RESOURCE LIBRARY I LESSON

Carbon Concerns

Students explore climate change and global warming with multimedia. They create a model of the greenhouse effect and then refine their findings using a demonstration and interactive. Next, students research and diagram carbon sources and sinks. Finally, they organize and analyze data to draw evidence-based conclusions regarding atmospheric carbon concentrations and local emissions. This lesson is part of the *Climate Change Challenge* unit.

GRADES

6, 7, 8

SUBJECTS

Conservation, Earth Science, Climatology

CONTENTS

5 Activities

ACTIVITY 1: HEATING UP I 50 MINS

DIRECTIONS

This activity is part of the Climate Change Challenge unit.

1. Facilitate a gallery walk to help students link climate change with its causes and consequences.

- Place copies of images from *The Greenhouse Effect and our Planet* around the perimeter of the classroom (or show sequentially using a projector).Focus and connect students to evidence of climate change and/or global warming in the photographs by asking:
  - *What do you see in this image, and how do you think it relates to changes in Earth's climate?*

    - (For each of these images, see the online caption for a description of the subject and its relation to climate change. Students may need help with some images more than others; this may be their first exposure to the fact that cattle ranching relates to climate change, for example).

- When students have completed the gallery walk, ask them to share their answers, keeping track of their ideas in a visible place. Prompt students to similarly record their own and peers' responses in their notes, which they will use in constructing the *Know and Need to Know* chart in Step 4.

2. Show a video depicting an impact of climate change and facilitate a student discussion in response to the content.

- Introduce the *Climate Change and California's Drought* video (1:49), previewing the following questions for students:
    - *What extreme weather event is occurring in this video?* (Drought)
    - *What evidence from the video demonstrates that this weather event is extreme?* (The reservoir is extremely low; water is far from docks and parking.)

- After the video viewing and discussion of factual information, connect to students' lives by drawing out their prior knowledge and experiences with the following question:
    - *What extreme weather events have you experienced in your lifetime?* (Student responses may vary. It may be helpful to bring up recent local events, to distinguish between weather and other events (such as earthquakes), and to prompt students to think of tornadoes, hurricanes, blizzards, and/or floods. Students from across the country and world may share interesting examples!)

3. Guide students as they define and distinguish climate change and global warming through short readings and a discussion.

- Assign half of the class to read the encyclopedic entry *Climate Change* individually or in pairs. Assign the other half to read the encyclopedic entry *Global Warming*. Prompt students to annotate as they read, especially relating to any text that describes the relationship between these terms.After students have finished reading, build conceptual understanding and reinforce differences between the two terms with the *Heating Up Meaning Maker* handout.

- Ask volunteers to contribute a definition for *climate change* and *global warming* in their own words, based on their respective readings. Edit and record these definitions in a visible location, such that students can complete both in the *Heating Up Meaning Maker*, regardless of their article topic.
- Invite students to list some characteristics or think of a way they could illustrate each conceptual term, and again, give students time to complete this element in their *Heating Up Meaning Maker*.
- Brainstorm examples and non-examples of each term as a class, focusing in particular on those that distinguish climate change from global warming.
    - For a relevant example, refer to the video from Step 2, showing how climate change can involve events such as drought, which are more complex than warming alone.

4. Introduce the unit challenge and record students' pre-existing knowledge and questions in a *Know and Need to Know* chart.

- Explain that the video *Causes and Effects of Climate Change* (2:49) will provide key information in response to the unit driving question: *How can we communicate evidence of climate change to convince our community to act?*Before showing the video, preview questions for students to consider as they watch:
    - *What are some pieces of evidence for global climate change?*
    - *Why is it important for us to slow and reverse the effects of climate change?* (Possible responses within the video or from students' prior knowledge)
- Show the video and then discuss volunteers' responses to the above questions, writing them in a visible location for use in the *Know and Need to Know* chart later in this step.Using these student responses as motivation, introduce the project for the *Climate Change Challenge* unit: Students will learn to communicate the relevance and reality of climate change. They will also design a Climate Change Challenge Pledge, asking community members to help take action to address the causes and effects of climate change on planet Earth. To prepare for this, students will examine local and global data, storing their analyses in a digital portfolio throughout the unit.Create a *Know and Need to*

Know chart based on the unit and its driving question. Ask students to discuss with a partner:

- *What do we already know about the evidence for causes and effects of climate change?*
- *What do we need to know about the evidence for causes and effects of climate change to convince our community to act?*

- Tell students they will revisit the chart throughout the unit as they learn new content and develop new questions. Keep the chart in a visible place in the classroom or easily accessible online for student use.

Tip

Step 1: *Cornell Notes*, a system to help students record and retain information, is one of many possibilities for structuring note taking. If you are using this system in your classroom, students can draw out key points from their notes as an exit ticket, or write a summary for homework to provide review and spacing.

Tip

Step 2: The *Heating Up Meaning Maker* is a version of the *Frayer Model chart*; the video and resource linked here can help you adapt this vocabulary-building tool to meet the needs of your students.

Tip

Step 3: Although students will explicitly encounter the differences between climate and weather during Lesson 2, it may be helpful to support them here in distinguishing between weather events (such as a single drought) and long-term weather patterns (more frequent droughts over multiple decades), which constitute climate.

Informal Assessment

Informally assess students' prior knowledge of global warming and climate change through their responses to the videos and gallery walk, as well as through the insights and questions they bring to the *Know and Need to Know* chart.

