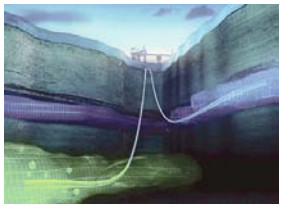
Carbon Sequestration, in Brief



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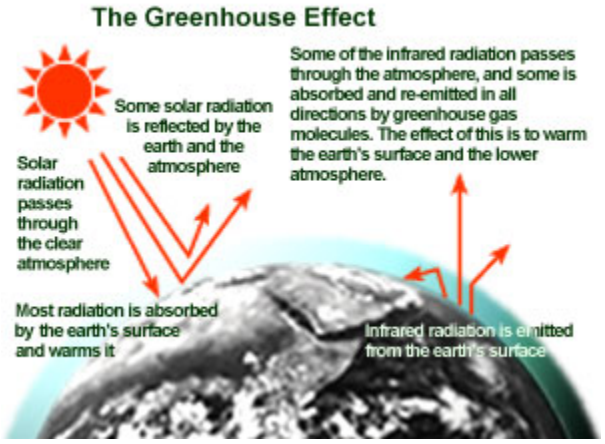
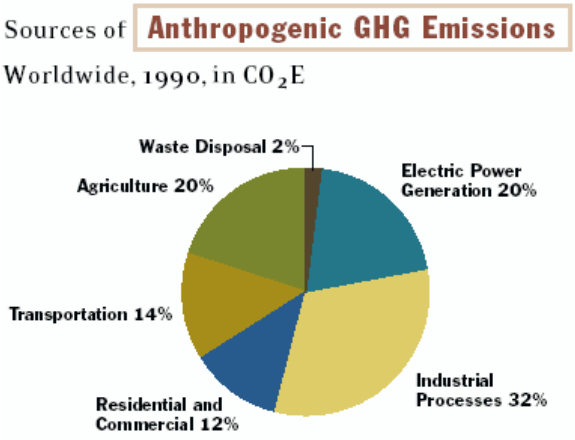
Definition and Purpose of Carbon Sequestration:

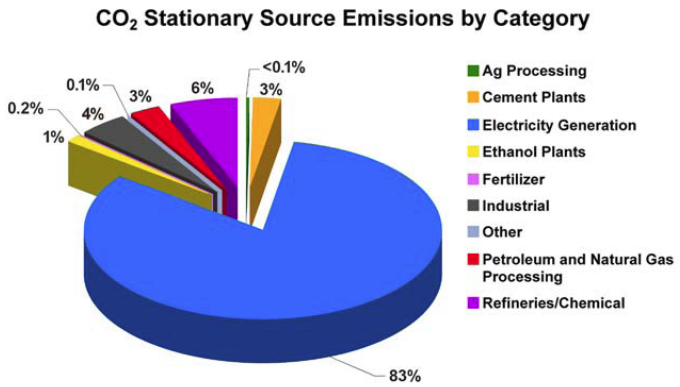
According to the U.S. EPA, gases that trap heat in the atmosphere are often called greenhouse gases. This section of the EPA Climate Change Site provides information and data on emissions of greenhouse gases to Earth's atmosphere, and also the removal of greenhouse gases from the atmosphere. The principal greenhouse gases that enter the atmosphere because of human activities are: carbon dioxide (CO_2), Methane, Nitrous Oxide, and Flourinated Gases. Among these, CO2 is the most abundant anthropogenicic greenhouse gas.

Carbon sequestration is simply the process of keeping CO_2 out of the atmosphere where, according to most scientific studies, it contributes to the *Greenhouse effect*, which causes global warming. The process of global warming is shown in the following figures (figure on the left from U.S. EPA, figure on the right taken from http://www.climatechange.ws/):





The concentration of carbon dioxide in the atmosphere has risen from 290 (ppm - parts per million) in 1900 to nearly 400 ppm. The multinational Arctic Climate Impact Assessment (ACIA) report concludes that in Alaska, western Canada, and eastern Russia, average temperatures have increased as much as 4 to 7 degrees Fahrenheit (3 to 4 degrees Celsius) in the past 50 years.



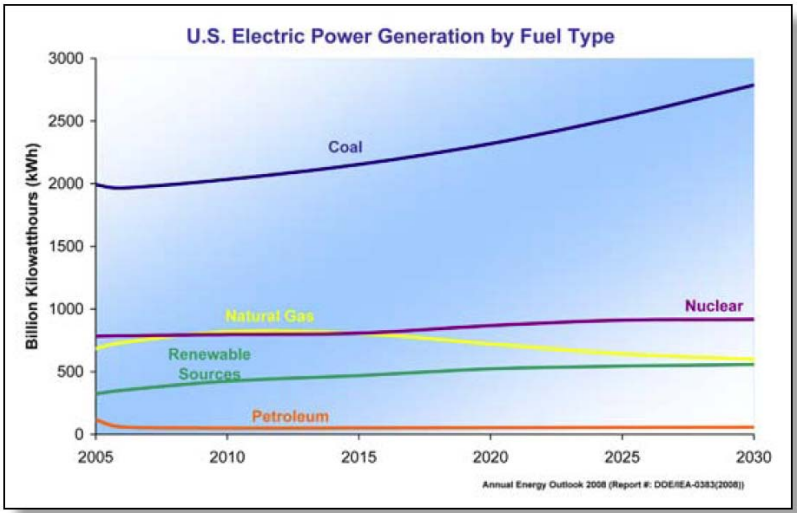
What is the current Source of atmospheric CO_2?

