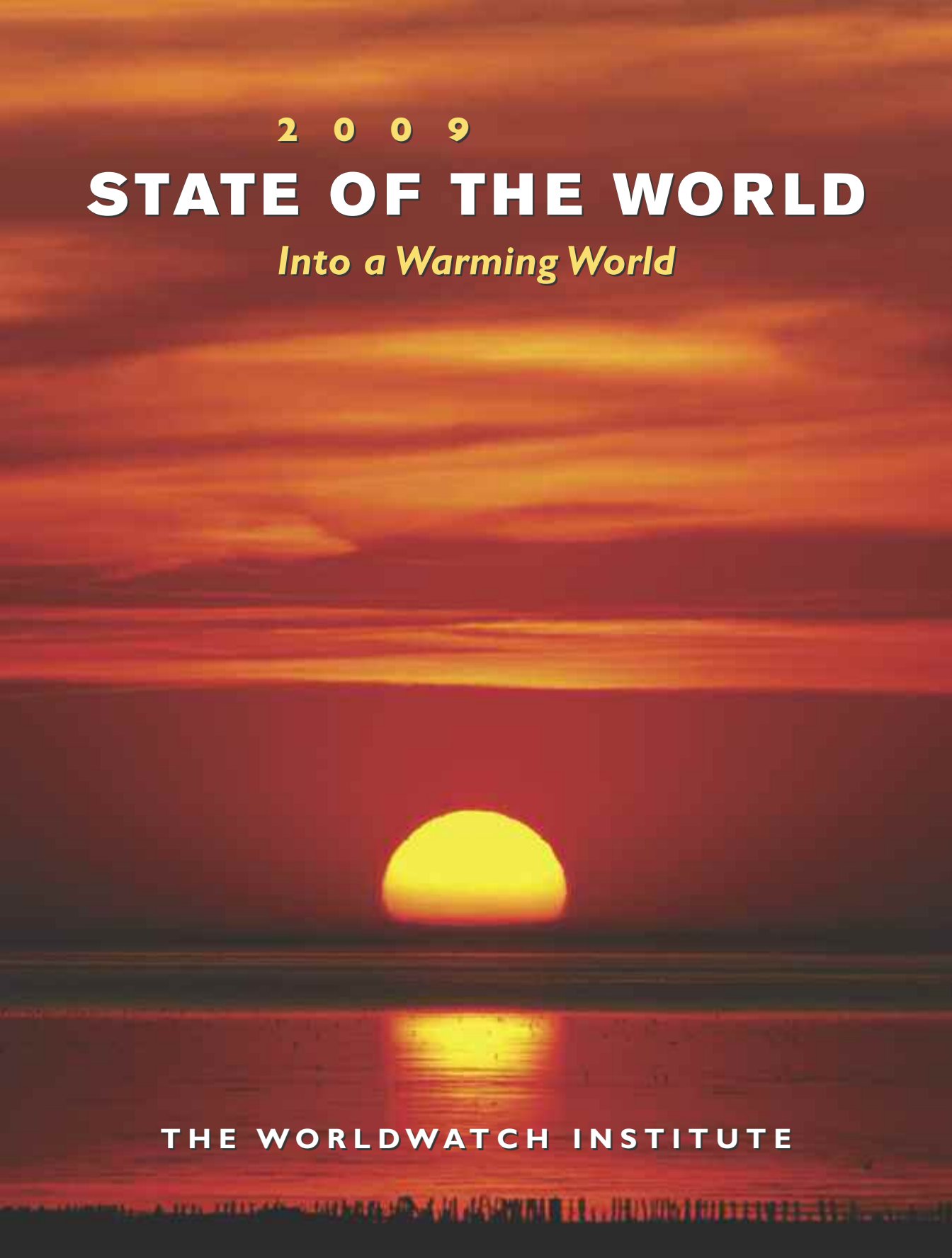


2009

# STATE OF THE WORLD

## *Into a Warming World*

THE WORLDWATCH INSTITUTE

# Climate Change Reference Guide and Glossary

*Alice McKeown and Gary Gardner*

At the heart of climate change is the greenhouse effect, in which molecules of various gases trap heat in Earth's atmosphere and keep it warm enough to support life. Carbon dioxide and other "greenhouse gases" (GHGs) are an important part of Earth's natural cycles, but human activities are boosting their concentrations in the atmosphere to dangerous levels. The result is rising global temperatures and an unstable climate that threatens humans, economies, and ecosystems.

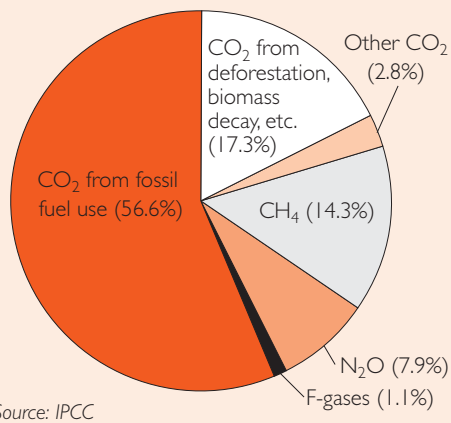
## Sources of Climate Change

### Global Emissions of Greenhouse Gases

The primary human-generated greenhouse gases are carbon dioxide, methane, chlorofluorocarbons (fluoride gases), and nitrous oxide. Greenhouse gases are only one source of climate change; aerosols such as black carbon and land use changes such as deforestation also affect warming.[1]

| Greenhouse Gas | | Generated by |
|---|---|---|
| Carbon Dioxide ($CO_2$) | | Fossil fuel combustion, land clearing for agriculture |
| Methane ($CH_4$) | | Livestock production, extraction of fossil fuels, rice cultivation, biomass burning, landfills, sewage |
| Nitrous Oxide ($N_2O$) | | Industrial processes, fertilizer use, land clearing |
| F gases | Hydrofluorocarbons (HFCs) | Leakage from refrigerators, aerosols, air conditioners |
| | Perfluorocarbons | Aluminum production, semiconductor industry |
| | Sulfur Hexafluoride ($SF_6$) | Electrical insulation, magnesium smelting |

