OUR CHANGING CLIMATE

background reading | climate change unit

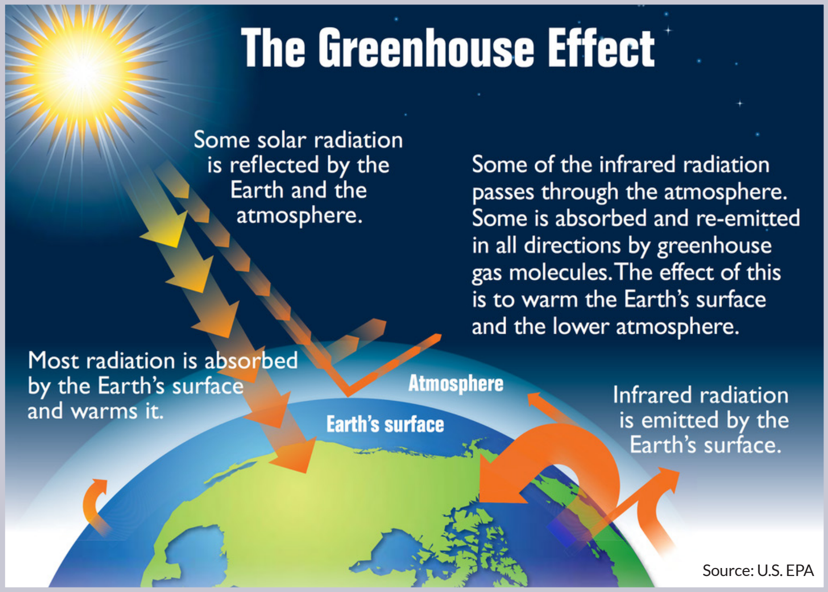
EARTH matters
Studies For Our Global Future

***"There's one issue that will define the contours of this century more dramatically than any other, and that is the urgent threat of a changing climate."* —President Barack Obama (UN Climate Change Summit, Sept. 23, 2014)**

Changes to Earth and its atmosphere used to be measured in geological time. Millions of years to form canyons. Ice ages lasting tens of thousands of years. We now live at a time when changes to the planet can be observed within one human lifetime and sometimes within a span of just a few years. That's due to **anthropogenic** causes (human activities), especially **carbon emissions** from fossil fuel combustion.

Starting about 150 years ago and escalating through the 20th and 21st centuries, these emissions have set in motion changes to our planet that may prove irreversible. Surface temperatures are rising, leading to melting of ice caps and sea level rise. The oceans are becoming warmer and more acidic, killing coral reefs and affecting marine life. As of this writing, the last seven years (2014-2020) have been the warmest years on record.[1] More extreme weather events – hurricanes, cyclones, flooding, heat waves and droughts – are making communities inhospitable and forcing people from their homes. **Climate change** is even affecting human health with impacts on the air we breathe, our access to clean water, our ability to grow nutritious food and our vulnerability to infectious disease from an expanding range for virus-carrying mosquitoes.

Averaged across land and ocean, the 2020 surface temperature of the Earth has increased by 1.8°F (1.0°C) warmer than the 20th century average.[2] This period is now the warmest in the history of modern civilization, and the warming trend is expected to continue. A 2021 assessment from the Intergovernmental Panel on Climate Change (IPCC) concluded that "Human influence on the climate system is now an established fact. It is unequivocal that the increase of CO_2, methane (CH_4) and nitrous oxide (N_2O) in the atmosphere over the industrial era is the result of human activities and that human influence is the principal driver of many changes observed across the atmosphere, ocean, cryosphere and biosphere."[3] In addition to warming temperature, the report documented trends in climate change impacts including melting glaciers, diminishing snow cover, shrinking sea ice, rising sea levels, ocean acidification, and an increase in extreme weather events.[4]



