Campus Conversations:

CLIMATE CHANGE AND THE CAMPUS

Carnegie Mellon
STEINBRENNER INSTITUTE
for Environmental Education & Research

Pittsburgh Climate Initiative

FOCUS THE NATION | EMPOWERING A GENERATION TO POWER A NATION

Southwestern Pennsylvania Program for Deliberative Democracy

The following booklet is an adaptation and updating of Global Warming and Climate Change, a brochure developed in 1994 by Granger Morgan, Head of the Engineering and Public Policy Department at Carnegie Mellon and Tom Smuts. Both this booklet and the brochure from 1994 were developed in a process that involved significant review and input from scholars with expertise in climate change and communication.

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Welcome

Thank you for joining our Deliberative Poll. America—and the world—is faced with the need to develop public policies that will address climate change. Scientists tell us that the climate of the earth is warming, and that the warming we are experiencing results from an increase of greenhouse gases, primarily carbon dioxide, that is a result of human's extensive use of fossil fuels. The use of fossil fuels is integrated into the foundation of the world economy and into the everyday things we do (driving) and use (electricity). Thus, to address climate change, we will need to address challenging questions about some of our most fundamental ways of doing things. Many believe that universities can make significant contributions to addressing the challenges posed by climate change. By working to become more sustainable communities, sponsoring research, and advocating stewardship through education and community outreach, universities can develop, test, and share the strategies that will ultimately help the world address climate change.

Science can reveal the facts, but what we do with these facts will be determined by the people, whose informed opinion can provide guidance to policy-makers. This makes climate change a public concern. To address public concerns Americans have, from the earliest days, developed forums for civil discussion. These discussions engage citizens in a consideration of issues so they can develop informed opinions that provide guidance to policy-makers. The Deliberative Poll® continues this tradition in ways that account for the increasing complexity and diversity of America. By providing a representative group of citizens with background information, the opportunity for group deliberation, and access to a resource panel of experts, we provide citizens a unique opportunity to work together as they develop informed opinions. These opinions become a valuable resource to policy-makers as they work to address critical issues.

Climate change requires us to make policy decisions at every level: campus, city, nation, and world. In the following booklet we review the scientific knowledge related to climate change (section 1), we discuss current projections of the effects we can anticipate from the changing climate (section 2), and we review the types of decisions that universities can make as they develop strategies to address climate change (section 3). At the end of section 3, we present some questions we hope to consider at the Deliberative Poll®.

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What is a Deliberative Poll?

Deliberative polling is a democratic decision-making process capable of articulating the informed voice of the people and potentially raising that voice to a level where it can be heard by those who make public policy. The process was developed and trademarked by Professor James Fishkin, now at Stanford University's Center for Deliberative Democracy. During a deliberative poll, people who have received balanced information about an issue develop their informed opinion by working with others to discuss and raise questions about the issue. The resulting informed opinions can then be shared with policy-makers who are considering taking action on the issue.

Deliberative polling has three main elements:

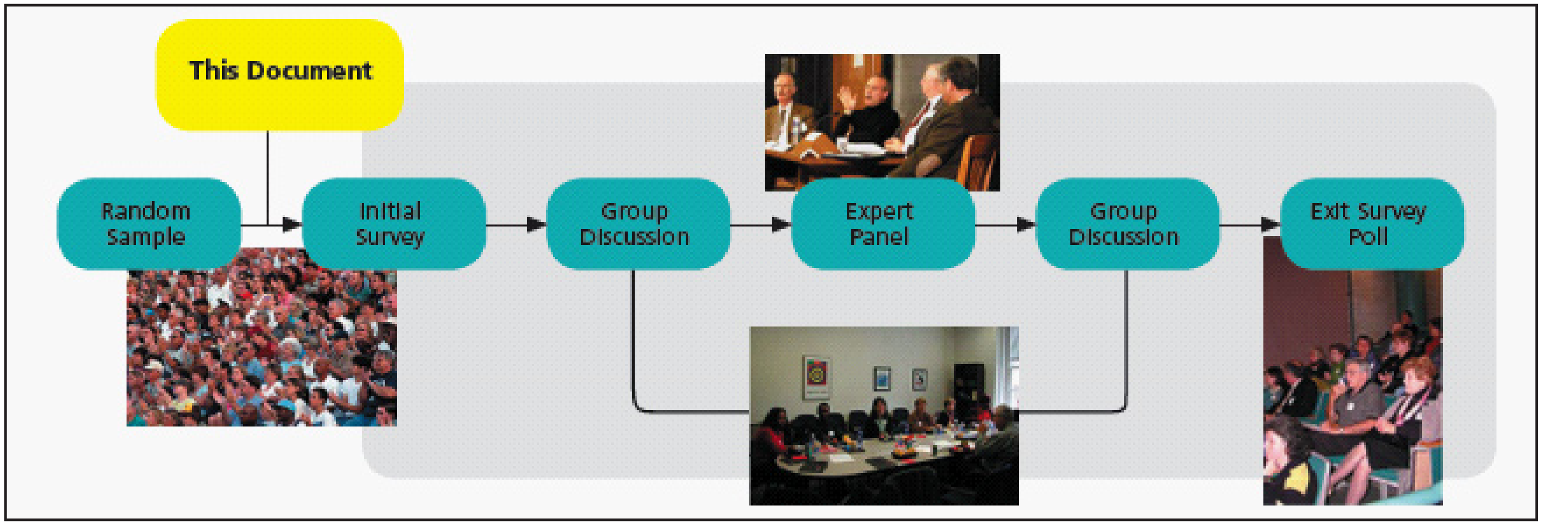
- Balanced information about the issues (e.g., this booklet)
- Discussion in small groups
- The opportunity for participants to pose questions to a resource panel of experts

The figure below details each element of a Deliberative Poll®, a unique process of small-group engagement accompanied by interaction with a resource panel of experts. These experts have not come to debate the issue; instead, they are here to answer participants' questions about the issue.

Ground Rules for Participating in a Deliberative Poll

- Please explain your own perspective.
- Please listen to other people's views; don't interrupt.
- Please focus on reasoned arguments, challenging experiences, and relevant facts.
- Please treat your group members with respect at all times.

Figure 1. The Deliberative Poll Process.



A Word About Scientific Knowledge

Scientific inquiry is a highly social activity. Scientific knowledge emerges through a process of inquiry and analysis called peer review (see figure 2). This process involves many individuals and teams of researchers working in a local, national, and international scientific community. This community is made up of professionals who have earned advanced degrees in the areas of their expertise. Scientists rely on this community to raise questions and conduct tests that will verify the results of individual scientific experiments.

The accepted scientific knowledge related to climate change has been subjected to this peer review process. Scientists specializing in various areas of climate change (meteorology, glacial geology, oceanography) have developed hypotheses and performed experiments to test their hypotheses. For example, researchers wishing to understand changing temperatures might devise an experiment to test whether the increased concentration of Carbon Dioxide in the atmosphere since the Industrial Age is causing the observed increase in temperatures. After getting results, the researchers write a paper that explains their experiment and provides an analysis of the results. This paper is then submitted for publication in a peer-reviewed journal like the "Bulletin of the American Meteorological Society."

The editor or editorial committee of the journal reviews the paper and decides whether it is ready to be sent out for a review by others in the scientific community. If they consider the paper ready for review, two or three scientists in the appropriate field are sent copies of the paper. The paper is sent out without the author's name and the reviewers remain anonymous. Reviewers look for errors or weaknesses in the paper. These may include bad data, faulty calculations, flawed experimental designs, or misinterpretations of results. Over a period of weeks each reviewer writes an evaluation of the paper and submits it to the editor. Based on these evaluations, the editor may reject or accept the paper; the editor may also request that the scientist who submitted the paper do further work.

If a paper survives this process of peer review, it gets published. The publication of the paper is only one step. Once it is published, the paper is read by other groups of scientists, and these scientists will seek to confirm or refute the paper's findings. They do this by attempting to replicate the findings in their own experiments, writing their own papers, and submitting these papers to the peer review process. A bad result or event a fraudulent paper can get past the peer review process. However, the process creates conditions that make the acceptance of bad results and fraudulent papers an unlikely exception. In addition, because of the process of ongoing peer review even after publication, it becomes increasingly unlikely that bad data or erroneous analyses will continue to be accepted.

Having emerged from this process of extensive peer review, scientific knowledge is described as an accepted view, because particular results have been verified and been found acceptable by many individual scientists and teams of researchers. All claims in the following sections that relate to the science of climate change are based upon findings that have appeared in peer-reviewed scientific journals. Current scientific consensus maintains that a) the climate is changing, that b) carbon dioxide (CO2) is a significant factor in the changing climate, and that c) human activities are contributing to the increasing amount of carbon dioxide in the earth's atmosphere.

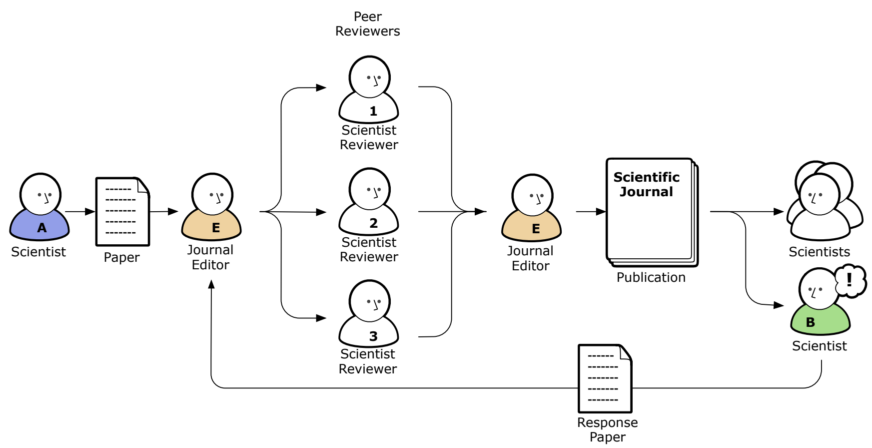
In section 1 we discuss the basic models and tools scientists employ as they develop an understanding of climate change, as well as discussing the international organization responsible for an ongoing review of climate science, the Intergovernmental Panel on Climate Change (IPCC)

In section 2 we discuss the source of disagreement within the scientific community. Given what they currently understand, climate researchers cannot make certain predictions about the near and long-term impacts of climate change. Thus, as we review the various projections, we also indicate the level of uncertainty related to these projections.

In section 3 we discuss the roles individuals and universities can play in shaping public policy to address climate change. As we discuss in this section, we can rely on the information--findings and projections—supplied by the international scientific community, but public policy decisions regarding how individuals, communities, nations, and the world should respond to climate change and its causes will require people to consider a variety of competing and respectable perspectives on this information.

Source: Dressler and Parson, The Science and Politics of Global Climate Change, 23-30.

Figure 2. Peer Review Process.



Is climate change just speculation?

No. The earth's climate has been changing continually for millions of years. Scientists know many of the things that cause changes in the climate, and they also know that, increasingly, human activities are contributing to climate change. For example, evidence taken from ice-core measurements show that the increases in atmospheric concentrations of carbon dioxide that have accompanied human industrial activity are unlike anything that has happened naturally over the last 650,000 years.

Currently the climate is changing as a result of a rise in average temperatures, commonly called global warming. As global warming occurs, not every day or every place will be warmer, but on average most places will be warmer. Warming will cause changes in the amount and pattern of rain and snow, changes in the length of growing seasons, changes in the frequency and severity of storms, and changes in sea level. These changes will, in turn, have an impact on many human activities.

The fact that climate does change continually, however, has encouraged some to challenge the scientific consensus concerning climate change. Two challenges have achieved prominence. First, while accepting that the earth is warming, some argue that human activities are not responsible. Second, some argue that future climate change will almost certainly be very small, and, as a result, will require humans to do very little to mitigate the effects or adapt their behavior to account for climate change. However, climate researchers point out that: "These skeptical arguments are rarely if ever advanced in scientific arenas, but in editorial pages, on the internet, or in policy arenas where more lenient standards for evidence and argument apply." Having been advanced in non-scientific arenas, skeptical arguments are then often uncritically recounted in the media to 'balance' against scientific arguments for climate change.

In this section:

Carbon dioxide and climate change.

Feedbacks and climate change.

Computer modeling and climate change projections.

The Assessment of the IPCC.

Section 1: What is climate change?

