AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

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1917

Visiting Geologists Program

Geologic
CO_2 Sequestration

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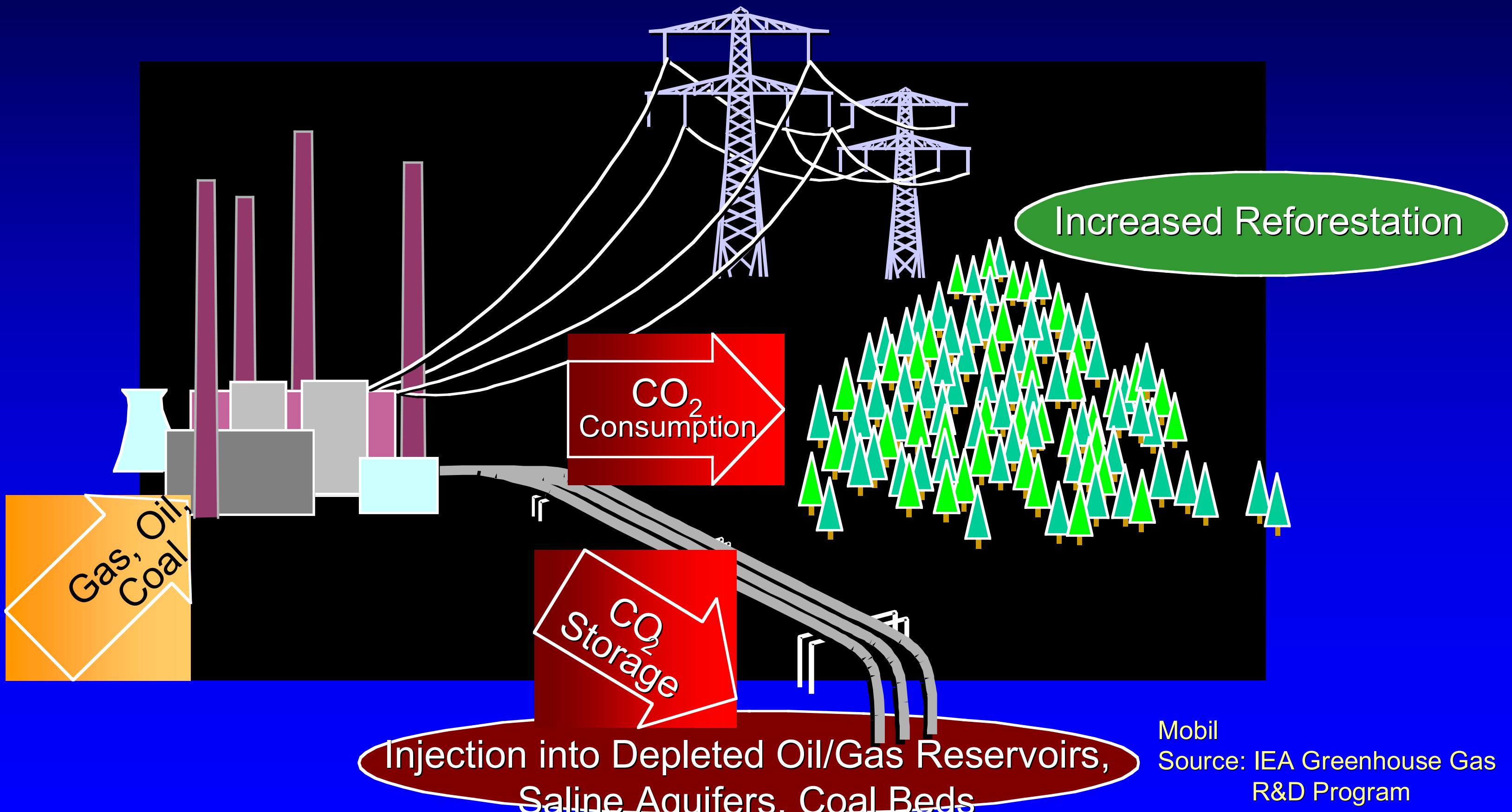
CO_2 Capture and Storage

Potential for Reducing CO_2 Emissions from Fossil Fuel Power Generation



Mobil
Source: IEA Greenhouse Gas R&D Program

JMA

Why Sequester CO_2?

- Like it or not, fossil fuels will remain the mainstay of energy production well into the 21st century.

- Availability of these fuels to provide clean, affordable energy is essential for the prosperity and security of the United States.

- However, increased concentrations of carbon dioxide (CO_2) due to carbon emissions are expected unless energy systems reduce the carbon emissions to the atmosphere.

- Anthropogenic Green House Gases (GHG's) may be contributing to Global Climate Change.

- To a degree, CO_2 is a useful byproduct. So, why not capture it?

Is The Air Getting Cleaner Or Dirtier?

According to the U.S. Environmental Protection Agency's (EPA) latest Ten-Year Air Quality and Emissions Trends report, there have been significant reductions in all 6 criteria pollutants and reductions are expected to continue.

The pollution reductions between 1986 and 1995 were:

Carbon Monoxide (CO)	down 37%
Lead	down 78%
Nitrogen Dioxide (NO2)	down 14%
Ozone	down 6%
Particulate Matter (PM-10) . . .	down 22%
Sulfur Dioxide	down 37%

What is Sequestration?

- Capturing and securely storing carbon emitted from the global energy system.

Types of Sequestration?

Ocean Sequestration: Carbon stored in oceans through direct injection or fertilization.

Geologic Sequestration: Natural pore space in geologic formations serve as reservoirs for long term carbon dioxide storage.

Terrestrial Sequestration: A large amount of carbon is stored in soils and vegetation, our natural carbon sinks. Increasing carbon fixation through photosynthesis, slowing down or reducing decomposition of organic matter, and changing land use practices can enhance carbon uptake in these natural sinks.

Geologic Sequestration Trapping Mechanisms

- **Hydrodynamic Trapping:** carbon dioxide can be trapped as a gas under low-permeability cap rock (much like natural gas is stored in gas reservoirs).
- **Solubility trapping:** carbon dioxide can be dissolved into a liquid – water and/or oil.
- **Mineral Carbonation**: carbon dioxide can react with the minerals, fluids, and organic matter in the geologic formation to forms stable compounds/minerals; largely calcium, iron, and magnesium carbonates.

Primary Geologic Sequestration Target Reservoirs

- Oil and Gas Pools/Fields
- Coal Beds
- Deep Saline Aquifers
- Unconventional Reservoirs – tight gas sands; organic shales; salt domes, etc.

Long-term storage of CO_2 in underground geologic formations has the potential to be viable in the near-term. Many power plants and other large point sources of CO_2 emissions are located near geologic formations that are amenable to CO_2 storage. Further, in many cases injection of CO_2 into a geologic formation can enhance the recovery of oil and gas which can offset the cost of CO_2 capture.

The use of CO_2 to enhance oil and gas recovery is a common industrial practice. In the year 2000 in the United States, 34 million tons of CO_2 were injected underground as a part of enhanced oil recovery (EOR) and coal bed methane recovery (E-CBM) operations. This is approximately equivalent to the CO_2 emissions from 6 million cars in one year. Research and development in this area will move the technology forward to make it applicable to a wider range of formations.

A novel process which currently experiences a broad interest is the injection of CO_2 in unmineable coalbeds, thus releasing the trapped methane. This process is called Enhanced Gas Recovery (EGR) or Enhanced CoalBed Methane production (ECBM), and is similar to the popular practice of using CO_2 injection to enhance production from oil reservoirs.

With EGR, the injected CO_2 is adsorbed by the coal and stored in the pore matrix of the coal seams, releasing the trapped methane that can be sold for profit. Future work in the area can lead to the design of efficient null-greenhouse-gas-emmission power plants that are fuelled either by mineable coal or by the methane released from the deep coal reservoirs. In this closed CO_2 process, the waste CO_2 produced from the coal or methane-powered plants is injected into the CBM reservoirs to produce more methane, and the cycle continuous.

In addition, a geological sink is established in the coalbeds, virtually eliminating any release of CO_2 to the atmosphere.

Saline formations do not contain oil and gas resources and thus do not offer the value-added benefit of enhanced hydrocarbon production. However, the potential CO_2 storage capacity of domestic saline formations is huge; estimates are on the order of several hundred years of CO_2 emissions.