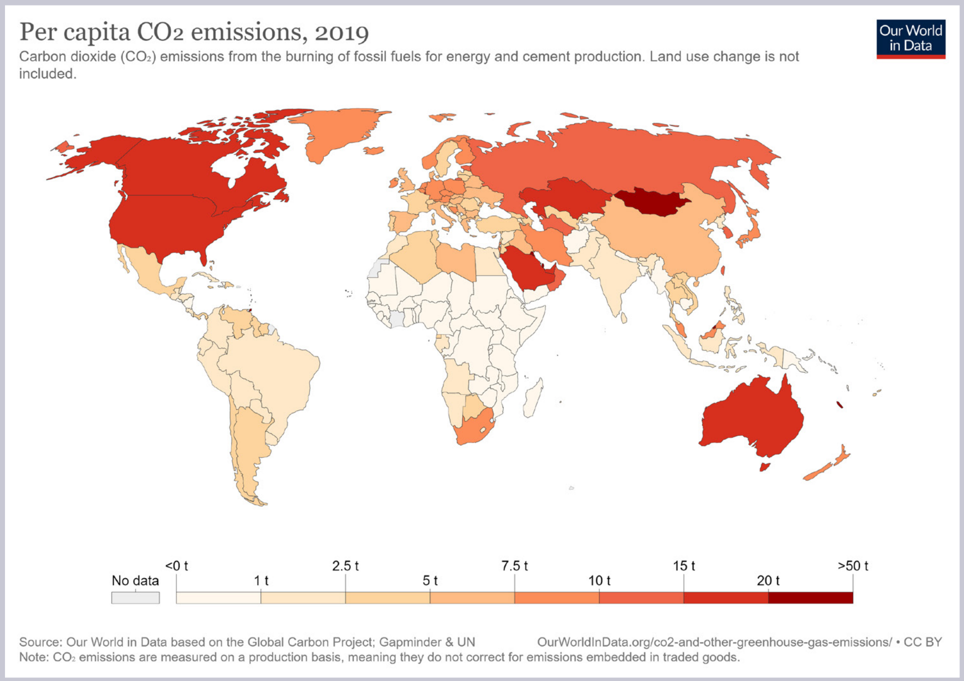
The greenhouse effect

To comprehend why the Earth's climate is changing, it's important to understand the **greenhouse effect** that regulates the climate in the first place. The Earth's atmosphere is a complicated system of gases and energy. It allows energy from the sun to pass through to the Earth and also allows energy from the Earth to escape into space. By delicately balancing this exchange of energy, the atmosphere regulates our climate.

The burning of oil, coal and natural gas has increased the concentration of certain gases in our atmosphere. These gases act like a blanket, trapping Earth's heat energy and preventing it from passing through to space. This energy exchange imbalance grows as the Earth's atmosphere traps increasingly more energy than it can release and causes the planet to warm. The process works much the way a greenhouse would, hence the gases that allow sunlight to enter the atmosphere freely, and trap heat energy in the atmosphere, are called **greenhouse gases (GHGs)**. These include **carbon dioxide (CO_2)**, **methane (CH_4)**, **nitrous oxide (N_2O)**, **chlorofluorocarbons (CFCs)**, and **ozone**. Fossil fuel combustion, coal mining, wastewater treatment, agricultural activity and natural gas and petroleum systems are all examples of human-influenced GHG emission sources.

Turning up the heat

For tens of thousands of years, the levels of oxygen, nitrogen and other gases in the Earth's atmosphere remained essentially unchanged. By the beginning of the 1800s, the world's population had grown to 1 billion and the Industrial Revolution in North America and Europe began to clear the land and foul the air with factory smoke. A century later, the population had doubled to 2 billion and the age of petroleum was dawning. After World War II, energy use skyrocketed. Between 1946 and 1968, the use of motor fuel doubled, electricity consumption nearly tripled and the production of petroleum-based plastics increased ten-fold. Worldwide, CO_2 emissions have more than doubled from 1970 (14.8 Gt CO_2e) to 2019 (36.4 Gt CO_2e) with emissions from the energy sector and industrial processes contributing the vast majority (88 percent) of the total increase. Agriculture, deforestation, and other land use changes have been the second-largest contributor.[5]

