The Research

Summary of Research Relevant to Multidisciplinary Climate Change Education

Climate Change Research: An Overview

Over the past 1 million years, the earth has gone through several cycles of warming and cooling, with ice ages alternating with warmer periods. Each of these cycles has lasted about 100,000 years.

By comparison, the earth's climate has remained relatively stable over the past 10,000 years. There is an important exception, though. Since the beginning of the Industrial Revolution in Europe in about 1750, climate scientists have measured a relatively rapid increase in global temperatures of approximately 1.3°F (0.7°C).

Evidence of Climate Change

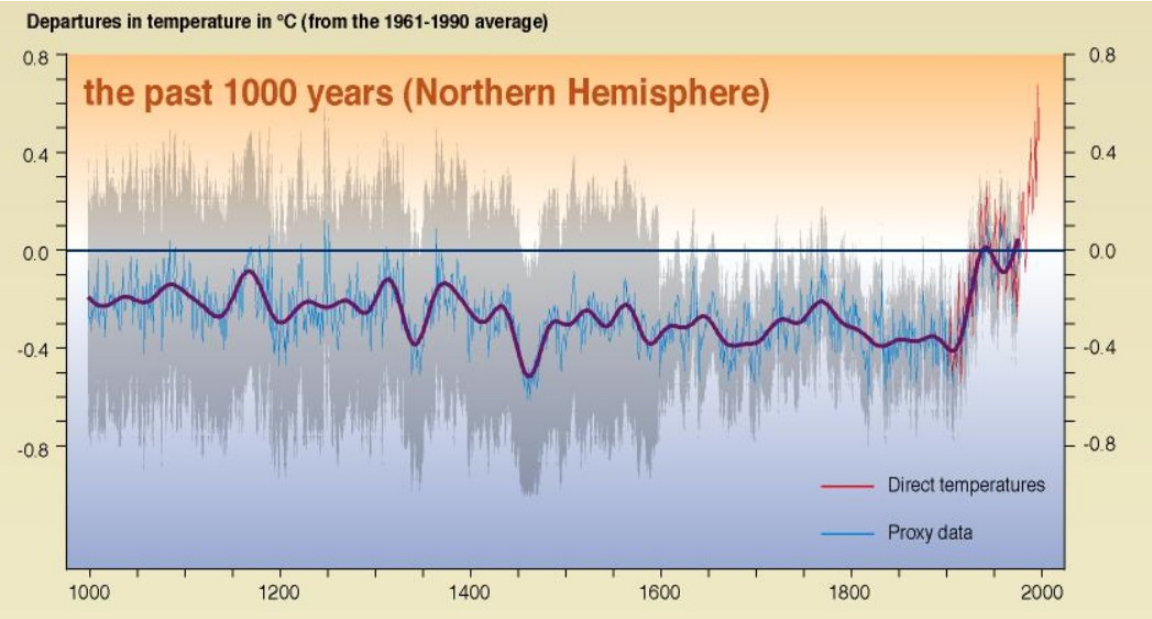
The Intergovernmental Panel on Climate Change (IPCC) is an agency formed in 1988 by the World Meteorological Organization and the United Nations Environment Program to study the extent of climate change and its effects. In August 2013, the IPCC prepared to issue its fifth assessment of the risks of climate change. According to the IPCC, there is at least a 95 percent certainty that humans have caused warmer temperatures through their activities.

The draft summary stated, "It is extremely likely that human influence on climate caused more than half of the observed increase in global average surface temperature from 1951 to 2010. There is high confidence that this has warmed the ocean, melted snow and ice, raised global mean sea levels, and changed some climate extremes in the second half of the twentieth

century." In its previous assessment, issued in 2007, the IPCC had predicted that global temperatures will rise between 2°F and 11.5°F by 2100.

The graph below was produced by the IPCC. Known informally as the "hockey stick" because of the shape of the graph, it shows the dramatic rise in global average temperatures since 1900. (Available at https://www.ipcc.ch/ipccreports/tar/slides/large/05.16.jpg)

Graph 1



Source: Intergovernmental Panel on Climate Change

The purpose of this section is to summarize research and provide links for further research into the causes of climate change (also known as global warming), the effects of climate change on the environment and on people, and potential solutions to slow the pace of warming. The IPCC has stated that if the earth continues to warm at current rates, the economic, ecological, and social consequences will be momentous.