The primary goal of research in this area is to understand the behavior of CO_2 when stored in geologic formations so that CO_2 can be stored in a manner that is secure and environmentally acceptable.

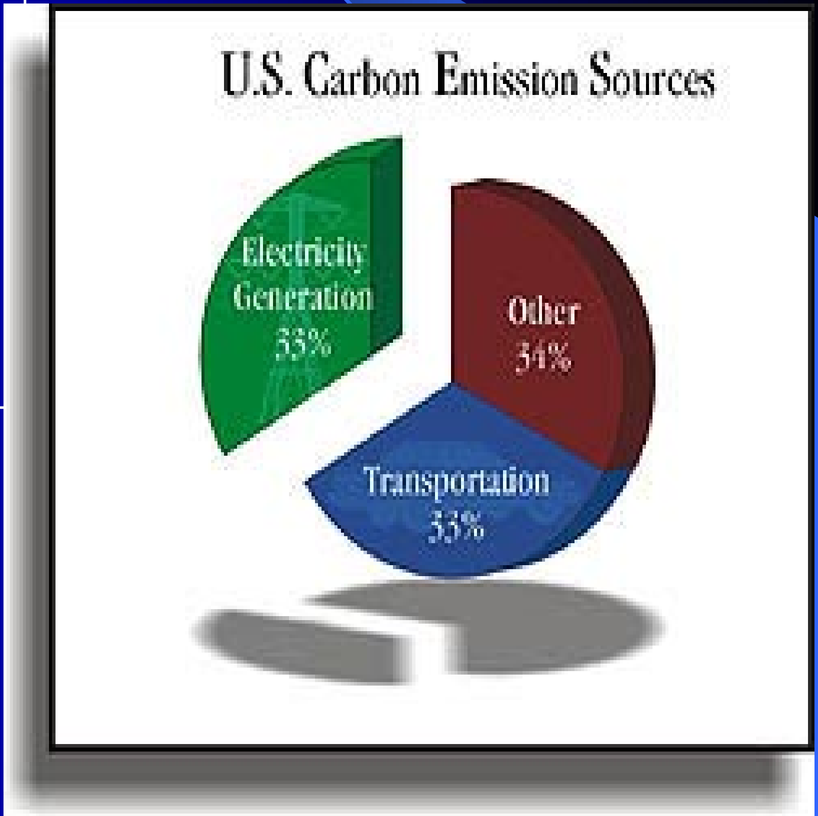
CO_2 Separation and Capture – The Achilles Heel?

CO_2 is currently recovered from combustion exhaust streams for use as a commodity chemical. However, the cost of CO_2 capture using current technology is much too high ($100-300/ton) for carbon emissions reduction applications. Research to reduce the cost is in the early stages, and the program is exploring a wide range of technologies, including membranes, solid sorbents, CO_2 capture via the formation of CO_2/water hydrates, and advanced gas/liquid contactors.

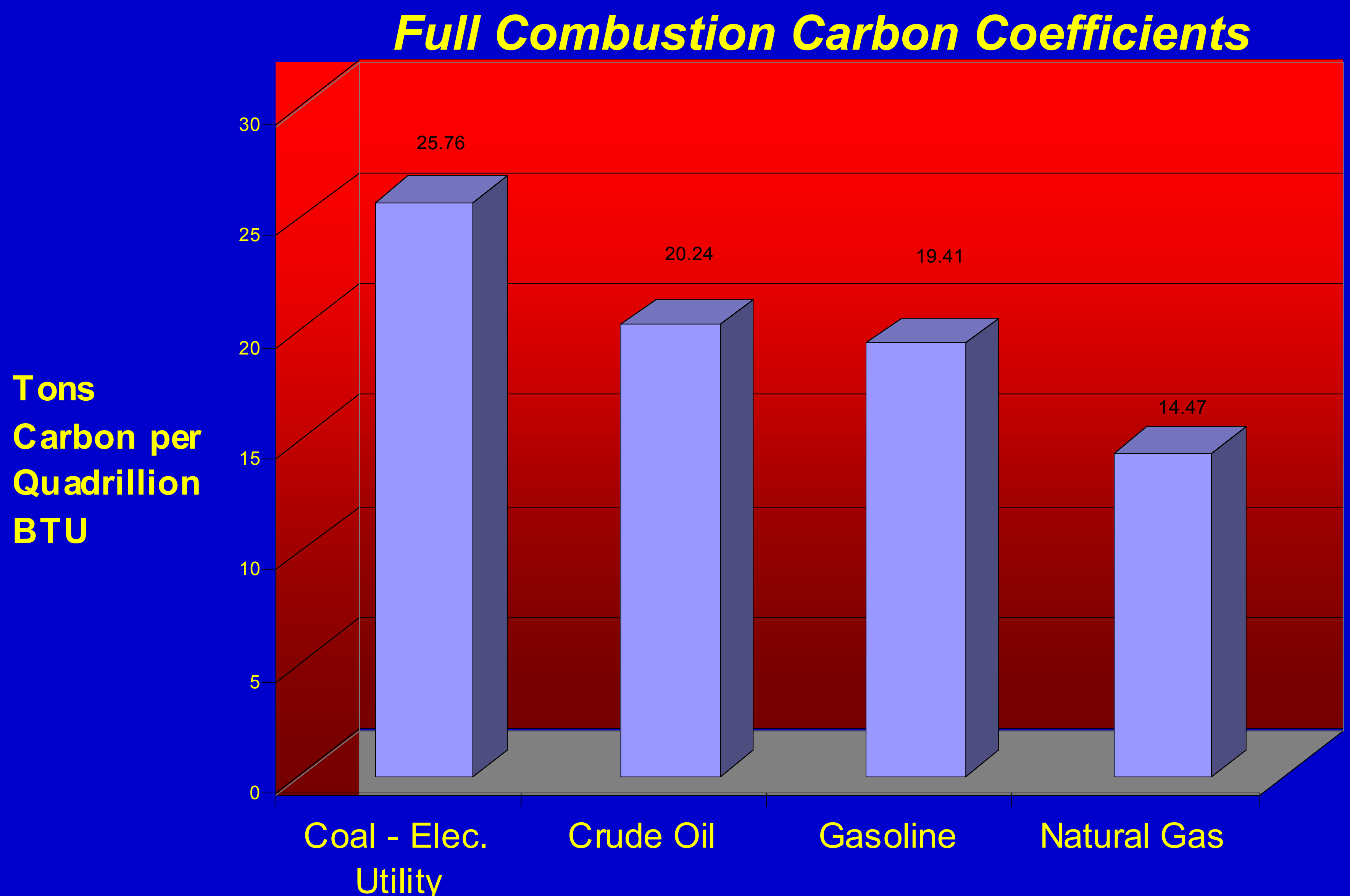
Another approach to CO_2 capture is to develop advanced fossil fuel energy conversion processes that exhaust CO_2 in a more concentrated form, significantly reducing the capital and energy penalty cost for CO_2 capture. Efforts in this area being pursued by the program are closely coordinated with DOE's Vision 21 Program.

What are the major sources of CO_2?

