 Key Data Sources

Data used to estimate GHG emissions from the 14 sectors included in this report were taken from a variety of sources. The following section describes in more detail some of the key data sources used, placed into categories by type of data provided (energy consumption, emission estimates, economic data).

Energy Consumption

U.S. Department of Energy, Energy Information Administration, 2005. *2002 Manufacturing Energy Consumption Survey*

The *Manufacturing Energy Consumption Survey* (MECS) is produced every four years by DOE/EIA. The manufacturing sector is defined by EIA as consisting of all manufacturing establishments in all 50 U.S. states and the District of Columbia. Data from the survey are based on a nationally representative sample of manufacturing establishments, which supply the information through mailed questionnaires. 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.[1] 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" category varies from sector to sector. More detail is provided in individual sector chapters.

Available online at: http://www.eia.doe.gov/emeu/mecs/contents.html

Emission Estimates

U.S. Environmental Protection Agency, 2007. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*

The *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005* is the official GHG emissions inventory submission of the United States produced by EPA in order to comply with commitments under the United Nations Framework Convention on Climate Change (UNFCCC). It is prepared according to the official reporting guidelines established by UNFCCC. The inventory contains estimates of national anthropogenic GHG emissions and sinks for source categories including Energy; Industrial Processes; Agriculture; Land Use, Land-Use Change, and Forestry; and Waste. The inventory describes the processes from these source categories that result in GHG emissions. Data for this report taken from the inventory were largely related to non-combustion estimates and information on these processes.

Available online at: http://www.epa.gov/climatechange/emissions/usinventoryreport.html

U.S. Department of Energy, Energy Information Administration, 2006. *Energy-Related Carbon Dioxide Emissions in U.S. Manufacturing*

EIA's *Energy-Related Carbon Dioxide Emissions in U.S. Manufacturing* estimates energy-related CO_2 emissions from manufacturing in 2002 based upon energy consumption statistics from MECS. The report focuses on 23 of the 473 six-digit North American Industry Classification System (NAICS) industries. The report provides some additional description regarding petroleum refineries, natural gas and electricity in the chemical manufacturing sector, iron and steel mills, nonmetallic mineral products, and trends in carbon dioxide intensity for some but not all sectors from 1991 to 2002.

Available online at: http://www.eia.doe.gov/oiaf/1605/ggrpt/pdf/industry_mecs.pdf

U. S Environmental Protection Agency, *Emissions and Generation Resource Integrated Database*

The Emissions & Generation Resource Integrated Database (eGRID) is a comprehensive inventory of environmental attributes of the electric power system developed and maintained by EPA. It is based on the available plant-

[1] U.S. Department of Energy, "2002 Manufacturing Energy Consumption Survey," Energy Information Administration, 24 Jan 2005 http://www.eia.doe.gov/emeu/mecs/mecs2002.

specific data for all U.S. electricity generating plants that provide power to the electric grid and report data to the U.S. government. eGRID contains generation data and air emissions data for nitrogen oxides, sulfur dioxide, CO_2, and mercury. eGRID provides estimates of CO_2 emissions factors (in lbs per kWh of generation). These factors are provided at the national, NERC[2] regional, NERC sub-regional, power control area, and state level.

Available online at: http://www.epa.gov/cleanenergy/egrid

The Global Reporting Initiative

The Global Reporting Initiative (GRI) is host to company-specific GHG emission information. Many companies report their GHG emissions to the GRI through a Corporate Sustainability Report. The reports require that the companies state what protocol they use when estimating their emissions. Each company's report is used to gauge organizational performance, demonstrate commitment, and compare performance over time. The goal of GRI is to stimulate the demand for sustainability information, which they hope will benefit the reporting organizations and the consumers who use this information.

Available online at: http://www.globalreporting.org/AboutGRI/WhatWeDo/

The Carbon Disclosure Project

The Carbon Disclosure Project (CDP) seeks information on risks and opportunities presented by climate change for the world's largest companies. These companies use the project's methodology and process for disclosing GHG emissions. The CDP has the world's largest repository of corporate GHG emissions data and hopes that by making this information publicly available it will stimulate policymakers, stakeholders, consultants, accountants and marketers to take action.

Available online at: http://www.cdproject.net

Economic Data

U.S. Census Bureau, 2004. *2002 Economic Census: Industry Series Schedule*

The U.S. Census Bureau's Economic Census profiles businesses every five years. The Industry Series reports contain fuel consumption data for some sectors (e.g., Mining) and dollars spent on fuel and electricity for other sectors (e.g., Construction). Census forms are mailed to more than five million companies. The Economic Census is mandated by law under Title 13 of the United States Code. Industries are classified based on the NAICS 2002 manual.

Available online at: http://www.census.gov/econ/census02/guide/INDSUMM.HTM

U.S. Geologic Survey, 1998 and 2002. *USGS Minerals Yearbook*

The *Minerals Yearbook* is an annual publication that contains data on materials and minerals, including information on economic and technical trends and developments. It includes information on approximately 90 commodities and over 175 countries. Production data from the yearbook was used to estimate emissions for some sectors, such as cement.

Available online at: http://minerals.usgs.gov/minerals/pubs/myb.html

[2] The North American Electricity Reliability Corporation (NERC) is the designated reliability organization that has a role in overseeing the reliability of the electric power grid. NERC regions reflect the organization structure of the regional reliability entities within with the owners of generation operate.

A.2 Emission Factors for On-site Fossil Fuel Combustion

Table A-1 presents the fuel-specific emission factors used in calculating GHG emission estimates from fossil fuel combustion in this report. For some sectors that derive their emission estimate using MECS data, energy consumption listed in the "other" category was distributed by fuel type. This distribution was estimated according to the different types of byproduct fuels, which may include waste gases, petroleum coke, purchased steam, and waste oils, among others.[3]

Table A-1: GHG Emission Factors by Fuel Type[4]

Fuel Type	GHG Emission Factor ($MMTCO_2E$/TBtu)
Residual Fuel	0.079
Distillate Fuel	0.073
Natural Gas	0.053
Liquefied Petroleum Gases	0.062
Coal	0.094
Coal Coke	0.114
Motor Gasoline	0.071
Misc. Products	0.074
Coke Oven Gas	0.047
Blast Furnace Gas	0.274
Other	
Still Gas	0.064
Petroleum Coke	0.102
Purchased Steam	0.068
Waste Gas	0.064
Waste Oils	0.074
Other Fuels (mostly petroleum)	0.074
Natural Gas	0.053
Tires	0.093

[3] Steam purchases were determined using MECS Table 7.7, which provides the amount of steam purchased from a non-utility. Steam purchased from a utility was excluded due to double counting. The remaining "other fuel" was calculated by subtracting purchased steam and byproduct fuels from total "other fuel."

[4] U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2005*, 15 Apr 2007, http://www.epa.gov/climatechange/emissions/usinventoryreport.html.

A.3 Emission Estimation Methods for Electricity Purchases

This appendix describes four different methods that were used to estimate CO_2 emissions associated with the generation of electricity purchased by the industrial sectors in this report.