Climate is the average pattern of weather in a particular region of the world. Climate usually remains relatively stable for centuries—if it is left to itself. However, the earth's climate is not being left to itself: Human actions impact the earth and its climate in significant ways.

Climate is different than weather. Weather is the condition of the atmosphere at a particular place and time. Weather is measured in terms of such things as temperature, humidity, and precipitation (rain, snow, etc.). Weather changes all the time, and, in most places, it can change from hour-to-hour, day-to-day, and season-to-season.

Climate, on the other hand, is the average pattern of weather. For example, Pittsburgh's climate is officially classified as a Humid Continental climate, which means that residents of Pittsburgh can expect cool, sometimes cold winters, and warm, humid summers with frequent clouds and precipitation.

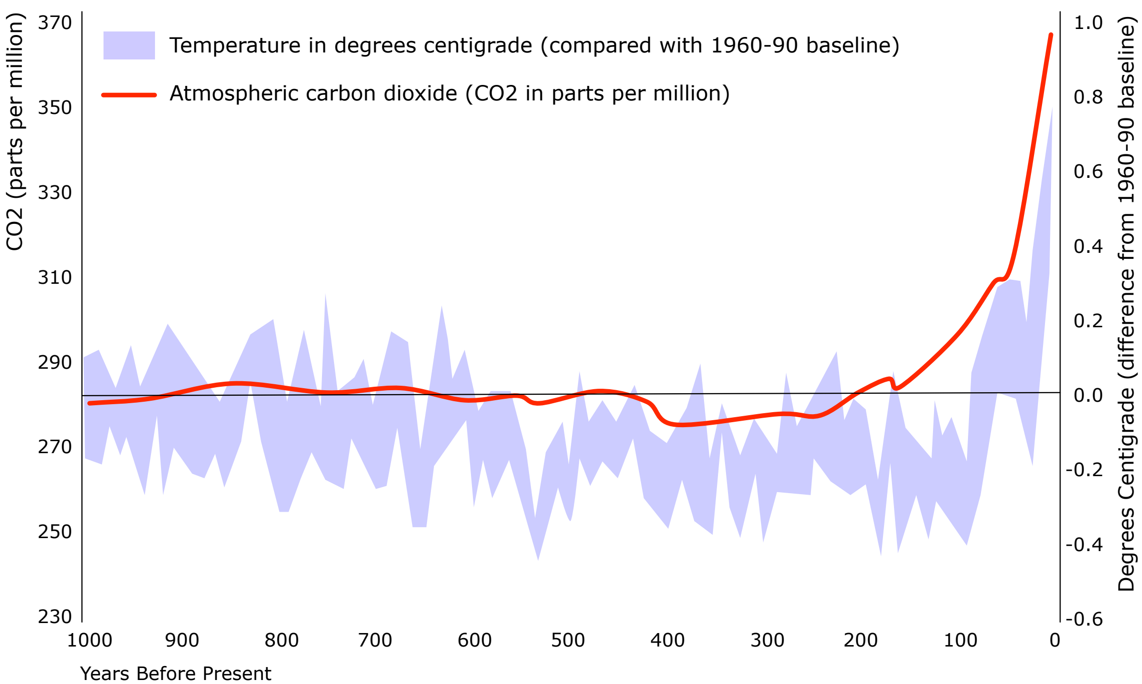
However, scientific research suggests that, over the next 50 to 100 years, the climate in Pittsburgh could change significantly. According to some projections, by the end of the 21st century, the climate in Pittsburgh could be more like the current climate in North Carolina.

Like the changes projected for Pittsburgh, climates around the world are projected to change over the next 100 years. For example, the climate in southeast Canada could become more like present-day New England. As a result, researchers project that plants and animals will need to 'migrate', and communities whose economies depend on agriculture and climate (e.g., ski resorts) would be challenged by the need to adapt.

Carbon dioxide and climate change

The single human activity that has a large impact on the climate is the burning of "fossil fuels" such

Figure 3. Carbon Dioxide and Temperature.



as coal, oil and gas. These fuels contain carbon. Burning them makes carbon dioxide gas. Since the early 1800s, when people began burning large amounts of coal and oil, the amount of carbon dioxide in the earth's atmosphere has increased by nearly 30%, and average global temperature appears to have risen between 1° and 2°F (see figure 3). This may not seem like much, but minor changes in average temperature can lead to significant changes in overall climate.

Carbon dioxide gas traps solar heat in the atmosphere, partly in the same way as glass traps solar heat in a sunroom or a greenhouse (see figure 4). For this reason, carbon dioxide is sometimes called a "greenhouse gas." As people burn more fossil fuel for energy they add more carbon dioxide to the atmosphere. As more carbon dioxide is added to the atmosphere, solar heat has more trouble getting out. The result is that, if everything else stayed unchanged, the average temperature of the atmosphere will increase. If nothing else changes, the best available projections suggest that by the end of the 21st century, the earth will have warmed by another 3-7°F (see figure 7).

However, not all things that enter the atmosphere cause warming. Dust from volcanoes, and from human activities, can reflect sunlight (like a window shade) and cool the earth. Researchers estimate that the amount of greenhouse gases in the atmosphere should have already increased the average temperature of the earth by about 2.3°F. However, it appears that the average temperature of the earth has only increased by between 1 and 2°F. Thus, it is likely that some other things have also changed. It is believed, for example, that small particles, such as sulfur, that are emitted when we burn coal, may help to cool the earth by reflecting sunlight.

The systems that regulate the Earth's climate are dynamic. The climate results from each element of this system interacting with other elements. Researchers use the term "feedbacks" to describe these interactions.

Feedbacks and climate change.

Feedbacks come in two kinds: negative feedbacks that will work to slow down or offset climate change and positive feedbacks that work to speed up or amplify climate change.

For example, carbon dioxide acts as a fertil-

Figure 4. The Greenhouse Effect.

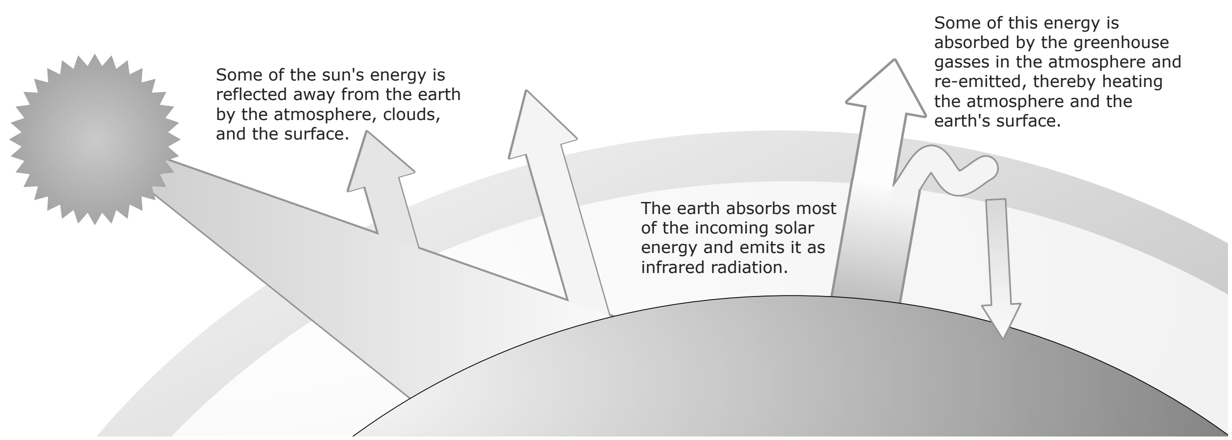
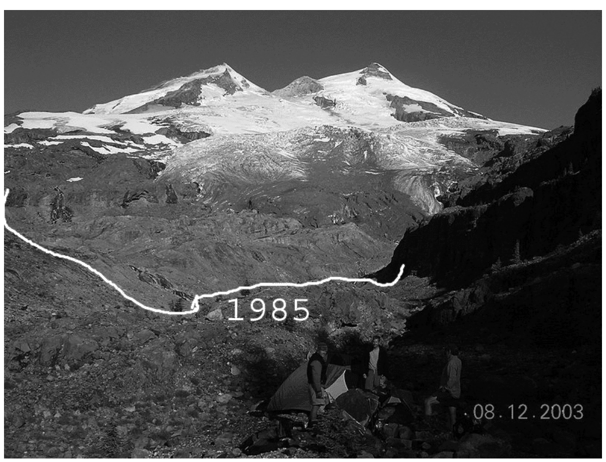


Figure 5. *The Boulder Glacier in Washington State retreated 450 meters from 1987 to 2003.*



izer that makes some plants grow faster. As the concentration of carbon dioxide in the atmosphere increases, these plants may grow faster and as a consequence take more carbon dioxide out of the atmosphere. This would result in a negative feedback, slowing the rate at which carbon dioxide increases, and hence slowing the rate of warming.

On the other hand, as the earth warms, some ice and snow are likely to melt (see figure 5). Ice and snow are good reflectors of sunlight. The dark ground that is exposed when the snow and ice melts absorbs light. When the ice and snow melt, less light energy from the sun will be reflected and more will be absorbed by the earth. This would result in a positive feedback that would tend to speed up the rate at which the earth warms.

Climate scientists have identified a number of positive and negative feedbacks in the climate system. Some of them are well understood. Others are still only partly understood. It is largely uncertainties about how these feedbacks will respond to changes—how changes in one element will change the whole system—that make the science of climate change so uncertain and controversial. Scientists use computer models of what they know about how feedbacks work to make projections about climate change.

Computer modeling and climate change projections.

Researchers rely on large computer models called General Circulation Models, or GCMs to study the possible effects of climate change. These models use the basic laws of science (conservation of mass, conservation of momentum, etc.) to represent the large-scale circulations and interactions of the atmosphere. Scientists have also connected General Circulation Models to similar models that have been built to study the oceans and the biosphere. All of these models predict roughly the same amount of warming when the amount of carbon dioxide in the earth's atmosphere is doubled. Some people see these similar predictions as a source of confidence that we can make reliable projections about the effects of climate change.

However, while the GCMs all give roughly the same overall answer, if you look at what is going on in the detailed physical process of each model, things are very different from one model to the next. The same answers come out of the models, but for somewhat different reasons. Finally, while the models all produce about the same result for global averages, the predictions for specific locations are quite variable.

In order to understand and predict the climate system better, we will need a more complete understanding of the basic science of climate process. Many ongoing research programs, in the

United States and around the world, are dedicated to producing better basic knowledge about climate change.

The Assessment of the IPCC.

In 1988, the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP) launched the Intergovernmental Panel on Climate Change (IPCC), a group of leading scientists from around the world organized into special working groups. The IPCC seeks to develop a coherent body of scientific knowledge concerning climate change. The working groups of the IPCC continually review relevant research from around the world and periodically produce assessment reports. IPCC assessments provide decision-makers and others interested in climate change with an objective source of information about climate change. These reports represent the consensus opinion from a group of the world's top scientists.

The current scientific consensus maintains that the climate is changing, that carbon dioxide is a significant factor in the changing climate, and that human activities are contributing to the increasing amount of carbon dioxide in the earth's atmosphere. In addition to these consensus findings, the most recent report, the Fourth Assessment Report released in 2007, presents several projections for future average global temperature change (see figure 6). While all of the projections present an increase in average global temperature, each of the projections reflect differing scenarios of population, economic growth, and resource use. Generally, higher temperature projections reflect no or minimal change in practices of energy production and consumption matched to ongoing population increases. Lower projections reflect attempts to change practices and a leveling off of population growth sometime in the middle of the 21st century. Based on these temperature projections, the IPCC also made projections for changes in snow cover, sea ice, and weather patterns (see "IPCC Findings" sidebar). As more research is done, scientists improve their understanding, which will help them make better projections.

Human activities that contribute to Climate Change

Major contributors

- Burning coal, oil, and natural gas releases carbon dioxide (CO2), which is the most important of all greenhouse gases

Modest contributors

- Deforestation: Living trees remove carbon dioxide from the atmosphere and store it in their wood. Because of this, climate researchers describe forests as 'carbon sinks'. Carbon sinks help to regulate the amount of CO2 that enters the atmosphere. When forests are cut down, for agriculture or logging, we lose the capacity of those trees to regulate atmospheric CO2. In addition, when trees are cleared through burning, they release their stored CO2.
- Methane: Rice paddies, cattle, gas pipelines, and landfills produce methane, a greenhouse gas that causes about 30% as much warming as CO2
- Nitrous Oxide: Fertilizers and other chemicals that humans use in agriculture and industry release nitrous oxide, a greenhouse gas which causes about 10% as much warming as CO2

No significant contribution

- Nuclear power
- Toxic waste
- Aerosol cans

IPCC Findings

The following assessments from the IPCC discuss changes that may result from the projected rise in average global temperature (Figure 8). You will find further information about the topics discussed below in Section 2 of this booklet.

