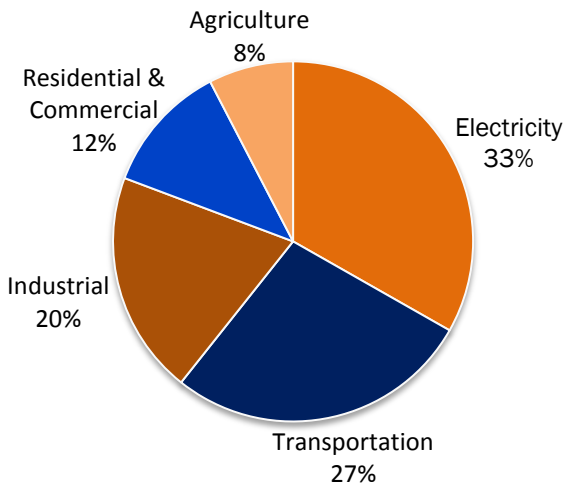
Electricity Emissions in the United States

The electricity sector is responsible for about one third of all U.S. greenhouse gas (GHG) emissions (see Figure 1) and 40 percent of total carbon dioxide (CO_2) emissions.

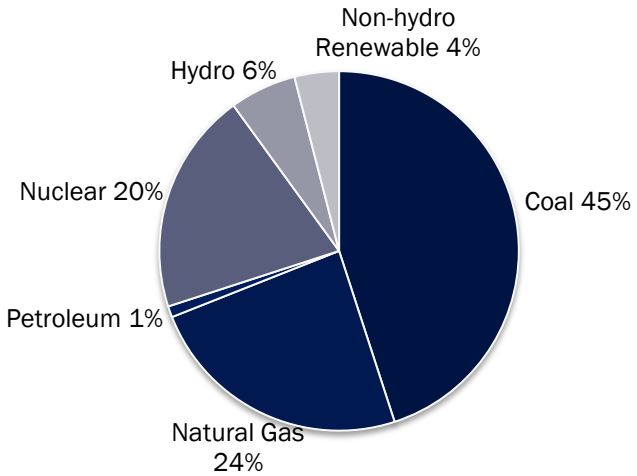
Figure 1: U.S. Greenhouse Gas Emissions by Sector (2009)



Source: U.S. Environmental Protection Agency (EPA), *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2009*, Table ES-7, 2011. http://www.epa.gov/climatechange/emissions/usinventoryreport.html

A snapshot of the fuels used in the United States for electricity shows that coal-fueled generation provides almost half of all electricity, natural gas and nuclear power each provide about 20 percent, and renewable sources, including large hydroelectric power, provide about 11 percent (see Figure 2).

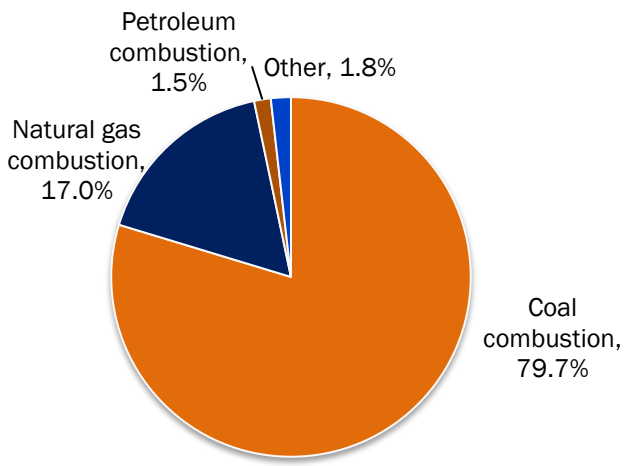
Figure 2: U.S. Net Electricity Generation by Energy Source (2009)



Source: Energy Information Administration (EIA), *Electric Power Monthly, June 2011*, Table 1.1, 2010. http://www.eia.gov/cneaf/electricity/epm/epm_sum.html

The GHG emissions associated with different sources of electricity varies significantly, depending on both the fuel and the technology being used. Carbon dioxide makes up almost 99 percent of the GHG emissions from the electric power sector, and CO_2 emissions from coal combustion account for over 80 percent of total emissions from the sector. The combustion of natural gas and petroleum account for most of the remaining CO_2 emissions (see Figure 3).

