ACTIVITY

2 Clearing the Air

Students learn about the scientific evidence supporting climate change, use this information to evaluate and improve conclusions some people might draw about climate change, and participate in a role-play to negotiate solutions. Through this activity, students explore the nature of science and better understand why there are various perspectives about climate change.

Subjects
Agriculture, Biology, Earth Science, Environmental Science, Language Arts, Social Studies

Materials
Student pages, answer keys, and presentations (see Activity Webpage link below)

Skills
Analyzing, Communication, Concluding, Decision Making, Discussing, Inferring

Time Considerations
Two to four 50-minute class periods and homework

Related Activities
This activity helps introduce climate change. It can follow an introduction to forests and climate (Activity 1) and be followed by any of the activities that help students explore the relationship between climate and forests (Activities 3, 4, or 5) or between climate and product life cycles (Activity 10).

Research Connection
Research on climate change and on its impacts to ecosystems is advancing very quickly. Additional research explores how people perceive climate change. This activity summarizes what we currently know about both.

Activity Webpage
Find online materials for this activity at https://sfcc.plt.org/section1/activity2

Objectives
By the end of this activity, students will be able to
- assess the scientific accuracy of conclusions or statements about climate change,
- explain two reasons for diverse perspectives on climate change, and
- explain the value of solutions that incorporate diverse perspectives.

Assessment
- Ask students to write an essay based on this prompt: Please summarize scientific evidence about global climate change. Describe one aspect of the issue that is misinterpreted by the public and explain why this might occur.
- Have students analyze an editorial article on climate change. They should identify the article's claim, the strength and source of the supporting scientific evidence, and assumptions made by the author.

Background

A variety of ideas, opinions, and beliefs surround the topic of ***climate change***. While some of these beliefs are supported by scientific evidence, others are not. Beliefs are ideas that we hold to be true and can be based on many things, such as past experiences, observations, faith, or the beliefs of others. Scientific conclusions are beliefs that are based on scientific evidence. The scientific process involves testing hypotheses, collecting data through standardized measurements and observations, and stating assumptions that are used to link the interpretation of data to conclusions. Understanding scientific evidence and the reasons that people might hold ideas that conflict with the scientific consensus are key aspects of working together to move toward solutions for mitigating and adapting to climate change.

Additional background information can be found in the **Section 1 Overview**.

The **Explaining the Evidence** presentation will help you provide students with a brief introduction to climate change, scientific evidence supporting human-induced climate change, and projected regional impacts. The background text here can be used along with the presentation notes found on the Activity 2 webpage.

Is Climate Changing?

Climate is the long-term average weather conditions in a particular location or region at a particular time of the year. For example, it is generally hotter in the summer than in the spring, and it is typically cooler in the upper latitudes than in the equatorial regions. ***Weather***, as opposed to climate, describes the atmospheric conditions at a specific place at a specific point in time. Weather is what is happening outside right now.

One example of climate-related variation is the ***El Niño-Southern Oscillation (ENSO)*** cycles in the Pacific Ocean

DUNCAN WILSON, OKLAHOMA STATE UNIVERSITY

Weather station towers, like the one pictured here, collect data on rainfall, temperature, and other measures.

that create El Niño and La Niña. They have important seasonal influences on regional climates on land, especially in the Southeast—leading to warmer, cooler, wetter, or drier years. Climate also fluctuates over longer periods of time. Climate is measured in increments of at least 30 years, but when considering historical climate changes, we often look at much longer timeframes, in the range of hundreds to thousands of years. Evidence of climate change can be seen in long-term alterations of temperature, ***precipitation*** patterns, sea ice extent, sea level, and the frequency of extreme weather events. Data about these variables are collected through weather instruments and records, tree rings, ice cores, satellite images, sedimentary layers, and other observations and technical measurements.

Temperature Trends

Collectively, data from meteorological weather stations, at airports, on mountains, on ships in the ocean, and by satellites, indicate that over the past 100 years the average surface temperature on Earth has increased by more than 0.8 degrees Celsius (° C), which is equivalent to 1.4 degrees Fahrenheit (° F) (NRC, 2012). Looking at global temperature from 1880 to today, studies show that most of the increase in average temperature has occurred since the 1970s (NASA GISS, 2012). In the Southeast, as with the global averages, the annual average temperature has increased the most since 1970, by approximately 1.1° C (2° F) (USGCRP, 2009). This average increase in global surface temperature is known as ***global warming*** and can create other changes in climatic conditions, such as changes in rainfall.

Precipitation Trends

While the total precipitation in the U.S. has increased by about 5 percent in the past 50 years, this increase has not been consistently experienced by all locations in the country (NRC, 2012). Precipitation frequencies and distributions vary widely with short distances, so it is more helpful to look at regional changes in precipitation rather than global changes. In the Southeast, observed precipitation changes from 1901 to 2007 show that average fall precipitation increased by 30 percent since the early 1900s, and that summer and winter precipitation decreased by almost 10 percent in the eastern part of the region (USGCRP, 2009). Seasonal changes such as these can be masked in annual averages, but they can be critically important when precipitation changes occur during the growing season.

Other Natural Trends

In addition to temperature and precipitation changes, climate research shows long-term changes to the extent of snow and ice cover. For example, measurements taken by the National Snow and Ice Data Center (2013) indicate that the monthly December Arctic

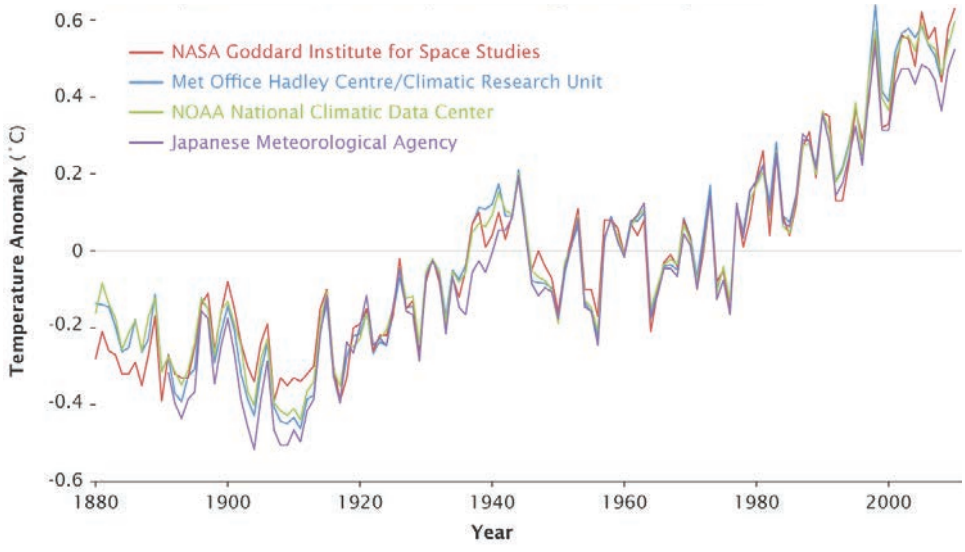
sea ice extent from 1979 to 2012 shows a decline of 3.5 percent per decade. In addition, the average Arctic sea ice extent for December 2012 was the second lowest month in the satellite records ranging from 1979 to 2012. It is important to compare the same months across years, as comparing the ice extent in December to the ice extent in July would represent a change in season rather than a change in climate.