Sources and quantity of CO_2, include the following from stationary and non-stationary sources:

CO2 source	CO2 amount (million of metric tons)	Source of information
Coal & Gas power plants	2356	Annual Energy Outlook 2009, data from 2007
Total US electricity generation	2656	Annual Energy Outlook 2009, data from 2007
Coal fired power plants	1980	Annual Energy Outlook 2009, data from 2007
Gas fired power plants	376	Annual Energy Outlook 2009, data from 2007
transportation	1887.4	2009 U.S. Greenhouse Gas Inventory Report, U.S. EPA, data from 2007
Iron and steel manufacturing	126	Energy-Related Carbon Dioxide Emissions in U.S. Manufacturing (2006) Mark Schipper1, Energy Information Administration (EIA),EIA/DOE report, data from 2002
Refineries	192	2008 Carbon sequestration Atlas of the United States
Cement manufacturing	96	2008 Carbon sequestration Atlas of the United States
Other	140.8	2008 Carbon sequestration Atlas of the United States

FIGURE: Stationary Sources of CO_2 generation by percent. (2008 Carbon Sequestration Atlas of the United States and Canada)

We can see from this figure that the majority of fixed-source CO_2 is from electric power generation. The following figure shows the importance of CO_2 emitting power plants to our overall current and projected power generation (current electric power generation includes 1. Coal =2021 billion kilowatt-hours (BKWH), 2. Oil and natural gas= 958 BKWH, 3. Wind, solar, Renewable = 352 BKWH, 4. Nuclear= 806 BKWH, 5. Other =22 BKWH :



How do we cut down on CO2 emissions?: There are a number of options available, including the following (estimates from Scientific American, 2006):

Alternative energy sources

- Drive cars on ethanol (2 billion cars would use 1/6 of world cropland)
- Increase wind power to make hydrogen for cars
- Increase solar power (a 700 fold increase would displace coal)
- Increase wind power (a 40-fold increase would displace coal)
- Increase nuclear (a 2 fold increase would displace coal)

Carbon Capture and Storage

- Install CCS at coal-fired power plants
- Install CCS at coal plants to produce hydrogen for vehicles
- Install CCS at coal-to-syngas plants

Energy Efficiency and Conservation

- Increase fuel economy of cars
- Drive cars fewer miles a year
- Cut electricity use in homes, offices and stores

Power Generation

- Install CCS at coal fired power plants
- Install CCS at coal plants that produce hydrogen for vehicles
- Install CCS at coal-to-syngas plants

Agriculture and Forestry

- Expand conservation tillage
- Significantly decrease deforestation

How do we keep CO2 out of the atmosphere? - sequester it

There are at least three potential means of sequestering CO2: 1. Dump the CO2 into the ocean depths (**oceanic sequestration**), 2. Bind the CO2 in plants (**terrestrial sequestration**), and 3. Bury the CO2 deep within the earth (**geologic sequestration**)

Oceanic Sequestration

Pumping CO2 into the deep ocean basins (350-3000 meters), where it is anticipated it may form lakes of liquid, supercritical, or solid hydrates. The thinking on this disposal scenerio is that it would stabilize in the ocean depths, or slowly dissolve into the ocean waters. This option has been under study for several years, but there are many potential environmental downsides to its implementation, and it is not a high priority research focus at this time.

Terrestrial Sequestration

Terrestrial sequestration consists of storing CO2 in soils and vegetation near the earth's surface. Tree-plantings, no-till farming, wetlands restoration, land management on grasslands and grazing lands, fire management efforts, and forest preservation. More advanced research includes the development of fast-growing trees and grasses and deciphering the genomes of carbon-storing soil microbes. NETL's Program efforts in the area of terrestrial sequestration include a focus on increasing carbon uptake on mined lands and quantifying sequestration benefits of growing biomass for power generation. These activities complement research into afforestation and agricultural practices.