**Share of Global Emissions, in Carbon Dioxide Equivalent, 2004**



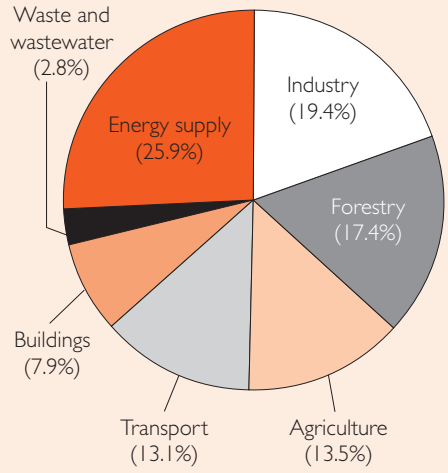

*Source: IPCC*

## Greenhouse Gas Sources, by Sector

Greenhouse gases come from a broad range of human activities, including energy use, changes in land use (such as deforestation), and agriculture.[2]

| Source | Sample Emission-generating Activities |
|---|---|
| Energy Supply | Generation of primary energy supplies, chiefly from fossil fuels; production of fuels for electricity, transportation, and heat; includes extraction and refining |
| Industry | Production of metals, pulp and paper, cement, and chemical production |
| Forestry | Deforestation, decomposition of biomass that remains after logging |
| Agriculture | Crop and livestock production |
| Transport | Travel by car, plane, train, or ship |
| Residential and Commercial Buildings | Heating, cooling, and electricity |
| Waste | Landfills, incineration, wastewater |

**Emissions by Sector, in Carbon Dioxide Equivalent, 2004**

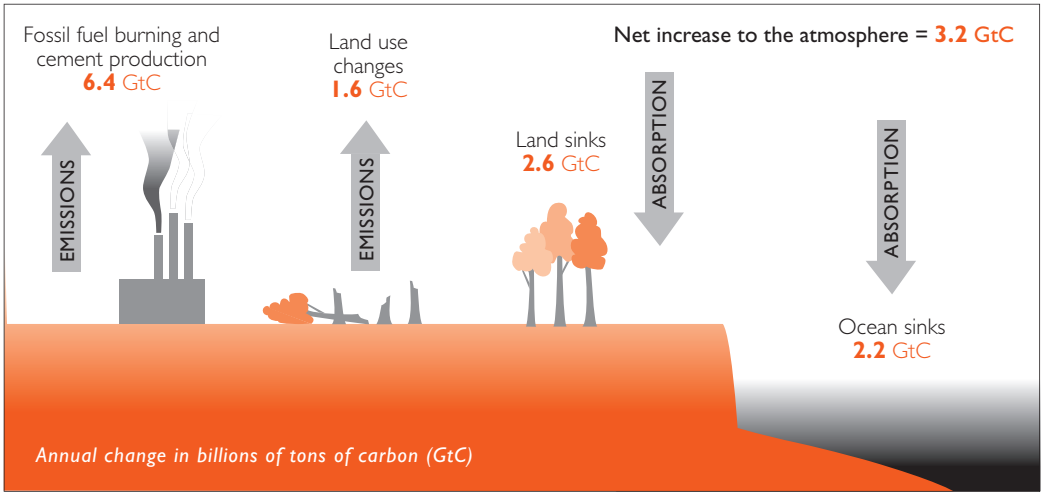



*Source: IPCC*

# Measuring Climate Change

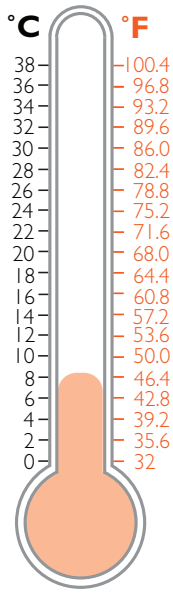
## The Carbon Cycle

Carbon flows among land, sea, and the atmosphere. But human activities since the mid-eighteenth century have changed carbon flows in ways that have lasting implications for the climate. This graphic depicts changes to global carbon flows in the 1990s relative to the preindustrial state.[3]




## Temperature Conversion

Changes to global temperature caused by climate change are usually measured in degrees Celsius. One degree Celsius is equal to 1.8 degrees Fahrenheit—meaning that a 2-degree Celsius rise is 3.6 degrees Fahrenheit. Actual temperature readings in the different scales are easily compared when placed side by side.