Increases in global surface temperature are reflected in the Earth's oceans. Like any body of liquid, a warmer ocean expands as the molecules move at greater speeds, and larger oceans encroach on shorelines, affecting ***ecosystems*** and built structures. This expansion of warm water has contributed to global ***sea level rise***, which is estimated to be about 20 centimeters (or 8 inches) higher than it was in 1870 (NRC, 2012). Sea levels are also affected to some degree by melting glaciers and polar land ice. Icebergs and sea ice already displace water, so these do not change sea level when they melt. Sea levels, which vary depending on location, are measured with tide gauges and satellite images. Warmer water also affects ocean currents, storm events, and weather patterns.

Finally, climate change can also be seen through long-term alterations to the frequency and intensity of weather events, such as periods of extreme heat or cold, droughts, floods, winter storms, thunderstorms, tornadoes, and hurricanes. Similar to precipitation, trends in extreme weather events are best identified regionally and must be considered with regard to the range of weather patterns that typically affect a specific area. In the southeastern region, the trends in weather events vary. The frequency of flood events has been increasing since the late 1800s, and particularly within the last two decades. This may be due to increases in impermeable surfaces in cities across the region as well as to climate change. At the same time, decadal frequencies of hurricane landfalls in the region have slightly decreased in the past 100 years. The frequencies of regional extreme maximum temperatures and extreme minimum temperatures have been decreasing across much of the region since the early 20th century. However, the majority of the southeastern region has been experiencing more minimum temperatures above 24° C, which is equivalent to 75° F (Ingram, Carter, & Dow, 2012).

Global Surface Temperatures

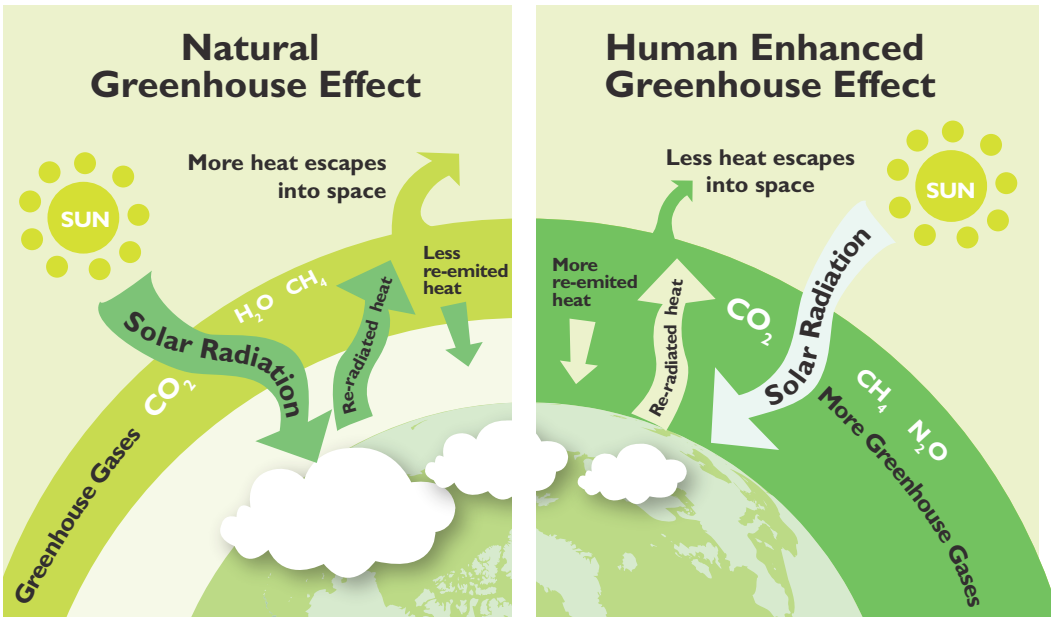
Four independent records show nearly identical long-term warming trends.



NASA EARTH OBSERVATORY/ROBERT SIMMON

Four major global surface temperature analyses show that Earth has warmed since 1880, with most of this warming occurring since the 1970s.

The greenhouse effect is a natural process where greenhouse gases absorb and trap heat radiating from the Earth's surface.



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Why is Climate Changing?

Changes in climate are driven by many factors. These factors include ***solar radiation***, ocean composition, ***greenhouse effect***, ***albedo*** effect, continental land arrangement, volcanic eruptions, ***fossil fuel*** combustion, and land-use change. Historically, the Earth has experienced 100,000-year cycles of ice ages and warmer periods, mostly due to changes in solar radiation. While natural forces explain historical climate shifts, those same factors do not account for the changes that are now being observed. Recent ***models*** of climate suggest that both natural and human-caused changes are responsible for recent increases in global temperature. Both the U.S. Climate Change Science Program (2006) and the Intergovernmental Panel on Climate Change (2013) agree that human activities, particularly increases in ***greenhouse gases***, are influencing the climate system. Greenhouse gases include the following:

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)
- Ozone (O_3)
- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs)
- Sulfur hexafluoride (SF_6)
- Water vapor (H_2O)

The Section 1 Overview contains a list of assumptions or confusions that your student may have regarding the causes of climate change.

The levels of greenhouse gases affect Earth's energy balance though the greenhouse effect—a natural process where greenhouse gases absorb and trap heat radiating from the Earth's surface. Measurements from ice core samples representing the past several thousand years indicate that until the late 1800s, CO_2 levels in the Earth's ***atmosphere*** had been fairly stable at about 280 parts per million (ppm). In summer of 2013, the daily average CO_2 level exceeded 400 ppm, which is a 40 percent increase from preindustrial levels (Bala, 2013). Researchers have noted that the rise in greenhouse gases coincides with rises in average global temperatures in the past. The Earth's atmosphere may have contained more than 400 ppm of CO_2 3 to 5 million years ago, and scientists estimate the global average surface temperature at that time was 2 to 3.5° C (3.6 to 6.3° F) higher than in the early 1800s (NAS and RS, 2014).

What Will Happen in the Future?

Because the global climate is a complex ***system*** and because there are many

possible changes to the factors that increase greenhouse gases and temperature, firm predictions about the impacts of climate change are not possible. Climatologists use climate models to make ***projections***, which describe how future climate is expected to respond to various scenarios with the factors that might affect climate change, such as population growth, ***greenhouse gas emissions***, and land development patterns.

