Climate 101: Introduction to Climate Change

From the CSIS Energy and National Security Program

By Michelle Melton and Sarah Ladislaw

Background

The average global temperature has risen 1.4°F (0.8^{0}C) relative to preindustrial levels, and is projected to rise between 2–11.5°F (1.1–6.4^{0}C) by the end of the century. While much remains unknown about the pace of warming, there is established scientific consensus that 1) warming is happening; 2) it is primarily caused by human actions; 3) it will have a significant impact on human population and the global economy through ecosystem changes such as widespread snow and ice melting, rising sea levels, and changing precipitation patterns, among others; and 4) different geographical areas will be affected by climate change differently.

While the Earth has gone through periods of cooling and warming in the past, the overwhelming majority of warming since 1750 is attributable to the rise in greenhouse gases (GHGs), which are gases that absorb energy and slow the loss of heat into space (see box on comparing greenhouse gases). Greater concentrations of GHGs in the atmosphere trap more heat on the planet. This is a naturally occurring process, but humans have added dramatically to GHGs in the atmosphere over the last 250 years, predominantly by clearing land and burning fossil fuels (coal, oil, and natural gas). Prior to the industrial revolution, the atmosphere contained about 280 parts per million (ppm) of carbon dioxide. Currently, the global average is 398 ppm of carbon dioxide, a 40 percent increase over preindustrial levels. Nearly all of this growth in carbon dioxide levels and subsequent warming is attributable to human activity (anthropogenic).

Because GHGs remain in the atmosphere for long periods of time, the impacts of climate change will continue to be felt for the foreseeable future even if the flow of GHG emissions into the atmosphere were reduced. Although the ultimate range of future temperature change is subject to uncertainty, the general trajectory of rising temperatures is clear. Climate change is expected to have many short- and long-term effects on ecosystems and human society, including surface temperature, weather (including precipitation, drought, and tropical cyclones), oceans (including rising ocean heat content, acidification, and sea level rise and coastal land loss), snow and ice, health and society (such as heat-related disease, Lyme disease, pollen season, and heating and cooling degree days, and increased economic, migration, health, and food security risks), and ecosystems (for example, wildfires, streamflow, bird ranges, species extinction, and leaf and bloom dates). These changes are not expected to be evenly distributed geographically, and both the impacts of climate change and the response options will be diverse. In the United States, for example, the southwest is expected to become more arid, changes in winter-spring precipitation could result in less flooding in New England, and the Rocky Mountain region could see a greater frequency of landslides due to an increase in winter precipitation. The ultimate impact of climate change depends on a variety of factors, including GHG emission levels, mitigation scope and pace, as well as natural

1616 RHODE ISLAND AVENUE NW
WASHINGTON, DC 20036
TEL. (202) 887.0200
FAX (202) 775.3199

influences on climate (such as volcanic activity).

GHG Emissions

There are many ways to account for GHG emissions, including by type of gas, by source/activity/industry, by region or country, and in terms of stock (the total cumulative emissions in the atmosphere) or flow (the amount of GHGs added or removed from the atmosphere over a set period of time). Of the net total warming caused by human activity, the majority is caused by long-lived GHGs, primarily carbon dioxide, but also methane, halogenated gases, and nitrous oxide. Human activities release approximately 40 billion tons of CO_{2eq} into the atmosphere annually. These activities are categorized into two groups: energy-related emissions and land-use emissions (sometimes called land use, land use change, and forestry, or LULUCF). Land-use emissions come from agricultural and forestry activities. Energy-related emissions are those related to the burning of fossil fuels including in electricity generation, transportation, industrial production, and residential and commercial heating. Globally, about 80 percent of emissions are energy-related and the remainder is agricultural and land-use-related; this proportion varies by country. In the United States, for example, energy-related emissions account for 80 percent of all U.S. GHG emissions and land use and forestry are net carbon sinks, while in Indonesia, land use accounts for about 60 percent of GHG emissions.