## Carbon, Carbon Dioxide, and Carbon Dioxide Equivalents

Carbon, the basis of life on Earth, is at the center of the climate crisis. Carbon is found in solid, liquid, and gaseous form. $CO_2$ is the most prevalent of human-generated greenhouse gases. $CO_2$ is so dominant that all other greenhouse gases are evaluated in terms of their equivalency to $CO_2$.

| Indicator | Carbon | Carbon Dioxide | Carbon Dioxide Equivalent |
|---|---|---|---|
| Molecular makeup | One atom of carbon. | One atom of carbon and two atoms of oxygen. | A measurement, not a chemical element, so no molecular formula. |
| Symbol | C | $CO_2$ | $CO_{2eq}$ or $CO_{2e}$ |
| Description | Carbon cycles among land, sea, air, and biological systems and is the building block of many but not all greenhouse gases. | A gaseous form of carbon, $CO_2$ is the breath people exhale, the fizz in soda—and part of the exhaust from burning fossil fuels. Most human carbon emissions are in the form of $CO_2$. | A unit of measurement that allows the global warming contribution of greenhouse gases to be compared with each other, even if they have a different molecular makeup. |
| Calculation | One ton of carbon = 3.67 tons of carbon dioxide. | Not typically converted to other units. Measured as emissions and as a concentration in the atmosphere. | Quantity of a greenhouse gas multiplied by its global warming potential. |

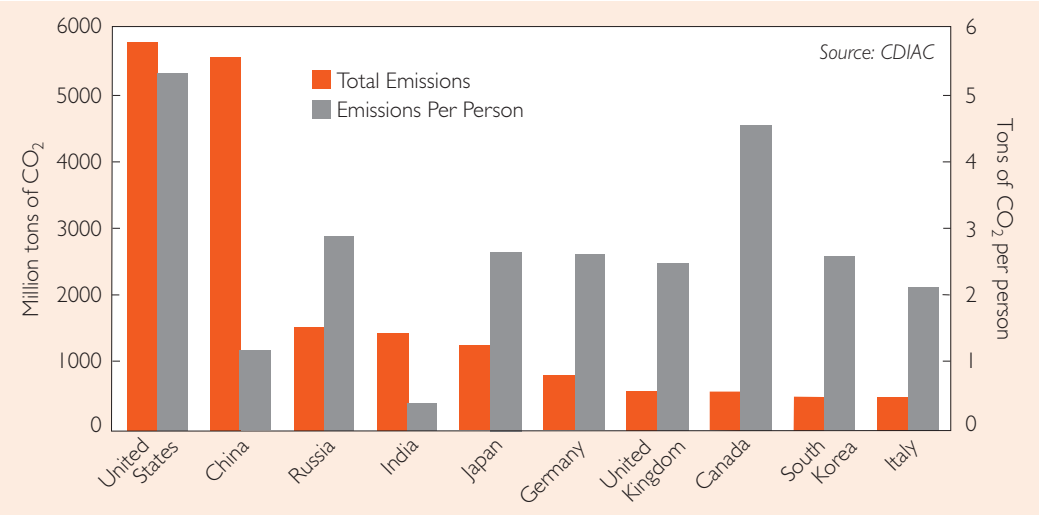
## Global Warming Potential of Selected Greenhouse Gases

Global warming potential (GWP) expresses a gas's heat-trapping power relative to carbon dioxide over a particular time period (this Table uses the common 100-year frame). GWP allows observers to compare the contributions to climate change made by various greenhouse gases that have different warming effects and life spans. A methane molecule, for example, has 25 times the warming potential of a carbon dioxide molecule, and some gases are hundreds or thousands of times more powerful.[4]

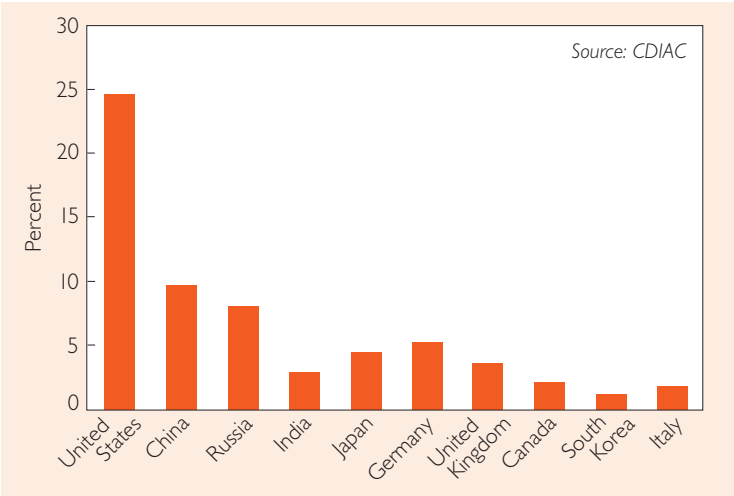
| Greenhouse Gas | Global Warming Potential |
|---|---|
| Carbon Dioxide | 1 |
| Methane | 25 |
| Nitrous Oxide | 298 |
| Hydrofluorocarbons | 124 – 14,800 |
| Perfluorocarbons | 7,390 – 12,200 |
| Sulfur Hexafluoride | 22,800 |

## Top 10 $CO_2$-Emitting Nations, Total and Per Person, 2005

National emissions levels vary greatly. Among the top 10 emitters, the United States generates 12 times more $CO_2$ than Italy does. The 10 leading emitters generate many more times the emissions of most developing countries, although emissions in those countries are rising rapidly and could soon overtake the annual emissions in industrial countries. The top 10 emitting nations also exhibit a broad range of emissions per person. Wealthy countries tend to emit more carbon dioxide per person than poor countries do.[5]