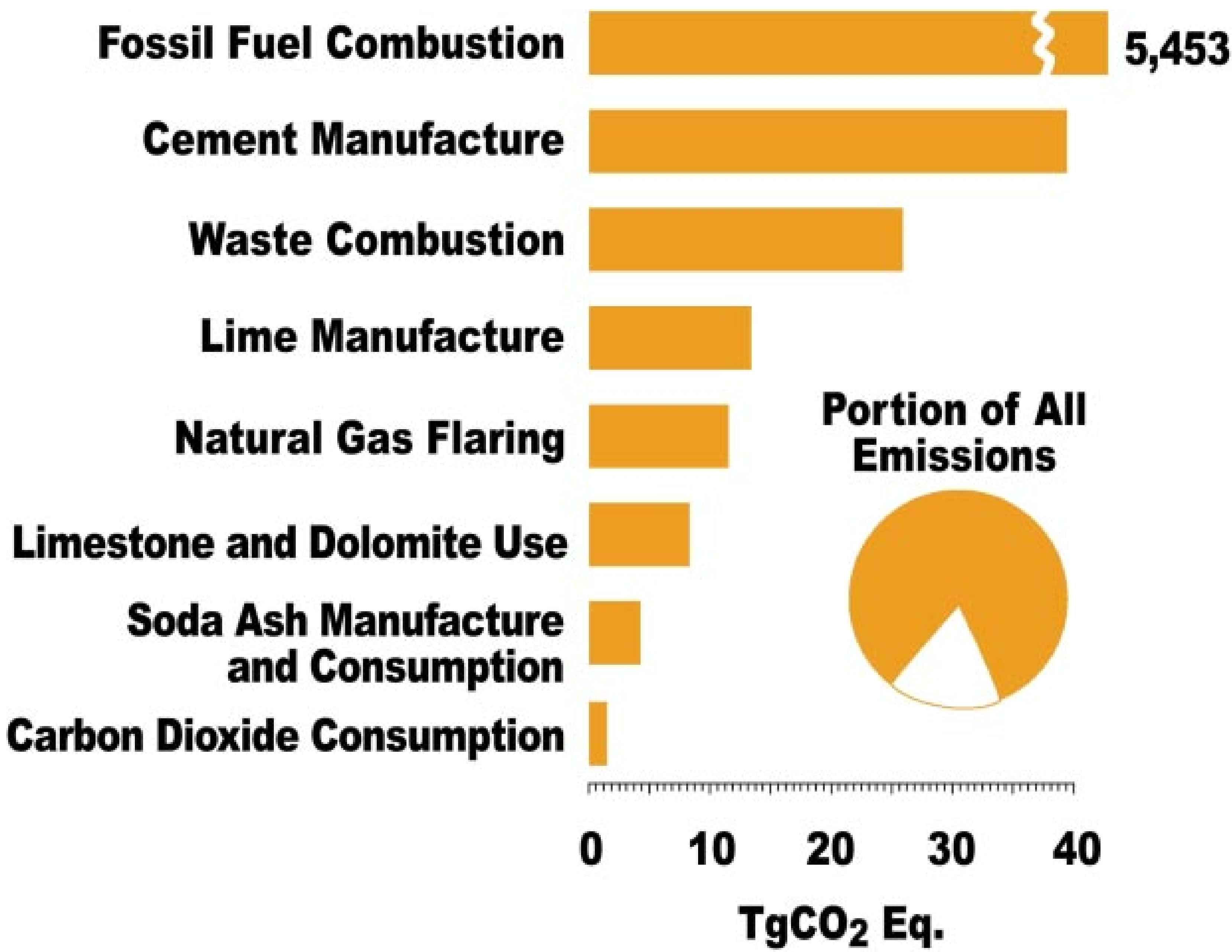
Roughly one third of the United States' carbon emissions come from power plants. These sources would be convenient for CO_2 capture except that most use air-fired combustors, a process that exhausts CO_2 diluted with nitrogen. Flue gas from coal-fired power plants contains 10-12% CO_2 by volume, and flue gas from natural gas combined cycle plants contains from 3-6% CO_2. Concentrated CO_2 (greater than 90%) is needed for most storage, conversion and reuse.



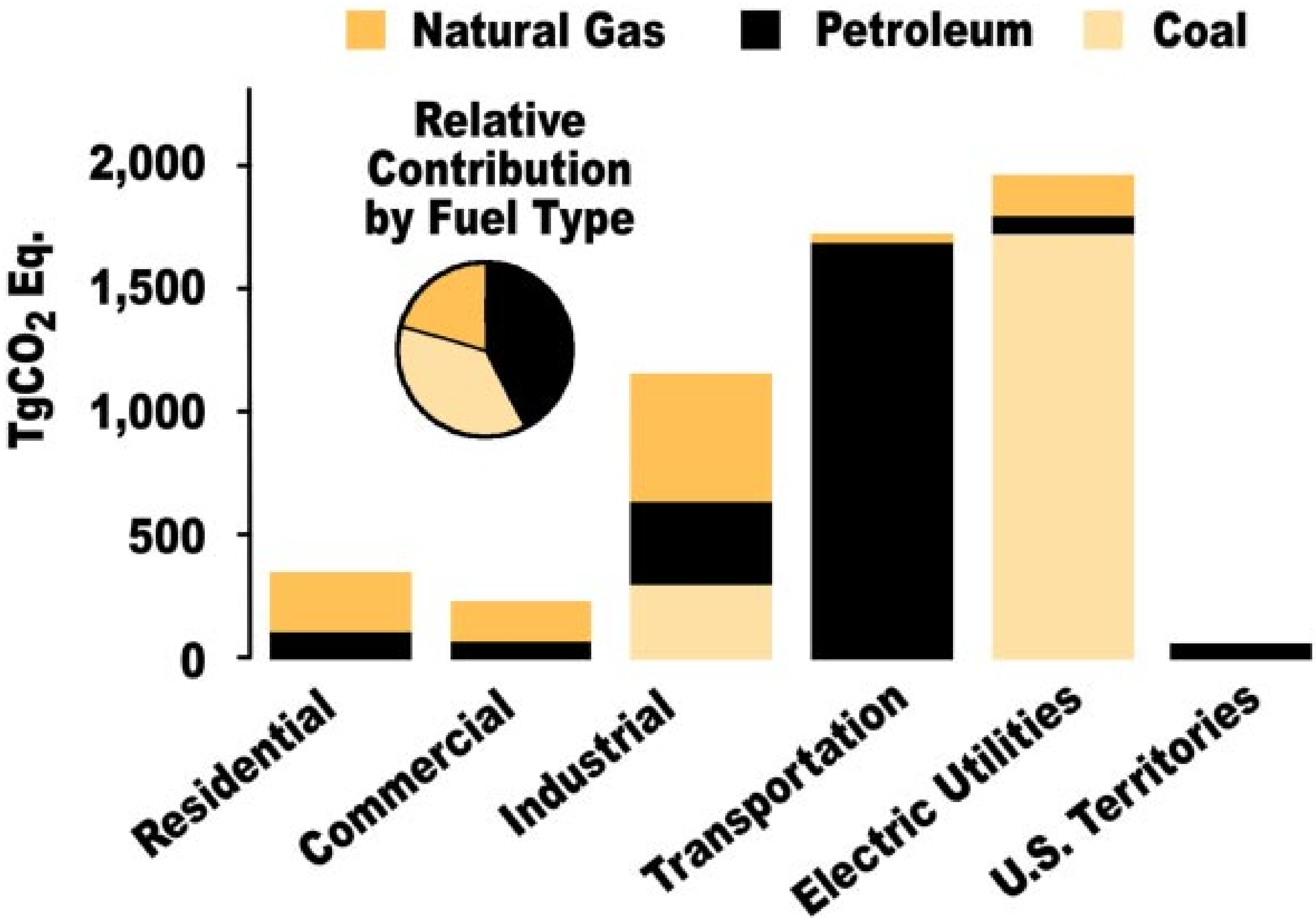
Source: U.S. DOE, NETL



Source: Energy Information Administration, Emissions of Greenhouse Gases in the United States 1998, DOE/EIA-0573