Comparing Greenhouse Gases

Greenhouse gases are gases that trap heat in the atmosphere. GHGs include water vapor, carbon dioxide (CO_2), methane, and nitrous oxide, among others. Different GHGs are more and less effective at trapping heat in the atmosphere, over different periods of time. The period of time that GHGs remain in the atmosphere is called an atmospheric "lifetime," and GHG lifetimes vary greatly, ranging from decades to centuries to millennia. All GHGs remain in the atmosphere long enough to be mixed evenly throughout the globe, meaning that the concentration of GHGs in the atmosphere is roughly the same all over the world. Greenhouse gas emissions are measured in terms of volume (tons).

In order to compare the warming impact of different GHGs, scientists use a concept called the "global warming potential" (GWP). GWP measures the effectiveness of GHGs in trapping energy in the atmosphere over a set time scale (the United States primarily uses the 100-year GWP although there are alternatives, such as a 20-year GWP). GHGs with a high GWP absorb more energy and last longer in the atmosphere than those with a lower GWP. All GHGs are measured in relation to the warming and lifetime of carbon dioxide, which therefore has a GWP of 1. For example, using a 100-year GWP, methane has a GWP of 28–36, whereas hydrofluorocarbons (HFCs) have GWPs in the thousands and tens of thousands. The GWP is used to convert non-CO_2 GHG emissions into a CO_2 equivalent, expressed as CO_{2eq}.

Even if all GHG emissions today stopped, atmospheric concentrations of GHGs would remain high for some time to come because of their atmospheric lifetimes.

About 90 percent of energy-related emissions are in the form of carbon dioxide released during fossil fuel combustion, while the remaining emissions are methane (mainly from oil and gas production, transmission and distribution) and nitrous oxide (primarily from burning fossil fuels). Emissions from the energy sector are growing, and the rate of growth is increasing. In the 1990s, global CO_2 emissions from energy-related uses grew about 1.2 percent per year; between 2000 and 2014 they grew by about 2.3 percent per year. Although GHG emissions have declined or plateaued in some regions of the world, the emissions growth in other regions more than makes up for the difference.

1616 RHODE ISLAND AVENUE NW
WASHINGTON, DC 20036
TEL. (202) 887.0200
FAX (202) 775.3199

When apportioning GHG emissions nationally (as opposed to by industry or sector), GHG emissions can be accounted for cumulatively, annually, or on a per capita basis. The world's largest GHG emitters on a per annum basis are China, the United States, the European Union, India, Russia, and Indonesia. While some Organization for Economic Cooperation and Development (OECD) countries are still significant emitters, the overall OECD share of global emissions is now less than a third of global emissions on an annual basis; moreover, OECD emissions are projected to remain relatively flat for the foreseeable future. Global emissions are shifting to the non-OECD countries, primarily China and India. According to the U.S. Energy Information Administration, through 2040 non-OECD countries will account for 94 percent of the total increase in global CO_2 emissions (China alone accounts for 49 percent of the world's total increase in CO_2 emissions in the projection period). On a per capita basis, however, the United States is by far the largest emitter and China falls lower down on the list. Regardless of how GHG emissions are measured, emissions remain relatively concentrated among a small group of countries; about 14 countries and Europe account for about 80 percent of global emissions (China, the United States, and India alone are responsible for nearly half of annual anthropogenic GHG emissions).

Climate Change Policy

Historically, there has been a strong relationship between energy use and economic growth. Because fossil fuels are a basic input in nearly every facet of economic production and life in industrialized societies, economic activity generates carbon dioxide emissions, although the amount of carbon dioxide per unit of GDP (referred to as "carbon intensity") has decreased over time in OECD economies. Still, all economies depend on burning carbon for much of their economic activity, and for that reason climate policy is closely linked with debates about economic policy, international development policy, and international competitiveness and trade policy. Many analysts believe that transitioning away from fossil fuels, even if technically possible, will have significant near-term costs and may result in lower growth in the near term. How to make this transition while promoting economic growth and minimizing the economic burden on affected groups—while also dealing with the impacts of climate change—is the primary objective of climate policy.