Varying warming

"Warming is expected to be greatest over land and at most high northern latitudes, and least over the Southern Ocean and parts of the North Atlantic Ocean."

Snow cover and Sea ice

"Sea ice is projected to shrink in both the Arctic and Antarctic . . . . In some projections, Arctic late-summer sea ice disappears almost entirely by the latter part of the 21st century."

"Snow cover is projected to contract. Widespread increases in thaw depth are projected over most permafrost regions."

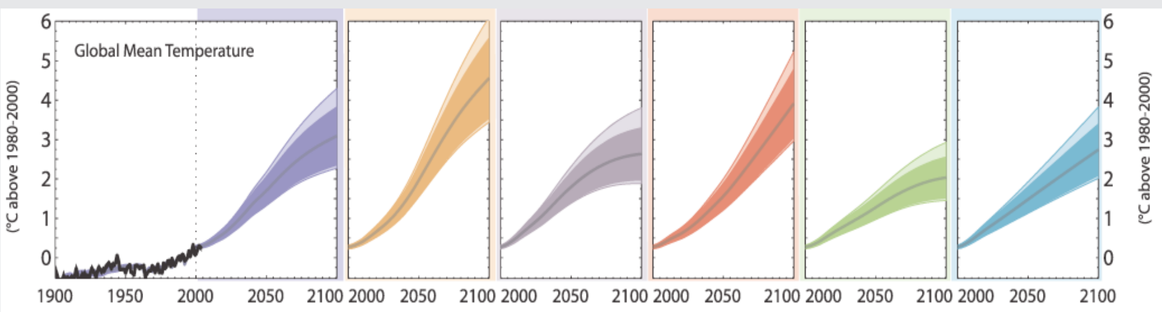
Weather patterns

"It is very likely that hot extremes, heat waves, and heavy precipitation events will continue to become more frequent."

"Based on a range of models, it is likely that future tropical cyclones (typhoons and hurricanes) will become more intense, with larger peak wind speeds and more heavy precipitation associated with ongoing increases of tropical [sea surface temperatures]…."

"Extra-tropical storm tracks are projected to move poleward, with consequent changes in wind, precipitation, and temperature patterns, continuing the broad pattern of observed trends over the last half-century."

Figure 6. Six projections for future global average temperature change from Working Group I's contribution report, The Physical Science Basis, to the IPCC Fourth Assessment. Across the different scenarios, estimates for warming by the end of the 21st century are as little as 3.2°F (1.8°C) or as high as 8.1°F (4.0°C).



"…scientists publishing in the peer-reviewed literature agree with IPCC, the National Academy of Sciences, and the public statements of their professional societies. Politicians, economists, journalists, and others may have the impression of confusion, disagreement, or discord among climate scientists, but that impression is incorrect."

—Naomi Oreskes, Scientific Consensus on Climate Change

Section 2: What scientists expect will happen as climate changes

While current scientific consensus maintains that the climate is changing, that carbon dioxide is a significant factor in the changing climate, and that human activities are contributing to the increasing amount of carbon dioxide in the earth's atmosphere, disagreements emerge among climate researchers when it comes to making projections about the impacts of climate change.

Most significantly, scientists are uncertain about whether climate change caused by human actions will be large enough and fast enough to cause serious damage. Many scientists believe that it may be. Others argue that as changes occur, the problems that result will be no worse than those caused by today's storms and droughts.

Nonetheless, any climate change will have consequences for the natural environment, including oceans, plants, and animals. As a result, climate change will also affect human activities, such as agriculture; human access to resources, such as water; and human needs, such as energy for heating and cooling. How climate change will ultimately affect humans will depend upon how much change there is, how fast it occurs, and how easily the world can adapt to the new conditions.

In this section we first review potential impacts on people, with a focus on how climate change may affect economic conditions, agriculture, and health. We then review potential impacts on the natural environment, including a discussion of rising sea levels and concerns that have been raised about particularly delicate ecosystems.

Impacts on people

The effects of climate change on people will differ from place-to-place. Economically developed societies, like those in North America, Europe and Japan, could use technology to reduce direct impacts. For example, they might develop new crop varieties, construct new water systems, and limit coastal development. Some northern countries, such as Canada and Russia, might even benefit from longer growing seasons and lower heating bills as the climate becomes warmer.

In contrast, economically less developed societies, like those in parts of Africa, Asia, and South America depend much more directly on climate, and these countries could be hit much harder by sudden or large changes. Places like coastal Bangladesh and low-lying islands could be flooded by storms or rising sea level. Droughts in Africa might become more serious. Developing countries have far fewer resources for adapting to such changes. They may not be able to afford large projects such as sea walls or aqueducts. Peasant

In this section:

farmers may have difficulty adopting new agricultural practices. The resulting social tensions could lead to political unrest, large-scale migrations, and they could contribute to serious international problems such as terrorism and war.

There is some chance that climate change will be abrupt, perhaps brought on by a sudden shift in the general pattern of ocean circulation. If that happens, the economic costs to wealthy countries like the United States could be very large. Much new investment might be needed in a very short period of time. Agricultural and water systems might not easily be modified in just a few years, especially if uncertainty makes planning difficult. Most scientists believe that such catastrophic change is unlikely, but not impossible.

Several economists have tried to estimate the overall economic cost of climate change. In 2006, the "Stern Review on the Economics of Climate Change" concluded that aggressive measures to address climate change by reducing the emission of greenhouse gases would cost, on average, 1% of global Gross Domestic Product (GDP) per year. Alternately, if no mitigations efforts are adopted, the problems resulting from climate change could cost 20% of GDP forever. Such calculations, of course, are very uncertain.

Economic impacts in wealthy countries

Most scientists believe that if significant climate change occurs it will take place gradually over a period of many decades. If change is gradual, the overall economic impact on wealthy countries such as the United States will probably be modest, and some regions or groups may experience large costs while others may experience large benefits.

American society already exists very successfully in Alaska, Arizona, and Florida, and these states span a range of climates much wider than any predicted changes. As climate changes farmers would have to adjust their crops, and in some cases, farming regions and other land-use patterns would shift. Some water supply systems would have to be modified. Low coastal areas would have to make adjustments. But our society regularly makes changes to adapt to natural and man-made fluctuations. Although American society could probably handle these additional changes without much trouble, nationally the total costs could add up to many billions of dollars.

While many of the impacts of climate change will be negative, some might be positive. Heating costs in northern areas might decline, agricultural productivity in places such as Canada, Scandinavia and northern Japan might be improved, and the amount of sunlight available for grain crops might increase as the regions where they grow shifts further north. Of course, not all northern regions would benefit. Some northern soils are not suitable for agriculture, some areas of permanently frozen ground (permafrost) might become large impassable bogs, and various insect pests and diseases might move north.

Economic impacts in poor countries

Whether it occurs rapidly or slowly, climate change is likely to have greater economic impacts on poor countries than on rich countries. Two factors lead to this conclusion. First, the economic activities of people in poor countries are closely connected to the climate. Second, poor countries have less capacity and resources to adapt to changes in the climate.

People in many poor countries live traditional lives in cultures that depend much more directly on a specific climate. Their agricultural practices, their housing, and many other aspects of their way of life, are adapted to local climate conditions. These traditional ways have been passed down for generations. Because of relatively low education levels and strong cultural traditions, changing these ways in response to climate charge may be very difficult.

Poor countries also have less capacity and fewer resources with which to respond to the effects of climate change. For example, compare the flooding by the Mississippi river in 1993 with various major floods you may have heard about in developing countries such as Bangladesh. While the Mississippi floods were serious, the U.S. was able to adjust to them remarkably smoothly. Very few people died, aid was supplied by other parts of the country, food prices were hardly affected, and people got on with their lives. A similar flood in many poor countries would kill tens of thousands of people and cause massive disruptions in food supply, widespread disease, and economic dislocation for many years.

Alternately, some countries, such as India and China, may become more wealthy over the course of the 21st century, and find it easier to cope with climate change. Countries that remain very poor may have so little capital investment to lose that changing to new circumstances may be less costly for them than for partly developed countries.

Agricultural impacts

Of all human activities, agriculture is potentially most vulnerable to the effects of climate change. However, the effects of climate change on agriculture are very difficult to project. How climate change will affect plant development, plant growth, and the productivity of crops will depend on how plants respond to a number of variables. In addition, projecting agricultural changes requires researchers to project how human economic activities will respond to the way plants change. Thus, as plants respond to changes, such as increases in atmospheric carbon dioxide concentration, higher temperatures, altered precipitation patterns, increased frequency of extreme weather events, and changes in weed, pest and disease pressures, humans can be expected to respond by altering their use of the land and potentially changing local industry and trade patterns as the climate changes.

Scientists work to understand how the relationships between the many variables might affect crop yields and access to food over the long-term. Nevertheless, there is still significant uncertainty about the magnitude of the impacts climate change will have on agriculture. There is also uncertainty about whether the impacts will, ultimately, be positive or negative. Below is a brief description of two recent studies of how changes in the climate could possibly affect agriculture across the globe:

Global Impacts: An international group of agricultural researchers used climate projections from five climate models (GCMs) to project regional climate changes at 112 locations in 18 countries under two different assumptions: (1) that the amount of carbon dioxide in the atmosphere had doubled or (2) that the amount of carbon dioxide in the atmosphere was stabilized at 550 parts per million. Under the carbon dioxide doubling scenario, average global temperature increased about 8°F. Under each scenario, regional agricultural experts projected the yields of wheat, corn, soybeans, and rice at each location. An economic model was then used to estimate patterns of world food prices and trade.

Assuming that farmers employ simple adaptation practices, such as changing planting times and seed varieties to match the changed local climates, these researchers estimate global food output to be unaffected for the case of one climate model, and to drop by 2%-6% for the other climate models studied. In these projections, the developing world is expected to experience the worst effects from climate change. Output in developed countries is projected to rise, by as little as 2% or as much as 14%, and developing country output is projected to fall, by as little as 2% or as much as 12%. With these changes, world food prices are projected to increase. The number of people at risk of hunger (due to higher prices) probably also increases, perhaps by 50%.

The researchers assumed that no major changes, such as construction of new irrigation projects, are undertaken. When such changes are included in the analysis, the agricultural impact on all but the poorest developing countries becomes very small. Nevertheless the number of people at risk of hunger will still probably increase, perhaps by 20%.

These findings suggest that major changes to agricultural practices, such as the installation of new irrigation systems, large shifts in planting times, increased fertilizer application, and the development of new crop varieties will be needed worldwide to adapt to climate change.

Sources: C. Rosenzweig and M. L. Parry, "Potential Impact of Climate Change on World Food Supply," Nature, Vol. 367, pp. 133-138, 1994 January 13; and M. Parry, C. Rosenzweig, and M. Livermore, "Climate change, global food supply and risk of hunger," Philosophical Transaction of the Royal Society B, Vol. 360, No. 1463, pp. 2125-2138, 2005 November 29.

Impacts on the U.S.: In a study of simulated climate change impacts under "business-as-usual" assumptions, researchers consulted two GCMs to determine the expected responses of 45 crop sites across the country in 2030 and 2090. For the U.S. as a whole, one climate model projected a 3.8°F average temperature increase by 2030 and a 10.4°F warming by 2095. The other model projected warming of 2.5°F and 5.9°F respectively.

Under the more pessimistic temperature change projections, hot and dry conditions decrease agricultural yields, at times up to 60%, in all of the following regions: Appalachian, Southeast, Delta, and South Plains. Major crops affected are soybeans and wheat. Rice and tomato yields also decrease in the South. With these types of yield declines, these regions will lose comparative advantage and production will shift elsewhere in the country. Producer losses are up to $5 billion in 2030. Nevertheless crop yield nationwide increases.

Under the more optimistic temperature change projections, warming is moderate and precipitation increases. Thus in all regions for the U.S., crop yields increase, up to 120% in the lake states. Economic welfare increases by $7.8 billion in 2030 and $12.2 billion in 2090.

