Findings of the U.S. Climate Change Science Program Synthesis and Assessment Report 2.2:

The First State of the Carbon Cycle Report: North American Carbon Budget and Implications for the Global Carbon Cycle

Summary and Frequently Asked Questions

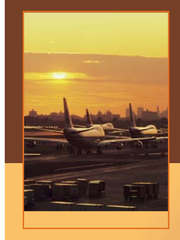
The increase in atmospheric carbon dioxide from human activity is recognized as the largest single agent of recent climate change. North America is currently a net source of carbon dioxide to the atmosphere, contributing to the global buildup of greenhouse gases and associated changes in the earth's climate.

North America contributes about a quarter of global fossil-fuel emissions.

- North America contributed 27% of global fossil-fuel emissions in 2003, approximately 85% of the North American emissions were from the United States, 9% from Canada, and 6% from Mexico.

Forests play a critical role in removing carbon dioxide from the atmosphere.

- Approximately 50% of North America's terrestrial sink is due to the regrowth of forests in the United States on former agricultural land that was last cultivated decades ago, and on timberland recovering from harvest.



In North America, more carbon dioxide is emitted to the atmosphere from energy use than is removed by plants and soil.

- In 2003, growing vegetation in North America removed approximately 30% of the fossil-fuel emissions produced from North America. The imbalance between the fossil-fuel source and the sink on land is a net release to the atmosphere.

Actions to reduce fossil-fuel emissions will likely be required.

- The large difference between current sources and sinks and the expectation that the difference could become larger suggests that addressing imbalances in the North American carbon budget will likely require actions focused on reducing fossil-fuel emissions.

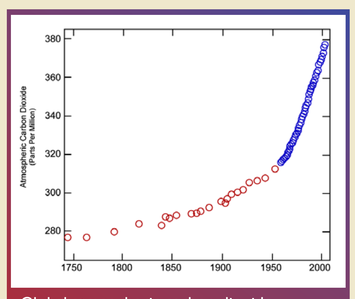
The primary source of human-caused carbon emissions in North America is the release of carbon dioxide during the combustion of fossil-fuels. Fossil-fuel carbon emissions for North America have increased at an average rate of approximately 1% per year for the last 30 years.

Why should we care about the global carbon cycle?

Carbon Dioxide in the Global Atmosphere

Humans have altered the Earth's carbon budget. Today, the cycling of carbon among atmosphere, land, and freshwater and marine environments is in rapid transition and out of balance. Over just decades, the combustion of fossil fuels has released quantities of carbon into the atmosphere that were accumulated in the earth system over millions of years. Forests that once held large quantities of carbon are being converted to agricultural lands, releasing additional carbon to the atmosphere. Both the fossil-fuel and land-use related releases are *sources* of carbon to the atmosphere. The combined rate of release is far larger than can be balanced by the biological and geological processes that naturally remove carbon dioxide from the atmosphere and store it in terrestrial and marine environments. These processes are known as *sinks*. Therefore, much of the carbon dioxide released through human activity has "piled up" in the atmosphere, resulting in a dramatic increase in the atmospheric concentration of carbon dioxide.

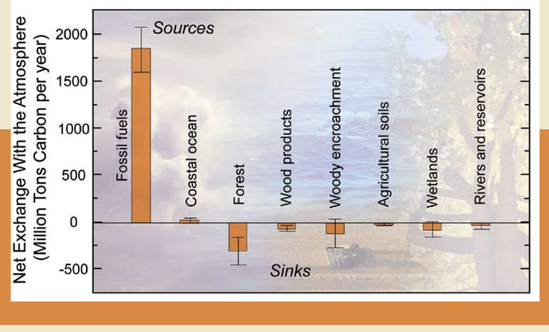
The atmospheric concentration of carbon dioxide increased by 31% between 1850 and 2003, and the present concentration is higher than at any time in at least the past 420,000 years.



Global atmospheric carbon dioxide concentration from 1750 to 2005. The data prior to 1957 (red circles) are from the Siple ice core and data since 1957 (blue circles) are from continuous atmospheric sampling at the Mauna Loa Observatory (Hawaii).

North America's Role in Global Atmospheric Carbon Dioxide Concentrations

In 2003, North America was responsible for approximately 27% of the carbon dioxide emissions produced globally by fossil-fuel combustion. The United States, the world's largest emitter of carbon dioxide, accounted for 85% of the North American total, while Canada accounted for 9%, and Mexico for 6%. Among all countries, the United States, Canada, and Mexico ranked, respectively, as the first, seventh, and eleventh largest emitters of carbon dioxide from fossil fuels in 2003.



North American carbon sources and sinks (million tons carbon per year).
Sources add carbon dioxide to the atmosphere (bars above the zero line); sinks remove it (bars below the zero line). The uncertainty in the estimates is noted by the thin lines. This graphic clearly shows that fossil fuels dominate the balance, resulting overall in a net source to the atmosphere.

What are the activities that produce emissions from fossil fuels in North America?

The conversion of fossil fuels to energy (primarily electricity) is the single largest contributor, accounting for approximately 42% of North American fossil emissions in 2003.

More than half of electricity produced in North America (67% in the United States) is consumed in buildings, making that single use one of the largest factors in North American emissions.

- The carbon dioxide emissions from United States buildings alone were greater than total carbon dioxide emissions of any country in the world, except China in 2003.
- In the United States, the major drivers of energy consumption in the buildings sector are growth in commercial floor space and increase in the size of the average home. Carbon emissions resulting from electricity use in buildings are expected to grow with population and income.