Figure 3: Electricity Generation-Related GHG Emissions (2009)



Source: EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2009*, Table 2-13, 2011.
http://www.epa.gov/climatechange/emissions/usinventoryreport.html

Key Generation Technologies in Use

Coal-fueled electricity is generated almost exclusively by pulverized coal (PC) power plants. These plants crush coal into a fine powder and then burn it in a boiler to heat water and produce steam. The steam is then used to spin one or more turbines to generate electricity.

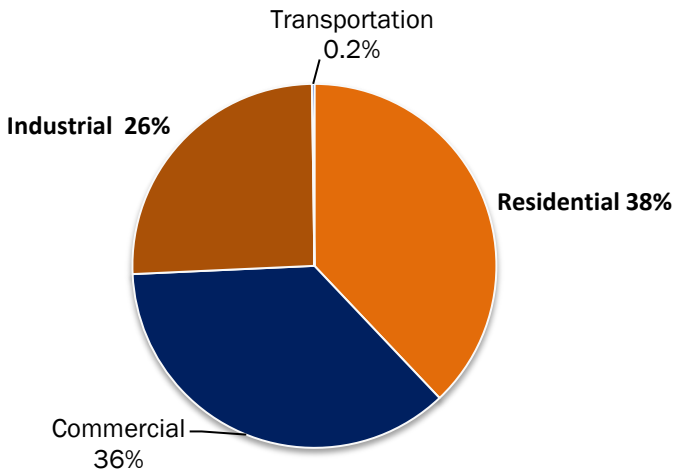
Electricity from natural gas is generated primarily from natural gas combined cycle (NGCC) power plants and from combustion turbines.

Currently, U.S. non-hydro renewable electricity generation comes mostly from biomass combustion and wind.[1]

U.S. nuclear power comes from 104 commercial nuclear generating units which are all either pressurized water reactors or boiling water reactors.[2] No new nuclear plant has been ordered and constructed in the United States since 1973, although 12 license applications are under active review by the Nuclear Regulator Commission for up to 20 new reactors.[3]

U.S. electricity sales are roughly even for the residential and commercial sector, and the industrial sector accounts for the remaining 25 percent (see Figure 4).

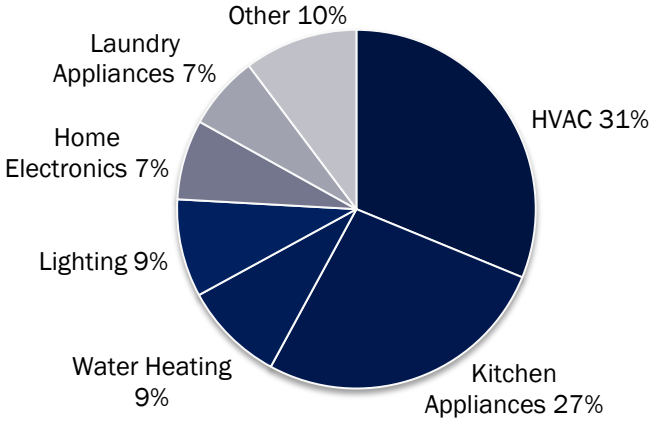
Figure 4: Retail Sales of Electricity to Ultimate Customers, Total by End Use Sector (2009)



Source: EIA, *Electric Power Monthly*, Table 5.1, April 14, 2011. http://www.eia.doe.gov/cneaf/electricity/epm/table5_1.html

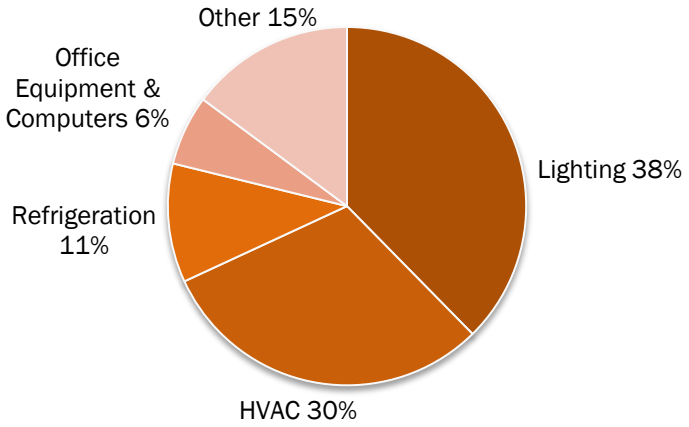
The primary end uses of electricity vary by sector. In the residential sector, heating, ventilation, and air conditioning (HVAC) and kitchen appliances (e.g., refrigerators and dishwashers) together account for more than half of household electricity use (see Figure 5). In the commercial sector, HVAC also accounts for nearly a third of electricity use, but lighting is an even larger electricity end use (see Figure 6). In the manufacturing sector, half of all electricity use is for powering electric motors (see Figure 7).