In recent years, climate scientists have observed ample evidence of the warming of the earth's atmosphere. The decade from 2000 to 2010 was the hottest ever recorded, and global temperatures reached new highs in 1998 and 2010. Glaciers around the world are melting. Glacier National Park in Montana, for example, once had 150 glaciers but now has only 25. Scientists have estimated that glaciers will disappear completely from the park by 2030.

Similarly, ice is melting in the Arctic Circle, with widespread consequences for wildlife such as polar bears, which depend on ice to migrate and hunt for food. Scientists have observed that birds and other wildlife are migrating to higher latitudes in the northern and southern hemispheres to stay within their accustomed temperature ranges.

Greenhouse Effect Simulator-University of Colorado Boulder

http://phet.colorado.edu/en/simulation/greenhouse

Global carbon dioxide levels near worrisome milestone-nature.com

http://www.nature.com/news/global-carbon-dioxide-levels-near-worrisome-milestone-1.12900

Global land temperatures have increased by 1.5 degrees C over the past 250 years-BerkeleyEarth.org

http://berkeleyearth.org/summary-of-findings

Causes of Climate Change

Scientists have linked the rise in global temperatures to the increase in certain gases in the atmosphere since the beginning of the Industrial Revolution around 1750. These gases result from the burning of fossil fuels, particularly coal, oil, and natural gas. The fossil-fuel emissions cause gases to enter the atmosphere, where they trap radiation from the sun and prevent some of that radiation from being reflected back into space. The trapped radiation increases temperatures on the surface of the earth. These gases are called greenhouse gases (GHG) because they function somewhat like greenhouses.

The three most common GHG are carbon dioxide, methane, and nitrous oxide. Carbon dioxide (CO_2) is the gas that all vegetation on Earth absorbs in the photosynthesis process. The amount of CO_2, emitted from smokestacks and other exhausts has increased from 280 parts per million (ppm) in 1750 to nearly 400 ppm in 2013. (A part per million is a measure of the amount of a contaminate in the atmosphere or in a body of water.) A molecule of CO_2 stays in the atmosphere between 100 years and 500 years.

The second most common GHG is methane (CH_4), which is the main component of natural gas. Methane lasts in the atmosphere only for about 12 years, but it is 20 times more potent than CO_2 as a GHG. It leaks into the atmosphere primarily during the process of producing natural gas. Livestock also emit methane as part of the animals' natural digestive process. Methane has increased from 715 parts per billion (ppb) in 1750 to 1774 ppb in 2005.