The primary differences across the sectors relate to (1) the disaggregation to regions of the electricity purchase estimates to capture the unique geographic distribution of each of the 14 sectors, and (2) the level of disaggregation in the estimate of carbon intensity per kWh of electricity generated to meet the sector's demand. Disaggregating to the extent data allow is important in order to capture the relative differences in the characteristics of electricity generation in the various regions. Specifically, Method 1 applies a national utility emissions factor for electricity generation to national electricity demand data for a sector, while Methods 2, 3, and 4 allocate the sector's electricity demand to NERC regions using a proxy (distribution of industrial demand, distribution of sector's value-add, or distribution of sector's production capacity) and then apply NERC regional utility emission factors to estimate total emissions. These methods are summarized in Table A-2 and are described in more detail. The latter three methods account for differences in emissions due to varying fuel mixes used by utilities in different regions of the country. For example, iron and steel manufacturers tend to be concentrated in the Midwest, while cement manufacturers are more dispersed throughout the country. This will influence the overall carbon emissions associated with the two sectors' electricity consumption.

Table A-2: Summary of Electricity Emissions Methodology

Method	Description	Applied to:
Method 1: National-Level Estimates	National-level electricity purchases, adjusted for transmission and distribution (T&D) and national emissions factor for electricity generation	Food and Beverages
Method 2: Regional-Level Estimates/ Customer Class Disaggregation	National and regional (census-based) electricity purchase estimates (adjusted for T&D losses) distributed geographically based on historic distribution and regional electricity factors	Plastic and Rubber Products, Construction
Method 3: Regional Estimates with Sector Level Disaggregation	National and regional (census-based) electricity purchase estimates (adjusted for T&D losses) are disaggregated further to states based on value added data.	Mining, Oil and Gas (Production), Textiles, Metal Casting, Semiconductors, Forest Products, Chemicals, Lime
Method 4: Facility Level Estimates	Information on facility level capacity, and regional utilization estimates and/or electricity intensity estimates are used to estimate production level at the plant level. National level electricity demand is than allocated to plants based on these factors and appropriate emissions factors are applied to derive total emissions.	Alumina and Aluminum, Oil and Gas (Refining), Cement, Iron and Steel

Data Sources

Purchased Electricity. Purchased electricity data is taken from the best available source data. Generally, electricity estimates were based on U.S. Department of Energy (DOE), Energy Information Administration (EIA) *Manufacturing Electricity Consumption Survey* (MECS) data for 2002 and 1998. Specifically, data on purchased electricity (as opposed to consumed electricity) were used (see MECS Table 3.1). For oil and gas, mining, and construction, alternative sources are used. For mining and oil and gas production, data from U.S. Census Bureau's 2002 and 1997 *Economic Census Industry Series Reports: Mining* are used. For construction, data from the U.S. Census Bureau's 2002 and 1997 *Economic Census Industry Series Reports: Construction* are used.

For all sectors, these data reflect electricity purchases from the grid and excludes consumption of electricity generated onsite, as these emissions are accounted for in the direct fossil fuel combustion emission estimates. These data reflect purchases at the end-use site and so must be adjusted for losses incurred in the transmission and distribution of the electricity from the generating station. For all methods and all sectors, electricity demand data was adjusted upward to account for losses associated with transmission and distribution (T&D) of electricity. Loss factors were developed based on generation and sales data collected by EIA.

Customer Sector Geographic Distribution. The carbon associated with electricity purchases depends in part on the location of the sector's facilities. Different regions of the country may have different mixes of generating technologies and fuel sources. A region more heavily dependent on coal-fired resources will have higher-intensity electricity production, while regions with larger shares of nuclear, renewables, and hydro resources will have lower intensities.

Because the grid is highly interconnected and each facility buys from a coordinated grid, it is only necessary to determine the broad geographic region within which a sector's facilities are located. However, determining where electricity demand occurs within a sector is not readily done without plant-specific data. Therefore, where no facility data were available, simpler methods using proxies for electricity demand were used (as described below).

Value added for each of the sectors is used as a proxy for distribution of electricity demand under Method 3. States with higher estimates of value added for a sector (based on *Economic Census* data) are presumed to have a proportionally higher share of demand for electricity. Using this as a proxy assumes that the electricity intensity of production activities are correlated with value added. This may not be the case for industries with diverse products and/or processes; however, absent a better indicator, this method using value added was applied.

For some sectors, value added data were not reported for certain states due to U.S. Census disclosure restrictions. Therefore, where the missing data were deemed to be significant, missing values were estimated for those states without reported data. Value added estimates were developed based on the assumption that all non-reporting establishments had a value added equal to the average of all non-reporting establishments. The Census reports total national-level value added for a sector and the number of non-reporting establishments, allowing one to estimate the average value added for missing establishments.

The relative share of a sector's total added value is used to apportion electricity demand to the states as described in Method 3.

Electricity Emission Factors are provided by eGRID.[5] The eGRID database combines plant-specific generation data and CO_2 emission estimates for U.S. electricity generating plants that provide power to the electric grid and report data to the U.S. government in order to estimate CO_2 emissions factors (in lbs per kWh of generation) at the national, NERC[6] regional, NERC sub-regional, power control area, and state levels.

Two vintages of eGRID were used: 1998 for the 1998 estimates and 2004 for the 2002 estimates. The eGRID database does not provide 2002 data, so 2004 data was used to create estimates. For each year, two types of emission factors are used. The first is a national-level emission factor (in lbs/kWh) that represents the average carbon intensity of the entire U.S. electricity system. The second emission factors are regional estimates representing the carbon intensity of generation of each NERC region. In 2004, estimates for nine NERC regions are defined in the eGRID data, while in 1998 twelve NERC regions are defined.

Table A-3 shows the eGRID data used in the analyses. NERC regional definitions have changed over time – both in terms of their name, but more importantly in their geographic definitions - as new reliability organizations have formed and power generators have decided to move from one organization to another. Figure A-1 illustrates the NERC regional structures applicable to the 2004 eGRID data set.[7]

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[5] U.S. Environmental Protection Agency, *Emissions and Generation Resource Integrated Database (eGRID) v2.1*, 21 May 2007, http://www.epa.gov/cleanenergy/egrid/index.htm.

[6] The North American Reliability Electricity Corporation (NERC) is the designated reliability organization that has a role in overseeing the reliability of the electric power grid. NERC regions reflect the organization structure of the regional reliability entities within which the owners of generation operate.

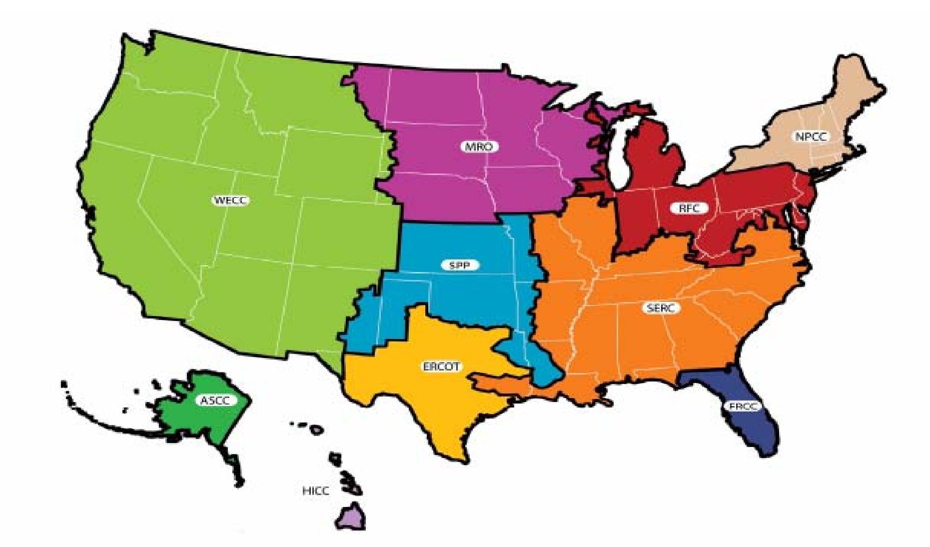
[7] NERC maps for eGRID 1998 were unavailable from government sources. The images available at the following website were assumed to be similar to the 1998 eGRID regions. The one notable exception was that Kentucky was changed to be part of SERC (rather than ECAR) to be consistent with the 2004 eGRID methodology. See http://www.green-e.org/docs/VerificationReport03.pdf.