The researchers concluded that risks from climate change to agriculture will more likely occur at regional levels depending upon changes in precipitation, variability of climate (e.g. changes in frequency and intensity of climatic events such as El Niño), or more complex climate-agriculture-environment interactions (e.g. changes in the geographical coverage of pests).

Source: J. Reilly et al., "U.S. Agriculture and Climate Change: New Results," Climatic Change, Vol. 57, Nos. 1-2, pp. 43-69, 2003 March.

Disease and health

At extremes of heat or cold, temperature itself can cause health effects on humans such as heat stroke or frostbite. In addition, some scientists have suggested that diseases borne by insects, such as mosquitoes, might become more common in a warmer world, or these diseases may shift their ranges into populations that do not have as many natural defenses.

Studies of the patterns of deaths in U.S. cities suggest that the residents of very warm or cold climates can take measures to adapt and protect themselves. Thus, it seems unlikely that temperature changes from climate change would have direct health consequences in the U.S. Moreover, compared to current threats to human health such as viral epidemics and environmental pollution, risks from gradual climate change are likely to be modest.

Impacts on the natural environment

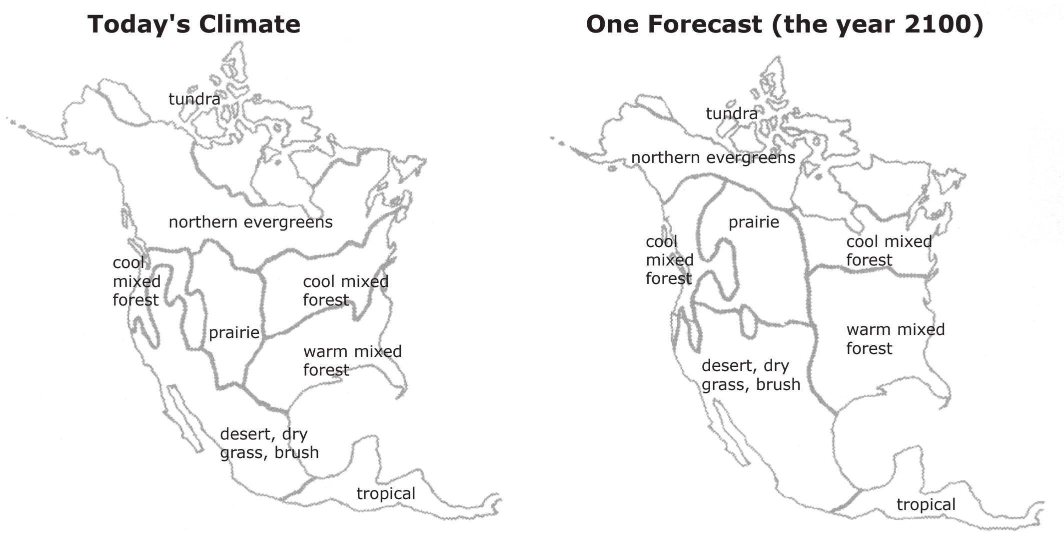
When scientists look at the past they discover that the natural environment has often adapted to gradual climate change that occurred over many thousands of years. However, they also find instances in which change occurred rapidly, brought about by events such as sudden shifts in ocean currents. Rapid change has often caused widespread species extinctions and the collapse of natural ecosystems. Scientists have also seen the effects of short-term climate variations, such as droughts. On a longer time scale, scientists have reconstructed the history of past climates, such as ice ages, and shown that the ecology of entire continents has undergone profound changes.

Of course, many factors other than climate can affect natural ecosystems. Among these, changes in human land use are probably the most important. For example, there have been enormous ecological impacts associated with the European settlement of the North American continent over the past 300 years. While the ecological disruptions caused by climate change may not be as large as those caused by major changes in human land use, they still could be severe. How severe depends critically on how rapidly climate changes. If climate change is gradual, animals and plants may be able to migrate to more suitable areas. However, not all species are likely to move at the same rate.

Even if change occurs slowly, the mix of species that inhabit a particular ecosystem may change as the climate changes. For example, some species may become trapped by natural barriers such as mountain ranges or large cities and be unable to move. One result may be that species that have developed a relationship of dependence with other species may face new challenges. For example, some birds have evolved a breeding cycle that is connected to the breeding cycle of certain butterfly species, which provide a resource of food for the birds. These birds may lose their food source if climate change alters the time of year when the butterflies or the birds breed. Unless humans intervene with preservation efforts, species challenged by climate change could become extinct.

People value natural ecosystems partly in terms of what they have gotten used to. For example, many New Englanders place a high value

Figure 7. One Forecast of Shifting Climates.



on the maples, birch, and white pines that make up their forests. In the future such a forest may migrate to Quebec or Ontario, while New England acquires a red pine and oak forest like that in the Carolinas (see figure 7). This might lead to significant, albeit, short-term changes in the culture and economy of New England. On the other hand, future generations may not be aware that any change has occurred, just as today's New Englanders do not recall the deforested landscape of the 1860s.

Sea level rise, thermal expansion and melting ice.

As global temperatures have increased, so have sea levels. However, scientist remain uncertain about how these two phenomena are connected. Scientists' best understanding attributes sea level rise to two factors: thermal expansion and melting ice across the globe.

Thermal expansion is the tendency of matter to change in volume in response to a change in temperature. When the temperature of the oceans increases, the particles that make up the ocean will start to move around more vigorously and by doing so will increase their overall volume, therefore causing a rise in average sea levels. Since 1961, the global average sea level has risen at an average rate of 1.8 mm/yr, and since 1993 at an average rate of 3.1 mm/yr.

Scientists have noted that the recorded sea level rise is larger than could be expected from thermal expansion alone. In its latest report, the IPCC attributes sea level rise to both thermal expansion and the melting of land-based glaciers, ice caps, and polar ice sheets. Mountain glaciers and snow cover have declined on average in both hemispheres, and these widespread decreases in glaciers and ice caps have been found to contribute to current sea level rise. In addition, data also shows that losses from the ice sheets of Greenland and Antarctica have also more likely than not contributed to the increased rate of sea level rise from 1993 to 2003. Though a somewhat warmer climate will cause more precipitation in some regions, ice loss from Greenland has still occurred because losses due to melting have exceeded accumulation due to snowfall.

Although scientists are secure in asserting that thermal expansion and melting ice contribute to rising sea levels, they nevertheless remain cautious with their conclusions. Thus, the latest report from IPCC indicates uncertainty about the exact processes involved: "The global average sea level rise for the last 50 years is likely to be larger than can be explained by thermal expansion and loss of land ice due to increased melting, and thus for this period it is not possible to satisfactorily quantify the known processes causing sea level rise."

Rising sea levels will impact humans, animals, and plants living on or near the coast. Almost fifty percent of the world's population lives close to the seashore. While the projected rise in sea level

Will more carbon dioxide in the atmosphere cause trees and other plants to grow more?

Maybe. Plants need carbon dioxide to grow. Using sunlight and photosynthesis, plants change carbon dioxide and water into food. If plants have all the nutrients they need, then giving them more carbon dioxide will cause many to grow more. Commercial growers often do this in greenhouses. However, plants growing in natural environments often do not have all the nutrients they need, and may not grow faster, even if there is more carbon dioxide. If some plants on land and in the oceans are naturally able to take more carbon dioxide out of the atmosphere, they will grow faster. This would change the mix of plants, but might also slow global warming.

should mean that flooding under normal weather conditions might be small, rising sea level would mean that hurricanes and similar large storms could do more damage than in the past. While some experts doubt such changes will occur, other experts argue that such storms would become more frequent and intense in a warmer climate. Rising sea level and more intense hurricanes could have a large impact on human settlements, plant life, and water systems along the world's coasts.

If climate change were to cause sea level to rise a couple of feet over the next century, two types of problems would result: permanent flooding of very low lying areas, and increased storm damage. Permanent flooding could pose problems for certain coastal ecosystems, for highly vulnerable cities such as Venice, and for some coastal drinking water supplies. However, the larger problems are likely to come with storms. When storm winds blow onto shore they cause water to "pile up." If the sea level rises, the amount of this "storm surge" may increase, with the result that coastal ecosystems may be flooded more often, some beaches may be eroded more rapidly, and building and other structures along the coast may suffer greater and more frequent damage.

Developed countries like the U.S., and even low lying developed countries like the Netherlands, can use a combination of land-use laws and technologies such as dikes and storm surge barriers to minimize damage. In contrast, heavily populated coastal areas in developing countries such as Bangladesh might suffer enormous losses of life and property.

In the long run, if sea level continued to rise, even developed countries might begin to experience serious costs. Many of the world's biggest cities are in low-lying coastal locations. If, as seems likely, these cities respond to sea level rise by building dikes, rather than by gradually relocating, the result over hundreds of years could be that a growing proportion of the world's population would live in locations below sea level that are vulnerable to sudden catastrophic floods.

Delicate Ecosystems

Because of the many uncertainties, it is not easy to be certain or specific about the effects of climate change on the natural environment. However, researchers have raised concerns about a number of important areas: ocean acidification, coral reefs, mangrove swamps, and insects.

Ocean Acidification: As carbon dioxide slowly dissolves into the oceans, this lowers the pH of the water causing it to become more acidic. Ice core measurements show that oceans have not been as acidic as they now are for at least 650,000 years. Because the current acidity is greater than that of the past, scientists are not able to determine how specific species will be affected by this corrosive water. However, raised acidity can eventually dissolve the shells of many organisms, deforming them and leaving them defenseless to predators.

Coral Reefs: Coral reefs sustain two-thirds of all marine fish species and support human communities by providing fisheries and storm protection. Climate change may affect coral reefs in at least three ways. First, corals may "bleach." Corals thrive in a fairly narrow range of water temperatures. If the temperature becomes too high, corals expel the algae that gives them their color and supplies their food. With their food source gone, the corals stop growing and corals may die within a few months. Scientists have observed a number of instances of bleaching, but the causes are uncertain. Whether modest global warming would damage corals through bleaching is unclear. Second, if storms increase in a warmer world, corals may be physically broken up and be unable to re-establish themselves. Wave action is particularly damaging to branching corals. Third, sea level rise may affect corals, but it can be either beneficial or destructive, depending on how much and how rapidly it occurs. Some scientists believe that the rates of sea level rise currently predicted will be "moderately beneficial" to reefs, allowing some to expand their current boundaries while not adversely affecting the others.

Source: The Pew Center on Global Climate Change report, "Coral Reefs & Global Climate Change: Potential Contributions of Climate Change to Stresses on Coral Reef Ecosystems"

Mangrove swamps: Mangrove swamps are found in coastal tidelands in Florida, India, Australia, Africa, and other subtropical and tropical zones. Mangrove trees provide protective habitat for a wide variety of species, and many coastal tropical fish are highly dependent on mangrove swamps for nursery, feeding, and spawning grounds. Mangrove trees also help maintain water quality, and they act as sediment traps that both build up and protect coastlines from erosion.

Mangrove ecosystems are threatened by the sea level rise associated with global warming. The IPCC predicts that global warming could cause sea level to rise just under 2 inches per decade. Most mangrove ecosystems can at most tolerate a rise of only about 0.5 inches per decade. The World Wildlife Federation has concluded that, because of the impact of human activities, the rate of sea level rise and the very limited options for protection, "the world's mangroves are likely to face severe disruption in the next few decades."

Insects: Insect populations that feed on farms, forests, and natural ecosystems might be affected by climate change. Because different plant species would likely migrate at different speeds, and with different levels of success, the mix of pests with which they would have to cope might change significantly. How changes might interact and affect overall pest populations, or the levels of destruction they cause, is something that we will not be able to estimate until biological scientists have conducted more studies.