OBJECTIVES

Subjects & Disciplines

- Conservation

  Earth Science
  - Climatology

Learning Objectives

Students will:

- Read to compare and contrast the terms climate change and global warming.
- Begin to link climate change and global warming with their causes and consequences.
- Orient to the driving question and project for the Climate Change Challenge unit.
- Collaborate to share prior knowledge and ask questions related to climate change and evidence of its causes and effects.

Teaching Approach

- Project-based learning

Teaching Methods

- Discussions
- Multimedia instruction
- Reading

Skills Summary

This activity targets the following skills:

- 21st Century Student Outcomes
  - Learning and Innovation Skills
    - Communication and Collaboration

    - Life and Career Skills
        - Initiative and Self-Direction
        - Social and Cross-Cultural Skills
- 21st Century Themes
    - Environmental Literacy
    - Global Awareness
- Critical Thinking Skills
    - Remembering
    - Understanding
- Science and Engineering Practices
    - Asking questions (for science) and defining problems (for engineering)

National Standards, Principles, and Practices

COMMON CORE STATE STANDARDS FOR ENGLISH LANGUAGE ARTS & LITERACY

• CCSS.ELA-LITERACY.RST.6-8.4:
Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics.

NEXT GENERATION SCIENCE STANDARDS

• Crosscutting Concept 2: Cause and Effect:
Cause and effect relationships may be used to predict phenomena in natural or designed systems.
• MS. Earth and Human Activity:
MS-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.
• Science and Engineering Practice 1:
Asking questions and defining problems

Preparation

BACKGROUND & VOCABULARY

Background Information

Climate change is a broad term for the many ways that Earth’s long-term weather patterns can change. Earth’s climate has always changed, for example, with periods of warmer or colder temperatures, and these periods often last thousands or millions of years. Recently, however, Earth’s climate has begun to warm at a rapid pace, relative to previous changes. This is called global warming, and it has led to many other changes, such as the melting of glaciers and rising sea levels.

An increase in the greenhouse effect is responsible for the recent rapid pace of global warming. This phenomenon occurs when certain gases, called greenhouse gases, such as carbon dioxide, trap energy from sunlight inside Earth’s atmosphere, gradually heating the surface of the planet. Many greenhouse gases are byproducts of human activities, like the burning of fossil fuels. As a result, the vast majority of scientists accept that these human activities are responsible for increasing the rate of global warming.

Prior Knowledge

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Recommended Prior Activities

- None

Vocabulary

Term	Part of Speech	Definition
climate	*noun*	all weather conditions for a given location over a period of time.
climate change	*noun*	gradual changes in all the interconnected weather elements on our planet.
drought	*noun*	period of greatly reduced precipitation.
global warming	*noun*	increase in the average temperature of the Earth's air and oceans.
reservoir	*noun*	large, concentrated supply or reserve.

Term	Part of Speech	Definition
weather	*noun*	state of the atmosphere, including temperature, atmospheric pressure, wind, humidity, precipitation, and cloudiness.

ACTIVITY 2: OUR GREENHOUSE | 1 HR 15 MINS

DIRECTIONS

This activity is part of the Climate Change Challenge unit.

1. Facilitate the design of an initial conceptual model of the greenhouse effect using a reading.

- Distribute the leveled article *Greenhouse Effect*. Assign students to read and annotate the first section of the article individually, highlighting or circling the following terms:
    - *Greenhouse gases*
    - *Atmosphere*
    - *Sunlight (sun's light)*
    - *Earth's surface*
    - *Heat*
- Have students Think-Pair-Share to assess the role each of these terms plays in the greenhouse effect.
    - Distribute the *Our Greenhouse Models* worksheet to students, and prompt students to use the reading and their notes to complete Part A. Their visual, conceptual model should contain each of the terms discussed previously, with these elements and their relationships clearly labeled.
- Connect students' models and initial ideas from the reading to the conclusions of the *Heating Up* activity, and explain that, today, they will collect their own data and use models to explain the processes responsible for global warming.

2. Demonstrate the greenhouse effect using a physical model and have students record and analyze resulting data.

- Introduce students to a physical model of the greenhouse effect.
  - See the *Setup* section for instructions on how to create this model prior to class.
  - Clearly emphasize the presence of carbon dioxide in the atmosphere within one bottle and its absence in the other.
- Have students Think-Pair-Share to relate this physical model to their visual, conceptual model with the following questions:
  - *How do the pieces of this model (lamp, bottles, bubbles, water, temperature) relate to your model of the greenhouse effect?* (The lamp models sunlight, the bottles model the atmosphere. The bubbles are made of carbon dioxide. Water models the Earth's surface, and temperature measures the heat produced.)
  - *What is your hypothesis for how the temperature will compare between these two bottles after we measure them for 20 minutes?* (Student hypotheses may vary but should include a statement regarding the relative temperature in the two bottles, and a justification using prior knowledge.)
- Turn students' attention to Part B of *Our Greenhouse Models*. Ask students to record temperatures in each bottle every 15 minutes until all three readings are taken.
  - Use the intervening times to introduce the definitions of mean, median, and range, and practice calculating each.
- If students have prior knowledge of the terms *mean, median,* and *range*, solicit student definitions of these terms. Otherwise, introduce them, encouraging students to record definitions in their own words for their notes.
  - *Mean* (Also known as the average. Mean is calculated by adding a group of observations, and then dividing by the number of observations in the data).
  - *Median* (This is the 'middle' number in a set of observations put in order from smallest to largest. If there are an even number of observations, the median is the mean of the middle two.)
  - *Range* (The difference between the smallest and largest value in a set of numbers. It gives a sense of the amount of variation in the dataset.)
  - Model calculating mean, median, and range with hypothetical temperature data, in an I do, we do, you do format. For example: *68, 64, 68* (Rewrite numbers in order (64, 68, 68) and then calculate Mean: (64+68+68)/3 = 65.33; Median: 68; Range: 68-64 = 4.)

