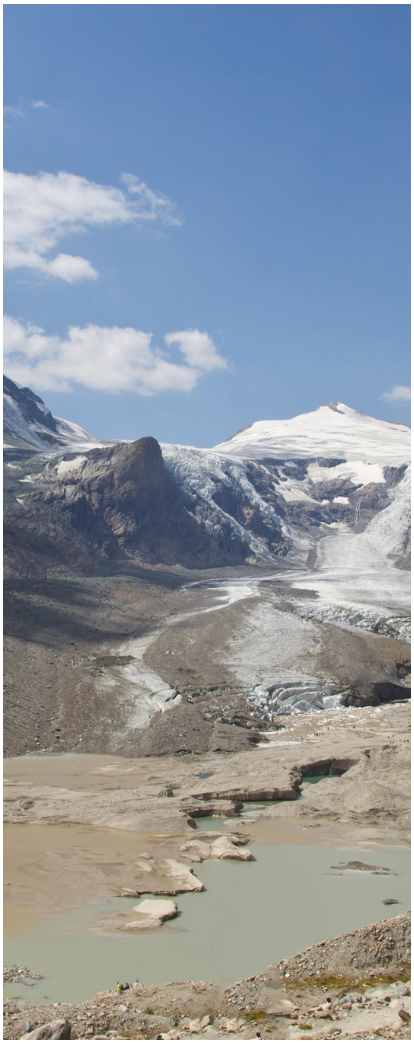
Climate Change 101: climate science basics



Physicians may be hesitant to talk about climate change because they aren't experts in climate science. In this section, you will find basic information about climate change — what it is, what causes it, and what we can do about it.

But you don't need to be a climate scientist to talk about the risks climate change poses to human health, or the health benefits of taking action on climate change. When physicians have a patient with a complex or rare illness, they often seek guidance from a sub-specialist with extensive training and education on that illness. Climate scientists are like sub-specialists — they are trained to understand climate patterns, and the sophisticated models that forecast those patterns in the future. If you were to consult with 100 climate scientists, you would find that:

97% of climate scientists agree:

- Climate change is happening now.
- It is being driven primarily by human activity.
- We can do something to reduce its impacts and progression.

What's the difference between weather, climate, climate variability and climate change?

- Weather is the temperature, humidity, precipitation, cloudiness and wind that we experience in the atmosphere at a given time in a specific location.
- Climate is the average weather over a long time period (30 – 50 years) in a region.
- Climate variability refers to natural variation in climate that occurs over months to decades. El Niño, which changes temperature, rain and wind patterns in many regions over about 2 – 7 years, is a good example of natural climate variability, also called natural variability.
- Climate change is "a systematic change in the long-term state of the atmosphere over multiple decades or longer."[1]
    - Scientists use statistical tests to determine the probability that changes in the climate are within the range of natural variability — similar to the statistical tests used in clinical trials to determine whether a positive response to treatment is likely to have occurred by chance. For example, there is a less than 1% chance that the warming of the atmosphere since 1950 could be the result of natural climate variability.

FAST FACT:

Carbon dioxide (CO_2) is the greenhouse gas responsible for greatest amount of warming to date.

What causes climate change?[2]

At its most basic, climate change is caused by a change in the earth's energy balance — how much of the energy from the sun that enters the earth (and its atmosphere) is released back into space. The earth is gaining energy as we reduce the amount of solar energy that is reflected out to space — just like people gain weight if there is an imbalance between calories in and calories out.

Since the Industrial Revolution started over 200 years ago, human activities have added very large quantities of greenhouse gases (GHG) into Earth's atmosphere. These GHG act like a greenhouse (or a blanket or car windshield) to trap the sun's energy and heat, rather than letting it reflect back into space. When the concentration of GHG is too high, too much heat is trapped, and the earth's temperature rises outside the range of natural variability. There are many GHG, each with a different ability to trap heat (known as its "global warming potential") and a different half-life in the atmosphere. GHG are sometimes called "climate active pollutants" because most have additional effects, most notably on human health.

FAST FACT:

Together, electricity production, transportation and industrial processes account for more than 80% of the CO_2 released into the atmosphere.