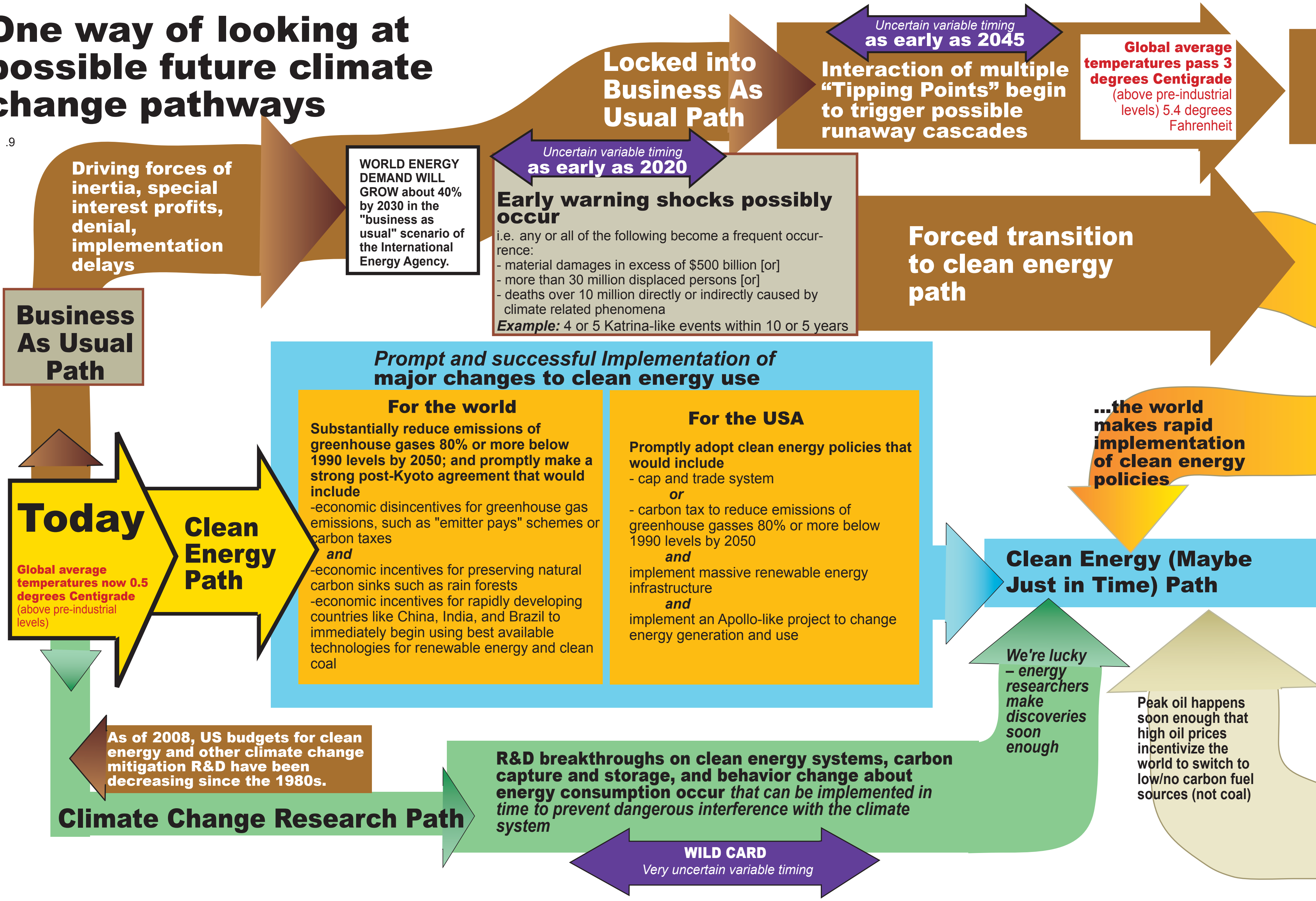
The diagram on the next page represents one possible set of scenarios for the environmental, technical, and political effects of climate change over 21st century. The diagram was developed by Bob Horn, who has developed the concept of Visual Language as a strategy for supporting our cognitive grasp of complex situations.

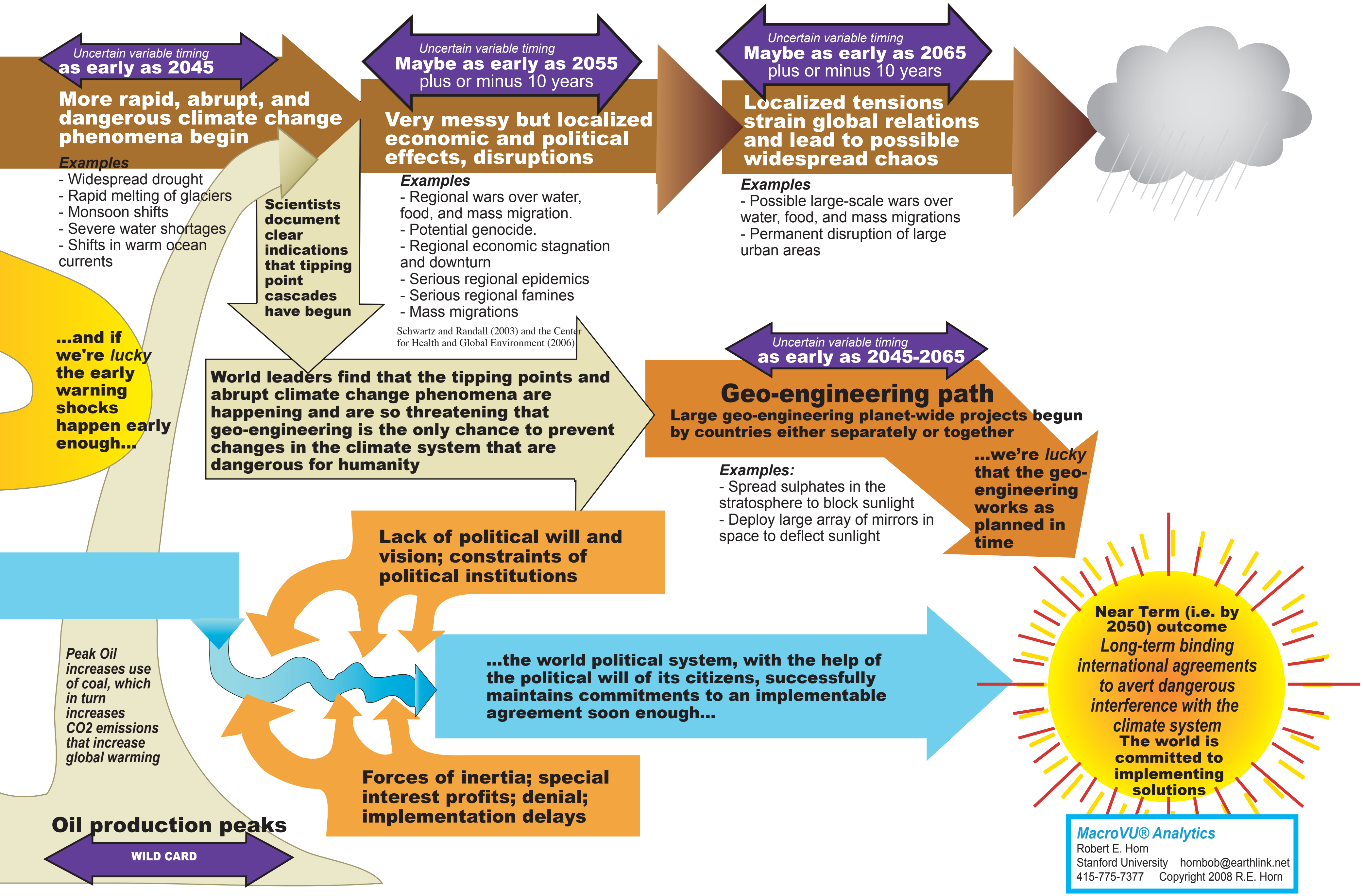
This diagram provides a representation of uncertain projections for future events; thus, it cannot represent established facts. Many might disagree, for example, with the timeline for impacts at the top of the diagram and with the descriptions of events under the timeline. More conservative estimates would probably push this timeline into the next century. Thus, this diagram also represents some of the principled disagreements over how serious climate consequences could be and how soon they could happen if no action is taken. The fact that principled disagreement exists indicates that the transition from scientific knowledge to uncertain projections to policy decisions presents a new challenge to us as we consider what to do about climate change.

Figure 8 (following pages). Decision Map.

One way of looking at possible future climate change pathways

V .9




Uncertain variable timing
as early as 2045
More rapid, abrupt, and dangerous climate change phenomena begin
Examples
- Widespread drought
- Rapid melting of glaciers
- Monsoon shifts
- Severe water shortages
- Shifts in warm ocean currents
Uncertain variable timing
Maybe as early as 2055
plus or minus 10 years
Very messy but localized economic and political effects, disruptions
Examples
- Regional wars over water, food, and mass migration.
- Potential genocide.
- Regional economic stagnation and downturn
- Serious regional epidemics
- Serious regional famines
- Mass migrations
Schwartz and Randall (2003) and the Center for Health and Global Environment (2006)
Uncertain variable timing
Maybe as early as 2065
plus or minus 10 years
Localized tensions strain global relations and lead to possible widespread chaos
Examples
- Possible large-scale wars over water, food, and mass migrations
- Permanent disruption of large urban areas
Scientists document clear indications that tipping point cascades have begun
...and if we're lucky the early warning shocks happen early enough...
World leaders find that the tipping points and abrupt climate change phenomena are happening and are so threatening that geo-engineering is the only chance to prevent changes in the climate system that are dangerous for humanity
Uncertain variable timing
as early as 2045-2065
Geo-engineering path
Large geo-engineering planet-wide projects begun by countries either separately or together
Examples:
- Spread sulphates in the stratosphere to block sunlight
- Deploy large array of mirrors in space to deflect sunlight
...we're lucky that the geo-engineering works as planned in time
Lack of political will and vision; constraints of political institutions
Peak Oil increases use of coal, which in turn increases CO2 emissions that increase global warming
...the world political system, with the help of the political will of its citizens, successfully maintains commitments to an implementable agreement soon enough...
Forces of inertia; special interest profits; denial; implementation delays
Oil production peaks
WILD CARD
Near Term (i.e. by 2050) outcome
Long-term binding international agreements to avert dangerous interference with the climate system
The world is committed to implementing solutions
MacroVU® Analytics
Robert E. Horn
Stanford University hornbob@earthlink.net
415-775-7377 Copyright 2008 R.E. Horn

In this section:

The roles of a university in the community

- Cooperation Among Universities

What can be done about climate change

- Setting targets for reducing greenhouse gas emissions: "Stabilization Wedges"
- Mitigation Strategies: Reducing Our Carbon Footprint
- Adaptation Strategies: Adjusting to a changing climate

Deliberating about climate change

- Three things to consider as you make decisions about climate change

Section 3: Climate change and the university

The climate is changing, and human activities that produce greenhouse gases are having a significant impact on the rate and extent of the change. As we make decisions about how to address climate change, we can rely on this accepted knowledge from the international scientific community. However, our decisions must also rely on projections, even the best of which are uncertain.

Moreover, any serious effort to address climate change will require international cooperation. Greenhouse gases are emitted from local sources (power plants, automobiles, household heating and cooking), but climate change is a global concern. Thus, to address climate change we will need to build relationships, from the interpersonal to the international, and coordinate actions across several levels: local (city and state), regional, national, and international.

In the end, climate change requires that we do the public work of citizenship. Supplied with accepted knowledge and credible projections, we must work together to make informed decisions about strategies in the present that will impact the future.

In this section we introduce a framework for thinking about how to address climate change that researchers consider promising, and we discuss strategies for addressing climate change. At the end of this section we suggest three things individuals should consider as they make decisions about climate change, and we introduce the types of questions we hope to consider at the Deliberative Poll. However, because our Deliberative Poll concerns the role universities can play in addressing climate change, we begin this section by considering the several roles universities play in their communities.

The roles of a university in the community

Universities provide great benefits to their communities, but they also can account for a large percentage of a community's greenhouse gas emissions. The energy used by thousands of students and employees commuting each day, combined with the energy needed to heat and cool buildings, power sophisticated lab equipment, light performance spaces and sports facilities, and power all the functions of a university creates a significant "carbon footprint."

However, universities can also play a valuable role in promoting changes that help us address climate change. As 'mini-cities' relatively free to set policies to manage their immediate local environments, universities provide a place to develop and test new strategies and to promote sustainable behavior. Importantly, this can be done on a scale that allows all members of the community (students, staff, faculty, and alumni) to appreciate how individual actions can contribute to significant change.

As a home to researchers from many fields in science and the humanities, universities can promote research, including cross-disciplinary research, that contributes to our knowledge about the complex and interacting natural, political, and social systems affecting the climate change problem. Moreover, the knowledge generated by this research can be readily disseminated through established national and international networks.

Universities also provide an environment to promote stewardship and innovation. In classes across all the colleges at a university, students can learn about the challenges and come to recognize the possibilities for innovation and economic development resulting from climate change. In addition, all members of the university community can work together and create networks that reach out to the surrounding community with research and education programs.