Table A-3: eGRID CO_2 Emissions Factors, 2002 and 1998

2002 NERC Region (eGRID 2004 region)	2002 CO_2 Emission Rate (lbs/kWh) (Based on 2004 eGRID)	1998 NERC Region (eGRID 1998 region)	1998 CO_2 Emission Rate (lbs/kWh) (Based on 2002 eGRID data release)	Fraction of 1998 region that is part of 2004 region
NPCC	0.91	NPCC	1.02	all
RFC	1.43	ECAR	2.01	all
		MAAC	1.20	all
		MAIN	1.55	part
MRO	1.82	MAPP	1.95	all
		MAIN	1.55	part
ERCOT	1.42	ERCOT	1.42	all
FRCC	1.33	FRCC	1.48	all
SERC	1.39	SERC	1.30	all
		MAIN	1.55	part
SPP	1.83	SPP	1.85	all
WECC	1.11	WSCC	1.00	all
ASCC	1.11	ASCC	1.38	all
HICC	1.65	HICC	1.60	all
National	1.36	National	1.42	

Source data:
eGRID2002 Version 2.01 Location (Operator)-Based NERC Region File (Year 1998 Data)
eGRID2006 Version 2.1 NERC Region Location (Operator)-based File (Year 2004 Data)

Figure A-1: 2004 eGRID NERC Regional Structure for 2002 Data[8]



[8] U.S. Environmental Protection Agency, Emissions and Generation Resource Integrated Database (eGRID) v2.1, 21 May 2007, http://www.epa.gov/cleanenergy/egrid/index.htm.

The differences in regional definitions of NERC regions in 1998 and 2004 are the result of the evolution of membership of the reliability system organizations, and of most recent eGRID's particular methodology. As opposed to the year of the reported data, 2004, eGRID defines the NERC geography to be consistent with that in place at the time of the eGRID release, 2006. For example, the state of Kentucky in 1998 was largely in the ECAR region, as defined by NERC and eGRID. In the 2004 eGRID data, Kentucky is located in the SERC region.[9] The result of this shift in the NERC regional definitions is that the CO_2 emission factor applicable to some regions changes from 1998 to 2006 as a result not only of the changes in the makeup of the generating system over time, but also due to the shift in membership of the reliability organizations and in generation included in each region relative to 1998. On a national level the shift in eGRID data locations changes the relative carbon intensities of the regions. For each year's analysis, the facility and regional data were assigned to the appropriate eGRID region.

Explanation of Methods

Four methods for estimating emissions from purchased electricity were used in this report. A summary of which method was applied to which sector can be found in Table A-2.

Method 1: National-Level Estimates

Estimates of emissions associated with electricity consumption in each sector were estimated based on purchased electricity by the sector and information on the CO_2 intensity of generation from the power system.

National-level electricity purchase estimates were based on MECS, EIA, U.S. Geological Survey (USGS), or other sources as defined in the main body of this report. Electricity data reflect purchased electricity and exclude consumption of electricity generated on site. These estimates were adjusted upwards to account for losses associated with the transmission and distribution of electricity.[10]

Estimates of the CO_2 emissions from grid-connected electricity generators were based on eGRID. eGRID is based on available plant-specific data for all U.S. electricity generating plants that provide power to the electric grid and report data to the U.S. government. eGRID contains air emissions data for nitrogen oxides, sulfur dioxide, carbon dioxide, and mercury. Combined with generation data from the same plants from eGRID, eGRID provides estimates of CO_2 emissions factors (in $MMTCO_2E$) per kWh of generation. These factors are provided at the national, regional, and state level. Two versions of eGRID were used: 1998 for the 1998 emissions estimates and 2004 for the 2002 emissions estimates.

National-level sector electricity purchases estimates (adjusted for T&D losses) were multiplied by the year-appropriate CO_2 emissions factor (in lbs/kWh) to derive CO_2 emissions attributable to the sector in that year.

Method 2: Regional Emissions Factors and Customer Class Data

Method 2 begins with the same national-level demand estimates as used in Method 1 (either based on MECS, EIA, USGS, or other sources depending on sector). In this method, however, the demand is allocated first to census region and then to eGRID NERC regions in order to more closely align the demand with the generation meeting that demand, and therefore refine the estimate of carbon emission reductions.

In cases where MECS data is used, typically census region data is also available. In some cases, disclosure rules prevent the reporting of one or more census regions, in which case missing data is estimated, typically based regional distributions for years when data are reported.

This census region-based data must in turn be "mapped" to the NERC regions. In Method 2, this mapping is achieved by assuming that the distribution of a sector's electricity demand to the NERC regions mirrors the distribution of electricity demand of the customer class of which the sector is a member. For example, it is assumed that the geographic distribution of electricity demand in the chemical manufacturing sector is the

[9] The eGRID regional definitions in the 2004 data release are defined according to the 2006 NERC geographic definitions.

[10] Loss estimates were based on EIA data. See U.S. Department of Energy, *Monthly Energy Review,* Energy Information Administration, October 2007, http://www.eia.doe.gov/emeu/mer/elect.html.

same as the industrial customer class overall. Information on the geographic distribution of industrial sales is based on the EIA 861 report[11] which reports customer class sales at the utility level. Summing these sales by customer class over the geographic area of interest, or NERC region, allows one to develop an estimate of the share of electricity demand by each NERC region. EIA 861 data for 2002 were used.

As in Method 1, the sector-level NERC region electricity demand, adjusted for T&D losses, is multiplied by the appropriate NERC CO_2 emissions factor to estimate the sector's total CO_2 emissions.

Method 3: Geographic Distribution of Electricity Purchases based on Value Added

This method is similar in concept to Method 2, except that instead of distributing electricity demand using customer class distributions, value added data are used to distribute sectoral electricity demand to states. Then, state-level demand is mapped to the NERC regions. As mentioned earlier, using value added as a proxy assumes that the electricity-intensity of production activities are correlated with the value added. For industries with diverse products and/or processes that are geographically concentrated, or where there are large regional differences in input costs or value of final shipments, this assumption may not hold. However, absent additional information on the distribution of electricity sales, this method was used.

The relative state share of a sector's national-level value added is used to share electricity demand to the states. States are then aggregated up to NERC regions. For states that lie in 2 or more NERC regions, it is necessary to distribute this demand further to the appropriate NERC region. The EIA 861 data for the appropriate customer class is used to make this disaggregation.

The disaggregated electricity demand is multiplied by the appropriate NERC CO_2 emissions factor to estimate CO_2 emissions for the sector.

Method 4: Plant by Plant Assessments

Method 4 was applied when sufficient data existed to allocate national electricity purchases to the plant level. This was the case in the cement, petroleum refining, primary aluminum, and iron and steel sectors. In general, the approach was to estimate electricity purchases at each facility (based on some proxy such as capacity or production). Because each plant's location is known, it then can be assigned to a specific NERC region, and thus, emissions can be estimated with a region-specific eGRID emissions factor. This emission factor multiplied by the estimated electricity purchase (adjusted for losses) results in the estimated emissions for that facility. Summing over all facilities results in national-level emissions for the sector. Specific methods for each sector are outlined below:

Cement

Facility-level data location, capacity, and process data for the cement sector were gathered from the following 2002 and 1998 Portland Cement Plant Information Summaries:

- U.S. and Canadian Portland Cement Industry Plant Information Summary. Portland Cement Association, December 31, 2002.
- U.S. and Canadian Portland Cement Industry Plant Information Summary. Portland Cement Association, December 31, 1998.