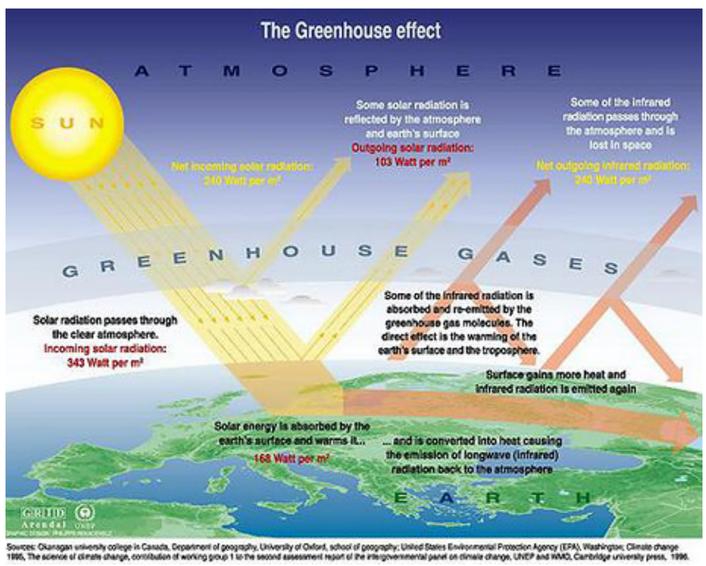


Photo credit: Marinebio

Carbon dioxide (CO_2) is the GHG responsible for greatest amount of warming to date. CO_2 accounted for 82% of all human-caused GHG emissions in the U.S. in 2013.[3] The majority of CO_2 is released from the incomplete combustion of fossil fuels - coal, oil, and gas — used for electricity production, transportation and industrial processes. Together, these three activities account for more than 80% of the CO_2 released into the atmosphere.

Other important GHG include methane, nitrous oxide, black carbon, and various fluorinated gases. Although these gases are emitted in smaller quantities than CO_2, they trap more heat in the atmosphere than CO_2 does. The ability to trap heat is measured as Global Warming Potential (GWP). As the most common and abundant greenhouse gas, CO_2 has a GWP of 1, so all other GHG warming potentials are compared to it. Fluorinated gases, for example, have GWPs thousands of times greater than CO_2, meaning that pound-for-pound, these gases have a much stronger impact on climate change than CO_2.

Summary Table of Greenhouse Gas Emissions [4] [5]

Name	% of U.S. GHG Emissions 2013	Sources	Lifetime in the Atmosphere	Global Warming Potential (GWP)
Carbon Dioxide (CO_2)	82%	Electricity production, transportation, numerous industrial processes.	Approximately 50-200 years. Poorly defined because CO_2 is not destroyed over time; it moves among different parts of the ocean–atmosphere–land system.	1
Methane (CH_4)	10%	Livestock manure, food decomposition; extraction, distribution and use of natural gas	12 years	25
Nitrous oxide (N_2O)	5%	Vehicles, power plant emissions	115 years	298
Black carbon (soot, PM)	>1%	Diesel engines, wildfires biomass in household cook stoves (developing countries)	Days to weeks	3,200
Fluorinated gases: PFCs, HFCs, NF_3, SF_6	>5%	No natural sources. These are synthetic pollutants found in coolants, aerosols, pesticides, solvents, fire extinguishers. Also used in the transmission electricity.	PFCs: 2600 – 50,000 years HFCs: 1-270 years NF_3: 740 years SF_6: 3200 years	PFCs: 7,000–12,000 HFCs: 12–14,000 NF_3: 17,2000 SF_6: 22,800

Why Short-Lived Climate Pollutants Matter

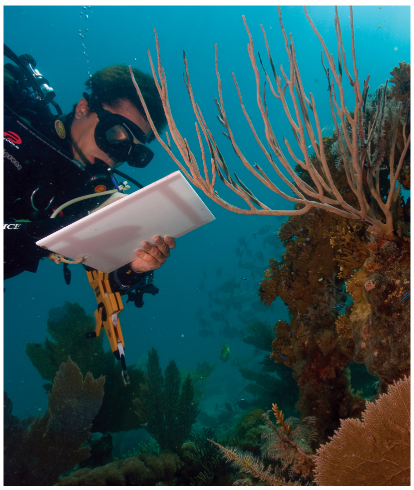
The greenhouse gases with a high global warming potential but a short lifetime in the atmosphere are called "short-lived climate pollutants" (SLCP). Key SLCP include methane, black carbon, and the fluorinated gases. Because of the combination of a short half-life and high GWP, the climate change impacts of the SLCP are front-loaded — more of the impacts occur sooner, while the full weight of impacts from CO_2 will be felt later.