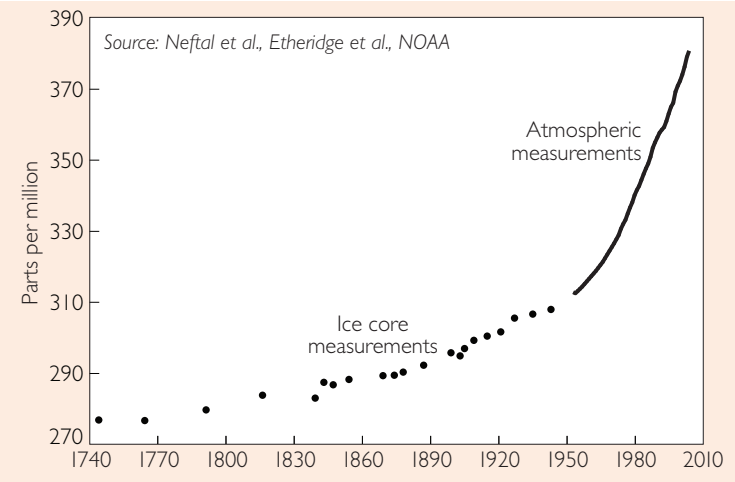



## Top 10 $CO_2$-Emitting Nations' Share of Global $CO_2$ Emissions, 1950–2005




Over time, early industrializing nations typically have emitted more carbon dioxide to the atmosphere than nations that industrialized later.[6]

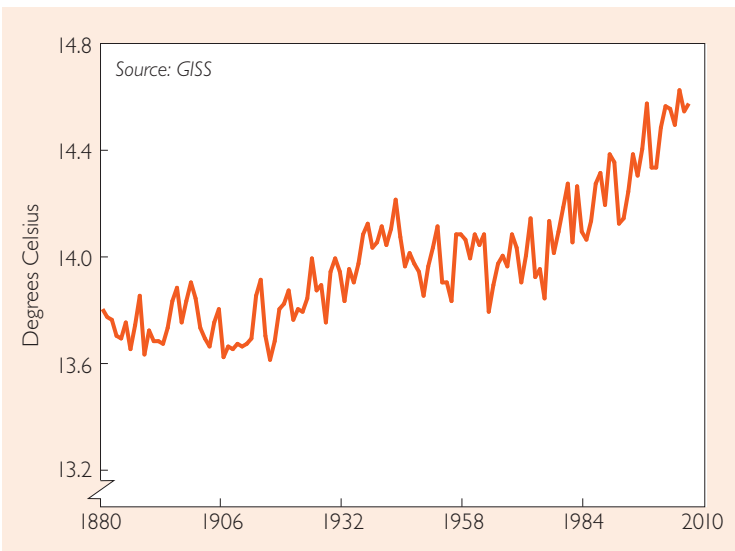
## Concentration of $CO_2$ in Earth's Atmosphere, 1744–2007




Since the mid-eighteenth century fossil fuel use and cement production have released billions of tons of $CO_2$ to the atmosphere. Carbon dioxide levels in the atmosphere before the Industrial Revolution were some 280 parts per million (ppm). By 2007, levels had reached 384 ppm—a 37-percent increase.[7]

# Consequences of Greenhouse Gas Buildup

## Average Global Temperature at Earth's Surface, 1880–2007




Average global temperature increased by 0.74 degrees Celsius between 1906 and 2005. The Intergovernmental Panel on Climate Change (IPCC) predicts an additional rise of 1.8–4.0 degrees Celsius this century, depending on how much and how soon greenhouse gas emissions are curbed.[8]

## The 10 Warmest Years on Record, 1880–2007

Direct temperature readings dating back to the nineteenth century show that the last 10 years had 8 of the 10 warmest years on record.[9]

| Ranking | Year |
|---|---|
| 1 | 2005 |
| 2 | 1998 |
| 3 | 2002 |
| 4 | 2003 |
| 5 | 2007 |
| 6 | 2006 |
| 7 | 2004 |
| 8 | 2001 |
| 9 | 1997 |
| 10 | 1995 |

## Climate Tipping Elements

Scientists believe that several "climate tipping elements" could destabilize the planet's climate by setting off chain reactions—"positive feedbacks"—that accelerate other climate changes. Once a tipping element is triggered by crossing a threshold or tipping point, there is no turning back even if all greenhouse gas emissions were to end. Some tipping elements, such as the loss of Arctic summer sea ice, may be triggered within the next decade if climate change continues at the same rate. Others—the collapse of the Atlantic ocean current, for instance—are thought to be many decades away.[10]