Efforts to address climate change fall into the general categories of mitigation and adaptation. Mitigation is a category of strategies and actions intended to reduce the release of emissions into the atmosphere to slow, stop, and reverse the anticipated effects of climate change. Replacing the use of fossil-based energy sources with low- or non-emitting sources of energy, capturing and storing or reusing emissions from fossil fuel combustion, increasing energy efficiency to reduce emissions, and changing land-use practices are all examples of mitigation strategies. Governments and companies utilize a wide array of technologies and policies to promote mitigation, such as market mechanisms (putting a price on GHG emissions via a tax or cap and trade system), government mandates (requiring a certain level of renewable energy or setting emission reduction requirements, for example), and other mechanisms such as channeling money to research and development programs aimed at mitigation. Despite progress in driving down the cost of various technologies and advancing climate-related policies, the size, scale, and potential cost of the effort required to impact global atmospheric concentrations of CO_2 has proven challenging.

1616 RHODE ISLAND AVENUE NW
WASHINGTON, DC 20036 | TEL. (202) 887.0200
FAX (202) 775.3199

If mitigation is an attempt to prevent further warming, adaptation is the response to the warming that has and is projected to occur by taking steps to protect society from those impacts. Examples of adaptation policies and initiatives include hardening infrastructure to withstand weather and climate conditions expected from climate change, updating building codes, enhancing the resiliency of at-risk communities whose economic livelihood depends on their natural surroundings, planning and managing rapid recovery from impacts that do occur, and protecting populations that face imminent danger from changes to their natural environment.

While the basic science of climate change and the role of human activities in contributing to it is well established and accepted in the scientific community, uncertainty is endemic to climate science and especially to climate policy, provoking disagreements about the appropriate policy responses. There are still considerable scientific uncertainties that stem not only from a lack of data, but from disagreement about interpreting data and even about the limitations of human knowledge in this realm. In addition, while many uncertainties are about the underlying science, others stem from uncertainty about how human economic, social, and political systems will respond to address and cope with climate change. In some cases, uncertainties can be expressed in probabilistic terms; in others, the uncertainties are not readily quantifiable. Compounding these difficulties are the different levels of risk different people and different societies are willing to accept. Given the inevitability of at least some level of uncertainty, the relevant question for policymakers is how to best manage uncertainty and act in spite of it.

U.S. Federal Climate Policy

The U.S. government and the private sector are engaging in both mitigation and adaptation efforts at the municipal, regional, state, and federal level.

In 2009, as part of the international Copenhagen Accord, President Obama pledged to reduce GHG emissions 17 percent below 2005 levels by 2020. To implement that pledge, the Obama administration set forth a specific Climate Action Plan. That plan has three pillars: 1) cut carbon pollution in the United States; 2) prepare the United States for the impacts of climate change; and 3) lead international efforts to address global climate change.

As part of the first pillar, the administration has worked to reduce emissions via a wide array of initiatives. The single-most ambitious effort is being led by the Environmental Protection Agency (EPA), which is using its existing authority under the Clean Air Act to regulate GHG emissions from new and existing fossil-fired power plants (electricity generation accounts for a third of U.S. GHG emissions). In August 2015, the EPA released the final Clean Power Plan, which will reduce emissions from the power sector by at least 32 percent relative to 2005 levels. Other significant federal policy initiatives to reduce emissions include regulating passenger and heavy-duty vehicle emissions, increasing industrial and residential energy efficiency, aggressively addressing HFC emissions, and addressing methane from the agricultural and oil and gas sectors, among others.

Under the second pillar, the administration has released an Executive Order on Preparing the United States for the Impacts of Climate Change. The executive order directs federal agencies to prepare to adapt to climate change and established a task force of state, local, and tribal leaders to advise the federal government on how it can respond to the needs of local communities in dealing with the impacts of climate change.

1616 RHODE ISLAND AVENUE NW
WASHINGTON, DC 20036
TEL. (202) 887.0200
FAX (202) 775.3199

Under the third pillar, the United States is also engaged internationally. As part of the U.S. Intended Nationally Determined Contribution (INDC) submitted in March 2015 to the United Nations Framework Convention on Climate Change (UNFCCC), the United States committed to reducing emissions 26–28 percent relative to 2005 levels by 2025. The United States also has many bilateral efforts to work on climate change. For example, climate change is part of the U.S.-China Strategic and Economic Dialogue.