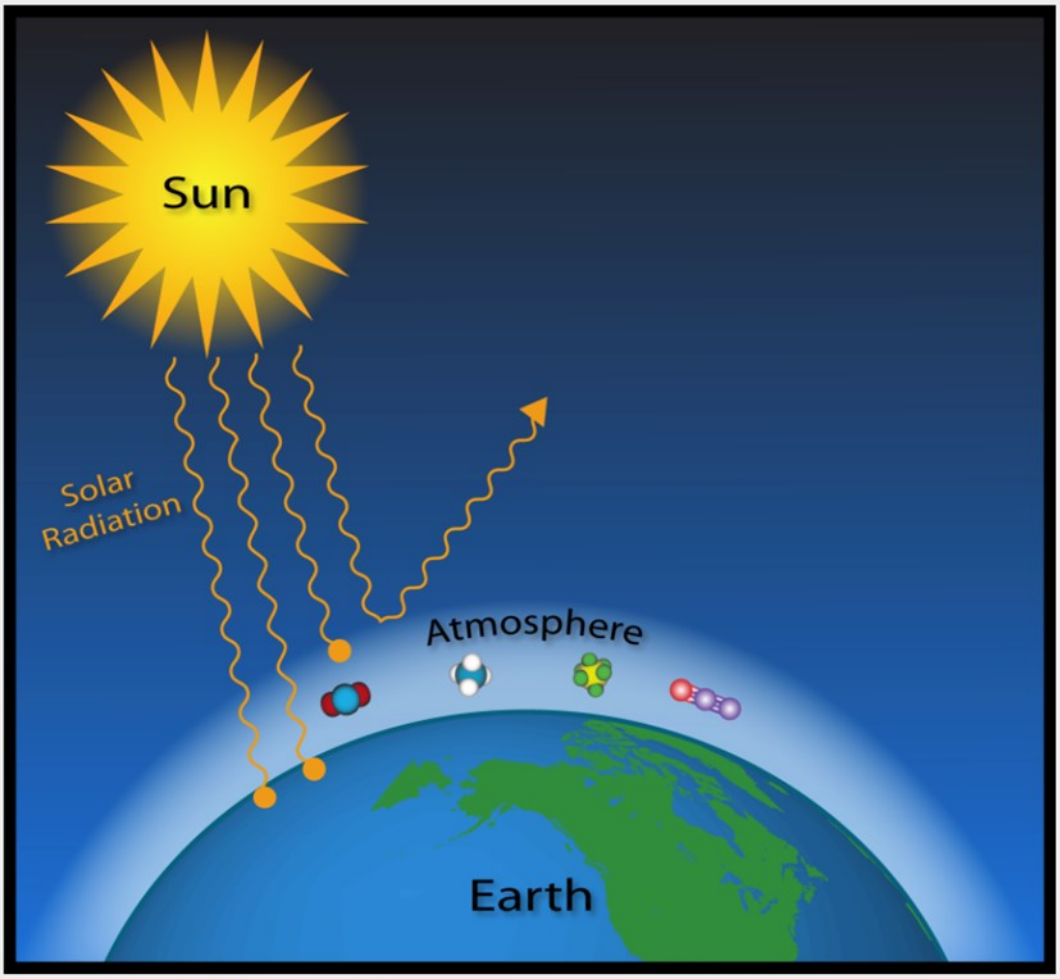
The third most common GHG is nitrous oxide (N_2O), which results from various industrial processes such as the burning of fossil fuels, agriculture, and the management of wastewater. This gas lasts in the atmosphere for about 120 years and is about 300 times as potent a GHG as CO_2. Nitrous oxide has increased from 270 ppb in 1750 to 319 ppb in 2005.

A fourth GHG is sulfur hexafluoride (SF_6), which is a human-made gas that is used primarily by the electric power industry.

Another major cause of climate change has been changes in land use. In the past 250 years, the human population has grown from 800 million to 7 billion. To accommodate this population expansion, people have cut down forests to harvest timber and cleared land for farms, cities, and suburbs. Trees absorb CO_2 as part of the photosynthesis process. However, because of deforestation, the earth has far fewer trees to absorb CO_2, leaving more of the gas in the atmosphere. Logging of rain forests, such as the vast rain forest of Brazil, has been a major contributor to deforestation and to climate change.

The two diagrams below show how GHG trap radiation in the earth's atmosphere.