For each year, the facility-level data were grouped into two sets. The grinding-only facilities were identified and their grinding capacities (metric tons/year) were noted. The remaining plants are full production cement facilities and are identified along with their process type (wet, dry, etc.) and clinker capacity (metric tons/year).

Next, using the known locations of all facilities, the facilities are assigned to NERC regions based on 2004 eGRID NERC regions. Facilities from the 1998 list were assigned based on 1998 eGRID NERC regions.

[11] U.S. Department of Energy, Annual Electric Power Industry Report: Form EIA-861, Energy Information Administration, http://www.eia.doe.gov/cneaf/electricity/page/eia861.html.

USGS Minerals Yearbooks (2002 and 1998 respectively) provided data needed to compute electricity consumed (kWh) by each facility.[12]

For each cement-plant (non-grinding only) facilities, a state-appropriate utilization factor[12] was applied to facility capacity to compute tons of clinker produced per year. The utilization factor is an estimate of how much the facility's equipment is run. It can be measured in terms of clinker or cement production capacity. USGS compiles utilization data by plant, and compiles and reports them by region (and by year). In this analysis we used clinker capacity and utilization. Based on each facility's clinker capacity and the applicable utilization factor, facility-level production was estimated.

Next, the total energy used (kWh) by each facility for finished cement production was computed. Based on which process the plant used (wet or dry), a different calculated electricity "intensity" for clinker production (kWh purchased per ton of finished clinker production) was used. These intensities were calculated based on USGS-reported total U.S. electricity purchases divided by clinker production. These were calculated for cement producing plants, distinguished by wet and dry processes, and for grinding-only plants. Electricity purchases were then estimated for each plant based on its clinker production multiplied by the appropriate intensity factor. Finally, because the analyses in this report are tied to the USGS energy use estimates, the calculated electricity purchase estimates were scaled again to the total USGS estimates of electricity purchased by cement facilities (not including grinding-only facilities).

For each grinding-only facility, an appropriate utilization factor[12] for cement production (that is, the grinding plant's cement production as a percentage of capacity) was applied to compute tons of cement produced per year. Because these estimates were tied to USGS data, the cement production numbers for these grinding-only facilities were scaled up to the total U.S. reported cement production (metric tons)[12] for grinding-only plants in that year.

Next the total energy used (kWh) by each grinding-only facility for finished cement production was computed using a calculated cement production intensity for grinding-only plants in kWh/metric ton cement.[12] Again, the electricity purchased numbers were scaled up to total U.S. electricity purchased by grinding-only facilities.

To compute emissions for both types of facilities, a NERC-appropriate emissions factor (lbs/kWh) was applied to the estimated electricity purchased for each facility in both 1998 and 2002. That is, for 2002, each facility had an eGRID 2004 emissions factor associated with its specific location (i.e., NERC region) which was multiplied by the estimated electricity (kWh) purchased by that facility to result in lbs. emission (lbs/kWh × kWh = lbs). Similarly, for 1998, each facility had an eGRID 1998 emissions factor that was multiplied by its estimated electricity purchases to estimate its total CO_2 emissions. Finally, for each year, emissions from the facilities were tallied up into a national CO_2 emissions estimate.

Iron and Steel

Iron and steel facility-level data were compiled using a list of facilities[13] that contained two categories of plants: integrated mills (integrated/BOF) and carbon steel minimills (EAF). The file contained the locations and capacities (tons of raw steel per year) for all facilities. Using zip code and county information about the location of each of the facilities, NERC regions were assigned to the facilities in two different ways. The first was based on 2004 eGRID NERC regions and the second was based on 1998 eGRID NERC regions.

The following reference sources were used to determine production by each facility and each facility's estimated electricity purchases:

[12] U.S. Geological Survey, *Minerals Yearbook: Cement Annual Report 2002,* 2003, http://minerals.usgs.gov/minerals/pubs/commodity/cement/cemenmyb02.pdf, and U.S. Geological Survey, *Minerals Yearbook: Cement Annual Report 1998*, 1999, http://minerals.usgs.gov/minerals/pubs/commodity/cement/170498.pdf.
[13] Facilities list prepared by EPA's Sector Strategies Program (7 Nov 2007).

- American Iron and Steel Institute (AISI) 2002 Annual Statistical Report, Table 23 contained data on raw steel production by type of furnace within the iron and steel industry during 2002 and 1998.[14]
- MECS 2002 and 1998 provided information about purchases of electricity and the breakdown of those purchases between BOF and EAF plants.

For each of the two years, 1998 and 2002, the facility-level production of iron/steel was determined by using the share of the total U.S. capacity that each individual facility represented (i.e., total U.S. production × % of total U.S. capacity that a facility represented) to distribute the known national production across all the facilities.[15]

Electricity consumed by integrated/BOF mills and EAF mills in both 1998 and 2002 was computed separately using the 1998 electric intensity data for various iron and steel industry operations reported in the DOE/OIT (2000) report and the AISI (2003) production data for the respective years.[16] For the EAF mills, the calculated electricity consumption was considered as purchased electricity. For integrated/BOF mills, the calculated total amount of purchased electricity included both purchased and onsite generated electricity, therefore, the purchased electricity for the integrated/BOF mills was calculated by subtracting the amount of electricity generated onsite in the iron and steel mills [which was calculated based on the data on cogeneration share from the total electricity consumption].[17]

Then, the EAF mills' purchased electricity consumption estimates were developed by applying the share of EAF mills' purchased electricity consumption to the MECS purchased electricity consumption estimates (for the iron and steel industry) for the respective years. For the integrated/BOF mills, purchased electricity consumption estimates were developed by subtracting the EAF mills' purchased electricity consumption estimates from the total purchased electricity consumption estimate. The MECS net electricity consumption estimates were adjusted for transmission losses (i.e., the amount of additional electricity that is lost during transmission to the end-users was added to the total using the loss factors, calculated using EIA data).[18]

Based on the purchased electricity consumption and the production estimates for the integrated/BOF and EAF mills for 1998 and 2002, the electricity consumption intensities were computed for integrated/BOF and EAF plants, using AISI (2003) raw steel production data for 1998 and 2002 for the respective plant, or furnace, categories (i.e., kWh net electricity purchased/tons production = kWh/ton).[19]

Next, the facility-specific estimate of electricity purchased (kWh) for each of the two years was calculated by multiplying the furnace-specific (integrated/BOF mills and EAF plants) electricity intensities by the production data.

Facility-level CO_2 emissions for 1998 and 2002 were computed by multiplying the NERC region-specific CO_2 emissions factors (lbs/kWh) for 1998 and 2002, and the respective facility-specific estimates of purchased electricity consumed. Because the eGRID data were not available for 2002, 2004 data were used as substitutes, without any adjustment. Underlying this method was the assumption that the regional emission intensities remained unchanged between 2002 and 2004. Finally, for each year, emissions from all the facilities were summed up to a national CO_2 emissions estimate.