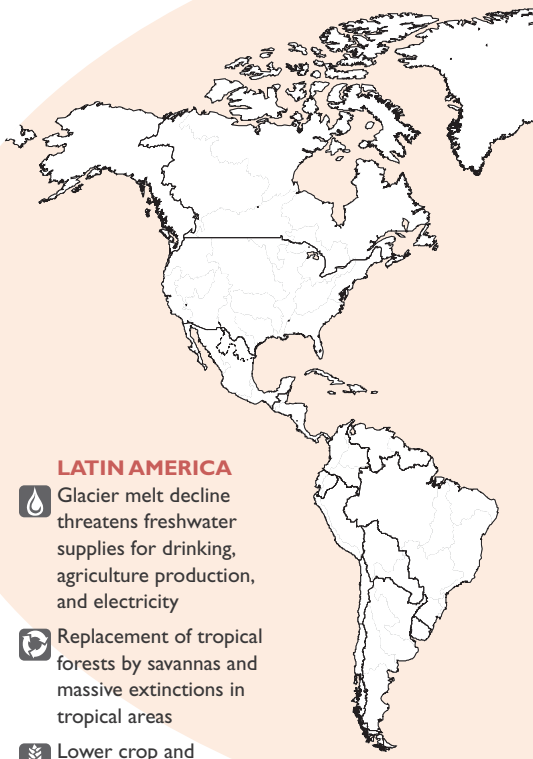
| Tipping Element | Expected Consequences |
|---|---|
| Loss of Arctic summer sea ice | Higher average global temperatures and changes to ecosystems |
| Melting of Greenland ice sheet | Global sea level rise up to 7 meters and higher average global temperatures |
| Collapse of West Antarctic ice sheet | Global sea level rise up to 5 meters and higher average global temperatures |
| Collapse of the Atlantic ocean current | Disruptions to Gulf Stream and changes to weather patterns |
| Increase in El Niño events | Changes to weather patterns, including increased droughts, especially in Southeast Asia |
| Dieback of boreal forest | Severe changes to boreal forest ecosystems |
| Dieback of Amazon forest | Massive extinctions and decreased rainfall |
| Changes to the Indian summer monsoon | Widespread drought and changes to weather patterns |
| Changes to the Sahara/ Sahel and the West African monsoon | Changes to weather patterns, including potential greening of the Sahara/Sahel—one of the few positive tipping elements |

## Expected Impacts of an Unstable Climate

| System or Condition | Changes |
|---|---|
| Fresh Water | • Increased droughts<br>• Increased heavy precipitation events and flooding<br>• Decreased drinking and fresh-water supplies and availability<br>• Glacier melt decline<br>• Increased salinization of freshwater sources |
| Ecosystems | • Massive extinctions<br>• Animal and plant migration<br>• Increased wildfires, flooding, and drought<br>• Decreased forest coverage, expanding arid lands, and other similar changes<br>• Ocean acidification and coral reef bleaching<br>• Spread of exotic, invasive plants and animals |
| Food and Agriculture | • Reduced crop yields<br>• Shifting growing zones<br>• Increasing hunger and malnutrition<br>• Declining fish yields |
| Health | • Increased deaths due to floods, heat waves, storms, fires, and drought<br>• Changes in the distribution of certain infectious diseases, including malaria<br>• Increased cardiorespiratory diseases<br>• Increased disease spread from contaminated and polluted drinking water supplies<br>• Increased diarrheal disease<br>• Increased malnutrition |
| Coasts | • Increased coastal flooding, especially in low-lying islands and heavily populated delta regions<br>• Increased soil erosion<br>• Increased intensity and strength of tropical storms |

**NORTH AMERICA**

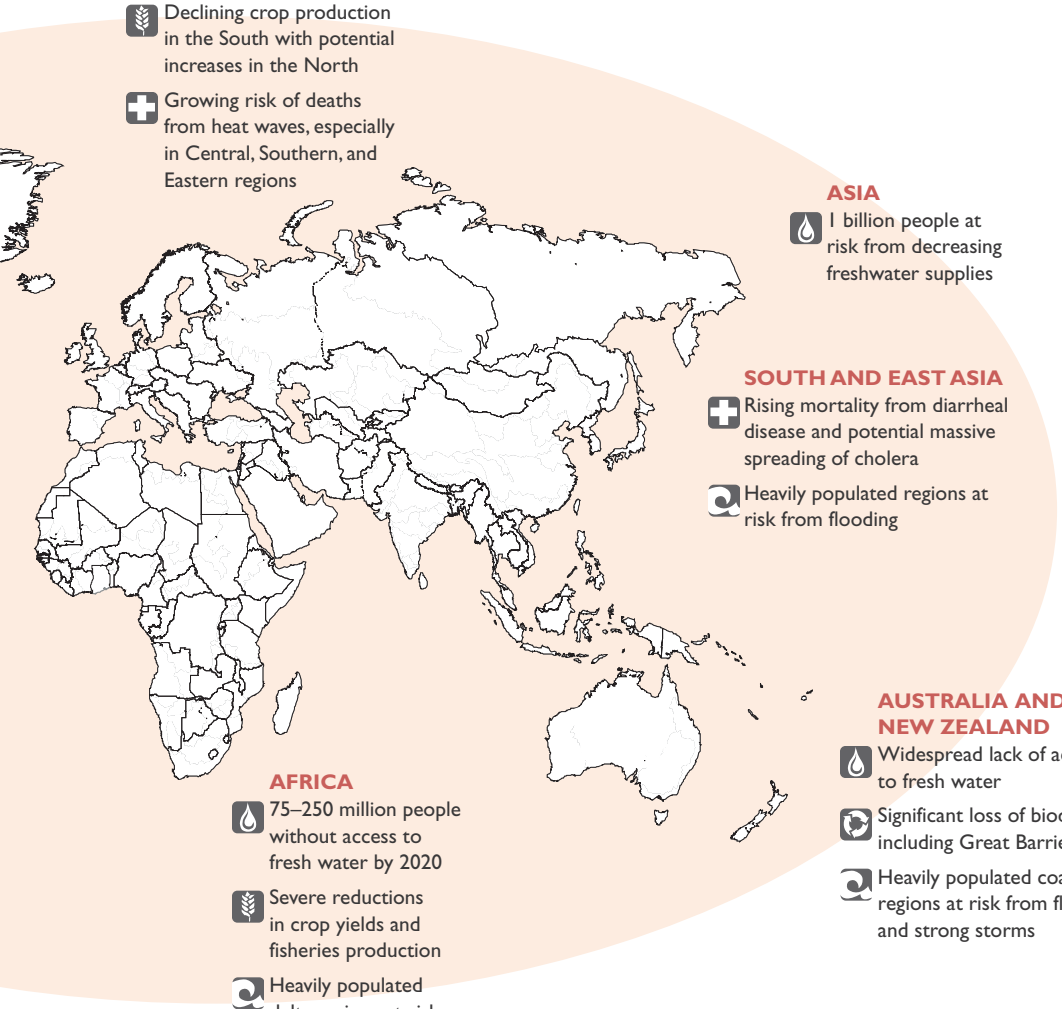
- Reduced snowpack and summer flows in West
- Greater fire risk and more areas burned
- Growing risk of deaths from heat waves