- Calculate mean, median, and range for the greenhouse effect data (extra carbon dioxide/seltzer) and the no greenhouse effect data (air/water). Discuss these statistics with the class by asking:
    - *How did these data change over time, from Reading 1 to Reading 3? Why?*
    - (Readings for both bottles likely increase with time, because the lamp heats the 'atmosphere' inside the bottles.)
    - *Which mean/median/range is higher? Why?*
    - (Mean and median for the greenhouse effect bottle will be higher, if the model has run for an extended period of time, such as 20 minutes. This is because the greenhouse gas carbon dioxide is helping the atmosphere inside that bottle trap more heat. Range may or may not be different for the two.)
    - *Was your temperature comparison hypothesis from before the experiment correct?*
    - (Student responses will vary, but look for novel incorporation of information related to the greenhouse effect as students revise their understanding.)

3. Use an interactive to help students revise conceptual models of the greenhouse effect.

- Introduce students to the *Carbon Dioxide in the Atmosphere* online interactive by projecting it, explaining that this tool will help them to build on their growing knowledge of the greenhouse effect. Use the following elements to demonstrate how releasing more carbon dioxide causes an increase in temperature and track an energy packet through the environment:
    - The Key (identifies carbon dioxide, heat, and solar radiation – sunlight). Click "Show Key" in the top left-hand corner of the interactive.
    - The *Play* button (necessary to start the interactive).
    - The *Erupt* button (necessary to release carbon dioxide into the atmosphere).
    - The *Slow-Fast* switch (slowing the interactive down is necessary to see the details of the greenhouse effect).
    - The *Follow energy packet* and *Follow CO_2* buttons (using these will make it much easier to see the details of the greenhouse effect).
    - The graphs (Air temperature and CO_2 graphs help students relate these two model components).
- Based on this model, assign students to revise their model of the greenhouse effect in Part C of the *Our Greenhouse Models* handout. Prompt students to incorporate the terms *greenhouse gases, atmosphere, sun's light (sunlight), Earth's surface,* and *heat* and their relationships, and using symbols such as arrows accompanied by + or - to show how one

element might influence another. Regardless of the accuracy of their initial model, students can illustrate this effect again in a novel way.Ask for volunteers to share their revised models with the class, and use information from these models to update the class unit *Know and Need to Know* chart,regarding the greenhouse effect. Prompt all students to complete Part D of the *Our Greenhouse Models* handout explaining what they learned from data collection and the interactive that helped them revise their model, as a reflection on their learning in this activity.

- Specifically, students might name general conclusions from data collection (the bottle with carbon dioxide heats more quickly under light than the bottle with air) or particular actions of the model elements (greenhouse gases, atmosphere, sunlight, heat, and Earth's surface) that they witnessed in the interactive.

Tip

Step 1: It may help students to view a *simple diagram* of the greenhouse effect as they read. Additionally, you may wish to elicit prior understanding in a low-stakes way by having students create their initial explanatory models. Then, have them revisit the models to see and show how their thinking changes as they learn, demonstrating a growth mindset approach. To learn more about explanatory models, read about engaging students in modeling from the *STEM Teaching Tools* website. Explore different model structures to use (small group, whole group, and so on) from the *Ambitious Science Teaching* website.

Tip

Step 2: Setting up the physical model of the greenhouse effect prior to using it in the classroom and testing its results using your own equipment may help you time when to begin this demonstration and anticipate any challenges that might occur. You may note that if the light was turned on at the beginning of the class period or day, differences might already be evident by the start of each class period. The goal is less for students to witness this process from start to finish, and more for them to collect multiple data points from which to calculate the descriptive statistics' mean, median, and range.

Modification

Step 3: After students have revised their models, consider organizing a gallery walk to view their peers' ideas (and possibly engaging in a final round of individual model revision), before coming to consensus through discussion.

Informal Assessment

Informally assess students' initial and revised models of the greenhouse effect. Look for the incorporation of all elements and a visual expression of their relationships in the diagram. For example, the transfer of energy from sunlight to Earth's surface and its re-emergence as heat might be depicted with a shape for each term, and arrows to show movement.

OBJECTIVES

Subjects & Disciplines

Earth Science

- Climatology

Learning Objectives

Students will:

- Collect data and calculate summary statistics to verify the role of carbon dioxide in the greenhouse effect.
- Draw conclusions from a simulation with a physical and digital demonstration of the greenhouse effect.
- Develop and revise an explanatory model of the greenhouse effect.