Figure 5: Residential Electricity Consumption by End Use (2001)



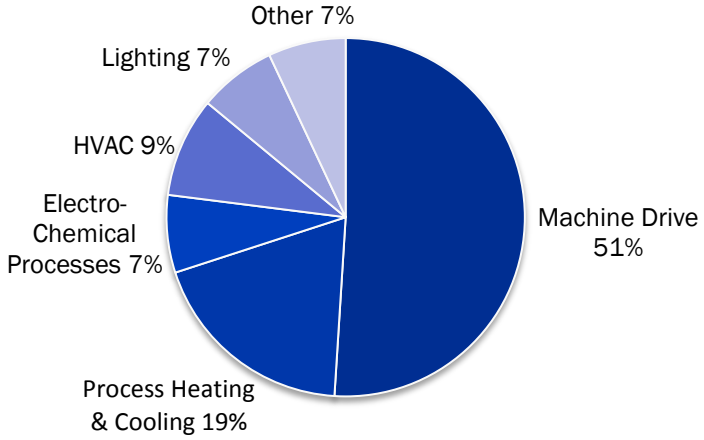
Source: EIA, *U.S. Household Electricity Reports,* Table US-1, 2005. http://eia.doe.gov/emeu/reps/enduse/er_contents.html

Figure 6: Commercial Sector Electricity Consumption by End Use (2003)



Source: EIA, *Commercial Buildings Energy Consumption Survey (CBECS)*, Table E5A, 2008. http://www.eia.doe.gov/emeu/cbecs/

Figure 7: Manufacturing Sector Electricity Consumption by End Use (2006)