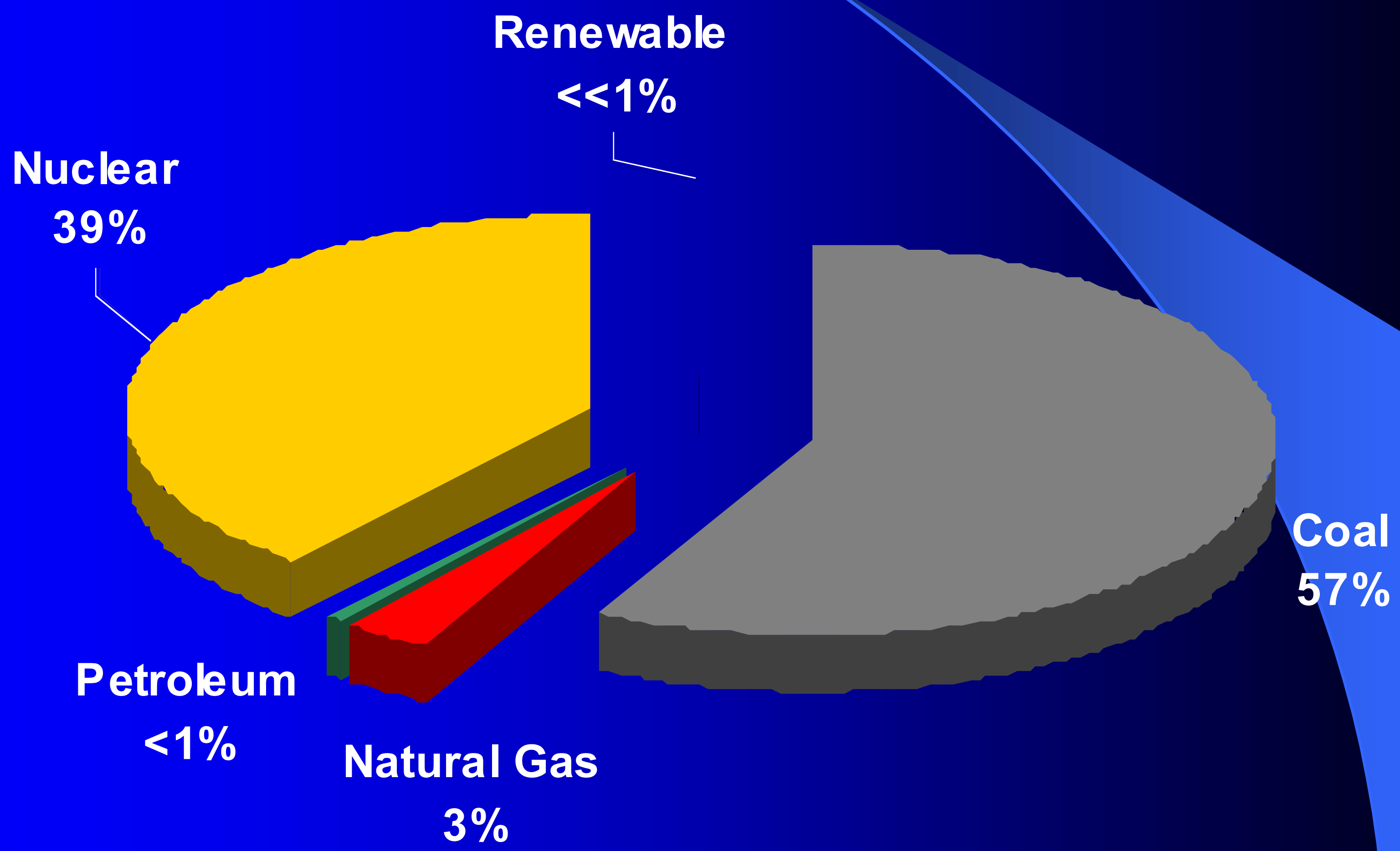


Fossil Fuel Combustion
5,453
Cement Manufacture
Waste Combustion
Lime Manufacture
Natural Gas Flaring
Limestone and Dolomite Use
Soda Ash Manufacture and Consumption
Carbon Dioxide Consumption
Portion of All Emissions
0
10
20
30
40
TgCO2 Eq.



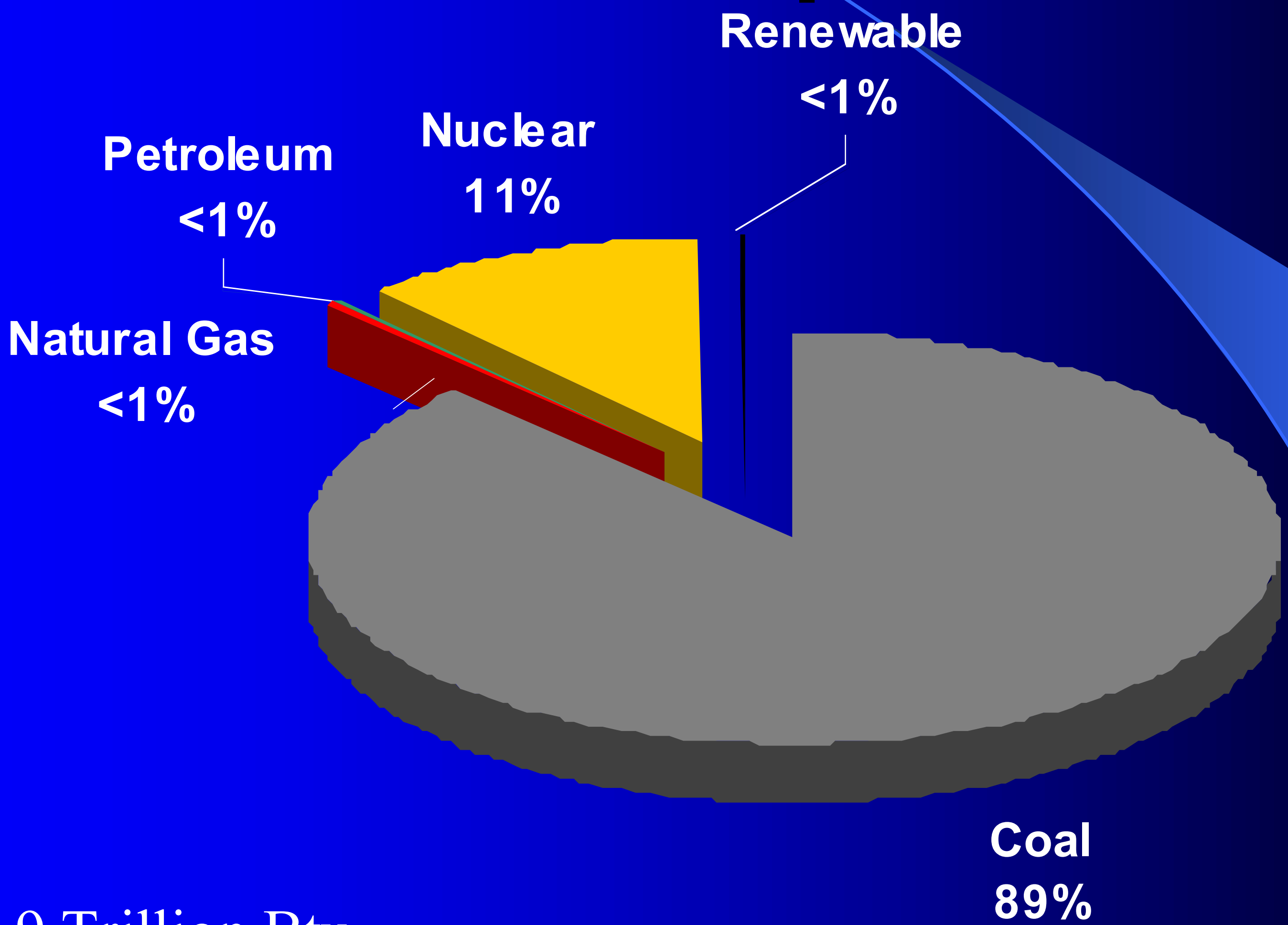
Note: Utilities also include emissions of 0.04 TgCO_2 Eq. from geothermal based electricity generation.