Teaching Approach

- Project-based learning

Teaching Methods

- Cooperative learning
- Demonstrations
- Reading

Skills Summary

This activity targets the following skills:

- 21st Century Student Outcomes
  - Information, Media, and Technology Skills
    - Information, Communications, and Technology Literacy
  - Learning and Innovation Skills
    - Communication and Collaboration
    - Critical Thinking and Problem Solving
  - Life and Career Skills
    - Social and Cross-Cultural Skills
- 21st Century Themes
  - Environmental Literacy
  - Global Awareness
- Critical Thinking Skills
  - Analyzing
  - Applying
  - Understanding
- Science and Engineering Practices
  - Analyzing and interpreting data
  - Developing and using models
  - Using mathematics and computational thinking

National Standards, Principles, and Practices

NEXT GENERATION SCIENCE STANDARDS

• **Crosscutting Concept 2: Cause and Effect:**
Cause and effect relationships may be used to predict phenomena in natural or designed systems.
• **MS. Earth and Human Activity:**
MS-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.
• **Science and Engineering Practice 2:**

Developing and using models

Preparation

BACKGROUND & VOCABULARY

Background Information

An increase in the greenhouse effect is responsible for the recent rapid pace of global warming. Carbon dioxide, methane, and nitrous oxide are all examples of greenhouse gases. They let the energy in sunlight pass through on its way towards Earth, but block the heat energy (created by sunlight striking the planet's surface) from leaving the atmosphere. This effect increases the average temperature on Earth.

Mean, median, and range are numbers used to summarize information about groups of observations; for this reason, they are called 'descriptive statistics.' To calculate the mean, divide the sum of all observations in a list by the number of observations. To find the median, choose the middle observation in an ordered list, or average the two middle observations if there are an even number of observations. To calculate the range, subtract the smallest observation in a list from the largest. These three descriptive statistics are useful for working with large amounts of data, in particular, to describe and compare the average observation or the spread of observations in two groups.

Prior Knowledge

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Recommended Prior Activities

- None

Vocabulary

Term	Part of Speech	Definition
atmosphere	*noun*	layers of gases surrounding a planet or other celestial body.

Term	Part of Speech	Definition
carbon dioxide	*noun*	greenhouse gas produced by animals during respiration and used by plants during photosynthesis. Carbon dioxide is also the byproduct of burning fossil fuels.
greenhouse gas	*noun*	gas in the atmosphere, such as carbon dioxide, methane, water vapor, and ozone, that absorbs solar heat reflected by the surface of the Earth, warming the atmosphere.
heat	*noun*	energy that causes a rise in temperature.
mean	*noun*	mathematical value between the two extremes of a set of numbers. Also called the average.
median	*adjective*	situated in the middle.
range	*noun*	difference between the smallest and largest value in a set of numbers.
sunlight	*noun*	visible radiation from the sun.

ACTIVITY 3: CARBON ALL AROUND | 50 MINS

DIRECTIONS

This activity is part of the Climate Change Challenge unit

1. Prompt students to define carbon source and carbon sink by reading an encyclopedia entry.

- To connect with knowledge from the prior activity, ask students to brainstorm responses to the following prompts:
  - *How does increasing the amount of carbon dioxide in the atmosphere change our planet?* (Students should recall from the previous lesson that additional carbon dioxide increases the greenhouse effect, which warms our planet).
  - *How do you think carbon dioxide gets into our atmosphere in the first place?* (Student answers will vary depending on prior experience, but may include burning fossil fuels).
  - *How do you think it comes out of the atmosphere?* (Student answers will again vary, but may include the uptake of carbon dioxide by green plants during photosynthesis).
- Assign students to read and annotate the *Carbon Sources and Sinks* encyclopedic entry. Explain that this article will help them become experts on the ways carbon dioxide enters

and leaves our atmosphere. Ask students to determine:

- *What is a carbon source, and what are some examples from the article?* (A process that releases carbon dioxide into the atmosphere; examples include burning fossil fuels, and raising livestock such as cattle.)
- *What is a carbon sink, and what are some examples from the article?* (A process that absorbs carbon dioxide from the atmosphere; examples include carbon dioxide absorption into the oceans and use by plants during photosynthesis.)

- Lead a brief class discussion to elicit student responses.
- Distribute the *Carbon Meaning Maker* handout. Direct students to complete the *Definition in your own words* section only for carbon source and carbon sinkat this time, using what they learned from the encyclopedia article.

2. Support students as they research specific carbon sources and sinks.

- Distribute the *Carbon Cycle* diagram and explain that this image depicts many carbon sources (represented by 'up' arrows) and sinks (represented by 'down' arrows) that are relevant to global warming on Earth.
    - In this diagram, information is presented on the amount of carbon moving between sources and sinks (numbers). This is less relevant to student learning than the direction of the arrows, and their association with physical, biological, and human elements, such as the ocean, organisms, and industry. Draw students' attention to the arrows and their associations. Explain that they will have help interpreting the sources and sinks using text and video sources after the class reviews an example together.
- Project the *Carbon Cycle* diagram and identify a familiar element, such as the smokestack, mentioned in the *Carbon Sources and Sinks* encyclopedia entry. Model this element's classification as a source or sink, as well as a description of the associated process, in a single sentence, for example:
    - *Source:* Burning fuels that contain ancient carbon releases carbon dioxide into the atmosphere
- In jigsaw pairs or small groups, assign students to perform their own research to become experts on either carbon sources or sinks. Have them write one-sentence descriptions of the processes that release or remove carbon from Earth's atmosphere for their diagrams

following the one-sentence model above. Resources available to identify a range of carbon sources and sinks include:

- *Carbon Sources and Sinks* encyclopedic entry
- *Amazon Deforestation and Climate Change* video (4:52)
- *Climate 101: Causes and Effects* video (2:49)
- *Climate 101: Deforestation* video (2:32)
- *Climate 101: Oceans* video (2:38)

