Union of Concerned Scientists
Skip to main content

Home » Global Warming » Global Warming Science and Impacts » Science

Global Warming FAQ

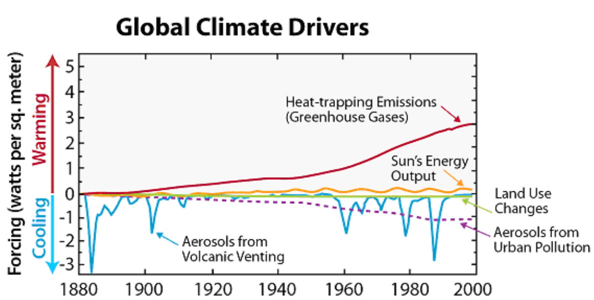
How do we know that humans are the major cause of global warming?

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) states: it is a greater than a 90 percent certainty that emissions of heat-trapping gases from human activities have caused "most of the observed increase in globally averaged temperatures since the mid-20th century." We all know that warming—and cooling—has happened in the past, and long before humans were around. Many factors (called "climate drivers") can influence Earth's climate—such as changes in the sun's intensity and volcanic eruptions, as well as heat-trapping gases in the atmosphere.

So how do scientists know that today's warming is primarily caused by humans putting too much carbon in the atmosphere when we burn coal, oil, and gas or cut down forests?

There are human fingerprints on carbon overload. When humans burn coal, oil and gas (fossil fuels) to generate electricity or drive our cars, carbon dioxide is released into the atmosphere, where it traps heat. A carbon molecule that comes from fossil fuels and deforestation is "lighter" than the combined signal of those from other sources. As scientists measure the "weight" of carbon in the atmosphere over time they see a clear increase in the lighter molecules from fossil fuel and deforestation sources that correspond closely to the known trend in emissions.
Natural changes alone can't explain the temperature changes we've seen. For a computer model to accurately project the future climate, scientists must first ensure that it accurately reproduces observed temperature changes. When the models include only recorded natural climate drivers—such as the sun's intensity—the models cannot accurately reproduce the observed warming of the past half century. When human-induced climate drivers are also included in the models, then they accurately capture recent temperature increases in the atmosphere and in the oceans. [4][5][6] When all the natural and human-induced climate drivers are compared to one another, the dramatic accumulation of carbon from human sources is by far the largest climate change driver over the past half century.
Lower-level atmosphere—which contains the carbon load—is expanding. The boundary between the lower atmosphere (troposphere) and the higher atmosphere (stratosphere) has shifted upward in recent decades. See the ozone FAQ for a figure illustrating the layers of the atmosphere. [6][7][8]This boundary has likely changed because heat-trapping gases accumulate in the lower atmosphere and that atmospheric layer expands as it heats up (much like warming the air in a balloon). And because less heat is escaping into the higher atmosphere, it is likely cooling. This differential would not occur if the sun was the sole climate driver, as solar changes would warm both atmospheric layers, and certainly would not have warmed one while cooling the other.

Figure 2. Twentieth Century History of Climate Drivers



(Click to image to enlarge) Heat-trapping emissions (greenhouse gases) far outweigh the effects of other drivers acting on Earth's climate. Source: Hansen et al. 2005, figure adapted by Union of Concerned Scientists.

Explore more about humans' role in global warming.