14 American Iron and Steel Institute, *2002 Annual Statistical Report*, 2003, Table 23.
15 AISI, 2003, Table 23.
16 U.S. Department of Energy, "Energy and Environmental Profile of the U.S. Iron and Steel Industry," Office of Industrial Technologies, 2000, http://www1.eere.energy.gov/industry/steel/pdfs/steel_profile.pdf.
17 AISI, 2003, Table 35.
18 U.S. Department of Energy, "Monthly Energy Review," 23 Nov 2007, http://www.eia.doe.gov/emeu/mer/elect.html.
19 AISI, 2003, Table 23.

Primary Aluminum

Facility-level production capacity data were compiled using USGS *Minerals Yearbooks for Aluminum* 1998 and 2002.[20] The locations and capacities (tons per year) of all facilities were noted. Using zip code and county information about the location of each of the facilities, the facilities from the 2002 list were assigned to NERC regions based on 2004 eGRID NERC regions, while facilities from the 1998 list were assigned based on 1998 eGRID NERC regions.

DOE's *Energy and Environmental Profile of the U.S. Aluminum Industry*, contained information about 1995 electricity consumption of primary aluminum production processes.[21] DOE/Office of Industrial Technologies (OIT) (2000; Table 1-6) provided estimates for specific energy consumption of the primary aluminum production processes in Btu/ton.[22] These estimates were converted to kWh/ton using the process-specific conversion factors used in the report. The sum of these specific energy intensities (in kWh/ton) is the overall energy intensity of primary aluminum production. This estimate was used in the calculations for both 1998 and 2002 due to lack of availability of more recent data.

The 2002 USGS *Minerals Yearbook* provided primary aluminum production estimates for 1998 and 2002 in million metric tons. Purchased electricity estimates for primary aluminum production were obtained from MECS 1998 and 2002. The net electricity consumption estimate for 1998 was readily available from MECS 1998. However for 2002, it was calculated by subtracting the other fuels (noted in MECS), data for some of which were withheld, from the total fuel consumed, yielding a conservative (or higher) estimate of purchased electricity consumption for 2002.

For each of the two years, facility-level production of primary aluminum was determined by multiplying the share of the total U.S. capacity that each individual plant represented by the national aluminum production for the respective years (i.e., total USGS national primary aluminum production × % of total U.S capacity that a facility represents).

Due to rounding, the total U.S. production capacity given for each year by the USGS slightly differed from the facility-level production capacity total. To adjust for this discrepancy, the individual facility-level production estimates were scaled to the national production estimates for that year. The industry-specific electric energy intensity (calculated based on the DOE/OIT, 2000 report) was applied to each facility's production estimate to get an estimate of electricity purchased by each facility.

The facility-specific CO_2 emissions were computed by multiplying the NERC region-specific CO_2 emissions factors (lbs/kWh) and the plant-specific purchased electricity estimates for the same years. The NERC region-specific CO_2 emission factors were obtained from eGRID for 1998 and 2004, which was used as a surrogate estimate for 2002 on the assumption that the electric intensity remained unchanged for this industry between 2002 and 2004. Finally, for each year, emissions from each of the facilities were summed to produce a national CO_2 emissions estimate.

Refineries

Refinery emissions are based on raw data collected from EIA refinery capacity databases for year 1998 and 2002.[23,24] The data for atmospheric distillation capacity as well as secondary unit capacities was organized such that it could be used to determine the "equivalent distillation capacity" (EDC) of each refinery in the United

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[20] Table 2: Primary Annual Aluminum Production Capacity in the United States, U.S. Geological Survey, *Minerals Yearbook: Aluminum Annual Report 2002,* 2003 http://minerals.usgs.gov/minerals/pubs/commodity/aluminum/alumimyb02r.pdf. U.S. Geological Survey, *Minerals Yearbook: Aluminum Annual Report 1998,* 1999 http://minerals.usgs.gov/minerals/pubs/commodity/aluminum/050498.pdf.

[21] U.S. Department of Energy, *Energy and Environmental Profile of the U.S. Aluminum Industry*, Office of Industrial Technologies. 1997, http://www1.eere.energy.gov/industry/aluminum/pdfs/aluminum.pdf.

[22] U.S. Department of Energy, *Energy and Environmental Profile of the Aluminum Industry, Table 1-6.*

[23] U.S. Department of Energy, *Petroleum Supply Annual, 1998: Vol. 1 Refinery Capacity Report,* Energy Information Administration, 1999, http://www.eia.doe.gov/oil_gas/petroleum/data_publications/refinery_capacity_data/refcap_historical.html Volume 1.

[24] U.S. Department of Energy, *Petroleum Supply Annual, 2002*, Energy Information Administration, 12 Jun 2003, http://www.eia.doe.gov/pub/oil_gas/petroleum/data_publications/petroleum_supply_annual/psa_volume1/historical/2002/psa_volume1_2002.html Volume 1.

States for the given year. EDC scales up capacity based on the complexity of the secondary units of the refinery. This value was calculated because it is believed that it will more accurately reflect the electricity purchasing needs of a refinery than the pure atmospheric distillation capacity alone. The EDC of each refinery was multiplied by its utilization for the given year, as provided by EIA's *Petroleum Supply Annual*, Table 16.[25,26]

The electricity purchases by refineries for each PADD in 1998 and 2002 were collected from EIA's *Petroleum Supply Annual*, Table 47 for each of these respective years.[27,28] These will give a more accurate purchased power estimate for the refineries of each PADD. The amount of this purchased power was apportioned to each refinery in each PADD based on its EDC using the formula below:

$$\text{Power purchased by refinery} = (\text{EDC of refinery}/\text{Total EDC of PADD}) \times \text{Power purchased by refineries in PADD}$$

Each refinery was mapped onto its corresponding NERC/eGRID region using a map for 1998 and 2002, specifically. From this the total power purchased by refineries in each NERC/eGRID region was summed. An appropriate emissions factor was applied to derive total regional emissions of CO_2. Regional estimates were summed to a national total.

[25] U.S. Department of Energy, *Petroleum Supply Annual, 1998: Vol. 1 Refinery Capacity Report,* Energy Information Administration, 1999, http://www.eia.doe.gov/oil_gas/petroleum/data_publications/refinery_capacity_data/refcap_historical.html Table #16.

[26] U.S. Department of Energy, *Petroleum Supply Annual, 2002*, Energy Information Administration, 12 Jun 2003, http://www.eia.doe.gov/pub/oil_gas/petroleum/data_publications/petroleum_supply_annual/psa_volume1/historical/2002/psa_volume1_2002.html Table #16.

[27] U.S. Department of Energy, *Petroleum Supply Annual, 1998: Vol. 1 Refinery Capacity Report*, Energy Information Administration, 1999, http://www.eia.doe.gov/oil_gas/petroleum/data_publications/refinery_capacity_data/refcap_historical.html Table # 47.

[28] U.S. Department of Energy, *Petroleum Supply Annual, 2002*, Energy Information Administration, 12 Jun 2003, http://www.eia.doe.gov/pub/oil_gas/petroleum/data_publications/petroleum_supply_annual/psa_volume1/historical/2002/psa_volume1_2002.html Table #47.

A.4 General Conversion Factors & Global Warming Potentials

Table A-4 and Table A-5 show general conversion factors and global warming potentials that are used in calculating emission estimates throughout this report.

Table A-4: Conversion Factors[29]

3,412	Btu/kWh
1,055	TJ/TBtu
1,000,000,000	kg/Tg
0.9072	Metric ton/ton
1,000,000	Metric ton/kg

Table A-5: Global Warming Potentials (100 Year Time Horizon)[30]

Gas	GWP
Carbon Dioxide (CO_2)	1
Methane (CH_4)	21
Nitrous Oxide (N_2O)	310
HFC-23	11,700
HFC-134a	1,300
CF_4	6,500
C_2F_6	9,200
C_4F_{10}	7,000
C_6F_{14}	7,400
SF_6	23,900

29 U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2005,* 15 Apr 2007 http://www.epa.gov/climatechange/emissions/usinventoryreport.html.