An increase of a few degrees in temperature is likely to have a variety of effects around the planet. While the polar regions are experiencing warmer winters, less sea ice, and glacial retreat, the equatorial regions are experiencing less temperature change. This is mainly because of a ***reinforcing feedback loop*** related to ice and albedo. Snow and ice in the Arctic reflect the sun's energy back to space, and as warmer temperatures cause snow and ice to melt, the darker exposed rock and water absorb more heat. In this cycle, temperatures continue to increase and snow and ice continue to melt. This reinforcing feedback continues and results in amplified warming in this region of the world. More heat in the atmosphere also will mean more ***evaporation*** from the planet's surface, which can reduce soil moisture and increase drought in some places and increase rainfall and extreme storm events in others. Changing temperature and precipitation may change ocean and atmospheric currents, creating new weather patterns with potentially welcomed, disastrous, or unanticipated effects depending on location. Changes in temperature and precipitation on the land are likely to bring about changes in the frequency and intensity of storms, including hurricanes and tornadoes. Plants and animals that currently live at the edge of their ranges may find the changing environment no longer meets their needs. Some populations may be able to migrate or shift; other populations may become smaller.

Through the 21st century, the southeastern region is expected to see increases in temperature, both increases and decreases in precipitation, and increases in the frequencies of major hurricanes. In particular, coastal communities in the region are threatened by sea level rise. Warmer temperatures can lead to more ***invasive species***, greater risk of ***wildfire***, and losses in forest ***productivity***. At the same time, increased levels of atmospheric carbon dioxide may benefit trees by increasing ***photosynthesis,*** if the other factors do not limit tree growth. The immediate impacts on forest ecosystems and agriculture are of great concern to many decision makers, researchers, resource managers, and farmers. Additionally, the long-term impacts may affect everyone through the availability and price of agricultural and forest products.

Why Doesn't Everyone Agree?

Climate scientists are confident that global warming is occurring, so why do people disagree about this issue? Of course the issue of climate change is complex and multifaceted, which makes it a difficult topic to explain and understand. Some people simply don't have the information to enable them to agree; they are appropriately confused and have a lot of questions. Some people have never had an Earth science class and

The **Explaining the Evidence** presentation allows you to explain areas of disagreement and why they exist. The **Analyzing Perspectives** student pages give students an opportunity to work with these ideas.

JOHN SEILER, VIRGINIA TECH

don't have background to understand some climate concepts. Without understandable explanations, it is easier to stick with what we have experienced in our lifetimes—a relatively stable climate that varies more from summer to winter than from year to year.

Others might understand the information and even acknowledge that changes are likely, but because they do not like or are uneasy with the possible solutions or social changes involved in mitigating or adapting to climate change, they find it easier to downplay the problem. Our economic dependence on fossil fuels to power industries and communities makes our entire nation vulnerable to changes that might occur with carbon emission policies, and some people who worry about the implications of these changes may prefer to find reasons to ignore climate change. In addition, it is hard to convince people to invest in changes when the benefits of those changes are not immediate.

Some strongly held and diverse opinions across America make the topic of climate change different from other environmental challenges. At the root of these various perspectives is a simple fact of human information processing: we more readily perceive and accept information that matches what we already know. Teachers demonstrate this every day by reminding students of previous lessons and experiences so that the new lesson "fits." Given a great deal of information, we are likely to pass over the information that doesn't fit our mental models and focus on the bits that reinforce our ideas. Thus, it is challenging to provide information to people who disagree with it, since they may not hear it or want to think about it.

This selective perception makes it possible for people to have partial information about climate change. By having only part of the story, people may arrive at conclusions that are only true some of the time and are not supported by all the evidence. The homework exercise for this activity helps students recognize some of these challenges.

When people don't have the time to learn about climate change, they are likely to accept the ideas of the political leaders and influential people they trust. Those leaders, like the rest of us, may only accept or understand some of the information, may have reasons to not support actions that address climate change, or may have beliefs about religion that conflict with the assumptions or conclusions of climate scientists. All of these factors contribute to the variety of opinions about the causes of climate change. Yale and George Mason universities have been conducting opinion polls with the general public over several years and have identified six different categories of beliefs. Although the percentage of the population in each category changes slightly with each new survey, there are people who are alarmed and concerned about the problem, people who are confused or not interested in learning more, and people who doubt climate is changing or are convinced that we should not make any changes to accommodate what they consider natural shifts in temperature. Your students'

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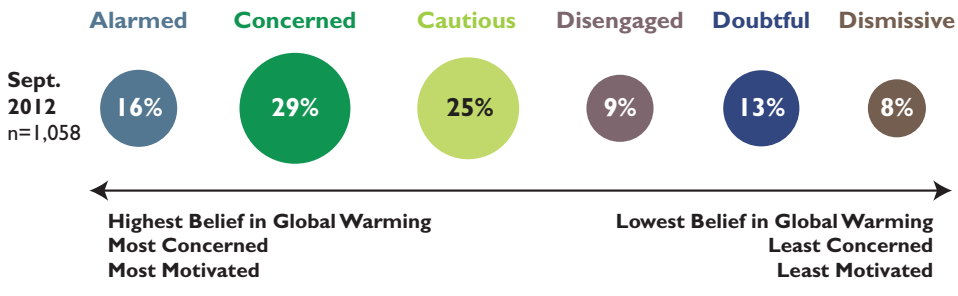


parents probably fall into all six categories. The Background section of this module includes information about addressing climate change in the classroom and provides tips for working with students, parents, and administrators who may have varying viewpoints. The student exercises in this activity and the other activities in this module are designed to help you provide science-based information, allow students to understand these concepts and debate the interpretations, and engage them in thinking carefully and completely about climate change.

Exploring Solutions

Information about climate change is important and interesting, but students also will likely want to know that there are people, communities, organizations, and nations who are currently doing something about the problem. Rather than being fearful of the future, students can adopt a problem-solving approach to climate change. For instance, in order to address climate change, community and business leaders must first consider what is likely to happen in the future. If the changes are projected to be bad and the risk of these changes occurring is high, then communities may be motivated to take action to reduce risk. If the changes are projected to happen to people living far away or to future generations, then communities may focus their discussions on obligations to other people and the degree to which those obligations should change current behavior with regard to climate change. These discussions could focus on the essence of ***sustainability*** by considering how our decisions might affect the quality of life for future generations.

Most climate change ***mitigation*** strategies involve reducing emissions or increasing sequestration of greenhouse gases, mostly methane and carbon dioxide. By understanding the sources of these gases in the atmosphere, people can think about how to move these compounds somewhere else, or not produce them in the first place. For instance, society could decide to increase energy efficiency to reduce combustion of fossil fuels as well as reduce reliance on products or systems that currently depend on fossil fuels. Some communities, such as Aspen, Colorado, are already taking action to help people reduce energy consumption with improvements in public transportation and building efficiency. In addition, churches and businesses are participating in programs such as the "10% Challenge" to encourage their members to conserve resources, reuse products, and reduce energy use. This program provides the tools and the information necessary to conserve energy at home and at work by encouraging people to calculate their current annual greenhouse gas emissions and pledge to take some action to reduce these emissions by at least 10 percent.