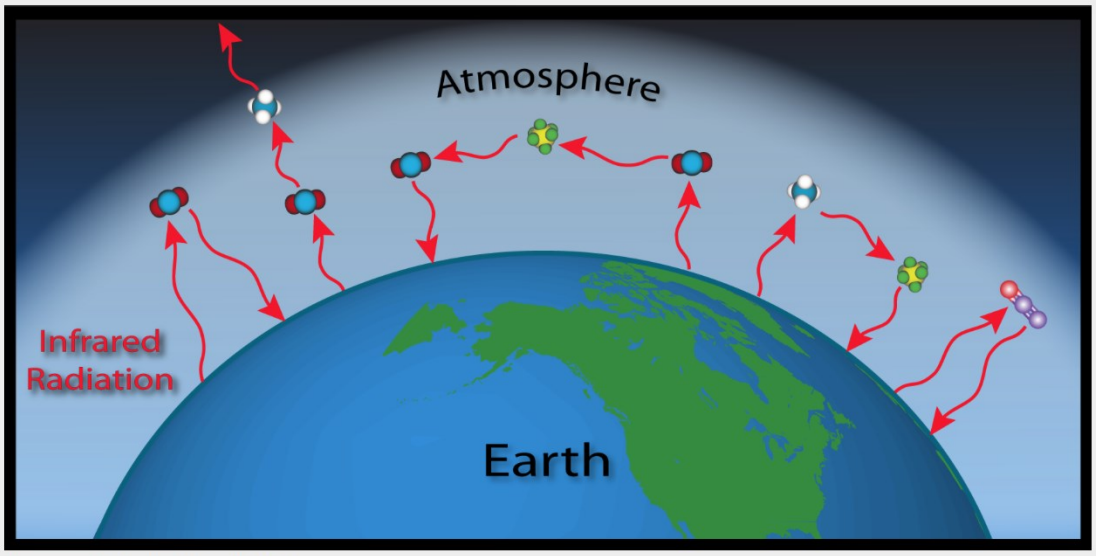
Diagram 1



Solar radiation enters the earth's atmosphere. Some escapes into space. The majority, though, is trapped in the atmosphere by gases, as the diagram shows (available at http://www.esrl.noaa.gov/gmd/education/carbon_toolkit/basics.html). These gases help make the earth warm enough for life to survive. From left to right, the gases represented are:

1. Carbon dioxide (CO_2)
2. Methane (CH_4)
3. Sulfur hexafluoride (SF_6)
4. Nitrous oxide (N_2O)

Diagram 2



Source: Barb Deluisi, NOAA

As more GHG gather in the atmosphere, the gases absorb infrared radiation, which causes increased warming. The diagram shows the process by which the GHG absorb radiation and reflect it back to earth. (Available at http:// www.esrl.noaa.gov/gmd/education/carbon_toolkit/basics.html)

Greenhouse Gas Emissions- EPA
http://www.epa.gov/climatechange/ghgemissions/

Climate Change Science-EPA
http://www.epa.gov/climatechange/science/

Climate Change Impacts and Adapting to Change- EPA
http://www.epa.gov/climatechange/impacts-adaptation/

Effects of Climate Change on Natural Environments

Climate scientists have observed and identified the effects of climate change in seven areas: (1) extreme high temperatures, (2) rising sea levels, (3) more floods and droughts, (4) increases in hurricanes and other extreme weather, (5) melting of glaciers, polar ice caps, and ice floes, (6) ocean acidification, and (7) loss of farmland.

As already noted, the decade from 2000 to 2010 was the warmest on record. In 2010, 19 countries experienced the hottest temperatures ever recorded, including Finland at 99°F, Niger at 119°F, and Saudi Arabia at 125°F. The scorching temperatures caused misery in cities such as Moscow, where few people had air conditioning and residents feared going outside because of the heavy smog.

As average temperatures have risen, the world's oceans have absorbed 80 percent of the atmospheric warming. As the water has warmed, it has expanded, raising ocean levels. In the draft summary of its fifth assessment, the IPCC predicted that if carbon emissions continue at current rates, ocean levels could rise by 21 inches to 3 feet by 2100, threatening coastal cities like New York and London.

The world has also experienced more severe floods and droughts, which most likely have resulted from changing weather patterns. In 2005, for example, more than 3 feet of rain fell on Mumbai, India, in 24 hours. Across the northern United States, the amount of precipitation has increased between 5 and 20 percent in recent years because rising temperatures have increased evaporation of water into the earth's atmosphere.

Yet other parts of the world have experienced greater drought as warmer temperatures take moisture out of the atmosphere. Several parts of the world, including the Sahel, the Mediterranean region, southern Africa, southern Asia, and the southwestern United States have suffered through extended droughts.

Climate scientists expect an increase in the severity of tropical storms, such as hurricanes, because rising temperatures will contribute to the build-up of energy unleashed by storms.

Warmer temperatures are causing glaciers, polar ice caps, and ice floes to shrink and even disappear. Arctic ice has shrunk by 2.7 percent per decade since 1978. Mountain glaciers and snow cover have been shrinking, contributing to the rise in ocean levels because of the runoff of water.

The large amount of CO_2 that the oceans are absorbing from the atmosphere is causing the ocean water to become more acidic. The increased acidity has a negative impact on shelled species, such as shellfish and corals, by impeding the process of building shells using calcium carbonate found in sea water.

Finally, rising ocean levels threaten farmland in coastal areas, where land in low-lying countries like Bangladesh will be lost for agriculture. For example, rising sea levels have already had negative effects on the growing of rice in the Mekong Delta in Southeast Asia and the growing of crops in several countries in coastal Africa.