As an economic engine and a resource for research, education, and community outreach, universities can have an influence on public policy. The policies and practices adopted at a university can be expected to affect change at the personal and local level, influence policy at the regional level, and, through education and research, the university develops the leaders, the strategies, and the relationships that can influence policies and practices at national and international levels. Moreover, this influence can be magnified if a region's universities work together, as is currently happening in Pittsburgh, Pennsylvania.

Cooperation Among Universities

In December 2007, the Pittsburgh Climate Protection Initiative invited representatives from Pittsburgh's universities to participate in a survey of climate protection activities at their institutions. The survey allowed respondents to rank their school's commitment to climate change mitigation actions under various categories, including Campus-wide Initiatives, Energy Consumption, and Education and Student Engagement. Five schools participated in the survey. In January 2008, representatives from Carnegie Mellon, Chatham, Duquesne, Point Park, and the University of Pittsburgh met to share their institutions' responses to the survey, and to develop recommendations for increasing the environmental sustainability of their campus communities (see "An Action Plan for Universities" box).

The recommendations devised by these university representatives indicate that universities will need to make decisions concerning all the ways they impact a community. Over the next few pages you will read about many strategies to address climate change. For each strategy we have

An Action Plan for Universities:

Complete a greenhouse gas inventory for each institution.

Subsidize and promote alternative transportation options (public transit, bicycles, zipcar).

Promote energy conservation and efficiency.

Change patterns of energy consumption.

Promote green building practices for new construction and renovations.

Adopt sustainable waste management programs (recycling, food composting).

Encourage efforts at "social marketing" of sustainable practices among students, faculty, and staff.

Source: "Pittsburgh Higher Education Climate Action Plan." Pittsburgh Climate Protection Initiative. April, 2008 used a code to help you consider how each strategy can effect or be affected by a university's day-to-day practices (p), as well as by a university's research (r), education (e), and community outreach (o) missions.

What can be done about climate change

Setting targets for reducing greenhouse gas emissions: "Stabilization Wedges"

Reducing greenhouse gas emissions is the most significant thing that can be done to address climate change. But how much reduction is necessary? Climate researchers measure greenhouse gas emissions in tons. However, when researchers consider the effect of these emissions on the atmosphere, they focus on a measurement of the atmospheric concentration of all greenhouse gases, which they represent collectively as a carbon dioxide equivalent (eCO2). The current atmospheric concentration of greenhouse gases is 377 parts/million.

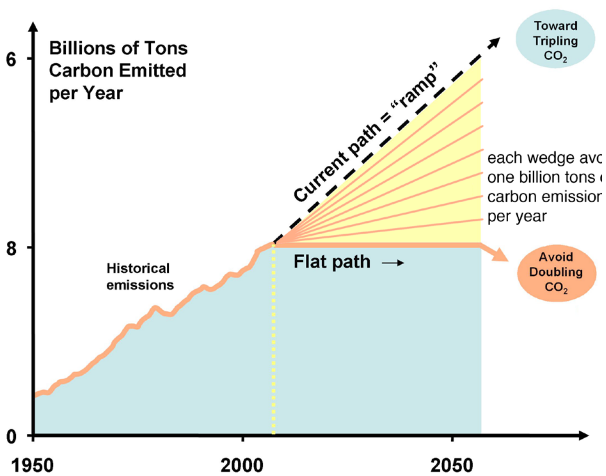
When making suggestions for reductions, climate researchers also focus on a date: 2054. Researchers believe that if we are able to reduce greenhouse gas emissions so that they are stabilized at around 500 parts/million by 2054 we can avoid the most severe impacts from climate change. Reaching this target by 2054 will require coordination of strategies at several levels: international, regional, and local.

Researchers find the concept of "stabilization wedges" helpful as a way to represent the scope of the challenge we face and as a way to imagine how we might coordinate strategies to reduce greenhouse gas emissions (see figure 9). Simply put, researchers represent the amount of emissions reduction we will need to achieve as a large wedge. They then segment the wedge into eight sections.

Achieving a target atmospheric concentration of 500 parts/million will require a global reduction of 200 billion tons of greenhouse gas emissions by 2054. Thus, the total wedge equals 200 billion tons. Achieving such a reduction will require that we reduce global emissions by an average of 8 billion tons per year. However, there is no single strategy that could achieve such a large reduction, so researchers divide the total wedge into segments. Each segment represents a 1 billion-ton reduction. If they are pursued at a large scale, individual mitigation and adaptation strategies—such as carbon capture and storage, the use of biomass fuels, stemming deforestation, or adopting new agriculture practices—can each contribute an annual 1 billion-ton reduction. The use of these strategies can then be coordinated to achieve the target of an annual 8 billion-ton reduction of emissions.

When making their projections, however, researchers have assumed that between now and 2054 we will commit both to scaling up our use of

Figure 9. Eight wedges are required to bring our current production of carbon down to acceptable levels. Source: Carbon Mitigation Initiative, Princeton University.



currently existing technologies and to increasingly adopting practices of conservation and efficiency. So, while in the near-term we cannot hope to achieve the annual 8 billion-ton target, over the long-term our commitment to research, development, and education will enable us to exceed the annual target in later years.

Mitigation Strategies: Reducing Our Carbon Footprint

Mitigation strategies attempt to decrease greenhouse gas emissions from individual and collective human activity. Many people find the notion of a "carbon footprint" helpful when thinking about mitigation strategies. As individuals and communities go through everyday activities, they create a carbon footprint. They can decrease the size of this footprint by emitting less greenhouse gases during their day-to-day activities. When thinking of a carbon footprint, it is important to consider the amount of energy required to create products and services, as well as the fuel used to transport goods over long distances.

Below, we have organized the discussion of mitigation strategies into four categories: conserve energy, practice energy efficiency, manage carbon dioxide emissions, and replace coal, oil and gasoline with cleaner energy sources and technologies. Whenever possible, we also provide examples of how universities have begun to adopt these strategies.

Choosing the appropriate combination of mitigation strategies will be challenging. Each strategy will cost money, pose problems, and offer benefits, and researchers cannot be certain about the costs, problems, and benefits of any particular strategy. Below we discuss examples within each of the categories. As you consider these examples, we encourage you to consider how a university—through its day-to-day practices and as an institution for research, education, and community outreach—can help communities meet the challenges and address the uncertainty related to these strategies.

Conserve energy

At its simplest energy conservation means making changes to the way that individuals, businesses, and institutions operate so that they will consume less energy. In addition to reducing emissions, many believe that individuals and institutions will save money as they conserve energy.

Adopt real-time energy monitoring: Devices have been developed to provide consumers with data on how they use energy. By making real-time energy consumption data available to individuals and institutions, consumers become aware of their energy consumption and may be encouraged to save energy. Real-time data also allows consumers to recognize which of their appliances or operations are consuming the most energy and when. Consumers can use this data to adjust their opera-

p day-to-day practices
r research
e education
o community outreach

tions to maximize energy efficiency. In some cases, institutions have used consumption data to save money by altering how and when they consume energy.

For example, the University of New Hampshire encouraged its community members to unplug equipment when not in use and before leaving for breaks. This saved over 159,000 kilowatt-hours (kWh) of energy, $22,721 dollars in energy and water costs, and over 50 metric tons of emissions of carbon dioxide equivalents during the fall of 2006. p r o

Promote transportation alternatives: Commuting by public transit (buses, trains, etc.), adopting strategies for car-pooling or short-term car rentals, and supporting the use of bicycles for transportation can reduce the amount of carbon dioxide emissions locally and have an impact regionally. However, programs to support many alternative transportation options will require participation and funding to move beyond the testing stage.

Universities throughout the Pittsburgh region subsidize public transit for their community members. Similarly, to reduce the number of individuals who use personal cars for short-term needs, universities and cities across the U.S. have recently begun contracting with Zipcar, which provides individuals with rental cars for short periods of time. To encourage the use of bicycles, universities may choose to devote resources to make cycling a safe, secure, and convenient option.
p r e o

Buy locally produced goods: Transporting goods long distances requires more energy, which means more greenhouse gas emissions all along the chain from producer to marketplace. The current structure and infrastructure of marketplaces, makes it difficult to imagine buying local: many of the products we use everyday are produced at a great distance from where they are consumed. Like other climate change concerns, a global supply chain for goods appears to offer benefits (e.g., lower costs), but these apparent benefits often fail to take account of possible long-term environmental consequences. As with attempts to reduce fossil-fuel dependence, strategies to buy locally produced goods will probably require infrastructural changes. Thus, these changes can be promoted and supported by individuals who intentionally choose to buy local goods, but they will also require political support and institutions willing to alter business-as-usual practices. p r e

Adopt new strategies for waste management and promote recycling: As solid waste decomposes, it produces methane. Although methane accounts for only a small share of the man-made greenhouse effect, it is a powerful greenhouse gas. Currently a number of universities in Pittsburgh are investigating the possibility of working with the waste management company AgRecycle to develop a joint strategy for composting waste rather than sending it to landfills. In addition to saving space in landfills, composting could provide usable products for landscaping and gardening in the region. Rough estimates prepared by the Pennsylvania Resource Council in 2006 suggest that a joint effort to adopt composting among universities in Pittsburgh could reduce greenhouse gas emissions by 3,720 tons/year.

Recycling also helps reduce carbon dioxide emissions. Among other benefits, recycling saves the energy that would be required to produce certain items from virgin materials.

Adopting new waste management and recycling strategies will require individual and institutional participation, and these strategies also introduce costs associated with purchasing new equipment. p r e

Practice energy efficiency.

Increasing energy efficiency in homes, offices, factories, and transportation is considered the best way we have to reduce carbon dioxide emissions without lowering our standard of living. If we make cars and appliances do their job just as well while using less energy, then we do not need to burn as much coal and oil. Many believe that if energy efficiency is pursued wisely it should also have positive economic effects, both saving money and creating jobs. Below are three examples of strategies that improve energy efficiency:

Reduce energy use in buildings: Heating, cooling, and lighting buildings consumes about 1/3 of all the energy used in the U.S., and 2/3 of all the electricity. In all, buildings account for 38% of U.S. greenhouse gas emissions.

Emissions can be reduced by installing improved insulation, furnaces, air conditioners, and lighting in commercial and residential buildings. Over time, reductions can be achieved by adopting “green building practices” for renovations and new construction. The U.S. Green Building Council, a 9,000-member coalition of corporations, builders, universities, government agencies, and nonprofit organizations provides guidance for green building with its LEED® (Leadership in Energy and Environmental Design) Green Building Rating System™

In Pittsburgh, Carnegie Mellon and Duquesne University have made commitments to seek some level of LEED® certification for all new construction and renovations, and other universities are committed to investigating LEED® certification on a project-by-project basis. Certification is offered at four levels (Certified, Silver, Gold, and Platinum). All levels reflect a commitment to energy efficiency and sustainable practice in the design, construction, and operation of the building. The average LEED® certified building uses 32% less electricity and saves 350 metric tons of CO2 emissions annually. p r e o

Make appliances more efficient: Currently available technology allows refrigerators, dish-

p day-to-day practices
r research
e education
o community outreach

washers, water heaters and other home appliances to be substantially more efficient than they are. In general, however, newer appliances are more efficient than older appliances, and, throughout the U.S. programs run by utility companies, state governments, or the federal government provide assistance or tax incentives to help people replace older appliances. p r

Improve fuel efficiency of new cars: Currently the average mileage obtained by new cars in the U.S. is 27.5 mpg. By contrast, Europe currently requires 40 miles per gallon, and Japan is expected to set a standard of 47 miles per gallon by 2015. Recently legislation was passed by the U.S. Congress to raise the average to 35 mpg by 2020. If this goal is reached and maintained over time, emissions reductions are projected to be significant. Estimates also suggest that the savings resulting from reduced fuel costs will outweigh any cost increases associated with producing more fuel-efficient cars. p r e

Manage Carbon dioxide emissions

Promote Carbon Offsets: Carbon offsets have been suggested as a cheaper or more convenient alternative to reducing one's own fossil-fuel consumption. Individuals or companies can make arrangements with commercial or not-for-profit corporations to pay for emission-reduction strategies elsewhere instead of reducing their own emissions. For example, people might offset the emissions they produce from daily commuting, home energy use, or personal air travel by paying to have trees planted or by providing funds to invest in renewable energy and energy conservation programs and research. Critics have raised a number of objections to carbon offsets. However, some object to carbon offsets. The carbon offset market is currently unregulated, which means there are no standards or enforcement mechanisms. Many also question the benefits of certain types of offsets, such as tree planting.