Producing energy without fossil fuels, but with ***renewable resources***, will help reduce atmospheric carbon. A great deal of information is available about ***biomass***, nuclear, solar, and wind power, and some communities have already explored and implemented these technologies. For example, communities in Kansas are using wind energy, and communities in Vermont using wood to produce power and electricity.

In addition to reducing the amount of carbon released into the atmosphere, actions that can increase forest cover can help sequester carbon. For example, solutions may include ***reforestation*** and ***afforestation*** projects, managing forests to optimize ***carbon sequestration***, and avoiding large wildfires through appropriate ***vegetation*** management. Technologies that capture and store carbon are also being developed, which might allow nations to continue to burn some fossil fuels. But in the end, it may be important for students to consider larger questions, such as these: What amount of resource use allows us to be content? What contributes to happiness? How many of us can the Earth support? How can we best protect the interests of future generations?

The nuanced details of these solutions will make them appropriate in some situations and

The **Exploring Solutions** presentation could be shown on the same day if the first portion goes quickly, or it could be saved for a second period. After explaining mitigation and adaptation, several examples of real communities taking action are provided. The role-play activity in Part B allows students to identify community members with different ideas about climate change and discuss potential solutions they might take.

TEACHERS SAY ...

We did a school-wide survey to determine if students knew anything about global warming. It turns out they were more knowledgeable than I anticipated.

—Honors and AP Biology Teacher, Florida

not in others. The simple strategy of eating less or different types of meat to reduce greenhouse gas emissions is a good example. Consider just a few of the factors that go into the production and transport of beef. Cows that are raised in feedlots are fed corn grown with fertilizers made from fossil fuels. The meat is shipped by trucks and trains across the continent, which requires more fossil fuel. Additionally, cows emit large amounts of methane during digestion. In general, the system of producing meat depends on petroleum and produces greenhouse gases. Eating beef from cows raised on a local pasture may use less fossil fuel. However, if this meat is more expensive, people may be discouraged from buying it. Another option is to eat less beef. The choices around what to eat are laden with cultural values that form different priorities as people decide what is most important to them: greenhouse gases, meat, or money. In Section 4: Life Cycle Assessment, the pros and cons of ***product life cycles*** can be explored in more depth by students.

In addition to considering how to reduce atmospheric carbon, communities around the world are planning and implementing climate change ***adaptation*** strategies. This process involves understanding projected climate impacts, assessing human and natural systems that are at risk of negative impacts, and determining ways to lessen those impacts. Adaptation strategies can take place in advance (by planning before an expected impact occurs) or in response to changes that are already occurring. Adaptation projects may take the form of new infrastructure, health programs, disaster preparedness, or agricultural and forestry practices.

Teaching This Content

This activity is designed to help students who may not have taken an Earth science course or been exposed to the science behind climate change. It is a complicated topic, but because the evidence is straightforward and compelling, the presentation can be coherent and helpful. The evidence can also be used to explore the process and nature of science, the development of competing hypotheses, and the variety of ways people can develop misconceptions.

While the process of science may occur without emotion, the implications of climate change are full of positive and negative attitudes. Policy changes, technological

Systems Thinking Connection

IN THIS ACTIVITY, students learn about the importance of understanding their own observations and experiences within the context of sound science. In the context of climate change, sound science supplements our observations and helps us understand the world. For example, some might be tempted to interpret a particularly warm day in January to be evidence for climate change or a cold day in late spring to be evidence against climate change. Scientific data help us understand long-term trends, not only of temperature, but also of atmospheric concentrations of greenhouse gases or rates of ***deforestation***, for example. With this information, we can explore how these variables affect each other over time. One of the important habits of a systems thinker is to focus on patterns of change rather than specific events. That is possible if we use and understand the data that scientists make available.

The concept of scale provides another way of considering this shift in thinking. Systems thinkers learn to evaluate an issue at multiple scales. At the finest scale, we might consider molecular properties of carbon dioxide or methane, which may involve interactions taking place in a fraction of a second. At the broadest scale, we might consider interactions between the Earth and the sun, which can involve cycles spanning millennia. Understanding climate change requires understanding how these various interactions happen at different levels of scale.

We have some experience doing this already. We know that as a year progresses from January to June, the weather will warm up in North America. However, no one expects every day during that period to be warmer than the last. We experience a cold snap in April without assuming that the general warming trend has reversed. The cold snap is due to interactions happening at a finer scale than the annual cycle of seasons. Two additional exercises to practice systems thinking skills are described in the Systems Enrichment Exercises section.

advances, and behavior changes are potential solutions that students can explore and debate. Communities are finding creative and meaningful solutions, but they tend to be more complex than simply recycling, which is often the answer that students suggest. By understanding climate change implications, students and everyone—including businesses, agencies, municipalities, and industries—can play a role in strategies to mitigate and adapt to our changing climate. Instead of being overwhelmed or depressed with the reality of change, students may be inspired to join those who are creating change.

The role-play in Part B is an opportunity for you to help students apply information about climate change and varying perceptions about the issue as they discuss potential community actions. If your students are not keen to play these roles, you can instead facilitate a discussion where students become a city council and consider the different perspectives being presented.

Getting Ready

The Activity 2 webpage provides **Teacher Tools** that you can use to become more familiar with this activity's background and procedure (https://sfcc.plt.org/section1/activity2).

Download the Explaining the Evidence and Exploring Solutions presentations from the Activity 2 webpage and review the presentations, background information, and presentation notes to decide how much you wish to present.

Consider whether to conduct Part A with student groups as suggested or to assign one or two student pages as homework. When students return to class, you can ask for volunteers to share how they rewrote the conclusions to be more accurate. See Modifications for additional options. Make copies of student pages after determining how you will conduct Parts A and B.

Doing the Activity

Part A: Climate Science and Analyzing Perspectives

1. Begin by explaining to students that people have different levels of knowledge and different viewpoints on climate change. Explain that some information we hear or read is based on scientific evidence, while other information is based on opinions or beliefs, which may or may not be supported by scientific evidence. You might say, "Since we are in a science class, our focus will be to learn how most climate scientists understand climate change. We will also discuss the range of opinions held by the public because this will help us consider potential actions that communities might take to reach agreement in order to implement adaptations or mitigations."

2. Distribute the Fact or Fiction student page. Ask students to read the statements and judge which statements they think are supported and which statements they think are unsupported by scientific evidence. Once students have completed the student page, ask them what they thought about the statements. Was it easy or difficult to decide the answers? Have they heard some of these statements about climate change in the news or in class or from friends or family?

3. Provide an overview of climate change science and why there are multiple perspectives using the Explaining the Evidence presentation. You are welcome to modify the presentation or supplement it with another resource.