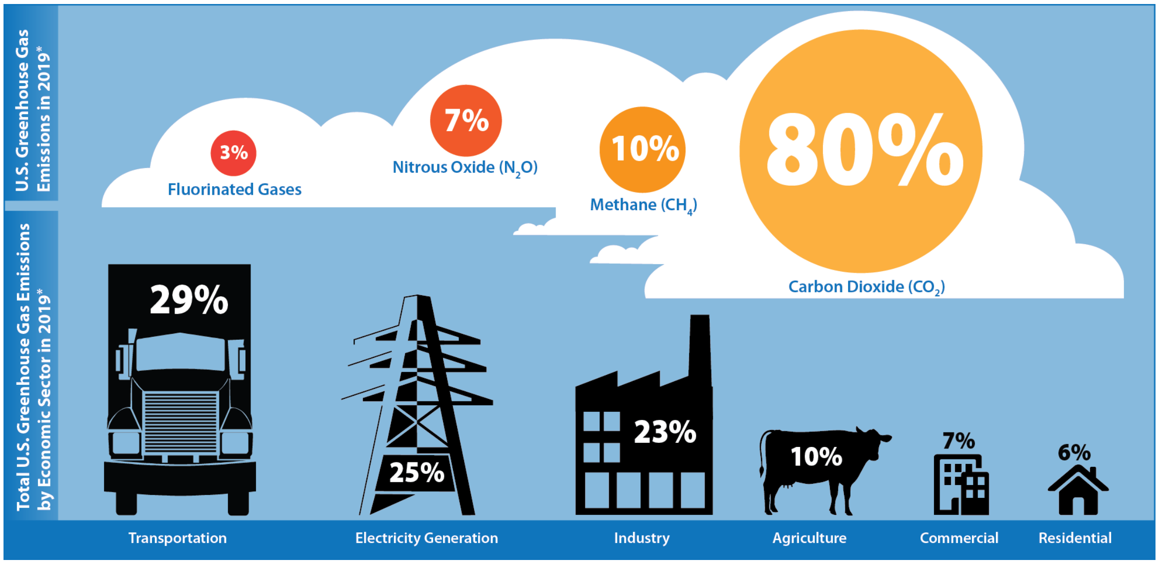


Oil, coal and natural gas power our automobiles, heat our homes, provide electricity for our appliances and allow us to enjoy an unprecedented standard of living. However, when burned (combusted), these carbon-based fossil fuels combine with oxygen to form carbon dioxide (CO_2). In the U.S., CO_2 formed by the burning of fossil fuels makes up 80 percent of greenhouse gases.[6] As a result of increased industrialization and combustion of these fuels, more and more carbon has been emitted into the atmosphere. The concentration of CO_2 in the atmosphere has increased by nearly 40 percent since the mid-19th century. CO_2 levels are now at their highest point in at least 800,000 years.[7] The levels of carbon emissions grew four-fold from 1960 to 2019 when nearly 10 billion tons of carbon were emitted.[8] Trees and other photosynthetic organisms take in CO_2, but they can only absorb about 3-4 billion tons worldwide. As deforestation continues, the Earth will be able to absorb less and less. A significant portion of the Amazon rainforest (18 percent since 1970) has already been cleared, disrupting an important **carbon sink**.[9]

The United States emits more tons of carbon per capita than any other country. In 2019, the U.S., though containing just 4 percent of the world's population, was responsible for producing 15 percent of the world's carbon emissions.[10] China is now the world's largest carbon emitter. But even with its rapid increases, China's carbon emissions per capita are still less than half of those of the United States. As industrialization escalates in Asia, Africa and Latin America, carbon emissions in the developing world are increasing rapidly too.

Other gases

Human activity is also directly related to the production of methane, another greenhouse gas. Methane is released by natural gas leaks, coal mining, oil and gas drilling, the burning of wood and garbage, the decomposition of organic matter (such as rice paddies) and digestion in some animal intestines. The atmospheric concentration of methane has increased 250 percent in the last 200 years and currently accounts for about 20 percent of all the global warming due to greenhouse gases.[11]



Source: U.S. Environmental Protection Agency

Worldwide production of methane is expected to increase as more cattle are raised and more rice is cultivated to feed increasing numbers of people. Although methane accounts for a smaller part of the greenhouse gas volume than does CO_2, it is more potent. Each methane molecule is 30 to 40 times more efficient at trapping heat than a CO_2 molecule. Like CO_2, methane concentrations have far exceeded the natural amounts of the last 800,000 years and remain in the atmosphere for years after they are emitted.

Nitrous oxide (N_2O), also known as "laughing gas," is a byproduct of fossil fuel combustion, bacterial reactions in soil and the breakdown of widely used fertilizers. Its atmospheric concentration has increased 23 percent over pre-industrial levels, and it accounts for about six percent of the total warming due to GHGs.[12]

Ozone-depleting substances (ODSs), such as chlorofluorocarbons (CFCs) and **hydrofluorocarbons** (HFCs), are completely human-made chemicals, unlike CO_2, methane and nitrous oxide. One CFC, commercially known as Freon, is used as a refrigerator and air conditioner coolant, as a chemical cleaner and in the manufacturing of foam and some aerosol sprays. Although CFCs make up a small portion of total atmospheric warming, they are the strongest insulators of all the GHGs. They are 10,000 to 20,000 times more effective at trapping heat than CO_2 and can live in the atmosphere for up to 100 years.[13] ODSs deplete the ozone in the upper atmosphere, which carries its own set of severe consequences. The decrease of ozone lets in more of the sun's harmful ultraviolet light, which is known to cause skin cancer and eye disease, to damage crops and to destroy the phytoplankton that support the marine food chain.

In 1985, scientists discovered an ozone hole the size of the U.S. over Antarctica. This discovery prompted an international agreement, the **Montreal Protocol**, which was signed in 1987 by 25 participating countries in an effort to stop the production of ODSs. Since then, 197 countries have agreed to dramatically phase out the production of ODSs and, having successfully done so, the level of ODSs in the atmosphere has declined.

Trends point to increased energy consumption in the future, particularly in the developing world, where the population is expected to grow the most. Globally, economic and population growth continue to be the most significant drivers of increases in CO_2 emissions from fossil fuel combustion. Both of these drivers are currently outpacing emission reductions from improvements in energy intensity.[14]

Measuring climate change

Some question whether climate change is really happening, and if so, whether it's a human-caused phenomenon. On both counts, the science is clear.