Carnegie Mellon University is currently exploring the idea of selling carbon offsets to its community members. In the scheme being considered, those who wish to offset carbon emissions from their personal activities could purchase carbon credits from the university. The university would then invest this money in the purchase of clean energy production on campus and/or around the region. Selling carbon offsets in Pittsburgh would keep money in the region while helping to build a demand for clean energy and the technology it requires. p r e o

Cap-and-Trade systems: Cap-and-Trade systems create a "carbon marketplace" in order to reduce emissions. Cap-and-trade systems set clear targets for emissions reduction but provide companies some flexibility as to the strategies and timeframe they will use to achieve the emission caps.

In practice, cap-and-trade systems create a financial incentive for emission reductions by assigning a cost to polluting. First, an environmental regulator establishes a "cap" that limits emissions from a designated group of polluters, such as power plants, to a level lower than their current emissions. The emissions allowed under the new cap are then divided up into individual permits—usually equal to one ton of pollution. Permits represent the right to emit a certain amount of carbon dioxide. Thus, permits that give a company the right to pollute take on financial value. Companies are free to buy and sell permits in order to continue operating in the most profitable manner. Those that are able to reduce emissions at a low cost can sell their extra permits to companies facing high costs. Although not a concern related to climate change, acid rain has been successfully addressed by employing a cap-and-trade system to decrease emissions of sulfur dioxide. r e

Carbon Capture-and-Storage (CCS): Programs are currently being developed and tested for capturing carbon dioxide emissions from large 'point sources' such as fossil fuel power plants. These programs capture emissions before they can be released into the atmosphere, liquefy the gas, and then store it by injecting it into underground geological formations.

The most significant questions raised by CCS programs involve the availability and stability of storage sites and a lack of information about impacts and problems, such as leaks, that may result from long-term storage of CO2. Nevertheless, many are encouraged by initial tests of CCS programs, and there are significant opportunities for research to develop CCS technology. r e

Replace coal, oil and gasoline with cleaner energy sources and technologies.
Developing and adopting cleaner and renewable energy sources would both conserve energy and improve efficiency. However, currently, there are few low-cost alternatives to coal, oil, and gasoline. Moreover, these alternatives cannot be expected to provide enough energy to replace what we currently generate by coal, oil, and gasoline. Thus, as we seek to reduce emissions, we will need research that focuses on both new energy sources and on making our present energy production methods more sustainable. Nonetheless, in the near-term, emissions can be reduced by coordinating the use of alternative energy sources with the use of traditional methods based on coal, oil and gasoline.

Replace gasoline with biomass fuels, hydrogen or electricity in cars and trucks: More research and development is necessary to make alternative fuel vehicles affordable and widely available to consumers. In addition to cost and availability, some researchers have raised about the sustainability of alternative fuels.

For example, ethanol, a fuel made from corn, is relatively affordable, and, if ethanol can be made from sustainable agriculture many believe it repre-

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sents a significant alternative to gasoline. However, ethanol can only be one part of a solution, and some have begun to argue that, even as a small part, it should not be the preferred option. Even if all available land were to be turned over to growing corn for ethanol production, it would only produce enough fuel to meet about 12 % of the current need, and many project that the environmental impact of producing so much corn (e.g., water run-off contaminated by fertilizers) would be extreme. Recently, researchers have experienced some success producing ethanol from uncultivated (naturally occurring) "switch grass" and organic waste.

Currently, at Carnegie Mellon, student shuttles use 20% biofuel, the police force vehicles are powered by an ethanol/gasoline blend, and the on-campus vehicle fleet features numerous vehicles powered by electricity. p r e o

Replace existing coal and oil fired electric power plants with new high efficiency plants that use natural gas: Natural gas, whether it is used to warm rooms or heat water, is more efficient than electric heat. As a result, it is also cheaper and releases far less carbon dioxide than the coal burned to make electricity. There may not be enough natural gas to replace all coal and oil power plants, but a significant reduction in emissions could be achieved if even some portion of the commercial and residential electricity was generated by natural gas.

Currently, Duquesne University produces 80% of its electricity from a clean-burning natural gas cogeneration plant, and through several additional measures the university now utilizes 100 percent clean energy. p r o

Replace half of the existing oil and coal fired power plants with solar power facilities: The amount of solar energy reaching the earth's surface each year is enormous, thousands of times greater than worldwide annual fossil fuel use. While costs are still high, technology currently exists to use solar energy to provide electricity, light, heat, and steam for buildings and industry.

Substantial progress is necessary before solar technology is affordable as a basic source of electricity. However, at Carnegie Mellon a solar installation at 300 S. Craig Street generates 10% of that building's power. In addition, in 2007 a team composed of five Carnegie Mellon departments headed by the School of Architecture, in a collaborative effort with the University of Pittsburgh and the Art Institute of Pittsburgh designed and constructed a Solar House that generates all of its energy, as well as some excess that can be redirected to power other activities. p r e o

Replace all fossil fuel plants with nuclear power plants: In 2008, nuclear power provided about 19% of electricity in the U.S., but ongoing concerns over the safety, cost, and environmental impacts of nuclear energy continue to slow development of nuclear capacity. If research was devoted to addressing the concerns about nuclear power, it may be considered an option for reducing carbon dioxide emissions. r e o

Adaptation Strategies: Adjusting to a changing climate

Adaptation strategies seek to manage the impacts humans will experience as the climate changes. These strategies may include changing how humans use land, cultivate crops, raise livestock, and manage resources, such as water. Generally speaking, adaptation strategies will require further and ongoing research.

Relocate people, agriculture and industry away from coastal areas: Almost fifty percent of the world's population lives close to the seashore. Some of these communities may need to relocate as climate change causes changes in temperature, sea level and water distribution. Currently, state and federal governments often subsidize the rebuilding of homes and replenishment of beaches in areas that have experienced severe storms or floods. If sea level rise makes devastating storms and floods more common, government could use subsidies to help people relocate instead of helping people to rebuild in vulnerable areas. r e o

Create "migration corridors" for plants and animals: If climate change occurs gradually, some scientists believe that natural ecosystems will be able to migrate with the climate. However, natural migration can be blocked by human development, such as cities, highways, and farms. Humans might help ecosystems adapt to climate change by creating corridors of undeveloped land through which ecosystems could migrate. r e o

Develop new crop strains: Currently, state, federal, and private labs cultivate and test thousands of strains of agricultural plants. There are, for example, about 450 different strains of corn in commercial use. Maintaining funding for research on crop varieties is a good way to prepare for the possible agricultural impacts from climate change. r e o

Country	% of current human CO2 emissions	% of world's population	Annual metric tons of CO2 per person.
United States	22.0	4.6	20.6
China	18.2	20.4	3.9
Russia	5.5	2.3	10.6
India	4.9	16.9	1.25
Japan	4.6	2.0	9.9

State	Population Rank	Per Capita Carbon Output	Carbon Total Output Ranking	Carbon Total Output (millions of tons)
Texas	#2	#10	#1	670.22
California	#1	#46	#2	388.95
Pennsylvania	#6	#23	#3	271.41
Ohio	#7	#19	#4	265.52
Florida	#4	#39	#5	243.89

Figure 10. Top five countries and top five U.S. states ranked by carbon output. Pennsylvania is the third highest carbon dioxide producing states in the United States, the world's largest carbon dioxide producer. Country data are for 2004 and are drawn from Marland, G., T.A. Boden, and R. J. Andres. 2007. Global, Regional, and National CO2 Emissions. In Trends: A Compendium of Data on Global Change. *Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A. Population data from the U.S. Census Bureau, International Data Base. State data from eredux.com.*

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Reduce methane emissions from agriculture: Although it accounts for only a small share of the man-made greenhouse effect, methane (CH4) is a powerful greenhouse gas. Methane emissions come from rice paddies, cows and other 'ruminant' animals. These emissions can be reduced by cultivating fast-growing rice or high-density paddies, by placing ruminant animals on diets that reduce the amount of methane they emit as a byproduct of digestion, and by handling plant and animal wastes in a manner that reduces the amount of methane produced as they decompose. r e o

Improve irrigation practices: Climate change will probably require people to develop strategies to use water more efficiently. For example, the efficiency of irrigation systems improved 35% between 1950 and 1980, and some researchers believe efficiency can be further improved by making some relatively cheap changes to existing technology. r e o

Create an international "forestry fund": Because trees remove carbon dioxide from the atmosphere, forests are a resource that researchers refer to as 'carbon sinks'. However, deforestation throughout the world threatens these resources. Because deforestation results largely from population and economic pressures, researchers believe that forests will only be preserved if they have more value standing than being cut down. One idea to address deforestation involves the creation of an international "forestry fund". Economically developed nations would contribute to this fund, and the interest from the fund would be given to people living near forests in need of protection. This money would support their efforts to develop sustainable agricultural and forestry practices. r e

Geo-Engineering: Although not technically an adaptation strategy, geo-engineering is another possible means to address climate change. Geo-engineering strategies seek to reduce the amount or effects of climate change by making changes to the earth's natural environment (e.g., atmosphere and oceans). For example, the amount of sunlight that strikes the earth might be reduced by putting more small particles into the high atmosphere. The idea here would be to offset the warming effect of more greenhouse gas by reflecting more sunlight back into space.

Presently, geo-engineering is not considered an ideal option. Given the earth's complex, and dynamic systems, many people worry that there might be unintended side effects to geo-engineering. Most believe that we should not consider attempts to change the earth's natural systems unless we are experiencing extreme and unmanageable effects from climate change. However, if rapid and severe climate change does occur, some are likely to press for geo-engineering, and such strategies may, ultimately, prove to be relatively inexpensive. r e

Actions that individuals can take to reduce the effects of climate change

Most effective

Since most of our energy comes from oil, coal and gas, actions that reduce energy use will reduce the emissions of carbon dioxide.

- When you buy a car, choose one that gets good mileage.
- Insulate and weatherize your home or apartment.
- Drive less, carpool, use public transit, use bicycles for transportation
- Replace old appliances {e.g., refrigerators, heat pumps) with the most efficient new models.

If the average U.S' citizen undertakes all of these actions, they can reduce their carbon dioxide emissions by about 25%, which equals about 5 tons of carbon dioxide per year.

Helpful actions

- Turn off lights and appliances when not in use
- Purchase carbon offsets (e.g., Plant trees, invest in renewable energy)
- Set the thermostat lower in winter (68ºF) and higher in summer (78ºF)
- Recycle

If the average citizen undertakes all of these actions, they can reduce their personal carbon dioxide emissions by about 3%, which equals just over half a ton of carbon dioxide per year.

Influence others

- Become informed and help your family and friends to learn about climate change.
- Find out what policy makers in your community, workplace, and at all levels of government are proposing to do about climate change
- Actively support the policies you decide are most appropriate.
- Send letters of support for policies you find valuable and letters indicating your lack of support for policies you do not see as helpful.

Source: J.M. DeCicco, J.H. Cook, D. Bolze, and J. Beyea, Chapter 6 in Energy Efficiency and the Environment, American Council for an Energy Efficient Economy, Washington, DC, 1991.

Actions that nations, regions, and states can take

Government regulation

Government can require desired behaviors (e.g. force auto companies to build more efficient cars). An advantage of regulation is that it specifies the desired outcomes and can force action. However, regulation can be inflexible and discourage innovation.

Prices and markets

Government subsidies and tax breaks can promote the use and development of alternative energy sources and encourage consumers to purchase more efficient devices. Higher prices for fossil fuels may also encourage people to save energy by promoting energy efficient devices and behavior (e.g., expensive gas prompts companies to make and people to buy more fuel efficient cars). An advantage of using prices is that they present a constant incentive to innovate. However, using prices can have undesirable side effects, such as imposing a relatively larger burden on the poor.

Information and education

People often do not know how to improve efficiency or reduce emissions. Government can provide people with the information they need to make better choices.

Research and development

Government and industry can support research to demonstrate and improve existing technology, and to develop new technologies that use less energy or emit no carbon dioxide (e.g., refrigerators that use less electricity, cheap practical solar water heaters, and inexpensive solar/hydrogen technology).

Deliberating about climate change

Three things to consider as you make decisions about climate change

Climate change affects everyone, and everyone has a stake in deciding what should be done to address it. You will decide what actions you should take as an individual (in your home, in your workplace, for your transportation, etc.). Equally important, as a citizen you will help shape public policies that seek to mitigate or adapt to the impacts of climate change.