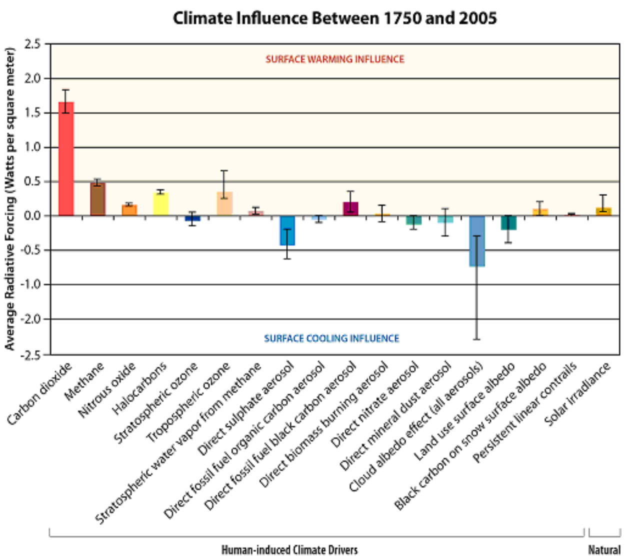
back to top

Why does CO2 get most of the attention when there are so many other heat-trapping gases (greenhouse gases)?

Global warming is primarily a problem of too much carbon dioxide in the atmosphere. This carbon overload is caused mainly when we burn fossil fuels like coal, oil and gas or cut down and burn forests. There are many heat-trapping gases (from methane to water vapor), but CO2 puts us at the greatest risk of irreversible changes if it continues to accumulate unabated in the atmosphere. There are two key reasons why.

CO2 has caused most of the warming and its influence is expected to continue. CO2, more than any other climate driver, has contributed the most to climate change between 1750 and 2005.[1, 2, 3] The Intergovernmental Panel on Climate Change (IPCC) issued a global climate assessment in 2007 that compared the relative influence exerted by key heat-trapping gases, tiny particles known as aerosols, and land use change of human origin on our climate between 1750 and 2005.[3] By measuring the abundance of heat-trapping gases in ice cores, the atmosphere, and other climate drivers along with models, the IPCC calculated the "radiative forcing" (RF) of each climate driver—in other words, the net increase (or decrease) in the amount of energy reaching Earth's surface attributable to that climate driver. Positive RF values represent average surface warming and negative values represent average surface cooling. CO2 has the highest positive RF (see Figure 1) of all the human-influenced climate drivers compared by the IPCC. Other gases have more potent heat-trapping ability molecule per molecule than CO2 (e.g. methane), but are simply far less abundant in the atmosphere and being added more slowly.

Figure 1. How Does CO2 Compare To Other Climate Drivers?



Source: IPCC 2007 WGI Table 2.12; Figure: Union of Concerned Scientists

Explore more about CO2 and other heat trapping gases.

back to top

What is the latest climate science?

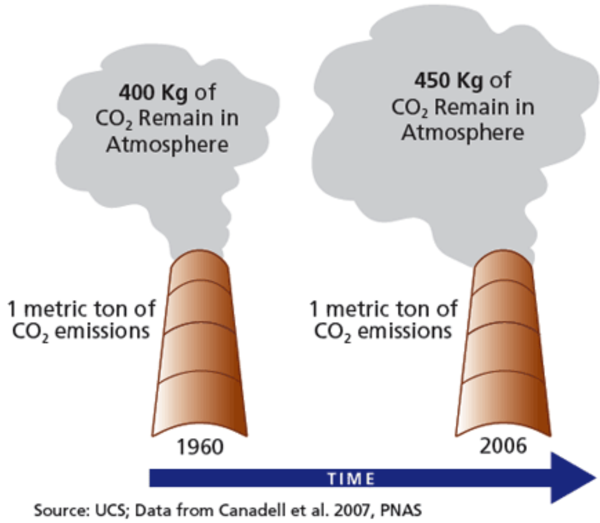
Major developments in climate change science have been reported since the publication of the comprehensive 2007 Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC).[1] Recent publications indicate that the consequences of climate change are already occurring at a faster pace and are of greater magnitude than the climate models used by the IPCC projected. A few of the most compelling findings are summarized below.