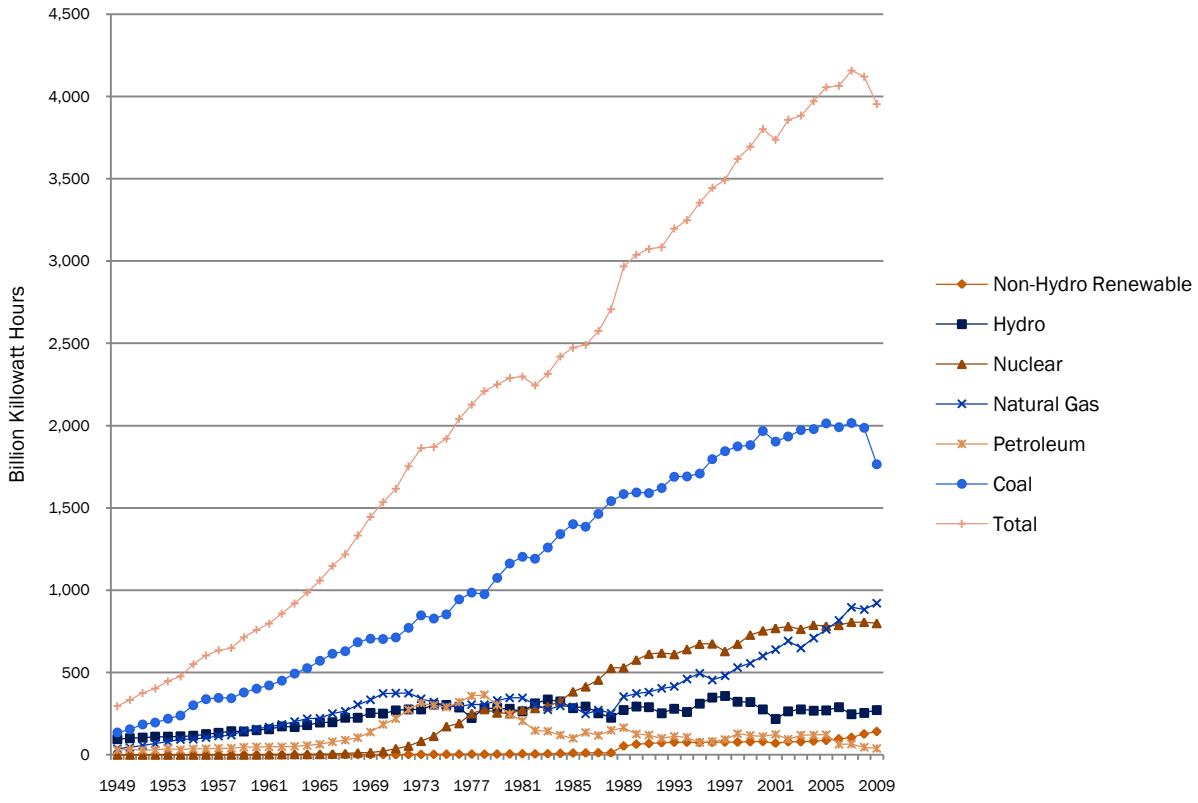


Source: EIA, *Manufacturing Energy Consumption Survey (MECS)*, Table 5.2, 2009. http://www.eia.doe.gov/emeu/mecs/

Historical Trends

Since 1949, U.S. electricity generation has grown dramatically, with an average annual growth rate of nearly 5 percent (see Figure 8). In the past decade, however, U.S. electricity generation has grown at an average rate of less than 1 percent. During this time, generation from natural gas, nuclear power, and non-hydro renewable energy has grown faster than coal-fueled generation.

Figure 8: U.S. Net Electricity Generation by Source (1949-2009)

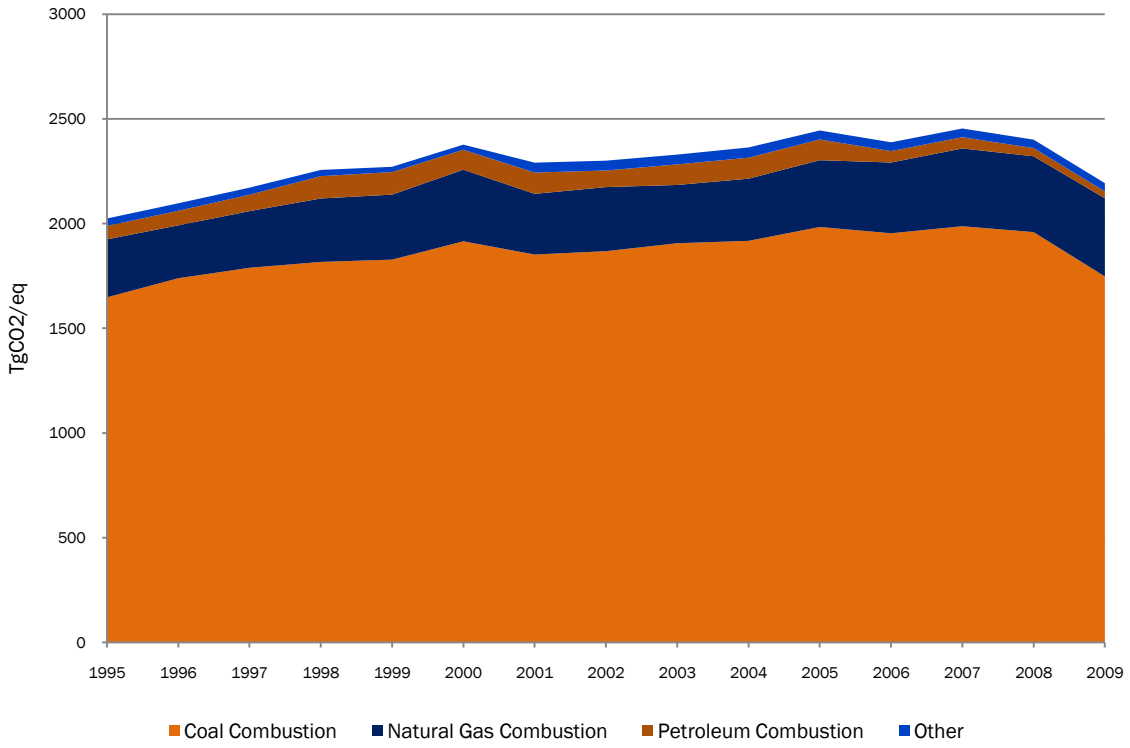


Source: EIA, *Annual Energy Review 2009*, Table 8.2a, 2010. http://www.eia.doe.gov/aer/

From 1995 to 2009, U.S. electricity generation-related GHG emissions grew an average of 0.6 percent per year, while a decrease in annual emissions was seen in several years (see Figure 9). During this time, the proportion of electricity generation-related GHG emissions from coal combustion stayed roughly constant, while the share of emissions from natural gas combustion grew and emissions from petroleum combustion declined.