While localized actions and strategies involving personal choices may be implemented relatively easily, the strategies that will have the most impact will require individuals, institutions, and communities to change the way they currently operate. Today, the world is powered by fossil fuels, and the global infrastructure reflects this reality.

Climate change, however, is also a reality. To reduce greenhouse gas emissions at the levels necessary to address climate change, we will need to make significant changes. Indeed, some have argued that addressing climate change will require an initiative like the "Manhattan Project," which developed the atomic bomb, or like the "Race to the moon," the concerted and concentrated effort that achieved a human lunar landing in less than a decade. Addressing climate change may require similar levels of political will and a similar commitment of financial resources that support the research and education necessary for such an initiative to be successful.

Suppose you or a friend wants to decide which public policies to support. Your decision should depend on at least three considerations. By combining your beliefs about these considerations, you or a friend can come to a general conclusion about which public policy to support.

Consideration 1: How much do you think climate will change, and what impact do you believe that change will have on the things you care about?

Your judgment not only depends on what you believe about climate change, but also on what you value. For example, two people might agree that climate change will destroy many of the world's most sensitive ecosystems, but disagree about how much they value those ecosystems. These people would rate the impact of climate change differently.

Consideration 2. How much do you think should be spent on mitigation and adaptation strategies?

Unlike the case above, where we were dealing with values, which are very difficult, if not impossible, to measure in dollars, here we are dealing with costs that can be quantified. Some believe we can spend small amounts to reduce emissions moderately in the near-term while we figure out what to do for the future. Others believe the future is clear and that we must act now to commit significant amounts of money to meet a target atmospheric greenhouse gas concentrations of around 550 parts/million by 2054. The "Stern Review on the Economics of Climate Change" concluded that supporting aggressive measures to reduce the emission of greenhouse gases would cost, on average, 1% of global Gross Domestic Product (GDP) per year, which in 2006 would have meant an annual global investment of $480 billion.

Consideration 3. Climate change is often seen as a moral issue as well as a political issue.

As a moral issue, climate change requires that we consider potential harms in terms of their impact on future generations and/or distant peoples. To assess potential harms we must understand the science of climate change and consider the implications—to ourselves, to others, and to future generations—of the policies we enact to address the impacts of climate change.

We also must consider how to manage the personal commitment any policy decision requires from individuals and institutions. That is, we must ask: How should individuals and institutions be held accountable for realizing policy decisions aimed at reducing their carbon footprint? To what extent, if any, should a university promote, encourage, support, or regulate the action of its community members? What responsibility should community members assume for promoting, encouraging, or regulating the actions of their peers? Should individuals and institutions take on the responsibility to promote practices (e.g., turning down heat at night in the winter) and behaviors (e.g., recycling) aimed at reducing carbon dioxide emissions? Or should we avoid this kind of 'social engineering' and 'peer pressure' and rely on individual choice for the realization of policy initiatives?

Questions for the Deliberative Poll®

Universities in our region have begun to consider how they can function as more sustainable communities. In this booklet we identified four areas that universities should consider as they work to address climate change: day-to-day practice, research, education, and outreach. We also introduced three things individuals should consider as they make decisions about climate change: How much you believe climate change will affect what you value, how much you think should be spent to address climate change, and the moral and political issues surrounding personal and institutional responsibility for addressing climate change. We ask you to consider all these as you review the questions below, which are the types of questions we expect to discuss during the Deliberative Poll®.

1. Considering the many roles a university has in a community—education, research, outreach, and a consumer of energy—how should the university manage its responsibility to address climate change?

Should the university commit financial resources towards changing its day-to-day practices? (e.g., To purchase wind-generated power, Carnegie Mellon has had to increase the amount it spends for electricity.)

Should the university encourage its community members to change their behavior to reduce their carbon footprint? (e.g., Encourage individuals to teleconference rather than consuming energy to travel to conferences.)

Should the university encourage changes in the curriculum and research priorities throughout the university to promote an ideal of stewardship?

2. How should a university seek to enforce the decisions it makes about addressing climate change?

Should the university reward individuals who adopt “green practices” (e.g., reduce parking fees for individuals driving hybrid vehicles to campus)?

Should the university levy a fee against individuals who consume a large amount of resources (e.g., water, electricity)?

3. Do you believe you have a personal responsibility to help the university address climate change? Why or why not?

4. Given what you know about climate change, how willing are you to take personal actions in order to address climate change? (e.g. conserve personal use of resources, encourage friends and colleagues to adopt green practices, champion green practices from your employer, etc.)

5. What strategies for addressing climate change would you be willing to actively support? (e.g., a transition to more use of renewable energy sources, nuclear power, a commitment to green building practices in all construction, initiatives for student and departmental energy conservation, etc.)

Glossary

aerosols: Extremely small particles of liquid or dust in the atmosphere. Burning coal releases sulfur dioxide which in the atmosphere is transformed into sulfate aerosols. One geo-engineering strategy would put more aerosols into the atmosphere to reflect sunlight back to space.

afforestation: Establishing new forests on unforested land. Afforresting large areas of land so that trees will absorb and store carbon from the atmosphere could slow carbon dioxide buildup.

Assessment Report: Periodic reports published by the Intergovernmental Panel on Climate Change (IPCC) that reflect the most up-to-date understanding of the physical science behind climate change, projected impacts on natural systems and human societies, and options for mitigation and adaptation.

Bali Climate Change Conference: The 13th meeting of the Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC). The Bali conference occurred in December of 2007. The purpose of this meeting was to begin negotiations on a post-2012 international agreement on how to address climate change.

biodiversity: The number of different kinds of plant and animal species that live in a region. On land, tropical rain forests have the highest biodiversity.

biomass: The amount of living matter in a particular region, usually expressed as weight (mass) per unit area (e.g., tons per acre).

cap-and-trade: A market-based regulatory scheme used to decrease emissions.

carbon capture and storage: The processes of capturing carbon dioxide that would otherwise stay in the atmosphere and storing it geologically deep underground. Carbon dioxide can be captured directly from smokestacks or from the surrounding air and then liquefied by compression. Liquefied carbon dioxide is then injected into a deep geological structure underground such as a spent oil or gas field or saline reservoir.

carbon cycle: The processes by which carbon is cycled through the environment. Carbon, in the form of carbon dioxide, is absorbed from the atmosphere and used by plants in the process of photosynthesis to store energy. Plants and animals then return carbon dioxide to the atmosphere through respiration when they consume this energy. On a much longer time-scale, carbon is also cycled into and out of rocks.

carbon dioxide: A gas made up of two atoms of carbon and one atom of oxygen which is produced whenever carbon-based fuels are burned (or oxidized more slowly in plants and animals). Carbon dioxide is the most important "greenhouse gas" which may cause climate change. Human sources of carbon dioxide include burning fossil fuels for electricity, transportation, heating, cooling, and manufacturing. Burning trees in the process of deforestation also produces carbon dioxide. Abbreviated CO2.

chlorofluorocarbons: A family of greenhouse gases used in air conditioning, as industrial solvents, and in other commercial applications. Abbreviated CFCs. CFCs destroy ozone in the stratosphere (see ozone). CFCs were once widely used in spray cans but in the U.S. this use has now been banned. Other uses are also being eliminated under and international agreement negotiated in Montreal in 1987.

climate: The average pattern of weather in a place. While weather may change substantially from day-to-day, when changes in climate occur, they usually happen gradually over many years.

Conference of the Parties (COP): A body comprised of all signatories to the United Nations Framework Convention on Climate Change (UNFCCC). The United States is a member of the COP.

deforestation: Cutting most or all of the trees in a forested area. Deforestation contributes to warming by releasing carbon dioxide, changing the albedo (amount of sunlight reflected from the surface) and reducing the amount of carbon dioxide taken out of the atmosphere by trees. Today, deforestation may contribute about 20% of possible warming.

energy intensity: The amount of energy used by an appliance or an industry to produce a product or service. For example, a fluorescent light requires only 20 watts to produce the same amount of light as a regular 100 watt light bulb, so its energy intensity is 5 times lower. Reducing energy intensity is one way to increase energy efficiency and emit less carbon dioxide.

feedback: The mechanism by which changes in one part of the earth-atmosphere system affect future changes in other parts of that system. Feedbacks come in two kinds. In climate change, negative feedbacks work to slow down or offset warming while positive feedbacks work to speed up or amplify warming.

fossil fuel: Coal, oil (from which gasoline is made), and natural gas are called fossil fuels because the chemical energy they contained is left over from plants and animals that lived long ago.

greenhouse effect: The process by which energy from the sun is trapped under the atmosphere to cause warming. Light energy can easily pass in through the atmosphere. Once some of this light is absorbed by dark surfaces, the resulting heat energy has greater difficulty getting back out. Through the naturally occurring greenhouse effect, water vapor, ozone and carbon dioxide have kept temperatures on the earth moderate for several billions years. Today, people are adding more gases which might increase the temperature.

greenhouse gas: Any gas in the atmosphere that contributes to the greenhouse effect. These include carbon dioxide, methane, ozone, nitrous oxide, CFCs, and water vapor. Most occur naturally as well as being created by people.

Intergovernmental Panel on Climate Change (IPCC): Committees of leading scientists from all around the world whose task it is to periodically review and report on the state of understanding of the climate problem. The IPCC was jointly established in 1988 by the World Meteorological Organization and the United Nations Environment Program.

Kyoto Protocol: A binding agreement under the United Nations Framework Convention on Climate Change (UNFCCC) designed to help developed countries set targets for decreasing their greenhouse gas emissions. The protocol was adopted in 1997 during the 3rd meeting of the COP in Kyoto. The first implementation phase of the Protocol runs from 2008-2012. The Clinton administration signed the Kyoto Protocol, but the US Senate refused to ratify it.

methane: A greenhouse gas consisting of one molecule of carbon and four molecules of hydrogen. Pound-for-pound it produces between 5 to 10 times more warming than carbon dioxide. Methane is produced naturally from rotting organic matter. Human sources of methane include agricultural activities such as growing rice and raising live stock, land-fills, coal mines, and natural gas systems. Abbreviated CH4.

Montreal Protocol: An international treaty signed in 1987 that limits production of chlorofluorocarbons.

natural gas: Gas obtained from wells used as a fuel. While it contains many chemicals the principle component of natural gas is methane.

nitrous oxide: A greenhouse gas consisting of two molecules of nitrogen and one molecule of oxygen. Pound-for-pound it produces about 300 times more warming than carbon dioxide. Nitrous oxide is created when fuels are burned and is also released during the use of nitrogen-based crop fertilizers. Abbreviated N2O.

ocean acidification: As carbon dioxide slowly dissolves into the oceans, this decreases the pH of the water causing it to become more acidic. This raised acidity can eventually dissolve the shells of many organisms, deforming them, leaving them defenseless to predators, or both.

ozone: An unstable gas in which three molecules of oxygen occur together. Ozone is a greenhouse gas in the atmosphere ozone occurs at two different altitudes. Low altitude tropospheric ozone is a form of air pollution (part of smog) produced by the emissions from cars and trucks. High in the atmosphere a thin layer of stratospheric ozone is naturally created by sunlight. This ozone layer shields the earth from dangerous (cancer-causing) ultraviolet radiation from the sun. Chlorine gas from chlorofluorocarbons speeds the breakdown of ozone in the ozone layer. While important, this is largely a different problem from the problem of global warming.

peak oil: A term used to describe the point in time when the rate of global petroleum production cannot go any higher, after which the rate of global petroleum production begins a terminal decline. Researchers in the energy field are divided over the timing of peak oil and whether or not it will ever be reached.

renewable energy: Energy derived from resources which cannot be exhausted over time such as the sun, wind, biomass, water flows, and tides.

sea level rise: An increase in the average level of the ocean caused by expansion when water is warmed and by addition of more water when ice caps melt.

sink: A place where material is removed or stored. For example, the oceans absorb about 50% of the carbon dioxide released into the atmosphere. Scientists refer to the oceans and large forests as carbon dioxide sinks.

sustainable development: Economic activities which can meet the needs of the present without compromising the ability of future generations to meet their own needs.

weather: The condition of the atmosphere at a particular place and time measured in terms in wind, temperature, humidity, atmospheric pressure, and precipitation (rain, snow, etc.). In most places, weather can change from hour-to-hour, day-to-day, and season-to-season.