We must transition to carbon-free transportation and energy systems, because CO_2 remains the greatest contributor to climate change. But reducing emissions of short-lived climate pollutants may "buy time" while we make the transition. Reducing global levels of SLCP significantly by 2030 will:[6]

- Reduce the global rate of sea level rise by 20% by 2050
- Cut global warming in half, or 0.6° C, by 2050 and by 1.4° C by 2100
- Prevent 2.4 million premature deaths globally each year
- Improve health, especially for disadvantaged communities

Many strategies to reduce SLCP also have immediate health benefits, such as:

- Reducing air pollution related hospitalizations
- Promotion of reduced meat consumption
- Stricter emissions standards, especially for diesel vehicles
- Cleaner household cook stoves in developing nations



Climate change is causing five critical global environmental changes:[7]

- **Warming temperature of the earth's surface and the oceans:** The earth has warmed at a rate of 0.13° C per decade since 1957, almost twice as fast as its rate of warming during the previous century.
- **Changes in the global water cycle ('hydrologic' cycle):** Over the past century there have been distinct geographical changes in total annual precipitation, with some areas experiencing severe and long-term drought and others experiencing increased annual precipitation. Frequency and intensity of storms increases as the atmosphere warms and is able to hold more water vapor.
- **Declining glaciers and snowpack:** Across the globe, nearly all glaciers are decreasing in area, volume and mass. One billion people living in river watersheds fed by glaciers and snowmelt are thus impacted.
- **Sea level rise:** Warmer water expands, so as oceans warm the increased volume of water is causing sea level rise. Melting glaciers and snowpack also contribute to rising seas.
- **Ocean acidification:** Oceans absorb about 25% of emitted CO_2 from the atmosphere, leading to acidification of seawater.

These global changes result in what we experience as changes in our local weather and climate:

- Greater variability, with "wetter wets", "drier dries" and "hotter hots"
  - More frequent and severe extreme heat events
  - More severe droughts
  - More intense precipitation, such as severe rains, winter storms and hurricanes
- Higher average temperatures and longer frost-free seasons
- Longer wildfire seasons and worse wildfires
- Loss of snowpack and earlier spring runoff
- Recurrent coastal flooding with high tides and storm surges

DID YOU KNOW?

Oceans absorb about 25% of emitted CO_2 from the atmosphere, leading to acidification of seawater.

- More frequent and severe floods due to intense precipitation and spring snowmelt
- Worsening air quality: Higher temperatures increase production of ozone (a key contributor to smog) and pollen, as well as increasing the risk of wildfires.
- Longer pollen seasons and more pollen production