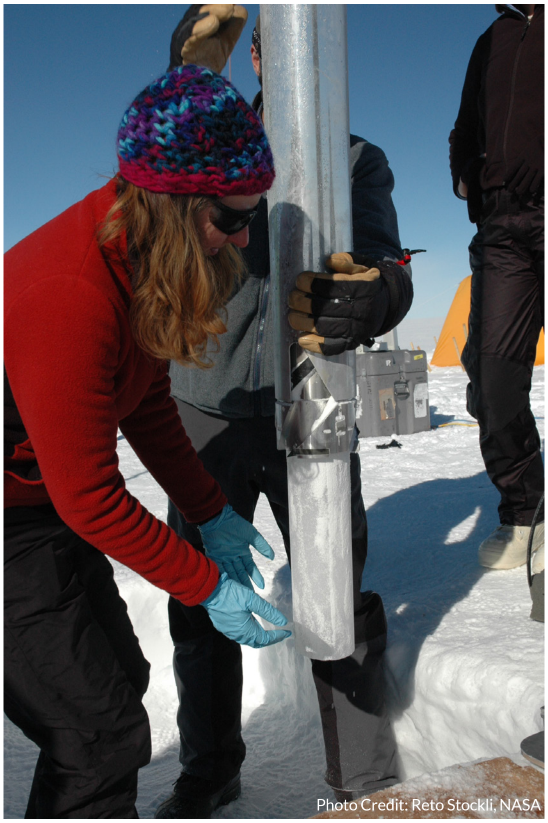


Photo Credit: Reto Stockli, NASA

Scientists can analyze ice cores from large glaciers and ice sheets to determine how modern amounts of carbon dioxide and methane compare to past concentrations.

How do we know the Earth is warming?

Evidence for a warming world comes from multiple independent climate indicators, from high up in the atmosphere to the depths of the oceans. They include changes in surface, atmospheric and oceanic temperatures; glaciers; snow cover; sea ice; sea level and atmospheric water vapor. Scientists from all over the world have independently verified this evidence many times. That the world has warmed since the 1800s is unequivocal.[15]

How do we know CO_2 in the atmosphere has increased?

High precision measurements of atmospheric CO_2 have been taken from dozens of sites around the globe over more than 60 years. The instruments have been calibrated according to rigorous, internationally agreed protocols and have produced consistent readings confirming increased CO_2 levels. Tiny air bubbles in Antarctic ice cores reveal a historic record of atmospheric GHG concentrations, in particular CO_2, CH_4 and N_2O. These bubbles were captured in the ice as new snow accumulated at the surface and solidified into ice over the past 740,000 years. These records provide proof that through ice ages and warm periods, atmospheric CO_2 varied between 180 and 280 ppm (parts per million), demonstrating that today's CO_2 concentration of over 400 ppm exceeds the natural variability seen over hundreds of thousands of years.[16]

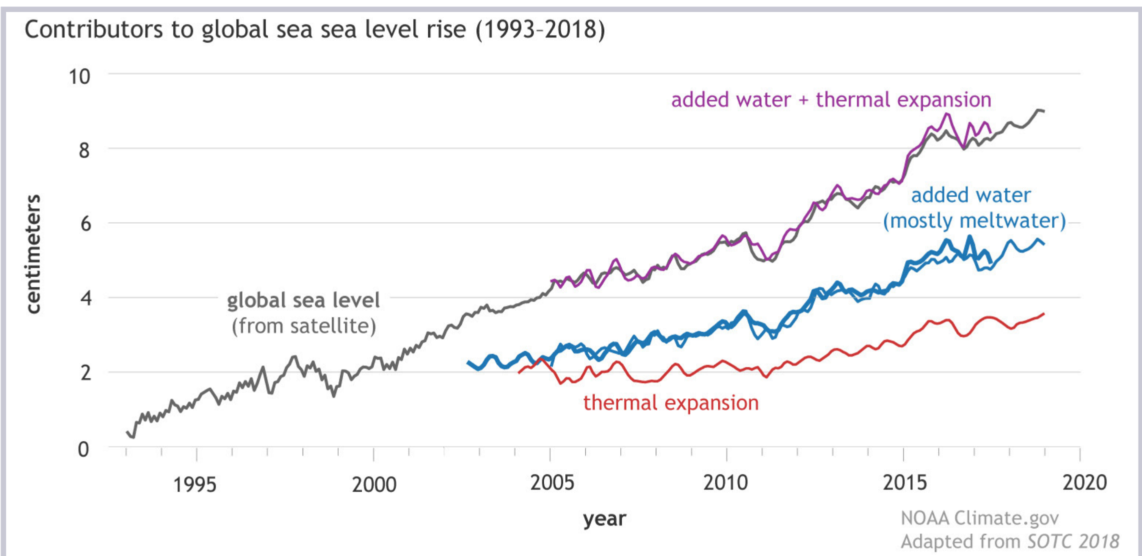
How do we know that these changes are human-caused, rather than naturally occurring?

For more than 10,000 years prior to the Industrial Revolution, atmospheric CO_2 levels were essentially constant, showing that the recent increase in CO_2 is not naturally occurring. In fact, the increase in CO_2 has closely mirrored the increase in fossil fuel burning over the past 60 years. Scientists have used radioactivity to distinguish industrial emission from natural emissions, showing that the extra CO_2 is coming from human activity.