Transportation is the second largest factor in North American emissions, accounting for 31% of total emissions in 2003.

- 87% of North American emissions from transportation comes from the United States.
- The growth in transportation and associated carbon dioxide emissions has been steady during the past forty years and has been most rapid in Mexico, the country most dependent upon road transport.
- The growth of transportation is driven by population, *per capita* income, and economic output. Energy use in transportation is expected to increase by 46% in North America between 2003 and 2025.

Emissions from North American industry (not including fossil-fuel mining and processing or electricity generation) are a relatively small (12%) and declining component of North America's emissions.

What are the activities in North America that remove carbon dioxide from the atmosphere?

Approximately 30% of North American fossil-fuel emissions are offset by a sink combining factors such as forest regrowth, fire suppression, and agricultural soil conservation.

- The primary carbon sink in North America (approximately 50%) is in the forests of the United States and Canada, which are still growing (accumulating carbon) after re-colonization of farmland 100 or more years ago.

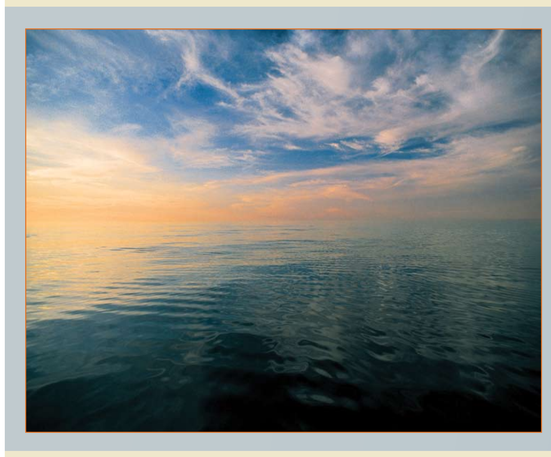
- The suppression of forest fires also increases the accumulation of carbon in forests.
- The contribution of forest regrowth is expected to decline as the maturing forests grow more slowly and take up less carbon dioxide from the atmosphere. However, it's far from certain how forests and other sinks will respond to changes in climate and carbon dioxide concentration in the atmosphere.

- Wood products are thought to account for about 13% of the total North American sink. This sink is growing because wood products are increasing, both in use (*e.g.*, furniture, house frames, *etc.*) and in landfills.
- The growth of urban trees in North America produced a sink that accounted for approximately 1% to 3% of North American fossil-fuel emissions in 2003.

What are the management options for reducing atmospheric carbon dioxide concentrations?

- **Options to enhance sinks** (*e.g.*, growing forests) can contribute to reducing carbon dioxide concentrations, but enhancing sinks alone is likely insufficient to deal with either the current or future imbalance.
- **Options to reduce emissions** include efficiency improvement, fuel switching, and technologies such as carbon capture and geological storage (see also back page).

- **Implementing these options** will likely require an array of policy instruments at local, regional, national, and international levels, ranging from the encouragement of voluntary actions to economic incentives, tradable emissions permits, and regulations.



Options for reducing carbon emissions include:

- Reducing emissions from the transportation sector through efficiency improvement, higher prices for carbon-based fuels, liquid fuels derived from vegetation (ethanol from corn or other biomass feedstock, for example), and in the longer run (after 2025), hydrogen generated from non-fossil sources of energy.
- Reducing the carbon emissions associated with energy use in buildings through efficiency improvements and energy-saving passive design measures.
- Reducing emissions from the industrial sector through efficiency improvement, fuel-switching, and innovative process designs.
- Reducing emissions from energy extraction and conversion through efficiency improvement, fuel- switching, technological change, and reduced demands due to increased end-use efficiency.
- Capturing the carbon dioxide emitted from fossil-fired generating units and injecting it into a suitable geological formation or deep in the sea for long-term storage (carbon capture and storage).

Options for managing land-based carbon stocks include:

- Maintaining existing terrestrial carbon stocks in vegetation and soils and in wood products.
  Reducing carbon loss associated with land management practices, including those of agriculture (e.g., reduced tillage in expanding croplands), and forest harvest (e.g., minimizing soil disturbance).
- Increasing terrestrial carbon sequestration through afforestation, reforestation, planting of urban "forests," reduced tillage in established crop lands, and similar practices.

This NOAA poster summarizes the U.S. Climate Change Science Program Synthesis and Assessment Report 2.2 , which provides a synthesis and integration of the current knowledge of the North American carbon budget and its context within the global carbon cycle. The report (1) summarizes our knowledge of carbon cycle properties and changes relevant to the contributions of and impacts upon North America and the rest of the world, and (2) provides scientific information for decision support focused on key issues for carbon management and policy.

The idea for a State of the Carbon Cycle Report (SOCCR) was first developed by the Carbon Cycle Interagency Working Group (CCIWG) of the U.S. Climate Change Science Program in consultation with its Carbon Cycle Science Steering Group. A subcommittee of the CCIWG, the Agency Executive Committee (AEC) facilitated the development of this report. The AEC included representatives of the lead and supporting agencies assigned to Synthesis and Assessment Product 2.2 (SAP 2.2) and the assigned Lead Agency Coordinator for SAP 2.2. Funding for the preparation and production of SAP 2.2 was provided by NASA, NOAA, DOE, and NSF. The peer review was led by NOAA, in collaboration with the Agency Executive Committee. Additionally, USDA and USGS contributed by supporting several of their scientists' participation on the Scientific Coordination Team and as chapter authors.

The full report can be found at: http://www.climatescience.gov/