More CO2 Remains in the Atmosphere

Human activities have pumped excessive amounts of carbon dioxide (CO2) into the atmosphere. Natural processes that absorb CO2 cannot keep up. As the ocean absorbs carbon dioxide, it becomes more acidic. This combined with increasing ocean temperatures, diminishes its ability to continue absorbing CO2. As a result, more CO2 stays in the atmosphere. In 1960, a metric ton (1,000 kilograms; ~2,205 pounds) of CO2 emissions resulted in around 400 kilograms (~881 pounds) of CO2 remaining in the atmosphere (Figure 1). In 2006, a metric ton of CO2 emissions results in around 450 kilograms (~992 pounds) remaining in the atmosphere.[2] Hence a ton of CO2 emissions today results in more heat-trapping capacity in the atmosphere than the same ton emitted decades ago.

Figure 1. Today's Ton Is Worse Than a Ton Emitted Decades Ago

The natural processes that have helped clean up the excess CO2 pumped into the atmosphere by human activities have not been able to keep up at the same rate.



Explore more about the latest climate science.

back to top

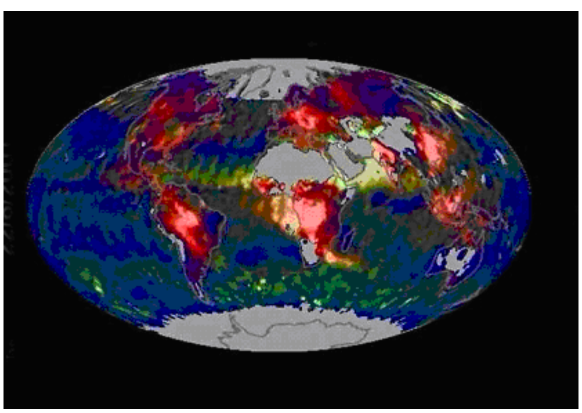
Does air pollution—specifically particulate matter (aerosols)—affect global warming?

Air pollution occurs when the air contains gases, dust, fumes or odor in harmful amounts—aerosols are a subset of air pollution that refers to the tiny particles suspended everywhere in our atmosphere. These particles can be both solid and liquid and are collectively referred to as ‘atmospheric aerosol particles’ [1]. Most are produced by natural processes such as erupting volcanoes, and some are from human industrial and agricultural activities (see Figure 1). Those particles in the lowest layer of the atmosphere, where our weather occurs, usually stay relatively close to the source of emissions and remain in the atmosphere only a few days to a week before they fall to the ground or are rained out; those higher up in the atmosphere travel farther and may linger in the atmosphere for a few years.

Light-colored aerosol particles can reflect incoming energy from the sun (heat) in cloud-free air and dark particles can absorb it. Aerosols can modify how much energy clouds reflect and they can change atmospheric circulation patterns—in short, aerosols can modify our climate [2].

Several climate engineering (so-called ‘geoengineering’) strategies for reducing global warming propose using atmospheric aerosol particles to reflect the sun’s energy away from Earth. Because aerosol particles do not stay in the atmosphere for very long—and global warming gases stay in the atmosphere for decades to centuries—accumulated heat-trapping gases will overpower any temporary cooling due to short-lived aerosol particles.

Figure 1. Small Particles (Aerosols) in the Atmosphere



Small particles suspended in the Earth’s atmosphere (aerosols) include fine aerosols such as pollution and smoke (red) and coarse aerosols such as dust and sea-salt (green). Image shows aerosol levels on April 13, 2001 as seen by a NASA satellite. Source: NASA

Explore more about air pollution and global warming.

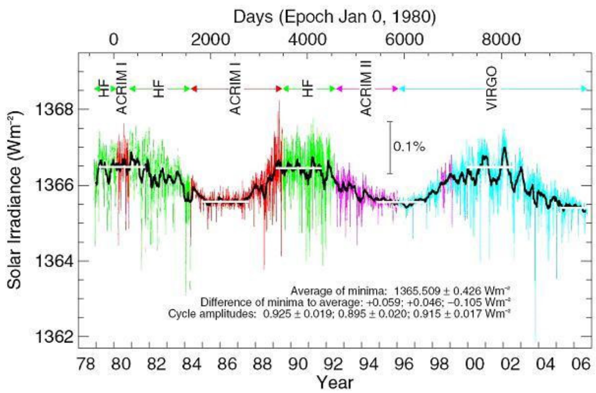
back to top

How does the sun affect our climate?