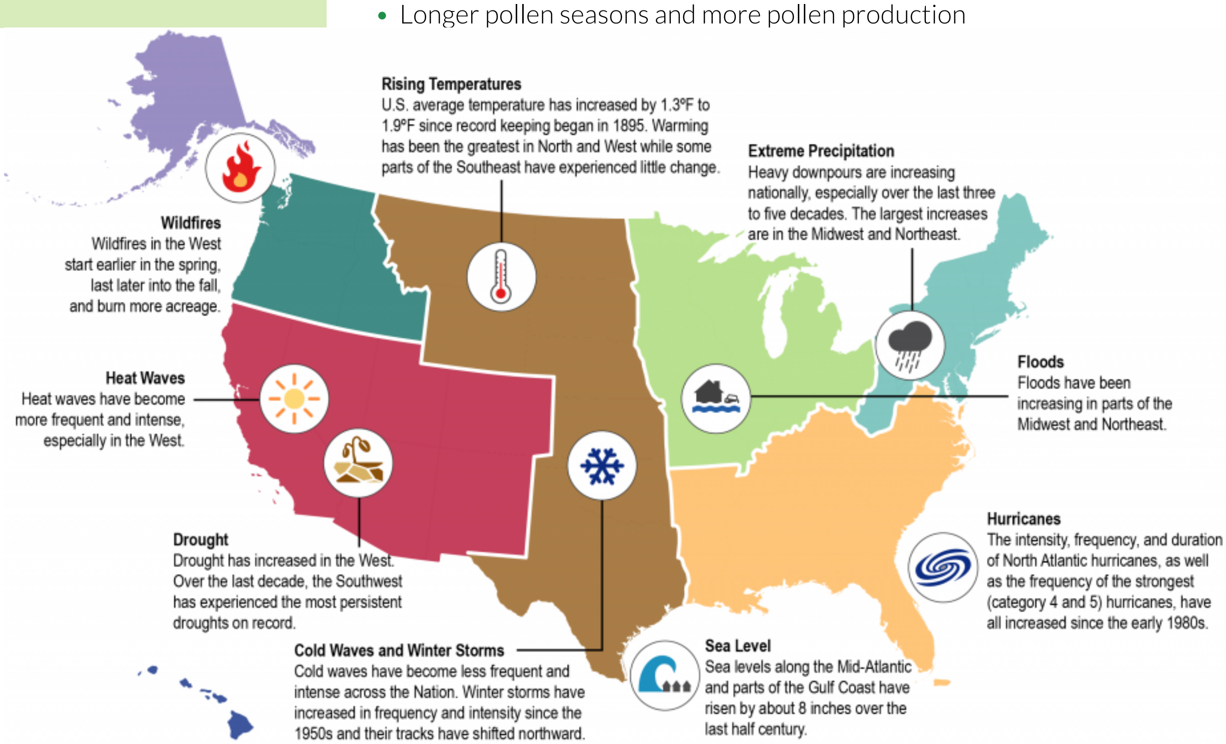
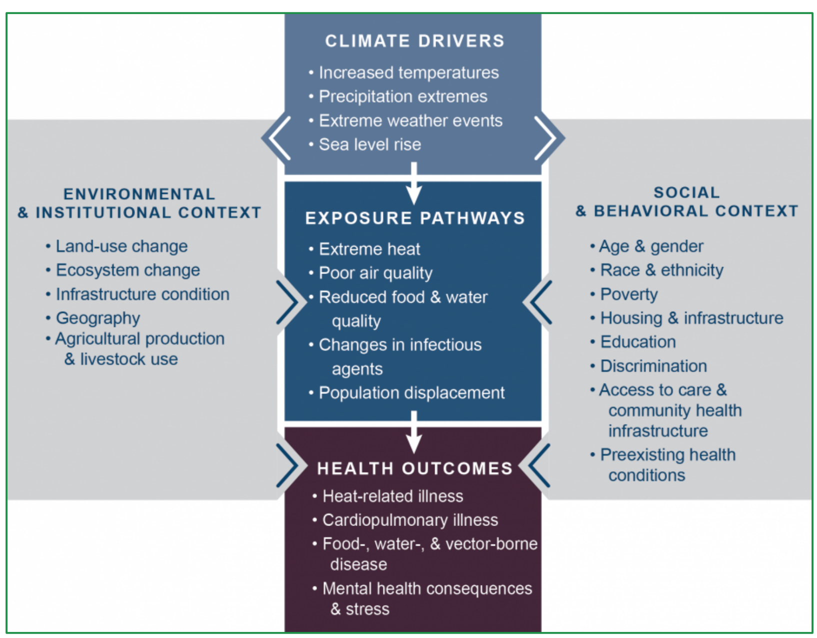


Photo credit: US Global Change Research Project Climate and Health Assessment

FAST FACT:

There is a less than 1% chance that the warming of the atmosphere since 1950 could be the result of natural climate variability.

In turn these regional and local climatic changes result in the environmental, social and economic changes that are associated with human health impacts. These impacts will be covered in greater detail throughout the guide, but the graphic below provides an overview of the pathways linking climate change and human health outcomes.