Illinois Electrical Energy Consumption



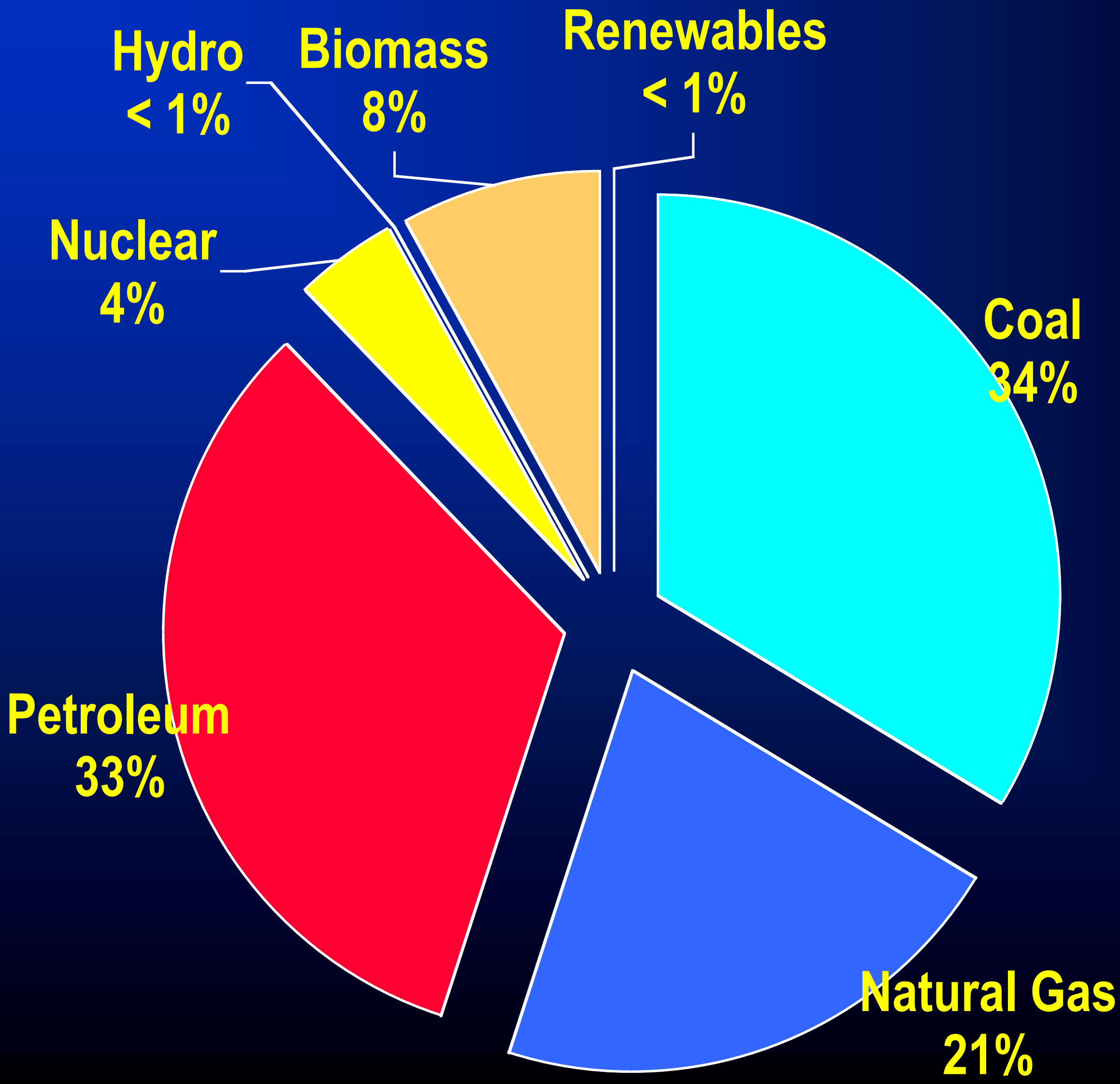
1397.6 Trillion Btu

Ohio Electrical Energy Consumption



1432.9 Trillion Btu

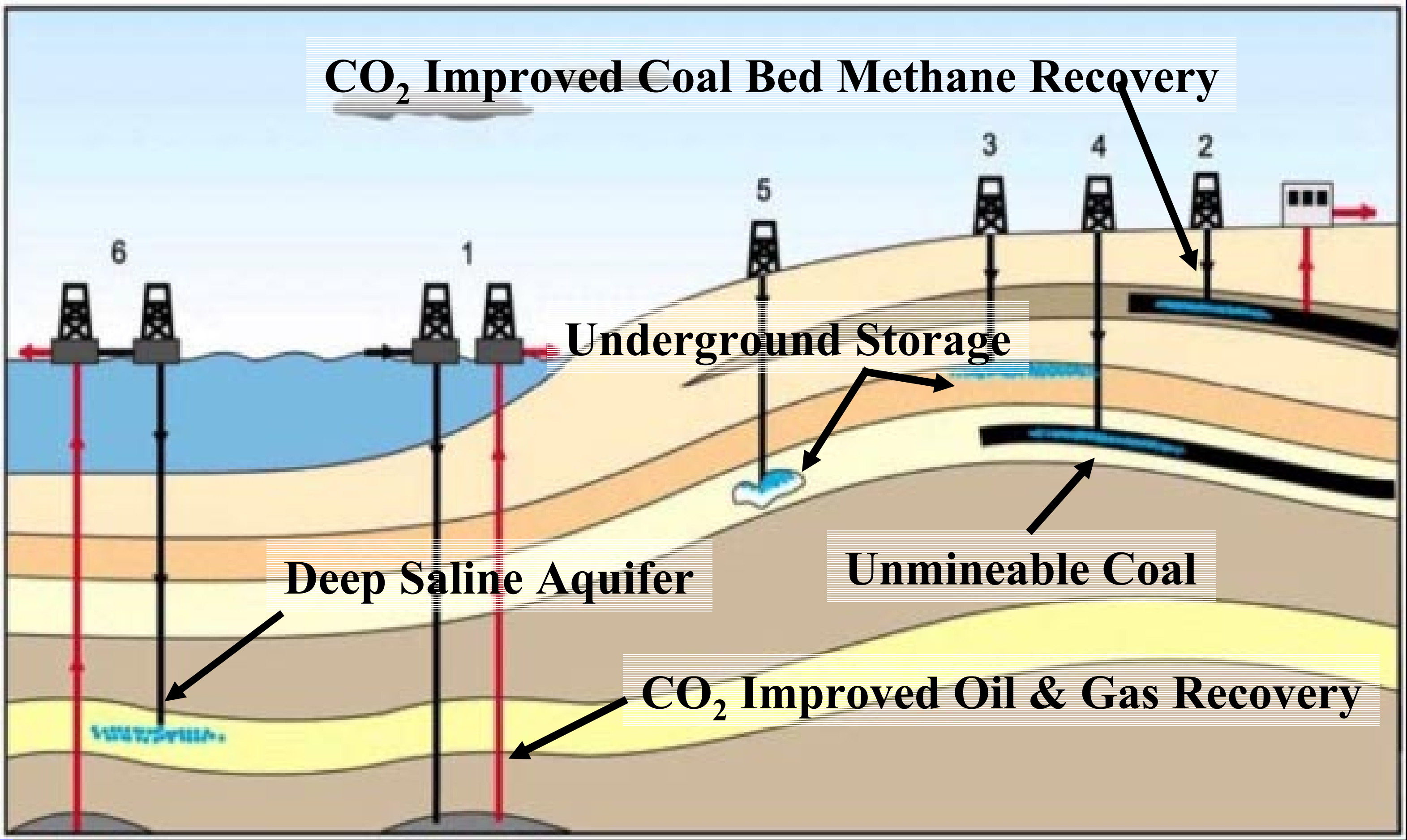
Total Ohio Energy Consumption by Source



CO_2 Sequestration - Sink Characterization

- Oil Reservoirs
  - CO_2 Miscible and Immiscible Flooding
  - Reservoir Fluid and Rock Properties
  - Geologic and Engineering Data
- Coalbeds - Enhanced Methane Recovery
- Saline Aquifers
- Conventional and Unconventional Gas Reservoirs - Enhanced Gas Recovery?