All these changes will have a major impact on the species of life on the earth. Scientists estimate the potential extinction of between 20 percent and 30 percent of all species because of disappearing habitats. Global warming will have a negative effect on ocean ecosystems, including coral reefs.

New USDA plant zones clearly show climate change- Washington Post
http://www.washingtonpost.com/blogs/capital-weather-gang/post/new-usda-plant-zones-clearly-show-climate-change/2012/01/27/gIQA7Vz2VQ_blog.html

NOAA's Tides and Currents: Sea Level Trends Map
http://tidesandcurrents.noaa.gov/sltrends/sltrends.html

What is Ocean Acidification?-NOAA
http://www.pmel.noaa.gov/co2/story/What+is+Ocean+Acidification%3F

The Antarctic's Ice Paradox-PBS.org
http://www.pbs.org/newshour/rundown/2013/05/why-climate-change-means-more----and-less----ice-for-the-antarctic.html

Effects of Climate Change on Humans

The effects of climate change will have major and perhaps catastrophic effects on humans, causing greater poverty, hunger and malnutrition, disease, injury, and death.

One of the major effects will be on food supply. In tropical regions, where much of the world's food is grown, crop yields will almost certainly decline because of increased drought. Malnutrition will increase as agricultural lands are lost to rising ocean levels and flooding. In addition, higher temperatures and dry conditions will bring more wildfires, which threaten the forests and croplands on which many people depend for their livelihoods. Today, 840 million people in the world are malnourished. With climate change, the IPCC estimates that the number of undernourished people will probably increase by 100 million to 240 million.

Climate change will probably worsen poverty in the world. Scientists predict that rising temperatures will lower the global gross domestic product by 20 percent during the 21st century, partly by eliminating agricultural lands that are now productive. The effects will be particularly serious in developing countries, causing mass migration from agricultural regions to cities and putting intense pressure on urban services ranging from education to medical care.

Scientists also predict that climate change will lead to higher occurrences of certain diseases. According to the World Health Organization, climate change caused more than 150,000 deaths in the year 2000. For example, malaria will probably increase because disease-carrying mosquitoes thrive in warm, moist weather conditions. Heat waves are major threats to people's health. In July 1995, 750 people in Chicago died as the result of record-breaking heat and humidity that plagued the city. Heart and lung diseases may also increase because of rising temperatures, ozone levels, and other forms of pollution.

Finally, climate change could well result in increased war and conflict. In its 2007 report, the IPCC pointed out that conflicts over fresh water, arable land, and food have played significant roles in wars in Malawi, Mozambique, Somalia, Ethiopia, Sudan, and other countries in Africa.

Climate Change Impacts and Adapting to Change
http://www.epa.gov/climatechange/impacts-adaptation/

Climate may crank storms into overdrive- Futurity.com
http://www.futurity.org/earth-environment/climate-may-crank-storms-into-overdrive/

Latest Forecast Shows the U.S. Drought Moving West-PBS.org
http://www.pbs.org/newshour/rundown/2013/05/latest-forecast-shows-the-us-drought-moving-west.html

Local Impacts

The global impact of climate change is very real, but students may ask, "How is climate change going to affect me and the area in which I live?" In fact, climate scientists have examined the likely impact of climate change on each of the major regions of the United States.

In the Northeast, the average temperature has risen by 2°F since 1970, and scientists expect temperatures to rise between 2.5°F and 4°F in the next century. Because of the region's long coastline, it will face potentially catastrophic floods, storm surges, property damage, and loss of wetlands. The region's large cities, such as New York and Philadelphia, could suffer through more than 30 days each year with temperatures over 100°F, with an accompanying increase in ozone and other forms of pollution. Such heat waves have the potential to cause hundreds, if not thousands, of fatalities.

The warm and humid region of the Southeast has experienced an average increase in temperature of 2°F since 1970. Average temperatures over the next several decades could rise between 4.5°F and 9°F. This region is particularly vulnerable to hurricanes, which scientists expect to increase in intensity as warmer ocean water feeds the energy that builds up in these storms. At the same time, scientists expect more prolonged droughts because of higher temperatures. Since the mid-1970s, the area of the Southeast suffering through long droughts has increased by 26 percent. Droughts could have widespread economic consequences for the agriculture in this region.