Currently, federal policy to address climate change is occurring through existing federal authorities and therefore on a sector-by-sector basis. There has been significant interest in addressing greenhouse gas emissions through a comprehensive policy that would treat all GHG emissions equally, regardless of their source, such as a carbon tax or economy-wide cap and trade program. Such a change would have to go through Congress. Congress took up climate legislation in 2009, when the House of Representatives passed a bill that would have established an emissions trading plan. The bill died in the Senate, and there is currently little political appetite for a legislative push to address climate change. Until there is sufficient support in Congress for addressing climate change, climate policy will continue to emerge from the federal government's regulatory authority and leadership at the state and local levels.

International Climate Policy

No one country can slow, stop, and ultimately reverse the effects of a changing climate. Given the global commons nature of the climate change challenge, cooperation is necessary to optimize the effectiveness of those efforts and discourage free riding.

Efforts to coordinate international action on climate change have been underway for decades. The first significant international action on climate change was a meeting that took place in 1992 that produced the United Nations Framework Convention on Climate Change (UNFCCC). The UNFCC is a treaty, ratified by most of the world's governments, which establishes the goal of stabilizing GHGs in the atmosphere at a level that will prevent "dangerous anthropogenic interference with the climate system." In addition to establishing a common objective, the treaty also set out agreed-upon principles (such as common but differentiated responsibilities and the promotion of sustainable development), established commitments to track and publicize data on GHG emissions, and created an institutional body to review progress on implementing the treaty. This institutional body, also called the UNFCCC, is tasked with responding to climate change. The parties to the treaty are also members of the UNFCCC, and they meet every year to further the goal of implementing the treaty.

Over the last several decades, the negotiations held under the auspices of the UNFCCC have established a framework for discussing and addressing issues related to climate change, furthered the science of climate change, established common measurement and reporting guidelines to promote greater uniformity and therefore understanding of climate change, produced several notable goals/targets (including a goal of limiting anthropogenic temperature rise to below 2°C relative to preindustrial levels—the threshold beyond which the impacts of climate change risk becoming irreversible, unpredictable, and dangerous according to scientific consensus)—and concluded several important agreements, such as the Kyoto Protocol. The Kyoto Protocol was adopted in 1997 and went into force in 2005. The protocol established legally binding emission reductions for developed countries, and nonbinding targets for developing countries. The permanent division of responsibility between countries that were developed and those that were developing in

1616 RHODE ISLAND AVENUE NW
WASHINGTON, DC 20036
TEL. (202) 887.0200
FAX (202) 775.3199

1992 was a source of considerable contention, and as a result the United States—at the time, the world's largest emitter—failed to ratify the protocol. The Kyoto Protocol may have reduced emissions in participating countries, but was unable to reduce global GHG emissions.

The issue of which countries should shoulder the burden for transitioning to a low-carbon economy—the issue that ultimately resulted in some OECD countries refusing to ratify the Kyoto Protocol—has been and remains at the heart of the international negotiations. In general, developing economies prioritize economic growth and perceive a tradeoff between development and GHG emission reductions. Many developing countries believe that it is doubly unfair to ask them to curtail emissions, because developed economies were allowed to develop by burning cheap fossil fuels, while developing economies are ask to bear the financial burdens of both transitioning away from fossil fuels and developing without them. Developed economies, by contrast, argue that they are also making economic sacrifices and that, because the developing world is responsible for a shrinking share of emissions, without inclusive participation, any agreement will fail to achieve the goals of the UNFCCC.

Attempts to negotiate a new international instrument have focused on how to achieve an agreement that is inclusive (has wide participation from both developing and developed countries), fair (accounts for the different capacities of countries to address climate change as well as their historical responsibility for emissions), and ambitious (achieves the goal of preventing dangerous anthropogenic interference). At present, 114 countries have pledged emission reduction goals for 2020. The current round of negotiations, culminating in Paris in December 2015, is aimed at securing emission reduction pledges for the period beyond 2020. To date, nearly 150 countries representing 90 percent of emissions have submitted pledges to reduce emissions beyond 2020.