**LATIN AMERICA**

- Glacier melt decline threatens freshwater supplies for drinking, agriculture production, and electricity
- Replacement of tropical forests by savannas and massive extinctions in tropical areas
- Lower crop and livestock yields from desertification and salinization as well as declining fish production

Climate changes are already occurring today and will continue to accelerate as greenhouse gas concentrations rise over time. While climate change is global, the impacts are felt differently from region to region.[11]



## Avoiding Dangerous Effects of Climate Change

Scientists talk about several potential climate stabilization levels that could help minimize the negative effects of climate change. Policymakers rally around these different stabilization points, using them to develop policies to rein in greenhouse gas emissions. But not everyone agrees on the same stabilization points, and recent studies indicate that the levels may need to be lower than once believed.[12]

| Potential Stabilization Points | Details |
|---|---|
| Global temperature increase of 2 degrees Celsius | According to the IPCC, the risks and threats of climate change increase dramatically when global temperature rises more than 2 degrees Celsius (3.6 degrees Fahrenheit). Government leaders and nongovernmental organizations have embraced 2 degrees as the maximum rise allowable if the worst effects of climate change are to be avoided. |
| Global greenhouse gas reductions of 15–20 percent below baseline levels within the next 10–20 years | Reduction needed to limit global temperature rise to 2–3 degrees Celsius, according to the IPCC. This goal suggests that carbon dioxide concentrations must peak by 2015–20 and then fall. Many policymakers use a variation of this number to set guidelines for action. |
| Atmospheric $CO_2$ at 350 ppm | NASA climate scientist James Hansen and his colleagues argue that many global warming tipping points have already been passed. Although current concentrations of $CO_2$ in the atmosphere exceed 380 parts per million, these scientists believe that atmospheric concentrations need to drop to 350 ppm or lower as soon as possible. |
| Atmospheric $CO_2$ at 450–550 ppm | U.K. economist Nicholas Stern advises that the uppermost stabilization levels for atmospheric concentrations of $CO_2$ should not exceed 450–550 parts per million in order to avoid global economic collapse. Based on climate models, this stabilization point takes into account predictions about technological developments and the time needed for widespread action. |

# The Diplomatic Road to Copenhagen

Fifteen years after international climate negotiations began at the Rio Earth Summit in 1992, and 10 years after the Kyoto Protocol was completed, the Bali Road Map and Action Plan outlined the steps needed to reach a new, post-Kyoto climate treaty in Copenhagen by the end of 2009. Beyond 2009, international negotiations on climate will likely continue in order to set new emission reduction targets, adapt to scientific advances, and adjust to a changing climate.

| | | |
|---|---|---|
| United Nations Framework Convention on Climate Change adopted | JUNE 1992 | Rio de Janeiro Earth Summit |
| Kyoto Protocol adopted to control greenhouse gas emissions through 2012 | DECEMBER 1997 | Kyoto Meeting |
| Kyoto Protocol enters into force | FEBRUARY 2005 | |
| The Bali Road Map and Action Plan outline the steps needed to reach a new international climate treaty by the end of 2009 | DECEMBER 2007 | Bali Meeting |
| Groundwork for the new agreement | | 2008 Meetings in Bangkok, Bonn, Accra, and Poznan |
| | | 2009 Meetings |
| Target date for agreement on a new international climate treaty | DECEMBER 2009 | Copenhagen Meeting |

# Additional Information

Intergovernmental Panel on Climate Change: www.ipcc.ch

United Nations Environment Programme: www.unep.org/themes/climatechange

United Nations Framework Convention on Climate Change: www.unfccc.int

Carbon Dioxide Information Analysis Center: cdiac.ornl.gov/faq.html

# Glossary: 38 Key Terms for Understanding Climate Change

**Adaptation:** Changes in policies and practices designed to deal with climate threats and risks. Adaptation can refer to changes that protect livelihoods, prevent loss of lives, or protect economic assets and the environment. Examples include changing agricultural crops to deal with changing seasons and weather patterns, increasing water conservation to deal with changing rainfall levels, and developing medicines and preventive behaviors to deal with spreading diseases.

**Additionality:** Emissions reductions that are greater than would have occurred under a business-as-usual scenario. For example, in order for emission credits to be awarded, projects under the Clean Development Mechanism and Joint Implementation must show that any emissions reductions are in addition to what would have occurred without the project. Additionality can also be used to describe other added benefits from the projects, including funding, investment, and technology.