The Midwest has also experienced rising average temperatures. Throughout the region, the last frosts in spring now come a week earlier than they used to, and heavy thunderstorms are twice as frequent as they were 100 years ago. Flooding has also become more frequent, as evidenced by record-setting floods in the Mississippi River Valley in 1993 and 2013. As previously mentioned, Chicago experienced an unprecedented heat wave in 1997 that cost the lives of more than 700 people. Scientists expect this trend to continue, as the region may experience severe heat waves as often as every other year. Meanwhile, water levels in the Great Lakes have been falling because of increase evaporation, with economic consequences for shipping, tourism, and water quality.

In the Great Plains, average temperatures have risen by 1.5°F since the 1970s, and temperatures over the next century could rise between 2.5°F and 13°F. This region is semi-arid, and rising temperatures will cause heat waves, drought, and increasingly heavy thunderstorms, with serious impacts on agriculture, ranching, health. One of the greatest threats is from declining water tables in aquifers. For example, the Ogallala aquifer, which stretches from Texas to South Dakota and is critical to irrigation in the region, has declined by 9 percent since 1950. Scientists expect water tables to continue dropping, with major impacts on irrigation and agriculture.

In the Southwest, average temperatures have increased by 1.5°F since 1960, and they are expected to increase by another 4 to 10 degrees over the next several decades. This already-arid region has already suffered from water shortages because of drought and reduced snowpack in the Rocky Mountains. As a result, agriculture and ranching in the region have suffered. Another serious threat is that of forest fires. Long periods of drought have created conditions for runaway fires. Also contributing to the fire threat has been insects like the pine park beetle, which are now able to survive through winters because of somewhat higher average temperatures. The beetles have killed millions of trees, turning them into tinder for forest fires.

In the Northwest, temperatures have risen by an average of 1.5°F over the past several decades. Scientists estimate that the average temperatures will increase by 3 to 10 degrees by 2100. Higher temperatures have already reduced snowpack in the Cascades and other mountain ranges, reducing the water that runs off into rivers and streams. As a result, there has been a reduction in hydropower, which generates about 70 percent of the region's electricity. Rising temperatures will also have a major impact on the region's forests, which are central to the economy. Drier conditions are making forest fires worse, as are insects like the pine bark beetle. In British Columbia in Canada, beetles have destroyed 33 million acres of trees.

Perhaps no region of the United States has undergone as much impact from climate change as Alaska. Over the past several decades, summer temperatures have risen by 3.4°F, while winter temperatures have soared by 6.3°F. These higher temperatures have caused shrinking glaciers and melting sea ice, and thawing permafrost. Temperatures in Alaska could rise anywhere between 3.5°F and 13°F over the next several decades. As in the Northwest, higher temperatures will lead to drought and insect infestation, worsening forest fires and threatening an important part of Alaska's economy. Warming ocean temperatures will also affect fish populations, negatively affecting another important part of the state's economy.

Global Climate Change Impacts in the United States
http://nca2009.globalchange.gov

Union of Concerned Scientists, Global Warming Solutions: Prepare for Impacts
http://www.ucsusa/org/global_warming/solutions/prepare-for-impacts

Possible Global Solutions

According to the IPCC's 2007 report, "The ultimate objective of the United Nations Framework Convention on Climate Change (UNFCCC) is to achieve the stabilization of (GHG) concentrations in the atmosphere at a level that would prevent dangerous anthropogenic [human-caused] interference with the climate system."

It is essential, climate scientists say, that countries limit the amount of carbon emissions into the atmosphere. The most important international effort to date has been the Kyoto Protocol to the UN Framework Convention on Climate Change, which was developed in 1997. It established binding goals for reducing emissions

of GHG. Most industrialized countries have ratified the Kyoto treaty, but the United States has not.

Countries signing the Kyoto Protocol agreed that by 2012, they would reduce GHG by an average of 5.2 percent below 1990 levels. The European Union met these goals, but emissions by the United States and China exceeded the reductions in Europe. In fact, global emissions increased by almost 40 percent from 1990 to 2009. If policies are not changed, fossil fuels will, by 2030, continue to supply 80 percent of energy needs, and GHG emissions will be 40 to 110 percent higher than they were in 2000.