CO_2 Geologic Sequestration Options



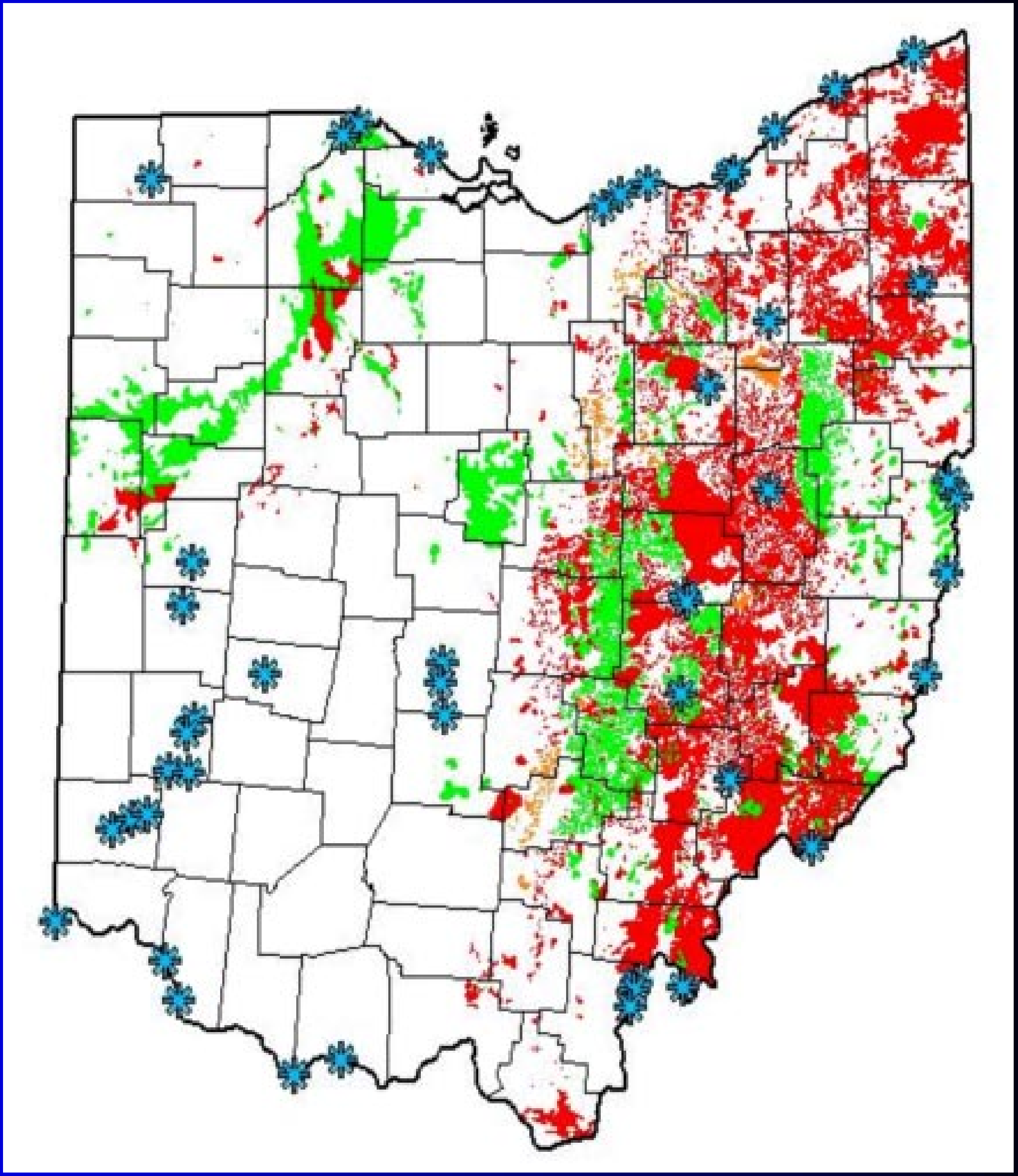
Modified from: http://www.spacedaily.com/news/greenhouse-00j.html