**Annex countries:** Groups of nations (for example, Annex 1 or Annex B) with different obligations under international climate agreements. Under the U.N. Framework Convention on Climate Change, Annex 1 countries include industrial countries and economies in transition that agreed to reduce their greenhouse gas emissions to 1990 levels collectively. Annex 2 countries are industrial countries that committed to help developing countries by providing them with technology, financial assistance, and other resources. Annex B countries have assigned emission reduction targets under the Kyoto Protocol. The category non-Annex 1 includes countries that are the most vulnerable to climate change. Some countries are included in more than one Annex.

**Anthropogenic emissions:** Greenhouse gas emissions that are caused by human activities. Also includes emissions of GHG precursors and aerosols.

**Atmospheric concentration:** A measure used by climate scientists to register the level of greenhouse gases in Earth's atmosphere. Atmospheric concentration is most often measured in parts per million of carbon dioxide and can be tracked over time to understand trends and make projections.

**Baseline:** A level or year against which subsequent greenhouse gas emission levels and concentrations are measured, especially in the context of emission reductions. For example, the Kyoto Protocol calls for 5-percent reductions in human-caused greenhouse gases below 1990 levels (the baseline) by the 2008–12 period.

**Black carbon:** Soot and other aerosol particles that come from the incomplete combustion of fossil fuels. Black carbon increases atmospheric warming by lowering the reflectivity of snow, clouds, and other surfaces and by absorbing heat from the sun. Some scientists believe that black carbon plays a large role in climate change and that reducing it may be one of the best opportunities to slow climate change in the short run.

**Cap and trade:** An approach to limiting greenhouse gas emissions that sets a maximum emissions level (a cap) for a region or nation and that requires participating emitters to obtain permits to pollute. Companies or governmental jurisdictions with extra pollution permits can sell or trade them to parties whose permits are insufficient to cover their full emissions.

**Carbon capture and storage (CCS):** A process in which carbon dioxide is separated and captured during energy production or industrial processes and subsequently stored (often by pumping it underground) rather than released into the atmosphere. Also known as carbon capture and sequestration.

**Carbon dioxide ($CO_2$):** The most widespread greenhouse gas. $CO_2$ is released to the atmosphere through natural and human activities, including fossil fuel and biomass burning, industrial processes, and changes to land use, among others.

**Carbon dioxide equivalent ($CO_{2eq}$):** A unit of measurement used to compare the climate effects of all greenhouse gases to each other. $CO_{2eq}$ is calculated by multiplying the quantity of a greenhouse gas by its global warming potential.

**Carbon dioxide intensity and carbon dioxide per capita:** Alternatives to total emissions for measuring a nation's greenhouse gas emissions. Carbon intensity measures emissions per unit of gross domestic product. $CO_2$ per capita measures emissions per person. Both measures can be used to look at emission differences between nations. For example, while China has recently taken the lead in total greenhouse gas emissions, its per capita emissions level is far lower than that in most industrial countries.

**Carbon tax:** A tax levied on carbon dioxide emissions that aims to reduce the total amount of greenhouse gas emissions by setting a price on pollution. A carbon tax can be used independently or in conjunction with other emissions controls such as a carbon cap. The tax generates revenue that can be used to underwrite further emissions reductions, technology development, cost relief for consumers, or other initiatives.

**Clean Development Mechanism (CDM):** A mechanism under the Kyoto Protocol that allows industrial countries to meet their emission reduction targets by investing in low- or no-emission projects in developing nations. The CDM also aims to stimulate investment in developing countries.

**Conference of the Parties (COP):** Regular meetings of governments that have signed an international treaty to discuss its status and possible revision. The fifteenth COP of the UNFCCC will be held in Copenhagen 30 November – 11 December 2009.

**Emission Reduction Unit (ERU):** One metric ton of carbon dioxide equivalent that is reduced or sequestered. Under the Clean Development Mechanism, industrial countries earn certified emission reduction units (CERs) for projects in developing countries that can be applied toward their national reduction targets. Countries can also earn emission reduction units under the Joint Implementation mechanism.

**Emission trading:** A market approach to reducing greenhouse gas emissions. Trading allows parties that emit less than their allowed emissions to trade or sell excess pollution credits to other parties that emit more than they are allowed. The European Union Emissions Trading Scheme (EU-ETS) is a mandatory emission trading scheme currently in place; the Chicago Climate Exchange (CCX) is a voluntary trading program.

**Forcing:** Changes to the climate system that are caused by natural (volcanic eruptions, for example) or human-caused (such as greenhouse gas emissions) factors. Scientifically, radiative forcing measures changes to the

natural energy balance of Earth's atmosphere that affect surface temperature. So named because it measures incoming solar radiation against outgoing thermal radiation, radiative forcing is expressed as a rate of energy change in watts per square meter. Human-caused forcing factors like greenhouse gases have a positive radiative forcing and cause surface temperature to heat. Other such factors, including some aerosols, have a negative radiative forcing and cause surface temperature to cool.

**Global warming potential (GWP):** A measurement of the relative strength and potency of a greenhouse gas as well as its projected life span in the atmosphere. GWP is based on carbon dioxide, the most common greenhouse gas, and allows comparisons among different greenhouse gases.