Impacts on people and the planet

A difference of nearly 2°F might not sound like much, but small differences in average temperature make a huge difference in the Earth's climate, affecting human communities and habitats for all species.

Ocean acidification: Oceans absorb CO_2 like a mop. This helps remove some CO_2 from the atmosphere but the increased levels in the ocean make the water more acidic. Since the beginning of the industrial era, oceanic uptake of CO_2 has resulted in acidification of the ocean. According to the National Oceanic and Atmospheric Administration (NOAA), the pH of ocean surface water has decreased by 0.1, corresponding to a 30 percent increase in acidity. This acidity, combined with warming temperatures, is killing coral reefs around the globe and interfering with the shell formation of organisms like oysters, clams, and snails.[17]



Species loss: Many species face an increased risk of extinction due to climate change. Most plant species cannot naturally shift their geographical ranges sufficiently fast to keep up with current and projected rates of climate change in most landscapes.

Sea level rise: Warming temperatures are causing land-based ice, such as glaciers and ice sheets, to melt. That, along with thermal expansion (water expands as it warms), is raising sea levels around the globe. In 2019, global sea level was 3.4 inches above the 1993 average (the highest recorded to date) and had risen as much as 6 to 8 inches in some ocean basins. Sea level continues to rise at a rate of about one inch every seven years. Sea level is expected to rise by at least one foot by 2100 (over 2000 levels), even after greenhouse gas mitigation efforts. A rise of as much as 8 feet by 2100 can't be ruled out if high rates of GHG emissions continue.[18] Higher sea levels mean that deadly and destructive storm surges push farther inland than they once did, which also means more frequent flooding. Forty percent of the U.S. population lives in coastal areas that are vulnerable to flooding from sea level rise.[19]

Effects on agriculture: Droughts and extreme weather events in tropical and temperate regions are expected to negatively affect food production, especially for the main grain crops – wheat, rice and maize.

Climate change could have particularly drastic effects on the Earth's polar regions.

Effects on fisheries: Warmer and more acidic waters will change the distribution of global marine species and reduce marine biodiversity, affecting the supply and variety of fish species.

Effects on communities and infrastructure: Greater frequency of extreme weather events and flooding will continue to threaten the viability of many communities. In addition to storm surges affecting coastal communities, inland communities can also be vulnerable to climate-related events including wildfires, landslides and droughts. Earlier spring melt and reduced snowpack in mountain regions will affect the availability of water resources in the region. With some regions becoming inhospitable, people will be forced to move to other areas, growing the ranks of **environmental refugees**.

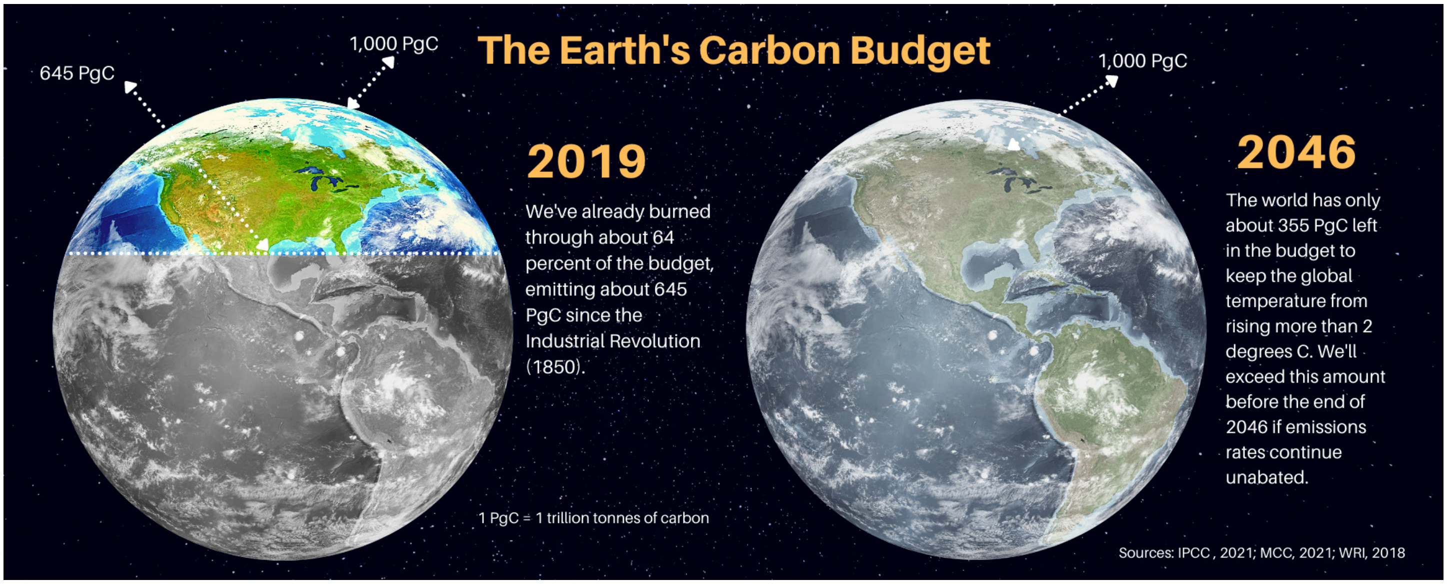
Threats to public health: Extreme weather events are already taking a toll on human health. From 2000 to 2019, they have claimed 475,000 lives. The number of vulnerable people exposed to heat waves climbed by 125 million from 2000 to 2016.[20] Warming temperatures have also expanded the region for mosquitoes, which can carry viruses such as malaria, dengue fever and Zika. Public health will also be affected by climate change's threats to food security and clean water availability.