3. Facilitate a jigsaw, in which students teach and learn about the carbon cycle from other students.

- Split initial expert pairs or small groups, and create mixed groups of students with one or more member(s) who focused on carbon sources, and one or more member(s) who focused on carbon sinks.Direct students to teach each other in their new pairs or small groups, adding their partners' elements to their diagrams, and asking clarifying questions if necessary.With the *Carbon Cycle* diagram projected, ask for volunteers to share out what they learned from group members' research. Have the volunteers add their one-sentence descriptions of carbon sources or sinks to the class diagram.
  - As students share out, highlight connections between their responses and global warming, as well as climate change.
- In a Think-Pair-Share, ask students to synthesize their understanding of sources and sinks by asking:
  - *Why do we refer to this diagram as the* carboncycle? (As carbon dioxide transitions between its many sources and sinks, it moves cyclically, hence the name "Carbon Cycle.")
- Prompt students to return to their *Carbon Meaning Maker* handout to complete the three additional elements (characteristics/illustration, examples, and non-examples), using what they have learned and recorded on their *Carbon Cycle* diagram.Return to the class *Know and Need to Know* chart, adding any insights or questions associated with the carbon cycle, as well as links between carbon sources/sinks and their previous work on climate change and global warming.

Tip

Steps 1 and 3: The *Meaning Maker* is a version of the *Frayer Model chart*. The video and resource linked here can help you adapt this vocabulary-building tool to meet the needs of your students.

Informal Assessment

Informally assess students' understanding of the carbon cycle by reading their one-sentence descriptions of carbon sources and sinks on the *Carbon Cycle* diagram and the *Carbon Meaning Maker* handout.

Extending the Learning

Step 2: Students can perform additional online research using search engines to classify and describe some of the more obscure carbon sources and sinks depicted in the *Carbon Cycle diagram*. They may benefit from teacher modeling of this task, asking questions such as, *What role does the surface of the ocean play in the carbon cycle?* and working to interpret search engine responses. You may also wish to have students perform research on how marine organisms incorporate carbon into their bodies.

To include information regarding other chemicals involved in the greenhouse effect, in addition to carbon dioxide, consider using NASA's *Climate Kids greenhouse cards*.

OBJECTIVES

Subjects & Disciplines

Earth Science

- Climatology

Learning Objectives

Students will:

- Read to compare and contrast the terms carbon source and carbon sink.
- Perform research and learn from peers to annotate a diagram of carbon sources and sinks.
- Link specific carbon sources and sinks to the greenhouse effect and global warming.

Teaching Approach

- Project-based learning

Teaching Methods

- Jigsaw
- Multimedia instruction
- Reading

Skills Summary

This activity targets the following skills:

- 21st Century Student Outcomes
  - Information, Media, and Technology Skills
    - Information, Communications, and Technology Literacy
    - Media Literacy
  - Learning and Innovation Skills
    - Communication and Collaboration
  - Life and Career Skills
    - Productivity and Accountability
- 21st Century Themes
  - Environmental Literacy
  - Global Awareness
- Critical Thinking Skills
  - Applying
  - Understanding
- Geographic Skills
  - Acquiring Geographic Information
  - Organizing Geographic Information
- Science and Engineering Practices
  - Obtaining, evaluating, and communicating information

National Standards, Principles, and Practices

COMMON CORE STATE STANDARDS FOR ENGLISH LANGUAGE ARTS & LITERACY

• **CCSS.ELA-LITERACY.SL.7.1**:
Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on Grade 7 topics, texts, and issues, building on others' ideas and expressing their own clearly.

NEXT GENERATION SCIENCE STANDARDS

• **Crosscutting Concept 2: Cause and Effect**:
Cause and effect relationships may be used to predict phenomena in natural or designed systems.
• **MS. Earth and Human Activity**:
MS-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.
• **Science and Engineering Practice 8**:
Obtaining, evaluating, and communicating information

Preparation

BACKGROUND & VOCABULARY

Background Information

An increase in the greenhouse effect is responsible for the recent rapid pace of global warming. Carbon dioxide, methane, and nitrous oxide are all examples of greenhouse gases. They let the energy in sunlight pass through on its way towards Earth, but block the heat energy (created by sunlight striking the planet's surface) from leaving the atmosphere. Although each of these greenhouse gases (and others) contributes to the heating of the planet, carbon dioxide emissions are the highest globally, so it contributes most to climate change.

Carbon source and *carbon sink* are two terms that refer to processes or activities that release or take up carbon dioxide, respectively. Major carbon sources include the burning of fossil fuels, as well as agriculture (farming and ranching). Major carbon sinks include Earth's growing forests, as well as the planet's deep oceans. These terms help us understand which processes or activities increase global warming through the production of this greenhouse gas, and which processes or activities reduce global warming instead.

Prior Knowledge

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Recommended Prior Activities

- None

Vocabulary

Term	Part of Speech	Definition
carbon cycle	*noun*	series of processes in which carbon (C) atoms circulate through Earth's land, ocean, atmosphere, and interior.
carbon sink	*noun*	area or ecosystem that absorbs more carbon dioxide than it releases.
carbon source	*noun*	process, area, or ecosystem that releases more carbon dioxide than it absorbs.
climate change	*noun*	gradual changes in all the interconnected weather elements on our planet.
fossil fuel	*noun*	coal, oil, or natural gas. Fossil fuels formed from the remains of ancient plants and animals.
global warming	*noun*	increase in the average temperature of the Earth's air and oceans.

ACTIVITY 4: GLOBAL TRENDS | 50 MINS

DIRECTIONS

This activity is part of the Climate Change Challenge unit.