Ohio

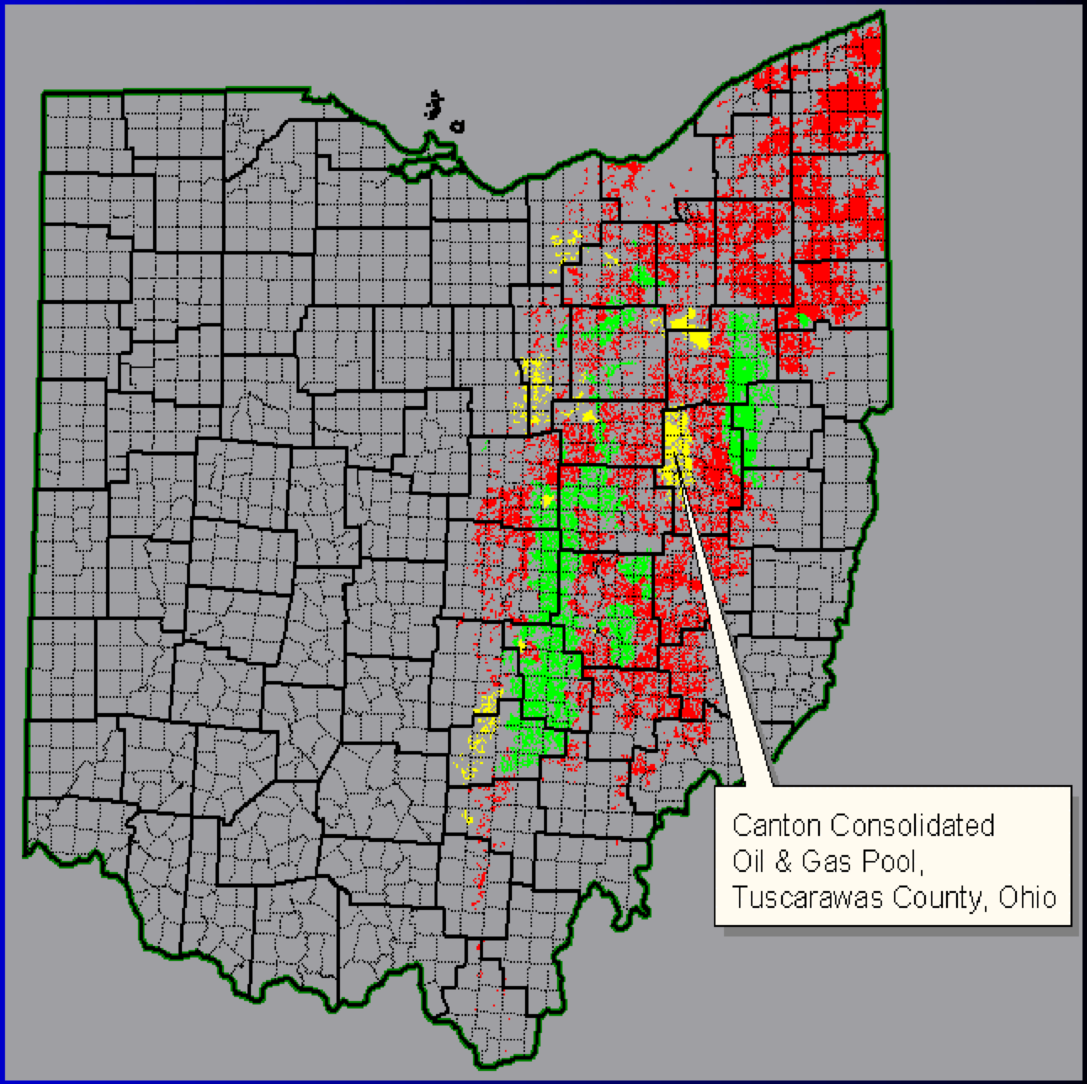
Oil & Gas Fields

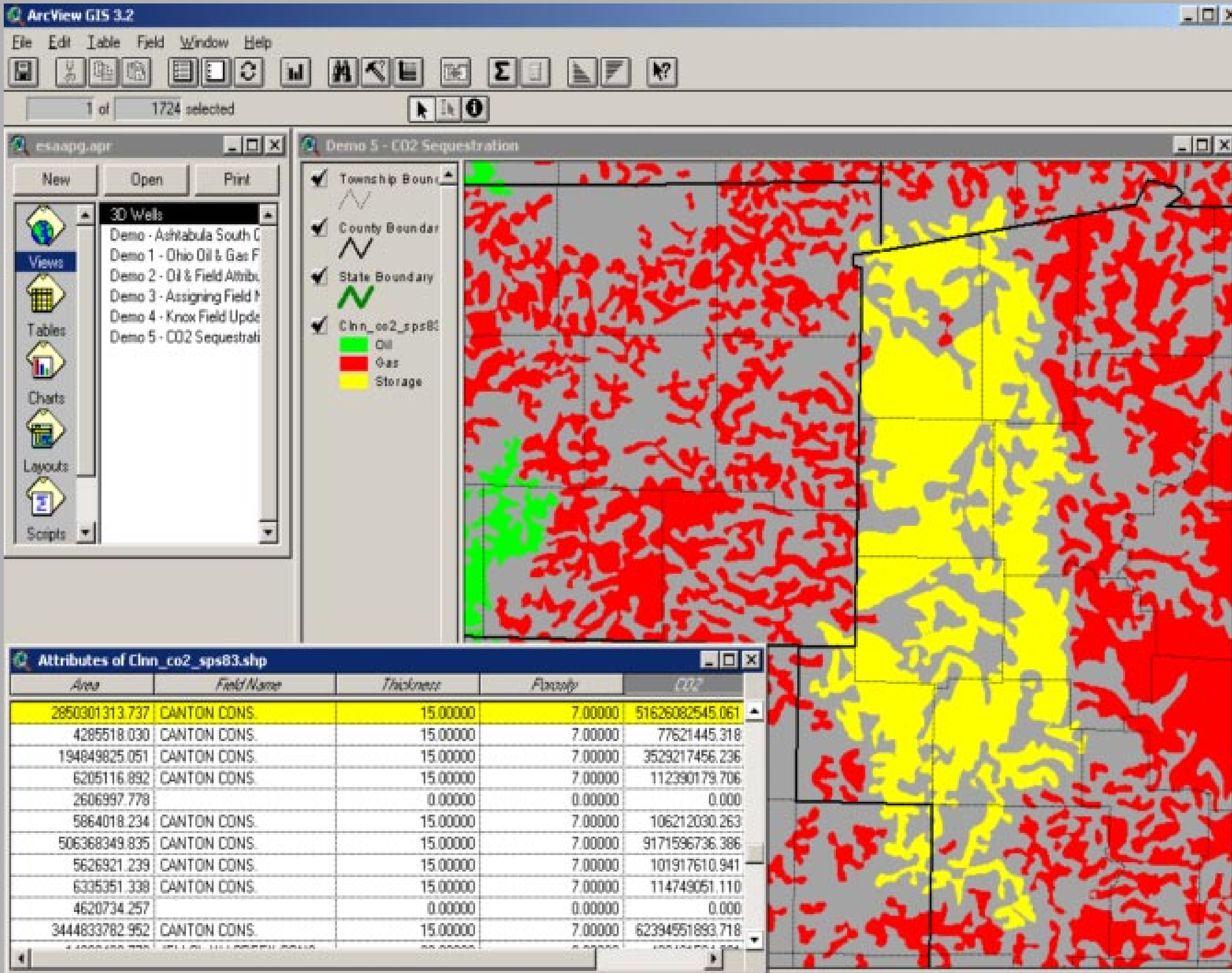
And

Power Generating Plants



The amount of CO_2 sequestration in oil & gas fields can be calculated using geographic information systems (GIS) technology. In this figure, the Clinton sandstone oil & gas pools GIS layer is displayed. Each pool in the GIS layer is represented by a color filled polygon and each of the polygons is tied to a record in the attribute table. Each pool has many different attributes associated with it, such as Average Thickness, Average Porosity, and Original Oil In Place. Using the attributes associated with each polygon, calculations can be made as to how much CO_2 can be sequestered in each oil & gas pool. These calculations are now an attribute associated with each polygon in the GIS. Highlighted in yellow, this pool of the Canton Consolidated oil & gas field can sequester over 51 billion tons of CO_2.

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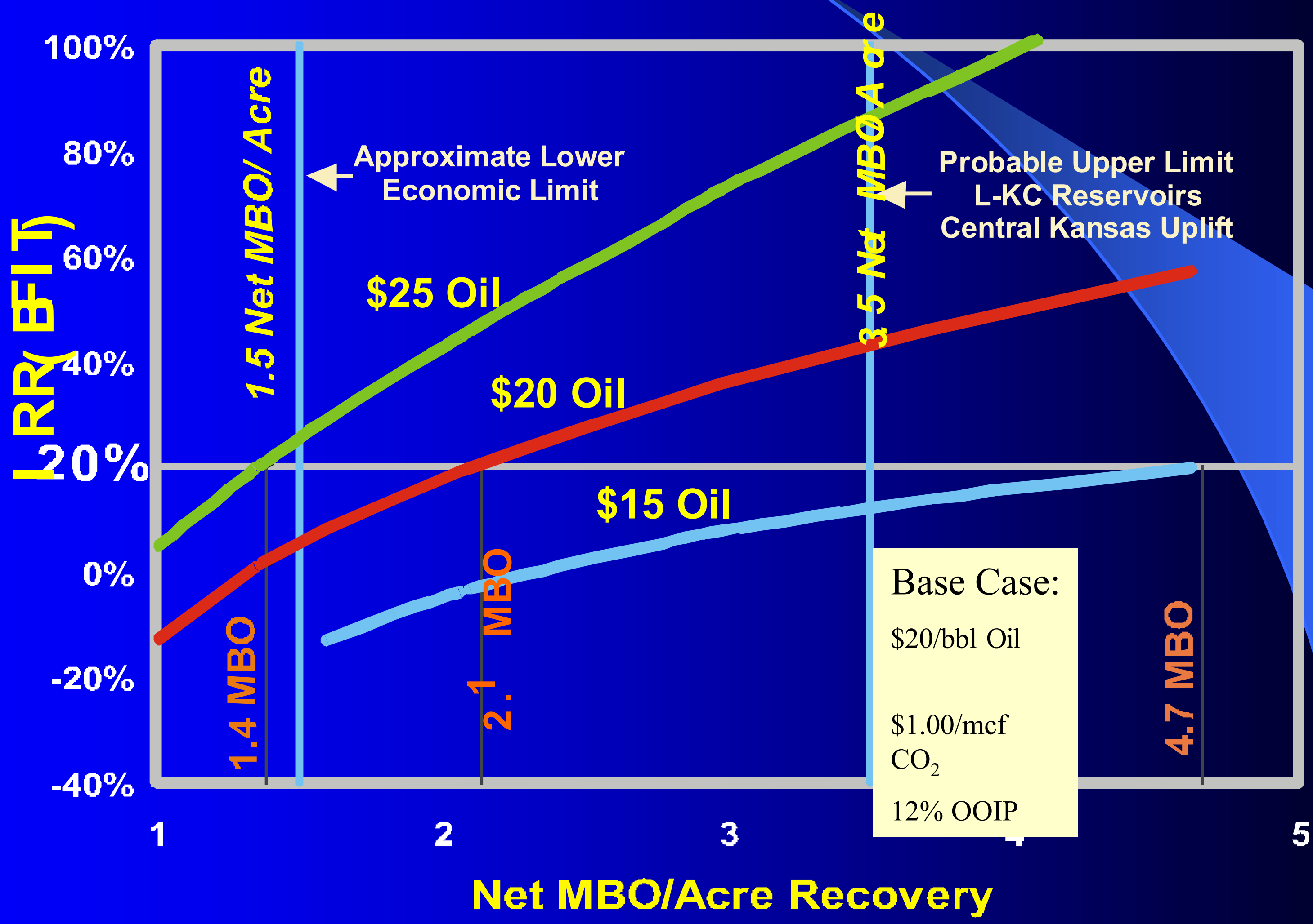
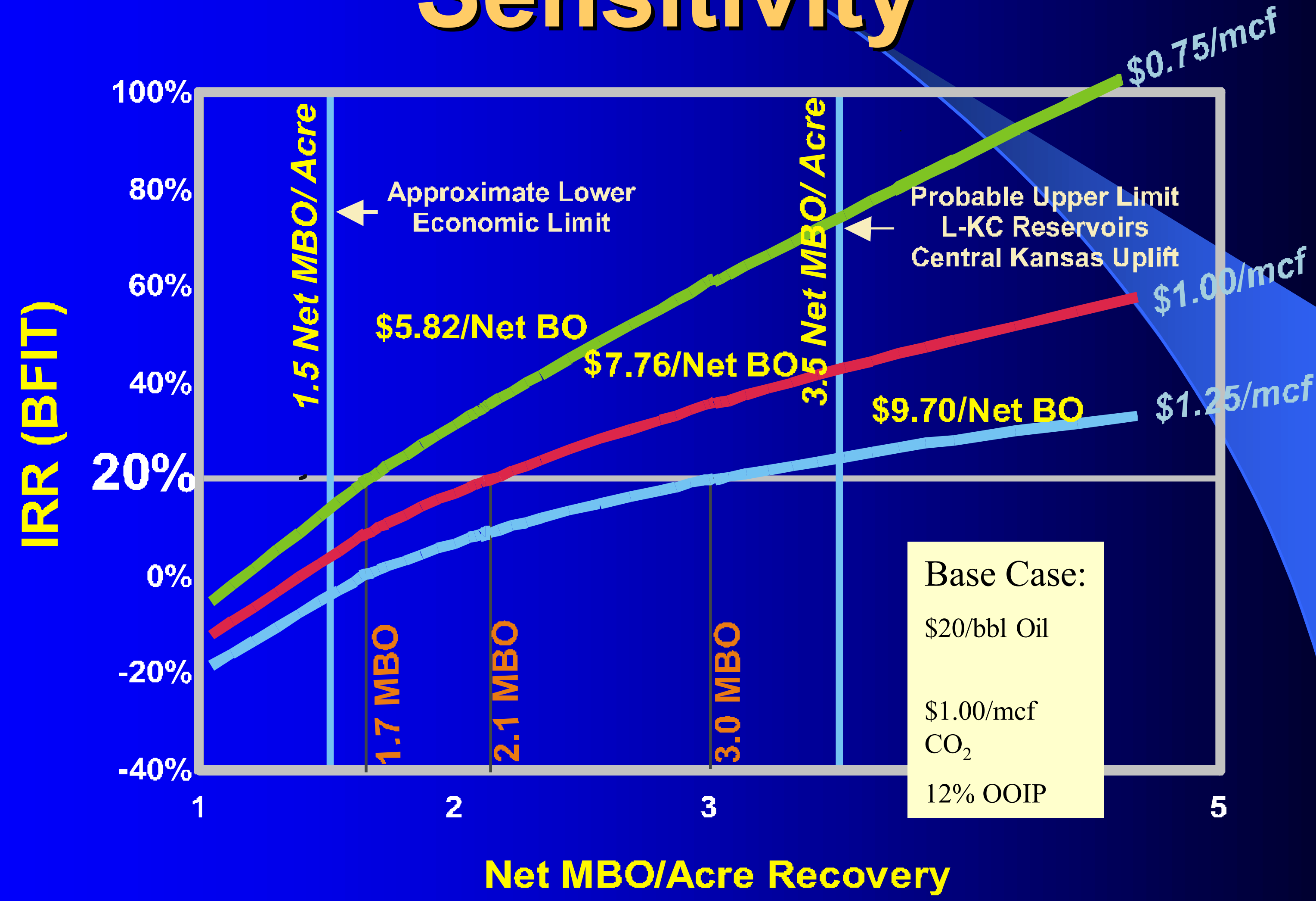
Demo - Ashtabula South
Demo 1 - Ohio Oil & Gas F
Demo 2 - Oil & Field Attribu
Demo 3 - Assigning Field
Demo 4 - Knox Field Upd
Demo 5 - CO2 Sequestrati
Demo 5 - CO2 Sequestration
Township Boun
County Boundar
State Boundary
Clnn_co2_sps8
Oil
Gas
Storage
Attributes of Clnn_co2_sps83.shp
Area | Field Name | Thickness | Porosity | CO2
2850301313.737 | CANTON CONS. | 15.00000 | 7.00000 | 51626082545.061
4285518.030 | CANTON CONS. | 15.00000 | 7.00000 | 77621445.318
194849825.051 | CANTON CONS. | 15.00000 | 7.00000 | 3529217456.236
6205116.892 | CANTON CONS. | 15.00000 | 7.00000 | 112390179.706
2606997.778 | | 0.00000 | 0.00000 | 0.000
5864018.234 | CANTON CONS. | 15.00000 | 7.00000 | 106212030.263
506368349.835 | CANTON CONS. | 15.00000 | 7.00000 | 9171596736.386
5626921.239 | CANTON CONS. | 15.00000 | 7.00000 | 101917610.941
6335351.338 | CANTON CONS. | 15.00000 | 7.00000 | 114749051.110
4620734.257 | | 0.00000 | 0.00000 | 0.000
3444833782.952 | CANTON CONS. | 15.00000 | 7.00000 | 62394551893.718