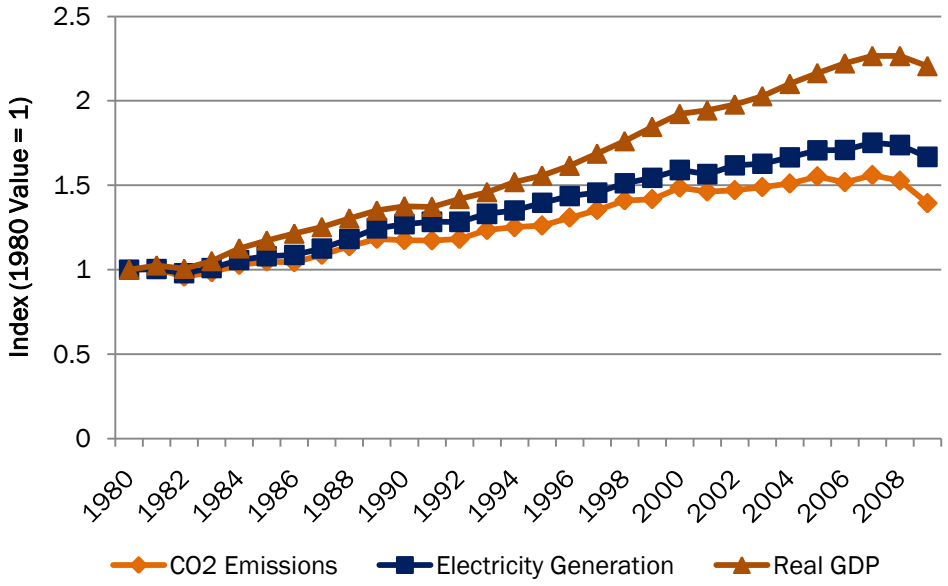
From 1980 to 2009, CO_2 emissions from electricity generation, electricity generation, and real gross domestic product (GDP) grew at annual average rates of 1.2, 1.8, and 2.8 percent, respectively (see Figure 10). This illustrates that the U.S. economy grew less electricity-intensive per unit of output while the electric power sector also became less carbon intensive over this period.

Figure 9: U.S. Electricity Generation-Related GHG Emissions (1995-2009)



Source: EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2009*, Table 2-13, 20010.
http://www.epa.gov/climatechange/emissions/usinventoryreport.html

Figure 10: Relative Growth of Electricity Generation, CO_2 Emissions from Electricity Generation, and GDP