1. Introduce global climate data collection with an encyclopedia article.

- Prompt students to recall prior knowledge in a Think-Pair-Share by asking:

- *What are some sources of carbon dioxide in our atmosphere?*
- *What are some carbon sinks?*

- (Student responses will vary, but will likely reflect sources and sinks from the carbon cycle diagram from the *Carbon All Around* activity.)
- Given their knowledge of carbon sources and sinks, assign students to predict how carbon dioxide in Earth's atmosphere has changed recently, and to write this hypothesis in their notes. Ask:

  - *Do you think carbon dioxide levels in our atmosphere have been increasing, decreasing, or staying the same? Why?* (Student hypotheses will vary but look for the inclusion of reasoning related to the greenhouse effect and carbon cycle.)

- Distribute copies of *The Keeling Curve* encyclopedia entry and assign students to read and annotate this article in pairs, previewing the questions for discussion to follow their reading:

  - *What is the Keeling Curve?* (A graph representing the concentration of carbon dioxide in Earth's atmosphere since 1958.)
  - *Why does the amount of carbon dioxide increase and decrease a small amount each year?* (The amount of carbon dioxide goes up in the winter when there is less photosynthesis and more plant decomposition releasing carbon dioxide (a carbon source). The amount of carbon dioxide goes down in spring and summer, when there is more plant photosynthesis absorbing carbon dioxide.)
  - *How does the Keeling Curve help you confirm or revise your hypothesis regarding carbon dioxide levels since 1950?* (Student responses will vary but should address their hypotheses with updated reasoning, if necessary.)

- Discuss volunteers' responses as a class.

2. Engage with an interactive Keeling Curve to compare short- and long-term carbon dioxide trends.

- Project the *SCRIPPS interactive Keeling Curve*. Explain that this resource will allow the class to "zoom in" on the Keeling Curve data, asking questions about the amount of carbon dioxide in the atmosphere right now and over time.

- With students, identify three critical elements of this graph (and others they will encounter in the unit):

  - Title (The title is frequently located above the graph. In this case, it is the current date, followed by "Carbon Dioxide Concentration at Mauna Loa Observatory").
  - Axis Labels (The x-axis label is typically found below this horizontal axis. In this case, it is a measure of the time or date. The y-axis label is typically found to the left of this vertical axis. In this case, it is a measure of the CO_2 concentration in parts per million (ppm)).
  - Key (if present). (The key helps to distinguish the nature of the data. It shows the meaning of colors or symbols, for example. In this case, the key helps to distinguish between averages taken at different time-scales).

- Moving the cursor over the following buttons, ask students to identify the direction of change (or trend) that they see in the data.

  - *One week* (Students will see daily fluctuations or cycles, but will not see an overall change.)
  - *One month* (Students may see a slight up or down trend, depending on the time of year.)
  - *Six months* (Students will see an up or down trend as part of the yearly fluctuation or cycle, depending on the time of year.)
  - *One year* (Students will see the yearly fluctuations or cycles. Prompt them to note whether the starting and ending points on the graph show a change.)
  - *Two years* (Students will see the yearly fluctuations or cycles. Prompt them again to note changes in the level of troughs and peaks in the curve.)
  - *Full record* (Only when the full record is visible is the long-term increase in carbon dioxide obvious).

- In a Think-Pair-Share, ask students to reflect on the following question:

  - *Why is it important for scientists to measure changes in carbon dioxide and the climate over long periods of time?* (Changes in long-term processes such as climate must be monitored over similarly long periods in order to accurately measure the trend).

3. Model data analysis across time to support student creation of an evidence-based carbon dioxide level comparison.

- Distribute the *Global Trends Calculation Tracker* handout to students.
- Ask volunteers to recall the meaning of mean, median, and range, using their notes from the *Our Greenhouse* activity. Record their definitions and any formulas they provide in a visible location.
- Project carbon dioxide data for twelve months of the first year (1959) in the *SCRIPPS Atmospheric CO_2 data* (use the monthly_in_situ_co2_mlo.csv link under "In situ CO_2 data"). Then model calculation of mean, median, and range for the 'CO_2 [ppm]' data by hand or with a calculator for these twelve months in a visible location, in a chart that mirrors Part A of the *Global Trends Calculation Tracker*.
- Repeat this step to model calculations with the whole class, using the last full year available in the dataset.
- Compare the mean, median, and range for these two years, asking students:
    - *Are these values different between 1959 and the most recent year?* (Yes, they are very different; the values for the current year are much higher.)
    - *Does this match what you saw in the Keeling Curve graphs?* (Yes, the Keeling Curve graphs also showed this increase over long periods of time.)
- Assign students to choose two other full years of data for which to compare mean, median, and range, and complete their calculations on Part A of the *Global Trends Calculation Tracker*.
    - They may wish to compare their birth year with the most recent full year, for example.
- Next, model how to write an evidence-based claim comparing 1959 and the most recent year. For example:
    - The year 2018 had more carbon dioxide than the year 1959: the mean and median are both over 90 ppm higher for 2018 than 1959, and these differences are much greater than the yearly ranges of only 4.96–5.71 ppm.
- Prompt students to reflect on the data from their two years of choice, and to write a similar evidence-based comparison of these years in Part B of their *Global Trends Calculation Tracker*.
- Revisit the class *Know and Need to Know* chart, prompting students to consider the connections between carbon sources, carbon dioxide levels in the atmosphere, and global temperatures.

Modification

Step 3: If students are already familiar with selecting, charting, and analyzing data digitally, they may move directly to calculating these statistics using a spreadsheet program, rather than the *Global Trends Calculation Tracker*. If students have less familiarity with digital technology, you may wish to wait until these skills are scaffolded in future lessons within the unit.