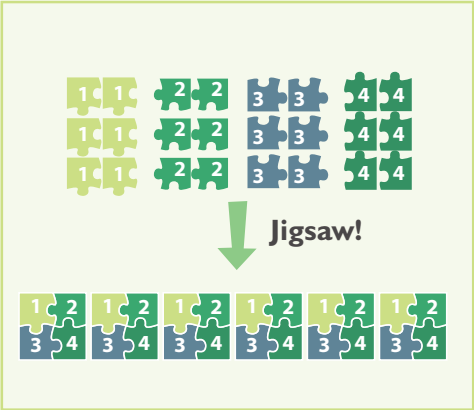
4. Organize the students into four equal groups. Give each group copies of one of the Analyzing Perspectives student pages (one per student). Explain that each group has been given a different short paragraph about climate change to read. As a group they should answer the questions to assess

TEACHERS SAY ...

I got students to buy in by showing the Climate Reality Project Video.

—Earth Science Teacher, Florida

When using the jigsaw technique, students begin in groups and focus on one topic. The students then "jigsaw" and form new groups, which allows them to share information and learn about all of the topics.



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the paragraph and conclusion. Students should discuss the questions before writing the answers and rewriting the conclusion. Visit each group as they are completing the task and ask students to explain their thinking about their conclusions and how they rephrased the conclusions to better represent the science about climate change. Help the groups arrive at science-based conclusions. Answer keys are available on the Activity 2 webpage.

5. Reform the groups using the jigsaw technique. Ask students in each group to count off so that each person within the group has a different number. The students should then create new groups according to their numbers. Each new group should contain at least one member of each old group. In the new groups, ask each student to explain the problem with the initial conclusion, why someone might arrive at that conclusion, and how the statement was revised to be more accurate.

6. In a class discussion, review some of the common pitfalls of the conclusions the students assessed.

- If these conclusions don't represent the scientific consensus about climate change, why do some people believe them?
  People may have partial or inaccurate knowledge about the issue. It is easy to focus on one piece of evidence and miss others. People hear, remember, and understand information that makes sense to them. They may discard or not pay attention to more complex or frightening information. People associate with friends and relatives who agree with what they think, so it is easy to confirm their ideas and hard to question them.
- Besides scientific knowledge, what other things do you think influence the way people feel about climate change?
  People might listen to opinions about climate change that are conveyed through the media, family, friends, and community leaders, and these people filter information through their views of the world, values, fears, hopes, and beliefs (political, religious, and cultural).

Part B: Role-play

1. Explain that despite their different perspectives, it is still important for people to work together in a community. Let them know that during this exercise, they will have the opportunity to practice talking to people with different perspectives.

2. Use the Exploring Solutions presentation to share information about the ways communities and nations are changing behaviors and adapting to climate change. Remind students of the different perceptions people have about this issue.

3. Ten role cards representing a range of views about climate change are provided so you can select at least the most relevant roles for your local context and for the number of students in your class. We suggest you select at least one role from each of the four categories to ensure that a diversity of perspectives is represented in each student group. Create groups of students based on the number of role cards you select, giving each student one role card and a copy of the Role-play Guide. Explain the scenario to students and ask them to read their role and complete the My Role box before they begin. It may be challenging for students to take on a new role, especially if the position is not one they agree with. Consider providing additional time

for students to think about their role so they can better understand the motivations behind certain attitudes and positions.

4. Explain the process of a role-play. Each student will convey a role to help the group realize the variety of perceptions and opinions that might exist in this community. The point of the exercise is for everyone to practice working with people who hold different beliefs and opinions. Help students think about the ways they can make sure they all stay in their roles and remain civil toward each other. Ask for volunteers in each group to be responsible for keeping the group on task, for making sure everyone has a chance to speak, for recording notes on page 2 of the Role-play Guide, and for keeping time. Groups may find they are more productive if they can use the white board or newsprint and markers.

5. Answer any questions about the scenario (each group is developing recommendations for Centerville's mayor to address climate change) and remind students that the actions they develop and support during the exercise should be consistent with their assigned roles. Explain how the groups should use the criteria on the Role-play Guide to assess each suggested action. Rating each criterion allows students to debate the relative advantages of an action that may be very effective, but not very practical or may cause other problems. In other words, actions will vary by criteria, and the committee should take all of those components into account. Students may realize that it is easier to obtain agreement on the least effective actions. You might ask them if that a useful way to begin making progress, or does it waste time in the long run? Provide the following timeframe for the role-play:

- 5 minutes: Each person introduces himself/herself in the assigned role and provides one idea for the community to address climate change.
- 5 minutes: The group takes one idea and rates it with the criteria on page 2 of the Role-play Guide.
- 15 minutes: Given the diversity of opinions in their community, the group chooses three other ideas and rates them.
- 5 minutes: The group discusses the rankings and selects one recommendation for the mayor.

6. Rotate among groups to ensure students are on task. Here are some questions to ask if a group is stuck.

- Are there some actions that most of you can agree would be worth doing in Centerville?
- For those you disagree upon, what is it about the action that is causing disagreement? Can some aspect of the action be modified or improved to make it more agreeable?
- Which action is most suitable for the community?

7. Once all the groups are finished, ask each group to present its recommendation to the class and explain how the decision was reached. Students should explain what the action is and how it relates to climate change, what members of the community will be affected by the action, and how or where it will be implemented.

8. Lead a class discussion about the experience of the role-play, the advantages and disadvantages of working with people with different perspectives, and how the students think communities might talk about climate change. You might ask the following questions:

- Which two roles were the least likely to agree on climate solutions? What about those perspectives makes it difficult to agree? How were you able to overcome this challenge?
- How well were you able to play your role? What made it difficult or easy?
- What are some reasons people may support climate change solutions even if they initially disagree about the issue?

TEACHERS SAY ...

The presentations fostered some excellent discussions, which in turn provided the perfect transition into the role-play portion of the activity.

—AP Environmental Science Teacher, Florida

TEACHERS SAY ...

My students truly enjoyed the role-playing. Again, I was surprised in their eagerness to participate. It was much better than taking notes.

—Earth and Environmental Science Teacher, North Carolina

- What are the advantages and disadvantages of a group of people agreeing to an activity but not agreeing on the reasons for the activity?
- Is the best action the one that is rated "high" for the most criteria, or is it the one that is not rated "low" for any criteria?

9. Systems Reflection: When discussing the experience of the role-play, instructors may want to emphasize that exploring a diversity of perspectives helps groups consider more elements of a system, and often a bigger system. In what ways might these additional aspects of the system help a group arrive at a better solution?

New and different perspectives can add variables to the system that we may not have considered at first. Systems thinkers can use these perspectives to alter their own perspective or the boundaries and scale of the system under consideration. Many of the perspectives in this role-play are not wrong, but they are incomplete. Students should be able to identify the faulty assumptions. For example, past climate changes are not predictive of future changes, since the current rate of change is much faster than it has been historically. When exchanging ideas with people who hold different perspectives, students should remember that these people might offer important insights or concerns that they had not previously considered.