30 IPCC Second Assessment Report (1996)—used for this report in accordance with the *Inventory of U.S. Greenhouse Gas Emissions and Sinks*. Intergovernmental Panel on Climate Change, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, 2007 http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.htm.

A.5 Energy Consumption Data

MECS data provide energy consumption by fuel type for 1998 and 2002 by NAICS code for some of the sectors covered in this report.[31] For some sectors, identified in Appendix A.6, CO_2 estimates for the "other" fuels category were obtained directly from EIA's Special Report *Energy-Related Carbon Dioxide Emissions in U.S. Manufacturing*.

Table A-6: 1998 MECS Fuel Consumption Data[32]

Industry	NAICS Code	Total (TBtu)	Net Electricity (TBtu)	Residual Fuel Oil (TBtu)	Distillate Fuel Oil (TBtu)	Natural Gas (TBtu)	LPG and NGL (TBtu)	Coal (TBtu)	Coke and Breeze (TBtu)	Other (TBtu)
Alumina and Aluminum	3313	441	246	*	1	184	1	Q	2	6
Chemical Manufacturing	325	3,704	577	50	9	1984	51	284	2	748
Food	311	1,044	213	14	16	568	5	129	2	97
Beverages	3121	88	20	*	*	41	*	*	*	4
Wood Products	321	504	72	1	12	73	4	2		341
Paper	322	2,744	240	151	9	586	5	277		1,476
Metal Casting	3315				1	137	2		30	1
Petroleum Refineries	324110	3,477	118	70	4	948	33	*	0	2,304
Plastics and Rubber Products	326	327	183	5	1	126	4	3	0	5
Semiconductors and Related Devices	334413	66	46	*	*	20	*	0	0	*
Textiles	313, 314, & 315	351	138	17	5	149	3	24	0	17

* Estimate less than 0.5. Q=Withheld because Relative Standard Error is greater than 50 percent.

Table A-7: 2002 MECS Fuel Consumption Data[33]

Industry	NAICS Code	Total (TBtu)	Net Electricity (TBtu)	Residual Fuel Oil (TBtu)	Distillate Fuel Oil (TBtu)	Natural Gas (TBtu)	LPG and NGL (TBtu)	Coal (TBtu)	Coke and Breeze (TBtu)	Other (TBtu)
Alumina and Aluminum	3313	351	193	*	1	130	1	0	*	26
Chemical Manufacturing	325	3,769	522	43	14	1,678	37	314	1	1,158
Food	311	1,116	230	13	19	575	5	184	1	90
Beverages	3121	85	22	1	2	42	1	8	-	10
Wood Products	321	375	72	1	10	57	5	1		228
Paper	322	2,361	223	100	13	504	6	234	4	1,276
Lime	327410	106	5	1	1	8	*	66	*	26
Metal Casting	3315			*	1	77	1	1	23	
Petroleum Refineries	324110	3,086	121	21	5	821	20	1	0	2,097
Plastics and Rubber Products	326	348	181	7	2	128	3	Q	0	5
Semiconductors and Related Devices	334413	66	44	*	*	21	*	0	0	Q
Textiles	313, 314, & 315	295	115	6	3	119	3	22	0	15

* Estimate less than 0.5. Q=Withheld because Relative Standard Error is greater than 50 percent.

[31] Fuel consumption was multiplied by the appropriate emission factor depending on fuel type to estimate emissions.

[32] U.S. Department of Energy, *1998 Manufacturing Energy Consumption Survey*, Energy Information Administration, 14 Aug 2001, http://www.eia.doe.gov/emeu/mecs/mecs98/datatables/contents.html#fuel.

[33] U.S. Department of Energy, *2002 Manufacturing Energy Consumption Survey*, Energy Information Administration 24 Jan 2005, http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/shelltables.html.

Note the following definitions from EIA's on-line glossary of terms:[34]

- **Coke (coal):** A solid carbonaceous residue derived from low-ash, low-sulfur bituminous coal from which the volatile constituents are driven off by baking in an oven at temperatures as high as 2,000 degrees Fahrenheit so that the fixed carbon and residual ash are fused together. Coke is used as a fuel and as a reducing agent in smelting iron ore in a blast furnace. Coke from coal is grey, hard, and porous and has a heating value of 24.8 million Btu per ton.
- **Coke (petroleum):** A residue high in carbon content and low in hydrogen that is the final product of thermal decomposition in the condensation process in cracking. This product is reported as marketable coke or catalyst coke. The conversion is 5 barrels (of 42 U.S. gallons each) per short ton. Coke from petroleum has a heating value of 6.024 million Btu per barrel.
- **Coke breeze:** The term refers to the fine sizes of coke, usually less than one-half inch, that are recovered from coke plants. It is commonly used for sintering iron ore.
- **Distillate fuel oil:** A general classification for one of the petroleum fractions produced in conventional distillation operations. It includes diesel fuels and fuel oils. Products known as No. 1, No. 2, and No. 4 diesel fuel are used in on-highway diesel engines, such as those in trucks and automobiles, as well as off-highway engines, such as those in railroad locomotives and agricultural machinery. Products known as No. 1, No. 2, and No. 4 fuel oils are used primarily for space heating and electric power generation.
- **Residual fuel oil:** A general classification for the heavier oils, known as No. 5 and No. 6 fuel oils, that remain after the distillate fuel oils and lighter hydrocarbons are distilled away in refinery operations. It conforms to ASTM Specifications D 396 and D 975 and Federal Specification VV-F-815C. No. 5, a residual fuel oil of medium viscosity, is also known as Navy Special and is defined in Military Specification MIL-F-859E, including Amendment 2 (NATO Symbol F-770). It is used in steam-powered vessels in government service and inshore powerplants. No. 6 fuel oil includes Bunker C fuel oil and is used for the production of electric power, space heating, vessel bunkering, and various industrial purposes.

Those sectors for which MECS data were not available or for which more sector-specific data were available (i.e. cement), data from a variety of sources were used, including the USGS *Minerals Yearbook* and the U.S. Census. Tables A-8 through A-12 below contain data from sources that were used to estimate GHG emissions for this report.

Table A-8: Clinker Production for Cement

Year	Clinker Production (1,000 metric tons)
1998[35]	75,842
2002[36]	82,959

[34] See http://www.eia.doe.gov/glossary/index.html.
[35] U.S. Geological Survey, *Minerals Yearbook: Cement Annual Report 2003,* 2004, http://minerals.usgs.gov/minerals/pubs/commodity/cement/cemenmyb03.pdf.
[36] U.S. Geological Survey, *Minerals Yearbook: Cement Annual Report 1999,* http://minerals.usgs.gov/minerals/pubs/commodity/cement/170499.pdf.

Table A-9: Dollars Spent on Fuel for Construction

Industry	NAICS Code	Fuel Type	Dollars Spent on Fuel (1,000 dollars), 1997[37]	Dollars Spent on Fuel (1,000 dollars), 2002[38]
Construction	23	Purchased electricity	$1,740,763	$2,325,050
		Natural gas and manufactured gas	$514,783	$977,067
		Gasoline and diesel fuel	$7,452,872	$9,344,097
		On-highway use of gasoline and diesel fuel	$5,335,645	$6,280,391
		Off-highway use of gasoline and diesel fuel	$2,117,227	$2,682,388

[37] U.S. Census Bureau, *2002 Economic Census Industry Series Reports Construction*, 22 Nov 2005, http://www.census.gov/econ/census02/guide/INDRPT23.HTM.
[38] U.S. Census Bureau, *1997 Economic Census Industry Series Reports Construction*, Jan 2000, http://www.census.gov/prod/ec97/97c23-is.pdf.