Climate change inequities

Climate change is a global phenomenon. Even so, some communities are affected more severely than others from the impacts of a warming planet. From the frequency of extreme weather to rising sea levels, the impacts of climate change often have disproportionate effects on historically marginalized or low-income communities, including Indigenous peoples, even though these communities typically contribute the least to greenhouse gas emissions. Subsistence farmers in less developed countries are at the mercy of changing agricultural outputs from more droughts and storm surges. In addition to more **food insecurity**, vulnerable populations will also see threats to their livelihoods, access to energy, water and safe shelters. In short, lower- and middle-income countries – home to most of the world's population – are less able to cope with the impacts of climate change.

These climate change impacts displace tens of millions of people around the globe from their homes each year. The majority of the world's **climate migrants** are internally displaced, meaning they stay within their country's borders. Still others cross borders in search of safety and sustenance. A recent example are the thousands of migrants leaving Guatemala and Honduras for the U.S. as the result of an unprecedented food crisis resulting, in part, from climate-change related droughts and floods that have decimated agriculture in parts of those countries.[21]

Other countries face the displacement of entire populations, mostly due to rising sea levels, like the Pacific island nation of Kiribati. Many of the most vulnerable places are also where the population is expected to grow rapidly in the coming decades, which can strain resources and create challenges to disaster response.



A carbon budget

The consensus among climate scientists is that continued emission of GHGs will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of severe, pervasive and irreversible impacts for people and ecosystems. Without additional steps to curb GHG emissions beyond what's in place today, emissions are expected to grow, driven by increases in global population (a likely 37 percent increase by 2100) and economic activities.

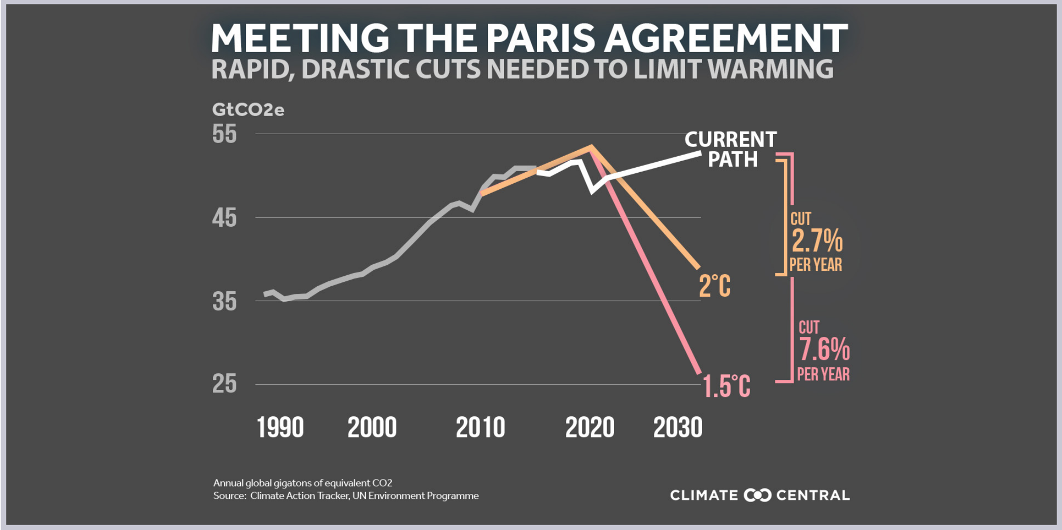
Baseline scenarios, those without efforts to mitigate GHG emissions, result in global mean surface temperature increases of 4.1°C to 4.8°C by the end of the century, compared to pre-industrial levels.[22] Yet climate scientists warn that a global temperature rise of more than 2°C would result in dangerous consequences including destabilization of the polar ice caps, devastating weather events, sea level rise and agricultural losses. In 2013, the IPCC released a groundbreaking report asserting that, as a global society, we must adhere to a "**carbon budget**" if we want to stay below the 2°C target.[23] The carbon budget is the maximum amount of carbon that can be emitted into the atmosphere to keep within a certain temperature threshold. If carbon emissions don't reach "net-zero," the global temperature continues to rise.