10. As you wrap up this activity, ask students to look again at the Fact or Fiction statements about climate change from the beginning of the lesson and confirm what statements are supported by evidence. Review the answers with students (see answer key on Activity 2 webpage), and make sure to clarify any remaining questions or misunderstandings. The complexity of the issue makes it challenging to talk about climate change in simple terms, and it is easy for brief statements to be misleading. These challenges and others make it likely that people will have different ideas about climate change, which may be reinforced by political positions or existing beliefs. The role-play exercise, however, should make it clear that even those who disagree about climate change can agree on productive and important steps they can take within their community to conserve resources and improve well-being.

Modifications

Consider shortening the Examining the Evidence presentation to the evidence that your students will most easily understand. Students can check their work on the Fact or Fiction student page as you go through the Examining the Evidence presentation.

You can reduce the number of Analyzing Perspectives student pages that you use, and you may wish to use **Activity 7: Carbon on the Move** prior to Emily's Perspectives on the Natural Causes of Climate Change student page.

In Part B, students could look for solutions fitting to their roles as you review the Exploring Solutions slide presentation.

Rather than dividing into small groups to role-play the committee, you could also keep the class together and facilitate a discussion with the class as the committee.

Rather than play roles, students could report on the various perspectives by reading several cards and explaining them. They can still generate potential actions and discuss the advantages and disadvantages based on the criteria on the Role-play Guide and the diversity of perspectives in the community. If the rating criteria are too challenging, consider reducing them to technical feasibility and expense (cost efficiency).

Rather than a discussion, students could be given a role card and asked to provide a written response that this person might use to promote a climate change action.

Systems Enrichment Exercises

SIMPLY FOCUSING ON PATTERNS IS NOT ENOUGH TO UNDERSTAND THE BEHAVIOR OF COMPLEX SYSTEMS. Consider our relationship to computers (or cell phones). You can use a computer without having any idea as to how it really works. You push a button, click the mouse, tap on the keyboard, and off you go. But what do you do when the computer acts in an unexpected way? Most of us are stumped by any computer problem that requires more than turning the computer off and back on.

To really understand why a computer is acting in an unexpected way, you have to learn more about how it works. The same idea holds for complex systems. In order to understand how complex systems work, it can be useful to think about the variables that make up the system (called stocks) and the relationship between those variables (called flows). Even systems that are familiar to us, such as a bathtub, can show unexpected behavior unless we think of them in terms of stocks and flows.

In the **Bathtub Dynamics** systems exercise, students graph the change over time of the volume of water in a bathtub. After working through the graphing exercise, students learn how understanding a bathtub can help them avoid a common confusion regarding climate change. For more details, see the slide presentation, instructions, and worksheet on the Activity 2 webpage.

Another systems exercise, **Riddle Me This,** enables students to explore the speed at which changes in complex systems can occur due to reinforcing feedback loops in the system. Reinforcing feedback can lead to changes that happen much faster than people expect when one variable increases as a consequence of its value—a pattern called ***exponential growth.*** This exercise contains three puzzles to help students practice thinking about exponential growth. It is also found on the Activity 2 webpage.

Several additional climate change information and education resources are found on the module website (https://sfcc.plt.org).

Enrichment

Have students create a few questions that they could use to interview at least three adults (e.g., family, neighbors) to learn more about other people's knowledge and views on climate change. Students should compile their data and summarize what they learned in a short paper.

Additional Resources

Climate Change: Evidence and Causes
National Academy of Sciences and the Royal Society, The National Academies Press, 2014
http://www.nap.edu/catalog.php?record_id=18730
This short pdf booklet provides clear answers to 20 common questions and background basics to climate change science.

Climate Change: Evidence, Impacts, and Choices: Answers to Common Questions about the Science of Climate Change
National Research Council, 2012
http://nas-sites.org/americasclimatechoices/files/2012/06/19014_cvtx_R1.pdf
This booklet summarizes the current state of knowledge about climate change, explains some impacts expected in the 21st century and beyond, and examines how science can help inform choices about managing and reducing the risks posed by climate change.

Climate Literacy Guidelines: The Essential Principles of Climate Science
U.S. Global Change Research Program, 2009
www.globalchange.gov/resources/educators/climate-literacy
This guide presents information for individuals and communities that want to learn about climate, impacts of climate change, and approaches to mitigation and adaptation.

The Climate Reality Project, Videos
The Climate Reality Project
http://climaterealityproject.org/video/
This website has several videos about climate change, carbon emissions, and

Students will likely be interested in knowing what types of actions can be implemented by communities and organizations to address climate change.

CENTRALINA CLEAN FUELS COALITION

solutions. Be sure to check out "Climate 101 with Bill Nye" to get a brief explanation of climate change and its potential effects on our planet.

Misconceptions about Science
University of California Museum of Paleontology
http://undsci.berkeley.edu/teaching/misconceptions.php
This portion of the Understanding Science website is dedicated to addressing misconceptions about the scientific process and includes explanations of some scientific terms that students might misunderstand.

Regional Climate Trends and Scenarios for the U.S. National Climate Assessment
U.S. Department of Commerce NOAA Technical Report
http://www.nesdis.noaa.gov/technical_reports/NOAA_NESDIS_Tech_Report_142-9-Climate_of_the_Contiguous_United_States.pdf
This document is one of the series of regional climate descriptions designed to provide input that can be used in the development of the National Climate Assessment.

Skeptical Science: Getting Skeptical about Global Warming Skepticism
John Cook, Global Change Institute at the University of Queensland
www.skepticalscience.com
This website reviews scientific, peer-reviewed literature to help explain climate change and to address common misconceptions about climate change.

Southeast Region Technical Report to the National Climate Assessment
Keith Ingram, Kirstin Dow, and Lynne Carter; 2012
http://downloads.usgcrp.gov/NCA/Activities/NCA_SE_Technical_Report_FINAL_7-23-12.pdf
This report summarizes the scientific literature that addresses climate impacts for the Southeast United States with a focus on literature published since 2004, and includes a chapter that specifically examines climate change and forests.

Teaching Controversy
Mark McCaffrey, 2012
http://www.nestanet.org/cms/sites/default/files/journal/Fall12.pdf
The author discusses why teachers should

not present climate change as a "theory" open for debate, but instead should focus on helping students understand climate change and the supporting scientific research. This article is part of a special issue on climate change education in *The Earth Scientist* published by the National Earth Science Teachers Association.

Yale Project on Climate Change Communication
Yale University
http://environment.yale.edu/climate
This website provides several reports, videos, and other resources that help explain research related to public knowledge and perceptions of climate change.