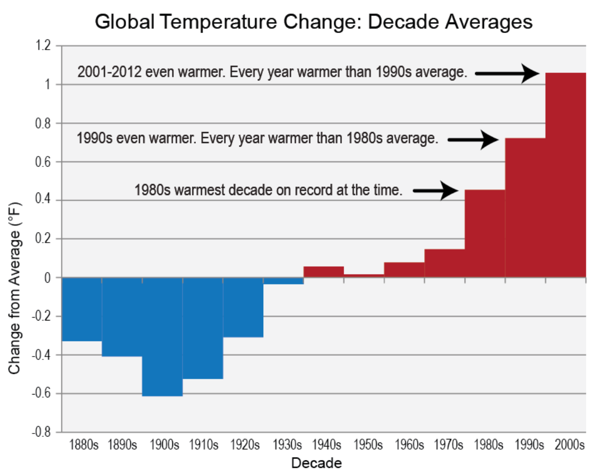


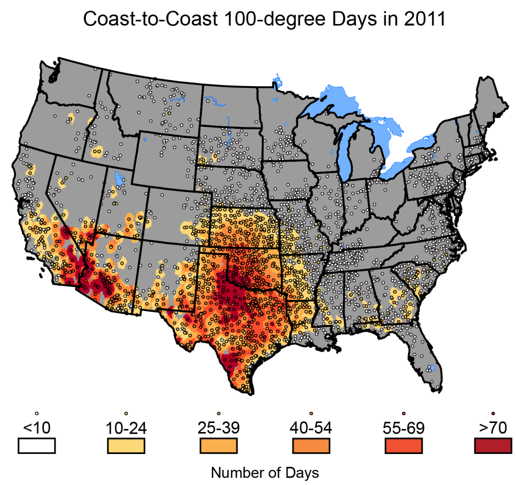
FAST FACT:

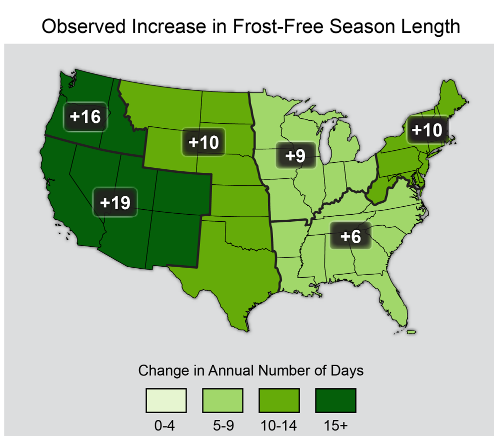
Climate change will appear differently in different regions of the U.S.

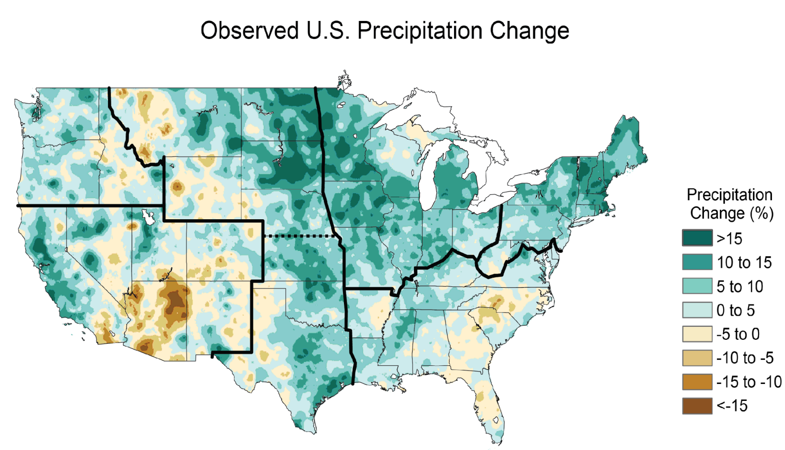
Climate change in the U.S.

Climate change will appear differently in different regions of the U.S., just as different patients may experience the same illness differently, depending on pre-existing health status, socioeconomic factors and environmental context. Below are a few snapshots of measured changes associated with climate change in the U.S.[8] For a more comprehensive view of how climate change is affecting the U.S. and specific regions, see the National Climate Assessment. California-specific impacts will be covered in greater detail throughout the Guide.









DID YOU KNOW?

Mitigation strategies that offer feasible and cost-effective ways to reduce greenhouse gas emissions include the use of clean and renewable energy for electricity production; walking, biking, and using low-carbon or zero-emission vehicles; reducing meat consumption; less flying; changing agricultural practices; limiting deforestation; and planting trees.

There is a lot we can do about climate change.