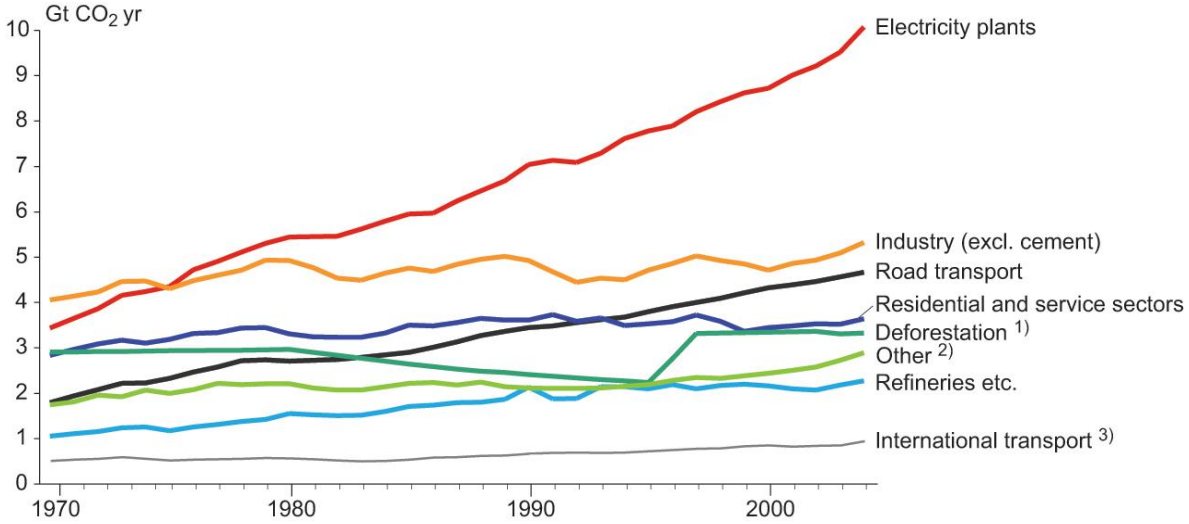


Source: EIA, *Annual Energy Review 2009*, Tables 12.2 and 8.2b, 20010. http://www.eia.doe.gov/aer; Bureau of Economic Analysis; Bureau of Economic Analysis.

Global Context

Globally, CO_2 is the most abundant anthropogenic greenhouse gas, accounting for 77 percent of total anthropogenic GHG emissions in 2004; the CO_2 emissions from fossil fuel use alone account for 57 percent of total GHG emissions.[4] Electricity generation is by far the largest single source of CO_2 emissions (see Figure 11).

Figure 11: Sources of Global CO_2 Emissions (1970-2004, Direct Emissions by Sector Only)



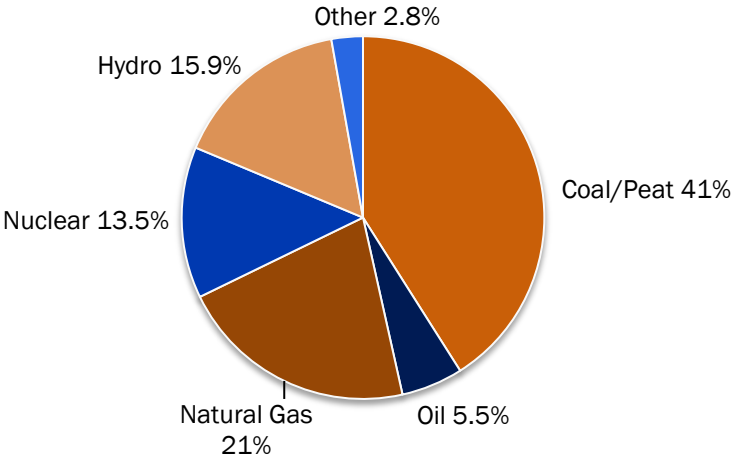
Source: Intergovernmental Panel on Climate Change (IPCC), "Introduction." In Mitigation of Climate Change. Contribution of

Working Group III to the Fourth Assessment Report. Cambridge: Cambridge University Press, 2007. Figure 1.2. http://www.ipcc.ch/ipccreports/ar4-wg3.htm

Notes: (1) Including fuel wood at 10% net contribution, large-scale biomass burning averaged data for 1997–2002, including decomposition and peat fires, excluding fossil fuel fires; (2) other domestic surface transport, non-energetic use of fuels, cement production, and venting/flaring of gas from oil production; (3) including aviation and marine transport.

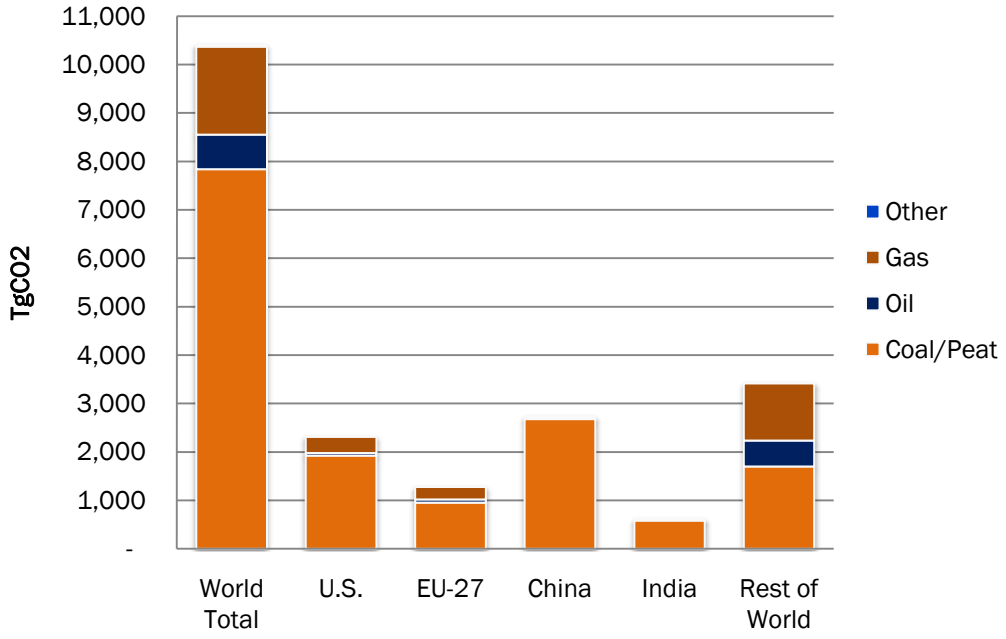
The generation profile of global electricity production is similar to that of the United States, with coal being the largest energy source for electricity production globally and in the United States (see Figure 12).[5] The United States contributes more than one-fifth of global CO_2 emissions from electricity and heat production, with China and the United States being by far the largest single emitters (see Figure 13).