Table A-10: Fuel Consumption Data for Mining

Industry	NAICS Code	Coal Consumed as fuel (short tons)	Distillate (light) grade number 1,2, 4 and light diesel fuel used as a fuel (1,000 barrels)	Residual (heavy) grade number 5, 6 and heavy diesel fuel used as a fuel (1,000 barrels)	Gas (natural, manufactured, and mixed) used as a fuel (billion ft^3.)	Gasoline used as a fuel (million gallons)	Gasoline used as a fuel (1,000 barrels)	Electricity Purchased (1,000 kWh)
Mining	212							
1997[39]		*2,249*	*21,605*	*2,199*	*102*	*77*	*1,824*	*45,601,869*
2002[40]		*2,257*	*11,296*	*2,363*	*77*	*36*	*862*	*40,057,191*

Table A-11: Fuel Consumption Data for Oil and Gas Extraction, 1997[41]

Industry	NAICS Code	Distillate Fuel (1,000 bbl)	Residual Fuel (1,000 bbl)	Gas (natural, manufactured, mixed) (billion ft^3)	Gasoline (million gallons)	Crude Petroleum (million bbl)	Natural Gas produced and used (billion ft^3)	Residue Gas	Electricity Purchased	Electricity Generated for own use
Crude Petroleum and Natural Gas Extraction	211111									
Fuel Consumption		*2,017.8*	*648.6*	*169.7*	*98.3*	*0.6*	*773*		*29,577,576*	*3,325,432*
Delivered Cost (1000 Dollars)			*$20,549*	*$459,812*	*$105,255*					
Natural Gas Liquid Extraction	211112*$61,219*									
Fuel Consumption		*47.7*		*60.5*	*1.9*			*427*		
Delivered Cost (1000 Dollars)				*$459,812*	*$105,255*					
Drilling Oil and Gas Wells	213111*$61,219*									
Fuel Consumption		*3,355.3*	*1,954.1*	*0.6*	*26*					
Delivered Cost (1000 Dollars)			*$51,921*	*$1,184*	*$26,348*					
Support Activities for Oil and Gas Operations	213112 *$107,442*									
Fuel Consumption		*1,424.8*	*1,032.1*	*1.4*	*37.6*					
Delivered Cost (1000 Dollars)		*$52,028*	*$24,203*	*$2,662*	*$59,115*					

[39] U.S. Census Bureau, *1997 Economic Census of Mining Industry Series Data*, Economics and Statistics Administration, 2000, http://www.census.gov/prod/www/abs/97ecmini.html.
[40] U.S. Census Bureau, *2002 Economic Census Industry Statistics Sampler: Mining*, 15 Feb 2006, http://www.census.gov/econ/census02/data/industry/E21.HTM.
[41] U.S. Census Bureau, *2002 Economic Census of Mining Industry Series Data*, Economics and Statistics Administration, 2005, http://www.census.gov/econ/census02/guide/INDRPT21.HTM.

Table A-12: Fuel Consumption Data for Oil and Gas Extraction, 2002[42]

Industry	NAICS Code	Distillate Fuel (1,000 bbl)	Residual Fuel (1,000 bbl)	Gas (natural, manufactured, mixed) (billion ft³)	Gasoline (million gallons)	Crude Petroleum (million bbl)	Natural Gas produced and used (billion ft³)	Residue Gas	Electricity Purchased	Electricity Generated for own use
Crude Petroleum and Natural Gas Extraction	211111									
Fuel Consumption		*3,716.4*		*102.4*			*731*		*26,926,558*	*254,098*
Delivered Cost (1000 Dollars)		*$109,965*	*$30,436*	*$341,552*	*$15,575*					
Natural Gas Liquid Extraction	211112									
Fuel Consumption			*121.6*					*382*		
Delivered Cost (1000 Dollars)		*$109,965*		*$341,552*	*$15,575*					
Drilling Oil and Gas Wells	213111									
Fuel Consumption										
Delivered Cost (1000 Dollars)		*$37,355*	*$7,278*	*$311*	*$12,681*					
Support Activities for Oil and Gas Operations	213112									
Fuel Consumption										
Delivered Cost (1000 Dollars)		*$30,946*			*$62,932*					

[42] U.S. Census Bureau, *2002 Economic Census of Mining Industry Series Data*, Economics and Statistics Administration, 2005, http://www.census.gov/econ/census02/guide/INDRPT21.HTM.

A.6 CO_2 Emissions for "Other" Fuels

The EIA special topic report, *Energy-Related Carbon Dioxide Emissions in U.S. Manufacturing*, reports CO_2 emissions for combustion of "other" fuels as described by MECS. This category includes a variety of other fuels (e.g., waste materials, woody materials, black liquor, petroleum coke, etc.) for which EIA has underlying data not provided in MECS that are used to produce the CO_2 emission estimates. Table A-13 provides estimates of CO_2 emissions from the combustion of other fuels for relevant sectors.

Table A-13: CO_2 Emissions for Combustion of Other Fuels[43]

Sector	CO_2 Emissions from "Other" Fuels (TBtu)
Alumina and Aluminum	4.0
Paper	0.8
Food	0.1

[43] U.S. Department of Energy, *Special Topic: Energy-Related Carbon Dioxide Emissions in U.S. Manufacturing*, Nov 2006, http://www.eia.doe.gov/oiaf/1605/ggrpt/pdf/industry_mecs.pdf.

A.7 Reporting Protocols

Certain companies in the aforementioned industrial sectors may voluntarily report their GHG emissions. Several programs have created protocols for designing and implementing a plan to estimate and track an entity's GHG emissions. The following protocols may be used by companies to guide them in estimating and reporting their GHG emissions.

EPA Climate Leaders

EPA's *Climate Leaders Greenhouse Gas Inventory Protocol* is an enhanced version of the WBCSD/WRI protocol for GHG emission reporting. EPA's program has enhanced the WBCSD/WRI protocol to better fit the requirements of the Climate Leaders program. The Climate Leaders *GHG Protocol* consists of three components: Design Principles, Core Modules and Optional Modules. The Design Principles aid Climate Leader partners to define boundaries, identify emission sources, assign a base year, report requirements, and set goals. The Core Modules guidance gives specific information on calculating direct and indirect emission sources. The Optional Modules guidance helps partners account for emissions that are associated with their company, but over which they have no control (e.g., employee commuting programs). Companies that are committed to Climate Leaders develop corporate-wide GHG reduction goals and inventory their emissions.

Available online at: http://www.epa.gov/stateply/docs/climateleadersdesignprinciples.pdf, http://www.epa.gov/stateply/resources/cross_sector.html and http://www.epa.gov/stateply/resources/optional.html

World Business Council for Sustainable Development (WBCSD) and World Resources Institute (WRI)

The WBCSD created two modules with WRI for accounting and reporting GHGs. The *Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard* provides guidance for design and reporting principles as well as standards for setting organizational and operational boundaries, tracking emissions over time, and reporting GHG emissions. The objectives of the protocol's guidance include helping companies prepare the inventory, simplifying and reducing costs of compiling the inventory, providing information that can build an effective strategy to manage and reduce GHG emissions, and increasing consistency and transparency in GHG accounting and reporting. The *GHG Protocol for Project Accounting* is similar, but helps companies report emissions for specific GHG emission reducing projects.