The sun is the source of most of the energy that drives the biological and physical processes in the world around us—in oceans and on land it fuels plant growth that forms the base of the food chain, and in the atmosphere it warms air which drives our weather. The rate of energy coming from the sun changes slightly day to day. Over many millennia in the Earth-Sun orbital relationship can change the geographical distribution of the sun’s energy over the Earth’s surface. It has been suggested that changes in solar output might affect our climate—both directly, by changing the rate of solar heating of the Earth and atmosphere, and indirectly, by changing cloud forming processes.

Over the time-scale of millions of years the change in solar intensity is a critical factor influencing climate (e.g., ice ages). However, changes in solar heating rate over the last century cannot account for the magnitude and distribution of the rise in global mean temperature during that time period and there is no convincing evidence for significant indirect influences on our climate due to twentieth century changes in solar output.

Figure 1. Record of Minimal Variation in Sun's Energy



(Click to image to enlarge) Figure 1. Two and a half solar cycles of Total Solar Irradiance (TSI), also called 'solar constant'. This composite, compiled by the VIRGO team at the Physikalisch-Meteorologisches Observatorium / World Radiation Center Davos, Switzerland, shows TSI as daily values plotted in different colors for the different originating experiments. The difference between the minima values is also indicated, together with amplitudes of the three cycles. Image courtesy of SOHO consortium a project of international cooperation between ESA and NASA.

Explore more about the sun's effect on our climate.

back to top

Is there a connection between the hole in the ozone layer and global warming?

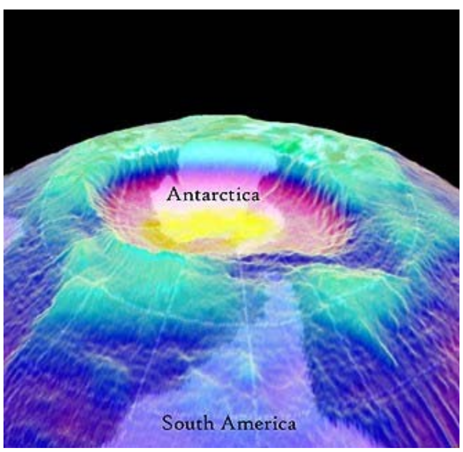
Ozone (O3) high in the atmosphere absorbs ultraviolet radiation from the sun, thereby protecting living organisms below from this dangerous radiation. The term 'ozone hole' refers to recent depletion of this protective layer over Earth's polar regions. People, plants, and animals living under the ozone hole are harmed by the solar radiation now reaching the Earth's surface—where it causes health problems from eye damage to skin cancer.

The ozone hole, however, is not the mechanism of global warming. Ultraviolet radiation represents less than one percent of the energy from the sun—not enough to be the cause of the excess heat from human activities. Global warming is caused primarily from putting too much carbon into the atmosphere when coal, gas, and oil are burned to generate electricity or to run our cars. These gases spread around the planet like a blanket, capturing the solar heat that would otherwise be radiated out into space. (For more detail on the basic mechanism of global warming, see carbon dioxide FAQ.)

Both of these environmental problems do, however, have a common cause—human activities that release gases into and alter the atmosphere. Ozone depletion occurs when chlorofluorocarbons (CFCs)—formerly found in aerosol spray cans and refrigerants—are released into the atmosphere. These gases, through several chemical reactions, cause the ozone molecules to break down, reducing ozone's ultraviolet (UV) radiation-absorbing capacity.

Because our atmosphere is one connected system, it is not surprising that ozone depletion and global warming are related in other ways. For example, evidence suggests that climate change may contribute to thinning of the protective ozone layer.

Figure 1. Seasonal thinning of the ozone layer above Antarctica.



Source: NASA.