Figure 12: World Electricity Generation by Fuel (2010)



Source: International Energy Agency (IEA), *Key World Energy Statistics 20010.* Paris: IEA, 20010.
http://www.iea.org/Textbase/publications/free_new_Desc.asp?PUBS_ID=1199
Notes: Other includes geothermal, solar, wind, combustible renewables & waste, and heat.

Figure 13: CO_2 Emissions from Fossil Fuel Combustion for Electricity and Heat (2006)



Source: IEA, *CO_2 from Fossil Fuel Combustion 2008.* Paris: IEA, 2008.
http://www.iea.org/Textbase/publications/free_new_Desc.asp?PUBS_ID=1825

Notes: Other includes industrial waste and non-renewable municipal waste. Emissions shown above are the sum of emissions from main activity producer electricity generation, combined heat and power generation, and heat plants. Main activity producers (formerly known as public utilities) are defined as those undertakings whose primary activity is to supply the public. They may be publicly or privately owned. Emissions from own on-site use of fuel are included. This corresponds to IPCC Source/Sink Category 1 A 1 a.

Electricity Sector Mitigation Opportunities

In general terms, GHG emission reductions from the electric power sector can be achieved either through efficiency and conservation (i.e., reducing the amount of electricity generated) or from low- and zero-carbon electricity generation technologies (i.e., reducing the emissions associated with electricity generation), such as renewable energy, carbon capture and storage, and nuclear power.

Many studies have analyzed the most cost-effective mix of emission-reduction options. Some of the most widely cited studies include:

- Electric Power Research Institute (EPRI), "The Full Portfolio," see http://mydocs.epri.com/docs/CorporateDocuments/AboutEPRI/DiscussionPaper2007.pdf.
- Intergovernmental Panel on Climate Change, "Special Report on Renewable Energy Sources and Climate Change Mitigation," see http://srren.ipcc-wg3.de.
- International Energy Agency (IEA), "Energy Technologies for a Low-Carbon Future: Insights from

Energy Technology Perspective 2008," see http://www.scribd.com/doc/5534059/IEA-Energy-Technologies-for-a-Low-Carbon-Future.

- Google's Clean Energy 2030 Plan, see http://knol.google.com/k/-/-/15x31uzlqeo5n/1#.

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[1] Energy Information Administration. *Total Renewable Net Generation by Energy Source and State.* Accessed May 24, 2011. Available at http://www.eia.doe.gov/cneaf/alternate/page/renew_energy_consump/table6.html

[2] Energy Information Administration (EIA). *U.S. Nuclear Reactors*. Accessed May 24, 2011. Available at http://www.eia.doe.gov/cneaf/nuclear/page/nuc_reactors/reactsum.html.

[3] NEI, Status and Outlook for Nuclear Energy in the United States, May 2011

[4] Intergovernmental Panel on Climate Change (IPCC). *Climate Change 2007: Mitigation*. Contribution of Working Group III to the Fourth Assessment Report. Cambridge: Cambridge University Press, 2007. See Figure 1.1b, available at http://www.ipcc.ch/ipccreports/ar4-wg3.htm.

[5] The International Energy Agency (IEA) reports electricity generation from coal and peat together. For definitions of coal and peat, see http://www.iea.org/Textbase/stats/defs/sources/coal.htm.