The IPCC's 2007 report emphasized the need for countries to improve energy efficiency and shift to renewable sources of energy, including solar energy, wind turbines, geothermal energy, hydroelectric power, biomass, and nuclear fusion and fission. In addition, scientists are experimenting with methods of capturing and storing carbon below ground to prevent it from entering the atmosphere.

The IPCC cited six areas of the global economy in which countries must use far greater proportions of renewable energy: (1) transportation; (2) residential and commercial buildings; (3) industry; (4) agriculture; (5) forestry; and (6) waste management, recycling, and reuse.

Since the Kyoto climate change conference and the 2007 IPCC report, scientists and conservationists around the globe have grown increasingly alarmed that countries are not making enough progress in reducing GHG emissions. In 2009, world leaders gathered in Copenhagen, Denmark, to try to create a path toward greater progress. Progress at the conference was slow, but it did issue a clear goal: to hold future global temperature increases to 3.4°F (2°C). One hundred sixty-seven countries agreed to this goal, although it was nonbinding. Scientists maintain that the atmosphere already has enough carbon to increase temperatures by 3.4°F (.8°C). Consequently, the earth is already well on its way toward the 3.4° F mark.

According to the draft summary of the IPCC's 2013 report, computer models show that humans can emit 565 more gigatons of CO_2 into the atmosphere over the next 5 decades to hold global temperature increases to 3.4°F. However, according to the Carbon Tracker Initiative, a nonprofit organization in Britain, energy companies worldwide hold some 2,795 gigatons of fossil-fuel reserves. If such huge amounts of carbon were to enter the atmosphere, the earth would heat up by much more than 3.4°.

Scientists are continually adding to the store of knowledge about climate change and its impact on the earth, humans, and other forms of life. An excellent source

to find updated information is on the Web site of Global Systems Science, created by the University of California's Lawrence Hall of Science and available at http://www.globalsystemsscience.org/home. The GSS Web site includes updates from the IPCC, the UN, and the U.S. government. It also provides lesson plans for teaching about climate change.

What is EPA Doing About Climate Change?
http://www.epa.gov/climatechange/EPAactivities.html

Obama Moves to Limit Greenhouse Gases Emissions Through Executive Order- PBS.org
http://www.pbs.org/newshour/bb/science/jan-june13/climate1_06-25.html

UN Framework Convention on Climate Change, *Report of the Conference of the Parties on its fifteenth session, held in Copenhagen from 7 to 19 December 2009.*
http://unfccc.int/resource/docs/2009/cop15/eng/11a01.pdf

Carbon Tracker Initiative, "Unburnable Carbon—Are the World's Financial Marketing Carrying a Carbon Bubble?")
http://www.carbontracker.org/carbonbubble

Global System Science, Lawrence Hall of Science, University of California, Berkeley
http://www.globalsystemsscience.org/home

Strategies for Students

The remainder of this e-workbook will suggest essential questions, activities, and projects to involve your students in slowing the pace of climate change and achieving sustainability through improved energy efficiency and use of renewable energy. The traditional touchstone has been the 3 R's: reduce, recycle, and reuse.

In these projects and activities, you will find individual and collective actions that are essential and achievable. Individual actions are those taken by an individual alone, such as voting, reducing resource use, managing habitat on one's own property, and taking action to encourage legislation (e.g., writing letters). For example, a student acting alone can ride a bicycle rather than rely on parents to drive him or her everywhere.

Students can also have an impact on their schools and households. They can measure their schools' and families' carbon footprints--the total of GHG that a person is responsible for emitting into the atmosphere. They can encourage their families to use LED light bulbs, use public transportation, and buy in-season, locally produced fruits and vegetables because less fuel is used in transporting these foods to market.

Collective actions are almost anything that can be done with more than one person. For example, students can work together on campaigns to legislate the use of renewable energies, organize outings to plant trees, and write to elected representatives to encourage the construction of wind turbines. The important thing is for such collective action to stem from students' questions about and desires to address a local situation. Their investigation of options for addressing the situation that are feasible from societal, legal, economic, and scientific perspectives, followed by their assessment of the initiative's success is important. Campaigns lacking such context and rigor may have a low or no likelihood of leading to improvements and may, in fact, lead to backlash.

Recent years have seen the emergence of important initiatives designed to increase sustainability and build community. These initiatives offer opportunities for students to do research and become involved.