Available online at: http://www.wbcsd.org/DocRoot/IX9QDY3RmB83EDgaeKUW/ghg-protocol-revised.pdf

U.S. Department of Energy, Energy Information Administration's *1605(b) Reporting Guidelines*

U.S. Department of Energy, Energy Information Administration's *1605(b) General Guidelines for Voluntary Reporting of Greenhouse Gases (April 2006)* and *Technical Guidelines for Voluntary Reporting of Greenhouse Gases (1605(b)) Program (April 2007)* provide guidelines for reporting greenhouse gas emissions, emission reductions, and carbon sequestration for all sectors of the economy, including the industrial sector. The Technical Guidelines provide specific protocols for calculating industrial emissions from a wide array of industrial processes, as well emission reduction calculation methods. This protocol provides support for reporting a number of activities that have reduced GHG emissions including reductions in greenhouse gas intensity, absolute emissions, changes in carbon storage, reduced emissions from purchased electricity, landfill methane recovery, coal mine methane recovery, geologic sequestration, anaerobic digestion at wastewater treatment plants and farms, recycling of fly ash, and combined heat and power.

Available online at: http://www.eia.doe.gov/oiaf/1605/aboutcurrent.html and http://www.eia.doe.gov/oiaf/1605/frntvrgg.html.

California Climate Action Registry

The *California Climate Action General Reporting Protocol* provides the approach, methodology and procedures required to report under the Registry. The protocol includes guidelines on determining geographic scope, organizational boundaries, operational boundaries and emission baselines. It also includes guidance for calculating indirect emissions from electricity, co-generation, imported steam and district heating and cooling, and direct emissions from mobile combustion, stationary combustion, process emissions and fugitive emissions. The Registry's online emission calculation and reporting tool (CARROT) helps participants to be effective and minimizes the burden of reporting.

Available online at: http://www.climateregistry.org/docs/PROTOCOLS/GRP%20V2-March2007_web.pdf

A.8 Economic Data

Table A-14: Economic Data

Sector	Year	Value added/ $million[44]	Value of construction put in place/$million[45]	Value of shipment/ $million	Production[46,47,48,49]
Aluminum	1998	11,071		31,904	3,713 thousand metric tons
	2002	8,711		26,107	2,707 thousand metric tons
Cement	1998	4,441			74,523 million metric tons
	2002	4,206			81,517 million metric tons
Chemicals	1998	230,219			
	2002	237,255			
Construction	1997		653,429		
	2002		802,971		
Agribusiness	1998	173,416			
	2002	218,874			
Forest Products	1998	101,349			
	2002	98,200			
Iron & Steel	1998	24,728			98,600 thousand metric tons
	2002	17,446			91,600 thousand metric tons
Lime	1997	755			20,100 thousand metric tons
	2005	723			20,000 thousand metric tons
Metal Casting	1998	17,334			14,725 thousand tons
	2002	14,242			13,081 thousand tons
Mining	1997	35,597			5,333 million short tons
	2002	33,593			5,535 million short tons
Oil & Gas	1998				38,090,616 billion Btu
	2005				35,719,530 billion Btu
Plastic and Rubber	1998	85,542			
	2002	85,697			
Semiconductors	1998	59,977			
	2002	41,499			
Textiles	1998	68,071			
	2002	48,466			

[44] U.S. Census Bureau, *Annual Survey of Manufactures (ASM): Statistics for Industry Groups and Industries*, 2005, http://www.census.gov/mcd/asm-as1.html, For mining and oil and gas, see U.S. Census Bureau, *2002 Economic Census of Mining Industry Series Data*, Economics and Statistics Administration, 2005, http://www.census.gov/econ/census02/guide/INDRPT21.HTM.

[45] U.S. Census Bureau, *Construction Spending: October 2007 Construction at a Glance*, 30 Nov 2007, http://www.census.gov/const/www/c30index.html.

[46] For aluminum, cement, iron and steel, lime, and mining-crude ore, see U.S. Geological Survey, *Commodity Statistics and Information, Minerals Yearbook: Annual Reports for Aluminum, Cement, Iron and Steel, Lime, Mining (crude ore)*, 10 Nov 2007, http://minerals.usgs.gov/minerals/pubs/commodity/.

[47] For mining-coal, see U.S. Department of Energy, *Coal Production in the United States*, 5 Oct 2006, http://www.eia.doe.gov/cneaf/coal/page/fig1_us_historical_production_bar_chart.xls.

[48] For oil and gas, see U.S. Department of Energy, *Crude Oil Production*, 26 Nov 2007, http://tonto.eia.doe.gov/dnav/pet/pet_crd_crpdn_adc_mbbl_m.htm, and U.S. Department of Energy, *Natural Gas Gross Withdrawals and Production*, 31 Oct 2007, http://tonto.eia.doe.gov/dnav/ng/ng_prod_sum_dcu_NUS_m.htm.

[49] For metal casting, see American Foundry Society, "Metal Casting Forecast & Trends: Demand & Supply Forecast," Stratecasts, Inc.

A.9 List of Acronyms

AA	Aluminum Association
ACC	American Chemistry Council
ACEEE	American Council for an Energy Efficient Economy
AF&PA	American Forest and Paper Association
AISI	American Iron and Steel Institute
Al_2O_3	Aluminum oxide
API	American Petroleum Institute
BOF	Basic oxygen furnace
C_2F_6	Perfluoroethane, hexafluoroethane
C_3F_8	Perfluoropropane
CF_4	Perfluoromethane
CFC	Chlorofluorocarbon
CH_4	Methane
CKD	Cement kiln dust
CO_2	Carbon dioxide
CRF	Common Reporting Format
CVD	Chemical vapor deposition
eGRID	Emissions and Generation Resource Integrated Database
DOE	U.S. Department of Energy
EAF	Electric arc furnace
EIA	Energy Information Administration (DOE)
EPA	U.S. Environmental Protection Agency
FS	Forest Service (USDA)
GHG	Greenhouse gas
GRI	Global Reporting Initiative
GWP	Global warming potential
HCFC	Hydrochlorofluorocarbon
HF	Hydrofluoric acid
HFC	Hydrofluorocarbon
HFC-23	Trifluoromethane
HIP	Hot isostatic pressing
IPCC	Intergovernmental Panel on Climate Change
IPR	Industrial process refrigeration
kWh	kilowatt-hour
lbs	pounds
LPG	Liquified petroleum gas(es)
MBtu	Million British thermal units
MECS	Manufacturing Energy Consumption Survey
$MMTCO_2E$	Million metric tons of carbon dioxide equivalent
N_2O	Nitrous oxide
NAICS	North American Industry Classification System
NCASI	National Council for Air and Stream Improvement
NERC	North American Electricity Reliability Corporation
NF_3	Nitrogen trifluoride
NGL	Natural gas liquids
NIR	National Inventory Report
NLA	National Lime Association
NMA	National Mining Association
PCA	Portland Cement Association

PFC	Perfluorocarbon
SF_6	Sulfur hexafluoride
TBtu	Trillion British thermal units
UNFCCC	United Nations Framework Convention on Climate Change
U.S.	United States
USDA	United States Department of Agriculture
USGS	United States Geological Survey
VAIP	Voluntary Aluminum Industrial Partnership (EPA)
WBCSD	World Business Council on Sustainable Development
WRI	World Resource Institute

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