According to the IPCC calculations, this budget allows for 1 trillion tons of carbon to be emitted into the atmosphere from the industrial era on. The calculations begin in the industrial era to account for the fact that CO_2 remains stored in the atmosphere for centuries after it is emitted. We've already churned through about 60 percent of the budget. At the rate we are going, we would reach the trillionth ton in 2049.[24]

Human activities have already caused approximately 1.0°C increase in the global temperature over pre-Industrial levels. In order to keep the temperature from rising above 1.5°C, CO_2 emissions would need to decline by 45 percent (from the 2010 level) by 2030 and reach net-zero emissions by 2050. Keeping the temperature under 2.0°C would require a 25 percent decrease in emissions by 2030 and net-zero by 2070. Achieving this would involve substantial changes in energy systems and land use around the world.[25]

The Paris Agreement

Getting these efforts to accelerate and keep warming below the 2°C threshold motivated world leaders to work together and pledge to reduce their countries' GHG emissions. In December 2015, these leaders met in Paris and reached a landmark deal, the **Paris Agreement**. The Paris Agreement is the latest step from the **UN Framework Convention on Climate Change (UNFCCC)**, an international treaty developed in 1992 to combat climate change. It follows the Kyoto Protocol, which committed developed countries to reduce their GHG emissions. The Paris Agreement brings all nations – developed and developing – together to combat climate change and adapt to its effects. It requires "all Parties to put forward their best efforts through 'nationally determined contributions' (NDCs) and to strengthen these efforts in the years ahead."[26] This includes requirements that all Parties report regularly on their emissions and on their implementation efforts. All countries have signed the agreement. The U.S., under President Donald Trump, had pulled out of the agreement, effective November 2020, but his successor, President Joe Biden, quickly rejoined the agreement upon taking office in January 2021.



Before and during the Paris conference, countries submitted comprehensive **national climate action plans**. These are not yet enough to keep global warming below 2°C, but the agreement traces the way to achieving this target. The agreement is supposed to be reviewed every five years, so that countries can ramp up their commitments. As part of the Agreement, more developed countries are also supposed to assist less developed countries with financial and technical resources to adapt to a changing climate.

Climate action plans include transitioning energy production and transportation away from fossil fuels. They also includes plans for land use changes, such as **afforestation** (planting trees in barren land to create forests) which can help absorb CO_2. Stabilizing population size and conserving resources are part of a long-term climate mitigation strategy. Universal education and equal roles for women in societies lead to smaller families, gradually reducing population growth.

Citizen solutions

The enormity of the challenge to reduce GHG emissions requires large-scale collective action and commitments by governments and industries. As citizens, we can demand carbon reductions from industries by speaking up to lawmakers and the media. As consumers, we can support businesses that are taking the lead on sustainable energy practices.

Scientists' warnings about the future, along with observable impacts of climate change today, have galvanized people worldwide to march, strike, and speak out on the changes our society needs to implement to reduce greenhouse emissions. **Climate activism** has grown in recent years as the window for making widespread changes to avert the worst predictions is closing. In 2019, millions of students, teachers, and workers participated in a Global Climate Strike to demand a transition off of fossil fuels and onto 100 percent clean energy. The strike took place across 4,500 locations in 150 countries with young people taking the lead.

As an individual there are many efforts (small and large) that can reduce one's **carbon footprint**. Anything that reduces your daily energy use also keeps carbon out of the atmosphere. Around your home this includes using energy-efficient appliances and lighting and adjusting the thermostat to use heating and air conditioning more conservatively. Our transportation choices directly impact our carbon footprint. Limiting car trips, using mass transit and taking fewer flights are just some ways make a difference. Because food choices influence land use, you can reduce your carbon footprint by eating lower on the food chain (livestock use tremendous amounts of energy resources and emit methane) and wasting less food in general. Using cleaner technologies, such as solar panels and electric cars, also lessen our carbon footprint.

Climate March, San Francisco. (2019).

The multiplication of carbon-mitigating efforts – by individuals, industries and governments – will be key to determining what kind of planet we will leave for future generations. The impacts of climate change are already observable. But the urgency of our response can make a difference on how much and how quickly our global climate changes, and how we can help communities adapt to those changes.

[1] NASA. (2021, January 14). *2020 Tied for Warmest Year on Record, NASA Analysis Shows*. Retrieved from https://www.nasa.gov/press-release/2020-tied-for-warmest-year-on-record-nasa-analysis-shows

[2] Lindsey, R. and Dahlman, L. (2021, March 15). *Climate Change: Global Temperature*. NOAA. Retreived from https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature

[3,4] IPCC, 2021: *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J. B. R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou (eds.)]. Cambridge University Press. In Press.