Explore more about the ozone hole and global warming.

back to top

What is the best source of scientific information on global warming?

In 1988, the United Nations Environment Programme and the World Meteorological Organization set up the Intergovernmental Panel on Climate Change (IPCC) to examine the most current scientific information on global warming and climate change. More than 1,250 authors and 2,500 scientific experts reviewers from more than 130 countries contributed to the panel's most recent report, Climate Change 2007: The Fourth Assessment Report (the full report will be released in November 2007). These scientists reviewed all the published and peer-reviewed scientific information produced during the previous few years to assess what is known about the global climate, why and how it changes, what it will mean for people and the environment, and what can be done about it.

The IPCC Fourth Assessment Report is the most comprehensive evaluation of global warming that serves as the basis for international climate negotiations. The most up-to-date assessment for the United States was released in June 2009 by 13 federal agencies participating in the U.S. Global Change Research Program (USGCRP). For impacts in American's back yards the report "Global Climate Change Impacts in the United States" is a valuable resource.

Explore more about the USGCRP report on US climate change impacts.

Explore more about the scientific consensus on climate change.

back to top

Will responding to global warming be harmful to our economy?

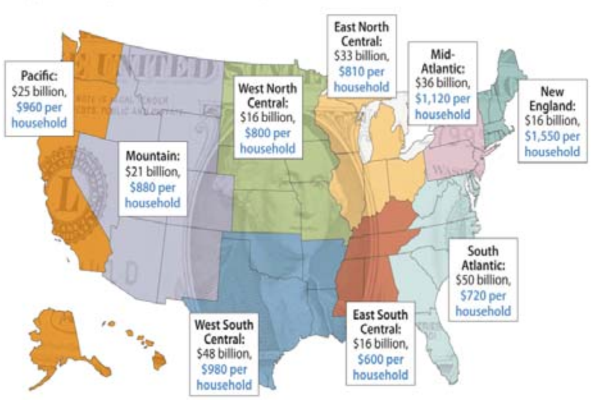
Reducing oil dependence. Strengthening energy security. Creating jobs. Tackling global warming. Addressing air pollution. Improving our health. The United States has many reasons to make the transition to a clean energy economy. What we need is a comprehensive set of smart policies to jump-start this transition without delay and maximize the benefits to our environment and economy. *Climate 2030: A National Blueprint for a Clean Energy Economy* ("the Blueprint") answers that need.

To help avoid the most dangerous consequences of climate change, ranging from extreme heat, droughts, and storms to acidifying oceans and rising sea levels, the United States must play a lead role and begin to cut its heat-trapping emissions today—and aim for at least an 80 percent drop from 2005 levels by 2050. Blueprint policies lower U.S. heat-trapping emissions to meet a cap set at 26 percent below 2005 levels in 2020, and 56 percent below 2005 levels in 2030.

The nation achieves these deep cuts in carbon emissions while saving consumers and businesses $465 billion annually by 2030. The Blueprint also builds $1.7 trillion in net cumulative savings between 2010 and 2030. Blueprint policies stimulate significant consumer, business, and government investment in new technologies and measures by 2030. The resulting savings on energy bills from reductions in electricity and fuel use more than offset the costs of these additional investments. The result is net annual savings for households, vehicle owners, businesses, and industries of $255 billion by 2030.

Under the Blueprint, every region of the country stands to save billions. Households and businesses—even in coal-dependent regions—will share in these savings.

Net Consumer and Business Savings under UCS's Climate 2030 Blueprint
(by Census Region in 2030, in 2006 dollars)



Net Annual Savings in 2030	**Total**	**$255 billion**
	Business	$129 billion
	Consumers	$126 billion
	Average Consumer	$900 per household

Note: Values may not sum properly because of rounding.