Geologic Sequestration

Geologic sequestration consists of capturing CO2 from stationary sources, like a power plant, and injecting it into the subsurface. The following a. Oil and Gas Reservoirs (138 bmt), b. unmineable Coal (157-178 bmt), and c. Saline Formations (3297-12618 bmt). The process of carbon capture and geologic sequestration, or storage, is shown in the attached figure:

References:

National Greenhouse gas emissions inventory: U.S. EPA http://www.epa.gov/climatechange/emissions/index.html
Intergovernmental Panel on Climate Change (IPCC) Report on the Physical Science Basis for Climate Change: http://ipcc-wg1.ucar.edu/wg1/wg1-report.html
Advancing the Science of Geologic Carbon Sequestration: A workshop held last spring at OSU. Presenters included many of the top scientists in the world working on this problem. Powerpoint presentations, including audio, can be found on the following website: http://www.earthsciences.osu.edu/carbseq
The National Energy Technology Laboratory (NETL), part of DOE's national laboratory system, is owned and operated by the U.S. Department of Energy (DOE). http://www.netl.doe.gov/technologies/carbon_seq/index.html
Geo-Seq Project: http://www.netl.doe.gov/publications/factsheets/project/Proj287.pdf
Information regarding facts and figures on energy: Energy Information Agency: http://www.eia.doe.gov/
Battelle and Midwest Regional Carbon Sequestration Partnership: http://216.109.210.162/

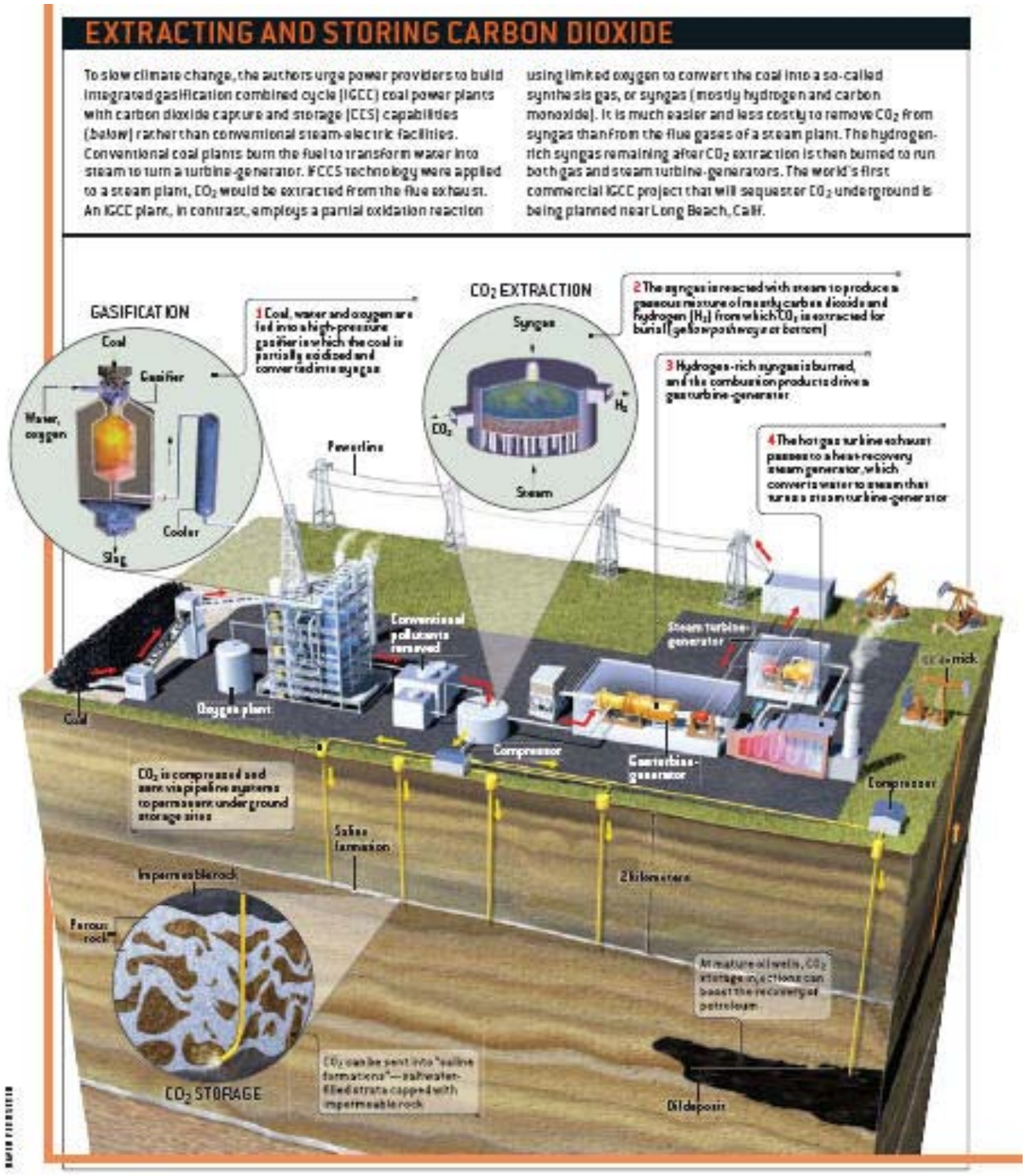


FIGURE: CO2 capture and geologic injection into subsurface rocks (from Scientific American special issue on energy and climate change, 2006)