[5] Climate Watch. (2021). Washington, DC: World Resources Institute. Retrieved September 1, 2021 from https://www.climatewatchdata.org

[6] U.S. Environmental Protection Agency. (2021, April). *DRAFT Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2019*. Retrieved from https://www.epa.gov/sites/production/files/2021-02/documents/us-ghg-inventory-2021-main-text.pdf

[7] NASA Global Climate Change. (n.d.). *Graphic: The relentless rise of carbon dioxide*. NASA. Retrieved April 5, 2021 from https://climate.nasa.gov/climate_resources/24/graphic-the-relentless-rise-of-carbon-dioxide/

[8,10] Global Carbon Atlas. (n.d.). Fossil Fuels Emissions. [Website]. Retrieved April 5, 2021 from http://www.globalcarbonatlas.org/en/CO2-emissions Data from Friedlingstein et al., 2020: The Global Carbon Budget 2020. Available at https://essd.copernicus.org/articles/12/3269/2020/

[9] Butler, R.A. (2020, January 4). *Calculating Deforestation Figures for the Amazon*. Mongabay. Retrieved from https://rainforests.mongabay.com/amazon/deforestation_calculations.html

[11] U.S. Environmental Protection Agency. (n.d.) *Importance of Methane*. Retrieved April 5, 2021 from https://www.epa.gov/gmi/importance-methane; 2° Institute. (n.d.). *Atmospheric CH4 Levels*. [Graph]. Retrieved from https://www.methanelevels.org/

[12] World Meteorological Organization. (2019, November 25). *Greenhouse gas concentrations in atmosphere reach yet another high*. Press Release Number: 25112019. Retrieved from https://public.wmo.int/en/media/press-release/greenhouse-gas-concentrations-atmosphere-reach-yet-another-high

[13] Fahey, D.W. (2003). Twenty questions and answers about the ozone layer. *Scientific assessment of ozone depletion: 2002. Global Ozone Research and Monitoring Project, Report No. 47*. The World Meteorological Organization and the United Nations Environment Programme.

[14,15] Intergovernmental Panel on Climate Change. (2014). *Climate change 2014: Synthesis report*. Contribution of Working Groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)].

[16] World Meteorological Organization. (2017, October 30). *WMO greenhouse gas bulletin*. No. 13.

[17] National Oceanic and Atmospheric Administration. (2020, April). *Ocean acidification*. Retrieved from https://www.noaa.gov/education/resource-collections/ocean-coasts/ocean-acidification

[18] Lindsey, R. (2021, January 25). *Climate Change: Global Sea Level*. NOAA. Retrieved from https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level

[19] National Ocean Service. (n.d.). *What percentage of the American population lives near the coast?* NOAA. Retrieved April 7, 2021 from https://oceanservice.noaa.gov/facts/population.html

[20] Eckstein, D., Künzel, V., Schäfer, L. (2021, January). *Global Climate Risk Index 2021*. Germanwatch. Retrieved from https://germanwatch.org/sites/default/files/Global%20Climate%20Risk%20Index%202021_2.pdf; Watts, N., Amann, M., Ayeb-Karlsson, S., Belesova, K., Bouley, et. al. (2017, October 30). The *Lancet* Countdown on health and climate change: from 25 years of inaction to a global transformation for public health. *The Lancet*. Retrieved from http://dx.doi.org/10.1016/S0140-5736(17)32464-9

[21] Podesta, J. (2019, July 25). *The climate crisis, migration and refugees*. The Brookings Institution. Retreived from https://www.brookings.edu/research/the-climate-crisis-migration-and-refugees/; Sieff, K. (2021, April 1). The reason many Guatemalans are coming to the border? A profound hunger crisis. *The Washington Post*. Retrieved from https://www.washingtonpost.com/world/2021/04/02/us-border-migrants-guatemala/; Bermeo, S. and Leblang, D. (2021, April 1). *Climate, violence and Honduran migration to the United States*. The Brookings Institution. Retrieved from https://www.brookings.edu/blog/future-development/2021/04/01/climate-violence-and-honduran-migration-to-the-united-states/

[22] Climate Action Tracker. (2020, December). *2100 Warming Projections*. Retrieved April 5, 2021 from https://climateactiontracker.org/global/temperatures/

[23] Freedman, A. (2013, October 4). *IPCC Report Contains 'Grave' Carbon Budget Message*. Climate Central. Retrieved from http://www.climatecentral.org/news/ipcc-climate-change-report-contains-grave-carbon-budget-message-16569

[24] Mercator Research Institute on Climate Change. (n.d.). That's how fast the carbon clock is ticking. Retrieved September 1, 2021 from https://www.mcc-berlin.net/en/research/co2-budget.html

[25] Rogelj, J., D. Shindell, K. Jiang, S. Fifita, P. Forster, V. Ginzburg, C. Handa, H. Kheshgi, S. Kobayashi, E. Kriegler, L. Mundaca, R. Séférian, and M.V.Vilariño, *2018: Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. In Press.

[26] United Nations Framework Convention on Climate Change. (n.d.). *Key aspects of the Paris Agreement*. Retrieved from https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement/key-aspects-of-the-paris-agreement