Informal Assessment

Informally assess students' ability to calculate mean, median, and range of months within years from carbon dioxide data, and to write evidence-based claims comparing years.

Extending the Learning

Step 1: Students can also read the encyclopedia entry *Mauna Loa Observatory* to gain an additional sense of where and how climate data are collected.

OBJECTIVES

Subjects & Disciplines

Earth Science

- Climatology

Learning Objectives

Students will:

- Analyze an interactive graph to identify short- and long-term trends.
- Write an evidence-based claim comparing carbon dioxide levels across years.

Teaching Approach

- Project-based learning

Teaching Methods

- Discussions
- Inquiry
- Reading

Skills Summary

This activity targets the following skills:

- 21st Century Student Outcomes
  - Information, Media, and Technology Skills
    - Information, Communications, and Technology Literacy
  - Learning and Innovation Skills
    - Communication and Collaboration
  - Life and Career Skills
    - Initiative and Self-Direction
- 21st Century Themes
  - Environmental Literacy
  - Global Awareness
- Critical Thinking Skills
  - Analyzing
  - Applying
- Science and Engineering Practices
  - Analyzing and interpreting data
  - Engaging in argument from evidence
  - Using mathematics and computational thinking

National Standards, Principles, and Practices

COMMON CORE STATE STANDARDS FOR ENGLISH LANGUAGE ARTS & LITERACY

• **CCSS.ELA-LITERACY.RST.6-8.7:**
Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).
• **CCSS.ELA-LITERACY.W.7.1.A:**

Introduce claim(s), acknowledge alternate or opposing claims, and organize the reasons and evidence logically.

NEXT GENERATION SCIENCE STANDARDS

• **Crosscutting Concept 1:**
Patterns
• **MS. Earth and Human Activity:**
MS-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.
• **Science and Engineering Practice 4:**
Analyzing and interpreting data
• **Science and Engineering Practice 5:**
Using mathematics and computational thinking
• **Science and Engineering Practice 7:**
Engaging in argument from evidence

Preparation

BACKGROUND & VOCABULARY

Background Information

In recent decades, carbon dioxide in Earth's atmosphere rose from approximately 315 to over 400 parts per million. The famous graph depicting this increase is called the Keeling Curve, after Charles David Keeling. Dr. Keeling began measuring carbon dioxide concentrations in 1958 at an observatory in Hawaii, and these measurements have continued to this day. Although yearly fluctuations in carbon dioxide concentrations occur as a result of photosynthesis by Earth's large northern forests, the overall trend shows a marked positive slope.

Mean, median, and range are numbers used to summarize information about groups of observations; for this reason, they are called 'descriptive statistics.' To calculate the mean, divide the sum of all observations in a list by the number of observations. To find the median, choose the middle observation in an ordered list, or average the two middle observations if there are an even number of observations. To calculate the range, subtract the smallest observation in a list from the largest. These three descriptive statistics are useful for working with large amounts of data, in particular, to describe and compare the average observation or the spread of observations in two groups.

Prior Knowledge

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Recommended Prior Activities

- None

Vocabulary

Term	Part of Speech	Definition
carbon dioxide	*noun*	greenhouse gas produced by animals during respiration and used by plants during photosynthesis. Carbon dioxide is also the byproduct of burning fossil fuels.
carbon sink	*noun*	area or ecosystem that absorbs more carbon dioxide than it releases.
carbon source	*noun*	process, area, or ecosystem that releases more carbon dioxide than it absorbs.
climate change	*noun*	gradual changes in all the interconnected weather elements on our planet.
global warming	*noun*	increase in the average temperature of the Earth's air and oceans.
Keeling curve	*adjective*	graph illustrating the amount of carbon dioxide (CO_2) in Earth's atmosphere as measured at the Mauna Loa Observatory in Hawaii.
mean	*noun*	mathematical value between the two extremes of a set of numbers. Also called the average.
median	*adjective*	situated in the middle.
range	*noun*	difference between the smallest and largest value in a set of numbers.

ACTIVITY 5: LOCAL EMISSIONS | 1 HR 15 MINS

DIRECTIONS

This activity is part of the Climate Change Challenge unit.

1. Model data analysis and response to an argument with evidence-based statements for students.

- Explain to students that today they will be working with a different dataset: one that shows how carbon dioxide emissions (carbon dioxide released into the atmosphere) have changed in each of the United States over time. Connect to knowledge from the *Global Trends* activity by asking students:

    - *Do you predict that our state's carbon dioxide emissions are going up or down over time?* (Student answers may vary, but should reference their understanding of global changes in carbon dioxide seen using the Keeling Curve and associated data).

- Project the EPA's *State CO2 Emissions from Fossil Fuel Combustion, 1990-2017* (XLSX version) from the EPA in a spreadsheet program. Find your state.Orient students to the form of the data by asking the following questions:

    - *What types of data are available here?* (Carbon emissions from commercial (businesses), industrial (manufacturing), residential (homes), transportation (vehicles), and electric power (electricity) sources. If time allows, students can look up the meaning of these terms and work through local examples; for example, the emissions from a pizza restaurant near the school would count as commercial.)
    - *What years is this information for?* (This data is available for every year from 1990 to 2017.)
    - *What are the units for these numbers?* (The units are million metric tons of carbon dioxide. That means a seemingly small number like 2.43 (Alabama's commercial emissions in 1990) actually means 2.43 x 1,000,000 x 2,204 lbs. = 5,355,720,000 lbs. or over 5 billion pounds of carbon dioxide. This is as much as 50 million students who each weigh 100 pounds!)