Your Warming World Interactive Map
New Scientist
http://warmingworld.newscientistapps.com
This interactive map allows users to click on any location on the planet and see a graph that shows differences in surface temperatures from 1880 to the present, relative to average temperatures for the three decades from 1951 to 1980.

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Fact or Fiction

NAME DATE

Please circle whether you think each of the following statements is or is not supported by scientific evidence. You can also circle that you do not know.

1. The Earth's climate is changing due to global warming.

   Supported by science Not supported by science I don't know

2. Climate change will affect regions of the Earth differently, with some areas becoming wetter and others becoming drier.

   Supported by science Not supported by science I don't know

3. The impacts of climate change will not really affect people or the systems we depend upon (such as food, water, places to live, etc.), just temperature.

   Supported by science Not supported by science I don't know

4. Sea level rise is mostly caused by melting icebergs and ice sheets.

   Supported by science Not supported by science I don't know

5. Burning fossil fuels is the only cause of global warming.

   Supported by science Not supported by science I don't know

6. Seasonal melting of Arctic Sea ice and glaciers is evidence of climate change.

   Supported by science Not supported by science I don't know

7. The greenhouse effect is a natural process that supports life on Earth.

   Supported by science Not supported by science I don't know

8. Many climate scientists disagree about the causes of climate change.

   Supported by science Not supported by science I don't know

Emily's Perspective on the

Natural Causes of Climate Change

NAME DATE

Imagine your friend Emily tells you she has been learning about the causes of climate change from reading and listening to news reports, searching the Internet, and talking with friends. All the information she has learned is **accurate and science-based.** However, the conclusion Emily makes using this information is **NOT** supported by science. Here's what Emily said.

Climate has changed in the past, and those changes were caused by several factors that are natural. Natural factors include variations in volcanic eruptions, solar flares, greenhouse gas concentrations, and other factors. In particular, concentrations of greenhouse gases, like carbon dioxide, have naturally fluctuated over time. The amount of carbon dioxide emitted from human activities is a tiny fraction of the total carbon cycling through the atmosphere, land, and oceans. Natural carbon dioxide emissions are 766 billion tons per year; human carbon dioxide emissions are only 20 billion tons per year. This current fluctuation in climate is similar to historic climate changes because human activities have not added that much carbon dioxide to the atmosphere. Therefore, climate change is a natural process that human activity is not impacting.

1. What were your initial thoughts as you read the paragraph?

2. What are the assumptions Emily makes to arrive at her conclusion?

3. What science-based information is relevant, but missing, from what Emily learned?

4. What would you say to Emily? REWRITE the conclusion to be more accurate, based on the additional information that challenges the conclusion.

Jamie's Perspective on the

Human Causes of Climate Change

NAME DATE

Imagine your friend Jamie tells you he has been learning about the causes of climate change from reading and listening to news reports, searching the Internet, and talking with friends. All the information he has learned is **accurate and science-based.** However, the conclusion Jamie makes using this information is **NOT** supported by science. Here's what Jamie said.

Many factors affect the global climate of the Earth. The key factor to consider regarding climate change is carbon dioxide. By burning fossil fuels, such as oil, natural gas, and coal, we have increased the amount of carbon dioxide in the atmosphere and changed where the carbon can be found. The level of atmospheric carbon dioxide is higher now than it has been over the past 800,000 years. This increased amount of carbon traps more of the heat radiated from the Earth's surface, which amplifies the greenhouse effect. In addition, land-use changes have altered vegetation patterns around the globe. Deforestation has resulted in fewer trees to remove and store carbon through photosynthesis. These land-use changes have also affected levels of atmospheric carbon. The impact of human activities on carbon in the atmosphere and ocean is so large that it completely overshadows any natural causes of climate change. Therefore, while natural factors have played a role in the past, current and projected climate changes are only the result of human activities.

1. What were your initial thoughts as you read the paragraph?

2. What are the assumptions Jamie makes to arrive at his conclusion?

3. What science-based information is relevant, but missing, from what Jamie learned?

4. What would you say to Jamie? REWRITE the conclusion to be more accurate, based on the additional information that challenges the conclusion.

Micah's Perspective on the

Greenhouse Effect

NAME DATE

Imagine your friend Micah tells you he has been learning about the greenhouse effect from reading and listening to news reports, searching the Internet, and talking with friends. All the information he has learned is **accurate and science-based.** However, the conclusion Micah makes using this information is **NOT** supported by science. Here's what Micah said:

Several gases contribute to the greenhouse effect, including carbon dioxide (CO_2), methane (CH_4), ozone (O_3), and nitrous oxide (N_2O). These gases absorb heat radiating off of the earth and trap that heat within the atmosphere. Greenhouse gas emissions have increased since the Industrial Revolution, which has amplified the greenhouse effect. Scientists have noted that this rise in greenhouse gases coincides with rises in overall global temperature. According to existing climate models, global temperatures are expected to rise anywhere between 2 and 11.5 degrees Fahrenheit by the year 2100. Results of global temperature changes of this magnitude include sea level rise, increase in ocean acidity, decrease in snowfall and permafrost, and changes in precipitation. The greenhouse effect is a negative and harmful process because it is warming the planet and creating climate change.

1. What were your initial thoughts as you read the paragraph?

2. What are the assumptions Micah makes to arrive at his conclusion?

3. What science-based information is relevant, but missing, from what Micah learned?

4. What would you say to Micah? REWRITE the conclusion to be more accurate, based on the additional information that challenges the conclusion.

Jayden's Perspective on the

Effects of Climate Change

NAME DATE

Imagine your friend Jayden tells you she has been learning about the effects of climate change from reading and listening to news reports, searching the Internet, and talking with friends. All the information she has learned is **accurate and science-based.** However, the conclusion Jayden makes using this information is **NOT** supported by science. Here's what Jayden said.

After analyzing climate observations, measurements, and data collected around the world, most climate scientists agree that the average surface temperature of the Earth is increasing. This is known as global warming. Most scientists also agree that human activities, which are increasing atmospheric levels of greenhouse gases, are partially responsible for this warming. As a result, the entire planet is and will continue to warm in the years to come. This warming will affect weather patterns around the world, changing climate averages and causing extremes in temperature and precipitation. The greenhouse gases that are causing global warming are found in the atmosphere, and the atmosphere surrounds the entire globe equally. Therefore, everywhere on Earth will be hotter and drier.

1. What were your initial thoughts as you read the paragraph?

2. What are the assumptions Jayden makes to arrive at her conclusion?

3. What science-based information is relevant, but missing, from what Jayden learned?

4. What would you say to Jayden? REWRITE the conclusion to be more accurate, based on the additional information that challenges the conclusion.