In general, climate solutions fall into two big buckets — "mitigation" and "adaptation." Increasingly, government and community organizations also talk about measures to increase climate "resilience." These concepts are not distinct, and are all inter-related. From the Global Change Research Project:[9]

- **Mitigation** refers to "measures to reduce the amount and speed of future climate change by reducing emissions of heat-trapping gases or removing carbon dioxide from the atmosphere."
- **Adaptation** refers to measures taken to reduce the harmful impacts of climate change or take advantage of any beneficial opportunities through "adjustments in natural or human systems."
- **Resilience** means the "capability to anticipate, prepare for, respond to, and recover from significant threats with minimum damage to social well-being, the economy, and the environment."

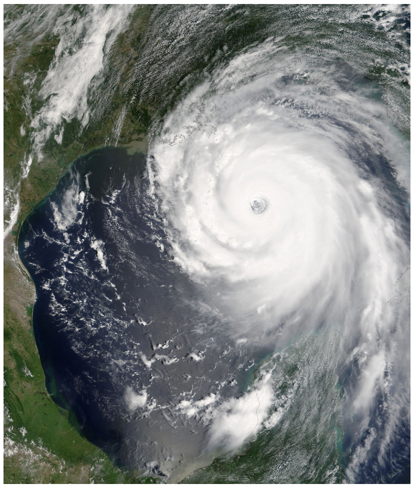
Mitigation

Mitigation is essential because scientists agree that the higher global temperatures rise, the greater the adverse consequences of climate change. Also, if emissions are unchecked, there is a greater danger of abrupt climate change or surpassing "tipping points." For example, collapse of the West Antarctic Ice Sheet could lead to very rapid sea level rise, or melting of permafrost could lead to large releases of methane that would further increase warming through a positive feedback loop. Catastrophic climate change could surpass our capacity to adapt. For example, a recent study suggests that heat levels in parts of the Middle East may exceed the body's survival threshold unless we reduce greenhouse gas emissions levels quickly.[10]

There are many mitigation strategies that offer feasible and cost-effective ways to reduce greenhouse gas emissions. These include the use of clean and renewable energy for electricity production; walking, biking, and using low-carbon or zero-emission vehicles; reducing meat consumption; less flying; changing agricultural practices; limiting deforestation; and planting trees.

Our Carbon Budget

In 2015, nearly 200 nations agreed in Paris that the risks are significantly reduced if we can keep global temperatures from rising more than 1.5° Celsius above pre-industrial levels. Currently, average global temperatures are around 1°C higher than pre-industrial levels, and if greenhouse gas emissions continue at the current rates ("business as usual"), the Earth's temperature will rise about 4° C by the end of the century. To stay below 1.5° rise requires that from now forward, total global emissions cannot exceed 240 billion tons of carbon into the Earth's atmosphere. This is referred to as our "carbon budget."[†][11] At current emissions rates, this carbon budget will be used up within the next 6 to 11 years. Therefore, drastic action is needed to significantly reduce emissions as soon as possible.



FAST FACT:

The impacts of climate change are already evident — in extreme weather, more explosive wildfires, higher temperatures, and changes in the distribution of disease-carrying vectors.

Adaptation

Adaptation strategies are needed to reduce the harmful impacts of climate change and allow communities to thrive in the face of climate change. The impacts of climate change are already evident – in extreme weather, more explosive wildfires, higher temperatures, and changes in the distribution of disease-carrying vectors. Because GHG persist in the atmosphere for a long time, more serious climate impacts would be experienced even if we halted all GHG emissions today.

Cool roofs, planting trees, and air conditioning are all effective adaptation strategies to reduce the impacts of rising temperatures and more frequent heat waves. Seawalls and restoration of wetlands are both strategies to address sea level rise. Emergency preparedness planning that takes climate changes into account is one way to adapt to the increased frequency of climate resilience: the capacity to anticipate, plan for and reduce the dangers of the environmental and social changes brought about by climate change, and to seize any opportunities associated with these changes.[12] For more on climate change resilience see Climate Change and Health Equity.