Even if an agreement is reached in Paris that establishes a long-term framework for emission reductions beyond 2020, the multilateral negotiations will continue to be an important feature of the climate policy landscape into the future. Several issues in the negotiating process are likely to remain challenging even if an agreement is achieved in Paris in 2015, including finance, technology transfer, adaptation, loss and damage, and long-term decarbonization. Addressing climate change from the perspectives of both mitigation and adaptation requires large-scale investments in physical assets, technology, research, and human capital. While the UNFCCC agreement provides for financing to assist developing countries transition to a low-carbon economy and adapt to the impacts of climate change, the form that financing takes, what countries must do to obtain financing, and where financing should come from all remain open issues. Similarly, technology transfer, also mentioned under the treaty, remains a point of contention. Technology transfer is essential for addressing climate change, but how and which technologies should be transferred, and to whom, remain vague. Further, the issue is politically sensitive because of its relationship with trade, economic competitiveness, and intellectual property. Third, the place of adaptation in the UNFCCC has evolved over time and is likely to continue to change. Over time, adaptation has become more formally integrated into the UNFCCC negotiations, and adaptation is now a pillar of the negotiations, along with mitigation. However, how and whether countries should develop and put forward formal adaptation plans, and whether such plans should be required, remain unresolved. Fourth, how to address the irreversible damage many countries will suffer as a result of climate change is likely to be an important

1616 RHODE ISLAND AVENUE NW
WASHINGTON, DC 20036
TEL. (202) 887.0200
FAX (202) 775.3199

issue in the decades to come. Mitigation and adaptation will not address all the changes and costs associated with climate change, as some groups, countries, ecosystems, and sectors of the economy will not be able to adapt. However, the association of this loss with liability and compensation (which many parties will not want to consider) makes this a sensitive and challenging topic. Finally, negotiators will continue to engage on the issue of how to ensure that national efforts to address climate change remain ambitious over the long term, in spite of changing national and international circumstances. Countries are likely to make commitments in Paris for the years between 2020 and 2030, and to establish the principle of long-term decarbonization. How to achieve the ambition necessary to meet this long-term goal remains uncertain. As global and national circumstances change, however, the international climate regime is likely to continue to evolve, and the intention is for the agreement to be able to accommodate those changes; whether it can do so, however, and whether such a framework can ultimately achieve deep decarbonization, remains to be seen.

About the CSIS Energy and National Security Program

The CSIS Energy and National Security Program is a leader in understanding the shifting global and domestic energy landscape. Through its collaboration with leaders in industry, government, academia, and nonprofits, the CSIS Energy and National Security Program identifies new energy trends and helps to illuminate the opportunities and challenges that we expect to confront policymakers and industry players in the coming years. To join our mailing list, contact energy@csis.org, or follow us on twitter @CSISEnergy.

Quick Facts on Climate

- From an atmospheric perspective, neither the source nor the location of GHG emissions matters; emissions from anywhere in the world mix in the atmosphere and affect climate everywhere. Carbon dioxide emitted in Malaysia due to deforestation has the same impact as carbon dioxide emitted from passenger vehicles in Chile. From a political perspective, however, the source of emissions matters a great deal. Historically, a relatively small group of GHG emissions are measured in metric tons (Mt) or million metric tons of carbon dioxide equivalent (MMtCO2e).
- Currently, 1 metric ton of CO_2 is generated to meet the average monthly demand of a typical American household.
- Global carbon dioxide emissions were 31.2 billion metric tons in 2010; they are projected to grow to 36.4 billion metric tons in 2020 and 45.5 billion metric tons in 2040.
- In 2011, the top 10 emitters comprised nearly 70 percent of the world's emissions, 60 percent of global population, and 74 percent of global GDP.
- The world's largest emitters on a cumulative basis are the United States, the European Union, China, Russia, Japan, and India.
- The world's largest emitters on a per capita basis are Canada, the United States, Russia, Japan, the EU, and Indonesia.

Michelle Melton is an associate fellow with the Energy and National Security Program at the Center for Strategic and International Studies (CSIS) in Washington, D.C. Sarah Ladislaw is a senior fellow and director of the CSIS Energy and National Security Program.

This report is produced by the Center for Strategic and International Studies (CSIS), a private, tax-exempt institution focusing on international public policy issues. Its research is nonpartisan and nonproprietary. CSIS does not take specific policy positions. Accordingly, all views, positions, and conclusions expressed in this publication should be understood to be solely those of the author(s).

1616 RHODE ISLAND AVENUE NW
WASHINGTON, DC 20036
TEL. (202) 887.0200
FAX (202) 775.3199