**Greenhouse development rights:** Within the context of climate change obligations, the principle that all societies have a fundamental right to reduce poverty, achieve food security, increase literacy and education rates, and pursue other development goals. Societies or countries below a certain income level are excluded from greenhouse gas emission reduction scenarios and are expected to concentrate their resources on raising their standard of living rather than lowering emissions.

**Greenhouse gases (GHGs):** Atmospheric gases that cause climate change by trapping heat from the sun in Earth's atmosphere—that is, produce the greenhouse effect. The most common greenhouse gases are carbon dioxide, methane, nitrous oxide, ozone, and water vapor.

**Intergovernmental Panel on Climate Change (IPCC):** The international scientific body established by the World Meteorological Organization and the U.N. Environment Programme in 1988 to provide an objective and neutral source of information on climate change. The IPCC releases periodic assessment reports that are reviewed and approved by experts and governments.

**Joint Implementation (JI):** An initiative of the Kyoto Protocol that allows industrial countries to earn emission reduction credits by investing in reduction projects in other industrial countries. JI is related to the Clean Development Mechanism, which involves reduction projects in developing countries. Many JI projects are located in Eastern Europe.

**Kyoto Protocol:** A binding agreement that requires 37 countries and the European Community to reduce their human-caused greenhouse gas emissions 5 percent collectively from 1990 levels in the period 2008–12. It was adopted in 1997 under the U.N. Framework Convention on Climate Change and lays out specific steps countries must take to comply. More than 180 countries have signed the protocol, which entered into force on 16 February 2005.

**Land use, land use change, and forestry (LULUCF):** Land use is the set of activities that occur on any given parcel of land, such as grazing, forestry, or urban living. Changes to land use such as converting forestland to agriculture can release significant amounts of greenhouse gases. These activities are considered during climate negotiations and when planning emission reductions.

**Mean sea level:** The average global sea level over time. Mean sea level eliminates variations due to tides, waves, and other disturbances. Sea level is affected by the shape of ocean basins, changes in water quantity, and changes in water density. Climate change is

expected to raise sea level by increasing glacier melts and sea temperatures.

**Mitigation:** Policies and behaviors designed to reduce greenhouse gases and increase carbon sinks.

**Models, predictions, and pathways:** Tools for analyzing alternative climate futures. Scientists use climate and atmospheric modeling to understand how the climate works and how greenhouse gas concentrations and other triggers lead to climate change. Models help scientists make predictions about climate changes resulting from biological, physical, and chemical variables such as greenhouse gas emissions and land use changes. Emission pathway scenarios are developed to understand what emission limits are needed to meet climate stabilization points, such as avoiding a 2-degree rise in surface temperature.

**Parts per million (ppm):** A ratio-based measure of the concentration of greenhouse gases in the atmosphere. Carbon dioxide is usually measured in parts per million; in 2007 the atmospheric concentration of carbon dioxide passed 384 ppm, an increase of more than 100 ppm since 1750. Other less widespread greenhouse gases may be measured in parts per billion or parts per trillion.

**Peak date:** The year that atmospheric concentrations of greenhouse gases must stop growing and begin declining if a given target concentration is to be achieved.

**Reducing emissions from deforestation and degradation (REDD):** A policy that aims to reduce greenhouse gas emissions from deforestation and forest degradation. In principle, REDD provides financial incentives for countries to maintain and preserve forestlands as carbon sinks rather than cutting them down. In December 2007, climate change negotiators in Bali agreed to consider including REDD as part of a new climate change agreement.

**Resilience:** The ability of natural or human systems to survive in the face of great change. To be resilient, a system must be able to adapt to changing circumstances and develop new ways to thrive. In ecological terms, resilience has been used to describe the ability of natural systems to return to equilibrium after adapting to changes. In climate change, resilience can also convey the capacity and ability of society to make necessary adaptations to a changing world—and not necessarily structures that will carry forward the status quo. In this perspective, resilience affords an opportunity to make systemic changes during adaptation, such as addressing social inequalities.

**Sink:** An activity, mechanism, or process that removes greenhouse gases, their precursors, or other small aerosols from the atmosphere. Removals typically occur in forests (which remove carbon dioxide from the atmosphere during photosynthesis), soils, and oceans.

**Stabilization:** The point at which the climate is stable and not undergoing additional systemic changes. Often discussed as carbon dioxide stabilization and measured as concentration of carbon dioxide in the atmosphere.

**Surface temperature (global):** An estimate of the average surface air temperature across the globe. When estimating climate change over time, only abnormal changes to the mean surface temperature—not daily, seasonal, or other common variations—are measured. Global surface temperature is

most commonly expressed as a combination of land and sea temperature.

**Technology transfer:** The flow of knowledge, equipment, and resources among stakeholders that helps countries, communities, firms, or other entities adapt to or mitigate climate change.

**UNFCCC:** United Nations Framework Convention on Climate Change. Adopted on 9 May 1992 and signed at the Rio de Janeiro Earth Summit, the convention established general principles to stabilize greenhouse gas concentrations and prevent dangerous human-caused interference with the climate system. The treaty includes requirements such as preparing national inventories of GHG emissions and a commitment to reduce emissions to 1990 levels. The convention has nearly universal membership, with more than 190 signatory countries.

**Vulnerability:** The degree to which an ecosystem or society faces survival risks due to adverse climate changes. Vulnerability includes susceptibility as well as the ability to adapt. The level of vulnerability determines whether an ecosystem or society can be resilient in the face of climate change.

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