Climate and Health Co-Benefits

Although climate change is the greatest health challenge of our century, action to address it has the potential for huge health benefits. Consideration of the health and equity impacts of various mitigation and adaptation strategies can help optimize the health benefits of climate action. For more information on the health co-benefits of climate actions, see the following "Climate Action for Healthy People, Healthy Places, Healthy Planet" briefs:

- **Transportation, Climate Change and Health:** Reducing vehicle miles traveled through walking, biking, and public transit increases physical activity, significantly reduces chronic disease risks and reduces greenhouse gas emissions.
- **Energy, Climate Change and Health:** Switching from coal combustion to clean, safe, renewable energy is one of the most important things we can do for our health and for the climate.
- **Food & Agriculture, Climate Change and Health:** Shifting to healthy diets and local, sustainable food and agriculture systems, offers significant health, climate, and environmental benefits.
- **Urban Greening & Green Infrastructure, Climate Change and Health:** Urban greening reduces the risk of heat illness and flooding, lowers energy costs, and supports health. Green spaces provide places to be physically active and trees sequester CO_2, improve air quality, capture rainwater and replenish groundwater.

† The carbon budget includes the remaining amount of all GHG that can be emitted to keep the earth's temperature below the target of 1.5° Celsius. In order to provide a single, standardized measurement, the global warming potentials of all GHG are converted to their CO_2 equivalent and this figure (240 billion tons) is the carbon budget.

DID YOU KNOW?

Because greenhouse gasses (GHG) persist in the atmosphere for a long time, more serious climate impacts would be experienced even if we halted all GHG emissions today.

For More Information

- Intergovernmental Panel on Climate Change Fifth Assessment Report
  https://www.ipcc.ch/report/ar5/syr/
- U.S. Global Change Research Project National Climate Assessment
  http://nca2014.globalchange.gov
- U.S. Environmental Protection Agency Climate Change site
  https://www3.epa.gov/climatechange/
- Climate Change in California
  - Our Changing Climate 2012: Summary report from the Third Assessment of Climate Change in California
    http://www.energy.ca.gov/2012publications/CEC-500-2012-007/CEC-500-2012-007.pdf
  - Cal Adapt: Web-based tool allowing users to identify climate change risks throughout the state http://cal-adapt.org
  - California Climate Change: Official State of California site with resources on statewide climate change and initiatives to reduce greenhouse gas emissions http://climatechange.ca.gov

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Citations

[1] Uejio, C.K., Tamerius, J.D., Wertz, K. & Konchar, K.M. (2015). Primer on climate science. In G Luber & J Lemery (Eds.), *Global Climate Change and Human Health* (p. 5), San Francisco, CA: Jossey-Bass.

[2] United States Environmental Protection Agency. Climate Change: Basic Information. Available at https://www3.epa.gov/climatechange/basics/

[3] United States Environmental Protection Agency (2016). Inventory of US greenhouse gas emissions and sinks: 1990-2014 (DRAFT). Available at https://www3.epa.gov/climatechange/ghgemissions/gases.html

[4] Ibid.

[5] California Environmental Protection Agency Air Resources Board. Proposed Short-Live Climate Pollutants Reduction Strategy. April 2016. Available at http://www.arb.ca.gov/cc/shortlived/meetings/04112016/proposedstrategy.pdf

[6] Climate and Clean Air Coalition (2014). Time to act to reduce short-lived climate pollutants. Available at http://www.ccacoalition.org/en/resources/time-act-brochure

[7] Uejio, C.K., Tamerius, J.D., Wertz, K. & Konchar, K.M. (2015). Primer on climate science. In G Luber & J Lemery (Eds.), *Global Climate Change and Human Health* (pp. 12-18), San Francisco, CA: Jossey-Bass.

[8] US Global Change Research Project (2014). National Climate Assessment: Climate Change Impacts in the United States. Washington, D.C. Available at http://nca2014.globalchange.gov

[9] USGCRP, 2016: Appendix 5: Glossary and Acronyms. The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment. U.S. Global Change Research Program, Washington, DC, 307–312.

[10] Pal, J. & Eltahir, E. (2016). Future temperature in southwest Asia projected to exceed threshold for human adaptability. *Nature Climate Change*, 6:197-200. Available at http://www.nature.com/nclimate/journal/v6/n2/full/nclimate2833.html

[11] IPCC, 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.)]. IPCC, Geneva, Switzerland, 151 pp.

[12] Island Press & The Kresge Foundation. (No Date). Bounce forward, urban resilience in the era of climate change. Island Press. http://kresge.org/sites/default/files/Bounce-Forward-Urban-Resilience-in-Era-of-Climate-Change-2015.pdf

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