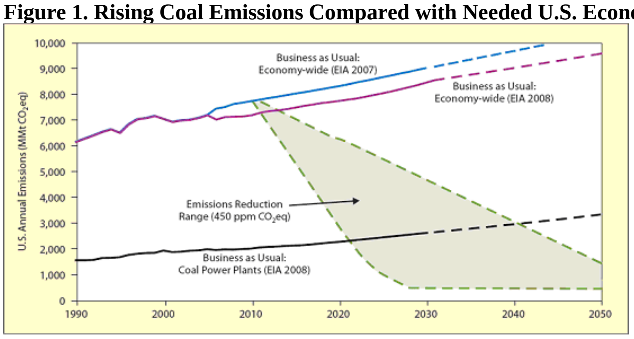
Access *Climate 2030: A National Blueprint for a Clean Energy Economy*.

back to top

What are the options for the vast stores of coal around the world?

If the countries of the world continue burning coal the way they do today, it will be impossible to achieve the reductions in carbon emissions needed to have a reasonable chance of preventing the worst consequences of global warming. Coal-fired power plants represent the United States' largest source of carbon dioxide (CO2, the main heat-trapping gas building up in our atmosphere and causing climate change).[1,2] While existing coal power technologies are incompatible with climate protection, advanced coal technologies not yet in widespread use may provide an opportunity for the world's coal reserves to continue playing a role in the energy mix of the future.

Figure 1. Rising Coal Emissions Compared with Needed U.S. Economy-wide Emissions Reductions by 2050



If CO_2 emissions from coal-fired power plants continue to rise at rates projected by the U.S. Energy Information Administration, it will be impossible for the United States to achieve the steep economy-wide emissions reductions it needs to have a reasonable chance of avoiding the worst effects of climate change. In fact, projected emissions from coal plants alone could exceed the level of total global warming emissions we can afford for the entire economy—including the transportation, residential, commercial, industrial, and agricultural sectors—between 2020 and 2040. The United States would need to reduce its total emissions at least 80 percent below 2000 levels by 2050 to achieve the range of reductions shown in the figure.

Source: Luers et al. 2007. *How to avoid dangerous climate change: A target for U.S. emissions reductions*. Projected emissions through 2030 from EIA, *Annual energy outlook 2007* and *Annual energy outlook 2008*, Reference case, extrapolated to 2050 by UCS. EIA emissions projections are lower in EIA 2008, largely because of the December 2007 passage of the Energy Independence and Security Act.

Explore more about coal and global warming.

back to top

Is global warming already happening?

Yes. The IPCC concluded in its Fourth Assessment Report, that nearly 90 percent of the 29,000 observational data series examined revealed changes consistent with the expected response to global warming, and the observed physical and biological responses have been greatest in the regions that warmed the most.

The kinds of changes already observed that create this consistent picture include the following:

Examples of observed climatic changes

Increase in global average surface temperature of about 1°F in the 20th century
Decrease of snow cover and sea ice extent and the retreat of mountain glaciers in the latter half of the 20th century
Rise in global average sea level and the increase in ocean water temperatures
Likely increase in average precipitation over the middle and high latitudes of the Northern Hemisphere, and over tropical land areas
Increase in the frequency of extreme precipitation events in some regions of the world

Examples of observed physical and ecological changes

Thawing of permafrost
Lengthening of the growing season in middle and high latitudes
Poleward and upward shift of plant and animal ranges
Decline of some plant and animal species
Earlier flowering of trees
Earlier emergence of insects
Earlier egg-laying in birds

back to top

More questions?

If you have other questions about global warming, check out our briefings, updates, recommendations, analyses, guides, and links.

In addition, there are many web sites that answer frequently asked questions. We recommend the following:

National Oceanic and Atmospheric Administration FAQ

The U.S. Environmental Protection Agency

The Carbon Dioxide Information Analysis Center

Findings of the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report summaries:
Working Group I: Climate Change Science
Working Group II: Climate Change Impacts
Working Group III: Climate Change Mitigation

back to top

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Global Warming
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Union of Concerned Scientists
National Headquarters
2 Brattle Square, Cambridge, MA 02238-9105