CO_2 Flooding: Oil Price Sensitivity



CO_2 Flooding: CO_2 Price Sensitivity



1995 Carbon Dioxide Emissions for Coal-Fired Utility Units

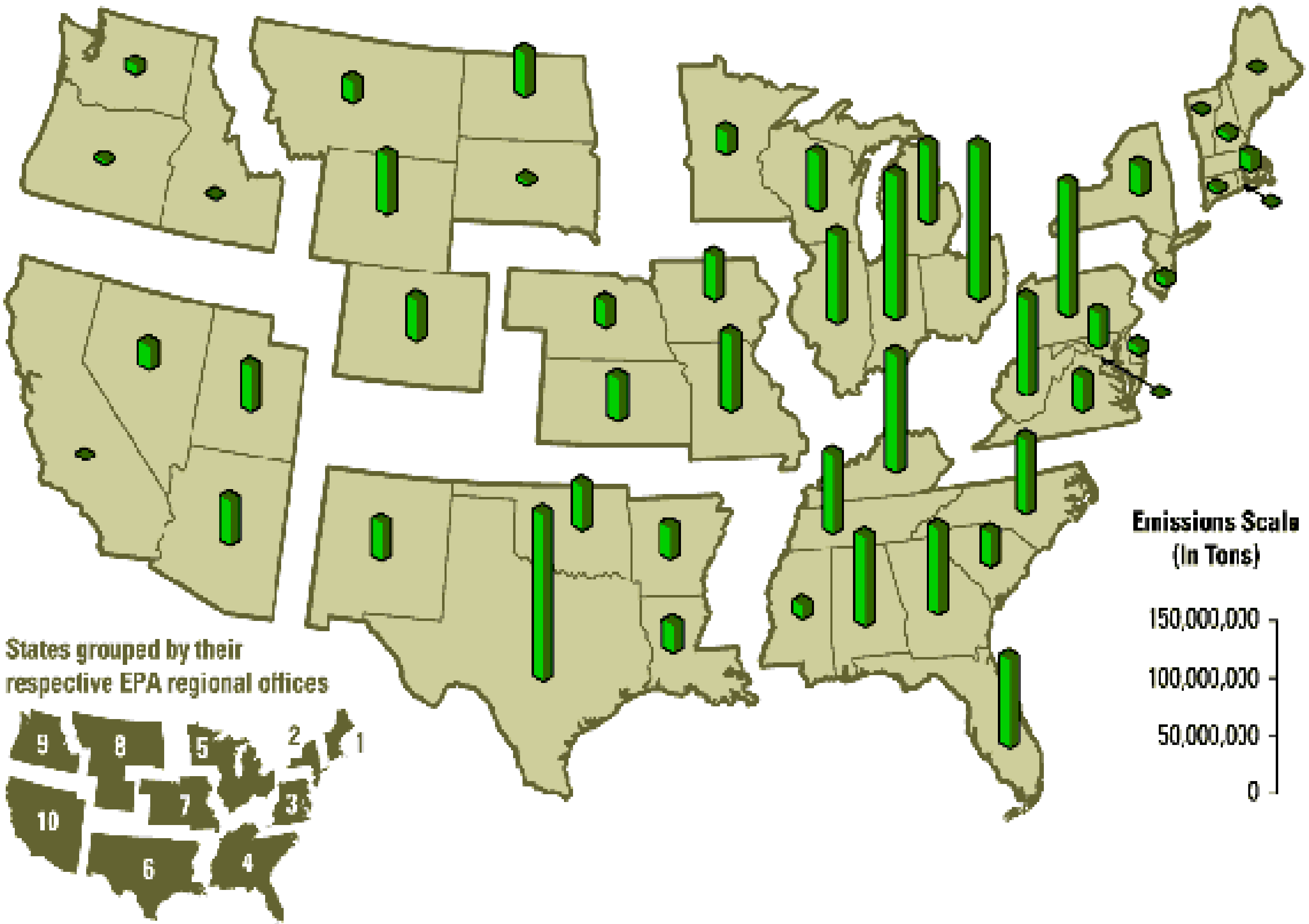


Table 1. Atmospheric CO_2 Data in U.S. Tons

(Source : Pollution Equipment News, June, 2001)

CO_2 in the earth's atmosphere	5.7×10^{13} tons/yr
CO_2 emitted by global soil and vegetarian	4.7×10^{11} tons/yr
CO_2 emitted by the world's oceans	3.6×10^{11} tons/yr
CO_2 emitted globally from fossil fuels	3.2×10^{10} tons/yr
CO_2 emitted by world's fossil fuel power plants	7.2×10^{9} tons/yr
CO_2 emitted by global transportation	5.6×10^{9} tons/yr
CO_2 emitted by American power plants	2.3×10^{9} tons/yr
CO_2 emitted by the world population breathing	3.3×10^{9} tons/yr