Climate Change Role Cards (1 of 2)

CATEGORY 1	**CASEY.** You are very concerned about climate change; you believe it is happening and that it is caused mostly by human actions. In particular, you know that burning coal, natural gas, and oil for energy production is increasing the amount of carbon dioxide in our atmosphere, which is causing climate change. You believe that people need to take immediate and substantial action to reduce atmospheric carbon dioxide and to adapt to projected changes in temperature, precipitation, and weather events. This is not a political issue to you but a matter of maintaining life on Earth. You heard about a tree planting campaign and are interested in starting something similar in your town.
	MORGAN. As a religious youth leader in your community, you have strong faith and believe that God created the world and will take care of the Earth. At the same time, you believe that humans are responsible for their actions. You believe that climate change is happening and it is mostly due to human actions. And, you are greatly concerned about the impacts of climate change in your community, such as extreme weather and its effects on both people's health and the surrounding forests and wildlife. You have spent much time thinking about climate change and it is a big concern for you. You believe that we are obligated to leave future generations a healthy planet.
CATEGORY 2	**KENDALL.** You work for a local environmental organization called Carbon Sink. You are very concerned about climate change; you believe it is happening and that it is caused mostly by human actions. In particular, you know that burning coal, natural gas, and oil for energy production is increasing the amount of carbon dioxide in our atmosphere, which is causing climate change. You believe that people need to take immediate and substantial action to reduce atmospheric carbon dioxide and to adapt to projected changes in temperature, precipitation, and weather events. This is not a political issue to you but a matter of maintaining life on Earth. You heard about a campaign to reduce fossil fuel dependence and you are interested in starting something similar in your local community.
	JESSIE. You work for a small grocery store in your town. You believe that climate is changing due to a combination of natural causes and human activities. Humans are playing a large role in increasing and accelerating natural climate change. You think that practical solutions are needed at the local, regional, national, and global level. However, you are concerned that people might not be willing to make large behavior changes for benefits that will occur in the future. You think that climate change solutions need to have more immediate benefits so that people will be more likely to adopt them. For example, reducing fossil fuel use saves people money, reduces air pollution, and helps reduce atmosphere carbon dioxide.
	QUINN. You are a school teacher, and you believe that climate is changing as a result of natural causes and human activities. You understand that humans are playing a large role in increasing and accelerating natural climate change. You believe that educating youth about climate change is the most important way to change behavior, since one day your students will be making decisions and voting as adults. In your classroom, you teach about the scientific process and how scientists use data to make conclusions. You are also interested in community education programs that teach adults and families about the environment and sustainable solutions for environmental issues.

Climate Change Role Cards (2 of 2)

CATEGORY 3	**KRIS.** You believe that climate change is happening, but that the climate has been changing for a long time and humans have nothing to do with it. Therefore, there is no way for people to affect climate change because they have no control over the climate. This theory about human-influenced climate change is all part of a political agenda and scientists are supporting it to fund their research. We really shouldn't be spending so much effort researching causes and solutions for climate change. We should focus on people's ability to adapt to this new climate, for example, by changing food production strategies or by improving community preparedness and disaster response.
	HARPER. You have strong faith and believe that God created a perfect world and there is nothing humans can do to affect it. In your mind, climate has been changing for a long time and humans have nothing to do with it. Therefore, there is no way for people to affect climate change. This theory about human-influenced climate change is all media hype. We really shouldn't be spending so much effort researching causes and solutions for climate change. We should focus on people's ability to adapt to this new climate, for example, by changing food production strategies or by improving community preparedness and disaster response.
CATEGORY 4	**TAYLOR.** You believe that the science on climate change is not at all clear. The news reports are contradictory. For example, when there is a heat wave, the headlines read "Global Warming Effects Being Felt in the Southeast!" But when we have a colder winter than usual, the headlines changes to "Snow in the Southeast? Who Said the Climate is Warming?" There are scientists on both sides of the issue making different conclusions about whether it is happening, the causes, and the effects. Once the science has been settled, and the news media are consistent, you will be receptive to either side. You are just not sure that we should be taking action on climate change when there is so much that is still being debated.
	JORDAN. You work for an international company and have traveled to different countries. You believe that the science on climate change is not at all clear. The news reports are contradictory. But you do know that some countries are already doing a lot to adapt to climate changes and other countries are very vulnerable to future disasters. Floods, typhoons, and drought will affect developing countries more severely than they affect the United States. You are confused, but you also care about people around the world. But you aren't sure what you can do.
	SAM. You believe that climate change is happening but you are not sure whether it is due to natural or human causes. You are also unsure whether or not a change to the climate is a bad thing. You do not spend much time thinking about climate change, so it is not a big concern for you. However, you are greatly concerned about other environmental issues, such as air pollution in your city and its effects on people's health and the surrounding forests and wildlife. Also, you think natural resource conservation is a good idea to ensure both healthy environments and productive economies for future generations.

Role-play Guide (1 of 2)

Before the Role-play

SCENARIO

You are a resident in the medium-sized town of Centerville. Due to your knowledge and leadership, the mayor of Centerville has appointed you to the Climate Change Adaptation and Mitigation Council. The mayor is concerned about the potential impacts of climate change and recognizes that there are a variety of beliefs in the community. While you may not agree with all the climate change issues, you are interested in community well-being, environmental health, and a thriving local economy.

The task for committee members is to work together to find a solution to help the community address potential climate changes. First, brainstorm at least four potential actions. Then select the best idea based on the criteria provided on page 2 of this worksheet. Develop that idea into a more detailed action plan to present to the mayor. You want to find a way to support the community effort, even if you don't fully agree with the reasons some group members provide.

Read the scenario and your role card. Fill out the "My Role" box to prepare your introduction when the role-play begins. Remember, for this activity it is important for you to imagine you are the person described in your role card, even if you do not agree with that position.

MY ROLE

Name:_____

Your ideas and opinions about climate change:

One initial idea for an action you are willing to support:

Role-play Guide (2 of 2)

In the left column, write the title of each action your group considers. Then, use the four criteria described below to discuss the advantages and disadvantages of each action. Rate each criterion as high, medium, or low and record the rating in the table. After discussing all the actions, compare them to one another and chose the "best" action for your community. The best action could be the one that has the most impact, the one that is the easiest to implement, or the one that is easiest to agree upon. Just be ready to justify your decision as a group!

CRITERIA					
	GHG Emissions Reduction Benefit	**Technical Feasibility**	**Cost Efficiency**	**Community Acceptability**	**Additional Comments**
ACTION 1:					
ACTION 2:					
ACTION 3:					
ACTION 4:					

Use the following criteria to evaluate the suggested actions for your community (American Public Transportation Association, 2011):

- **Greenhouse Gas Emissions Reduction Benefit:** Does the proposed action reduce greenhouse gases? In what way—by sequestering atmospheric carbon dioxide or by reducing emissions?
- **Technical Feasibility:** Does technology already exist to implement the proposed action? How easy is this action going to be to implement?
- **Cost Efficient:** How expensive will this action be? Will it result in long-term savings? How will the project be funded?
- **Community Acceptability:** How will citizens feel about this action? Who benefits from this action? In what ways? Who might be negatively impacted from this action? In what ways?