One initiative is smart growth—the planning and creation of communities that are more energy-efficient and that use resources more wisely than do communities today. To reduce commuting time, for example, smart-growth communities include offices and industries so that people can live near where they work, reducing drive times. Smart-growth communities also include plans for public transportation.

Zero waste refers to efforts by industries, communities, and municipalities to reduce the amount of waste they generate by recycling, reclaiming used resources, and eliminating emissions. The ultimate goal is to eliminate waste completely, substantially reducing the amount of GHG released into the atmosphere.

A third initiative is biomimicry—the effort to imitate strategies and patterns found in nature. By emulating plants and animals, engineers can design products that use and recycle energy more efficiently. One Web site on biomimicry cited, for example, a solar panel that emulates a leaf in its design.

The projects and activities that follow draw on a variety of sustainability initiatives. There should be emphasis on engaging students in the designing of activities and scaffolding of them so that students will experience success. In the activities, the

students will develop the higher-level skills of analysis, synthesis, decision-making, communication, and self-assessment.

LED Light bulb prices are falling and so will household power consumption - Cleveland Plain Dealer
http://www.cleveland.com/business/index.ssf/2012/01/led_lightbulb_prices_are_falli.html - comments

What You Can Do- EPA
http://www.cleveland.com/business/index.ssf/2012/01/led_lightbulb_prices_are_falli.html
http://www.epa.gov/climatechange/wycd/

Collective Actions

Biomimicry 3.3
http://biomimicry.net/about/mimicry

Climate Smart Communities: Local Action to Combat Climate Change- New York State Department of Environmental Conservation
http://www.dec.ny.gov/energy/50845.html

Preparing for Climate Change- CityofBoston.gov
http://www.cityofboston.gov/climate/adaptation/

State and Local Climate and Energy Program-EPA
http://www.epa.gov/statelocalclimate/

Welcome to the Zero Waste Alliance
http://www.zerowaste.org/

Why Smart Growth?
http://www.smartgrowth.org/why.php

Resources to back up entire document:
Massachusetts Climate Change Adaptation Report
http://www.mass.gov/eea/air-water-climate-change/climate-change/climate-change-adaptation-report.html

Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX)-IPCC

http://ipcc-wg2.gov/SREX/report/

Summary

http://ipcc-wg2.gov/SREX/images/uploads/SREX-SPMbrochure_FINAL.pdf

U.S. 2013 National Climate Assessment: Key Findings-Scott Doney (WHOI)
U.S. Global Change Research Program
http://www.whoi.edu/fileserver.do?id=149804&pt=10&p=91553

Global Warming & Climate Change Article Archive- New York Times
http://topics.nytimes.com/top/news/science/topics/globalwarming/index.html?inline=nyt-classifier

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Cleannet.org. *Climate Literacy: The Essential Principles of Climate Sciences: A Guide for Individuals and Communities.* March 2009. www.climatescience.gov. (accessed 6/1/13).

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Henson, Robert. *The Rough Guide to Climate Change: The Symptoms, The Science, The Solutions*. London: Rough Guides Ltd., 2011.

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Intergovernmental Panel on Climate Change. *Climate Change 2007: Working Group III: Mitigation of Climate Change.*

Karl, Thomas R., Jerry M. Melillo, and Thomas C. Peterson, editors. *Global Climate Change Impacts in the United States.* New York: Cambridge University Press, 2009.

Union of Concerned Scientists. *Global Warming Solutions: Prepare for Impacts.* http://www.ucsusa.org/global_warming/solutions/prepare-for-impacts. (accessed 10/4/2013).

UN Framework Convention on Climate Change, *Report of the Conference of the Parties on its fifteenth session, held in Copenhagen from 7 to 19 December 2009* http://unfccc.int/resource/docs/2009/cop15/eng/11a01.pdf

U.S. Environmental Protection Agency. "Climate Change: Overview of Greenhouse Gases: Methane Emissions." http://epa.gov/climatechange/ghgemissions/bases/ch4.html (accessed 8/15/13).

U.S. Environmental Protection Agency. "Climate Change: Overview of Greenhouse Gases: Nitrous Oxide Emissions." http://epa.gov/climatechange/ghgemissions/bases/n2o.html (accessed 8/15/13).