- Encourage students topractice asking questions about carbon dioxide emissions using data. Record suggestions for questions and corresponding data in a visible location:

    - *What are some questions about our state's emissions we could answer using this dataset?* (Students will likely bring up questions about the relative importance of different emissions types or changes in emissions over time.)
    - *What data would we need to address each of these questions?* (Help students move from suggesting single data points to choosing groups of data that could be

summarized with mean, median, and/or range to address the question).

- To help prepare students for the coming assessment, model responding to an argument about their state's carbon dioxide emissions with evidence from data.
  - Introduce a hypothetical argument made against your state, writing it in a visible location:
  - *Electricity use in your state is accelerating global warming: electric power carbon dioxide emissions went up from 1990–1994 to 2010–2014.*
  - Choose the data necessary to address this argument. Organize it in a visible location, using a chart that mirrors Part B of the *Local Emissions Analysis* handout (to be distributed to students in the next step).
  - Prompt students to help you calculate mean, median, and range for these data, entering the values in your chart.
  - Elicit help from students to create and record an evidence-based response to the argument in a visible place, such as:
  - *Electricity use in our state is accelerating global warming. The mean and median carbon dioxide emissions were lower from 1990 to 1994 than they were from 2010 to 2014, and the ranges for both periods were small compared to the differences between them.* (Note that all states do not show the same trends; some have shown progress in reducing carbon dioxide emissions in this comparison.)

2. Prompt students to ask questions and analyze arguments regarding local carbon dioxide emissions independently.

- Distribute a copy of the *State CO2 Emissions from Fossil Fuel Combustion, 1990–2017* data for your state and 2–3 neighboring states (see Teacher Tips below) and a copy of the *Local Emissions Analysis* handout to each student in class.
- Explain that their data analysis will be formally assessed and become part of their digital project portfolios and possibly chosen for incorporation to the Climate Challenge final product.
- Assign each student to choose one neighboring state they'd like to compare with their own for Part A of the *Local Emissions Analysis*, and to record this on their handout.
- Assign each student one of the three arguments listed in Part A of the *Local Emissions Analysis*, or allow students to choose an argument to address for themselves.Prompt students to complete Part B of the *Local Emissions Analysis* handout. They will:

- Choose data from the *State CO2 Emissions from Fossil Fuel Combustion, 1990–2017* that is relevant to the argument.
- Add the data to the chart, labeling each column.
- Calculate summary statistics from the data.

- After students have collected and analyzed data in Part B of the *Local Emissions Analysis*, direct them to complete Part C using the evidence-based statement developed in Step 1 above, as well as their evidence-based claim from the *Global Trends Calculation Tracker* as examples.Now that students are well-oriented to the data, have them complete Part D of the *Local Emissions Analysis*. Here, they must consider what additional questions they could address with this dataset and what data, in particular, would allow them to do so.

3. Facilitate self- and peer-assessments of carbon dioxide emissions analyses.

- Distribute two copies of the *Local Emissions Analysis Rubric* to each student.
- Assign students to complete one of the rubrics by examining their own work, and give time for students to revise their responses and analysis, if necessary.
- Assign students to use a second rubric to assess another student's work, preferably a peer who addressed a different argument. Give time for students to share their assessments with their partners, and to revise their responses and analysis if necessary.
- Collect the *Local Emissions Analysis* handout from all students for assessment.
- Return to the class *Know and Need to Know* chart. Add any new insights or questions associated with local carbon emissions and their connections to global trends, sinks and sources, global warming, or climate change.

Tip

Step 1: It may be helpful to prepare a copy of carbon dioxide emissions data from your state and a few neighboring states to share with students ahead of time. Use the EPA's *State CO2 Emissions from Fossil Fuel Combustion, 1990–2017*. The units in this chart are in Million Metric Tons of CO_2 ($MMTCO_2$). For a given number on the chart, multiply by 1,000,000 and then by 2,204 lbs./metric ton to get the number of pounds of carbon dioxide gas released by this sector in a year.

Rubric

Use the *Local Emissions Analysis Rubric* to formally assess students' progress towards NGSS PE *MS-ESS3-5*: Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.

Extending the Learning

Step 2: If students are already familiar with selecting, charting, and analyzing data digitally, have them perform the calculations for their assessment products in a spreadsheet program. In this case, you may also wish to have them create simple digital bar graphs of the means. If students have less familiarity with digital technology, you may wish to wait until these skills are scaffolded in future lessons within the unit.

OBJECTIVES

Subjects & Disciplines

- Conservation
  Earth Science
  - Climatology

Learning Objectives

Students will:

- Select and chart relevant carbon dioxide emissions data to address a claim about global warming.
- Independently calculate summary statistics from carbon dioxide emissions data.
- Begin to connect particular human activities with carbon dioxide emissions and global warming.

Teaching Approach

- Project-based learning

Teaching Methods

- Cooperative learning

- Modeling
- Reflection

Skills Summary

This activity targets the following skills:

- 21st Century Student Outcomes
    - Information, Media, and Technology Skills
        - Information, Communications, and Technology Literacy
    - Learning and Innovation Skills
        - Communication and Collaboration
        - Critical Thinking and Problem Solving
    - Life and Career Skills
        - Initiative and Self-Direction
        - Productivity and Accountability
        - Social and Cross-Cultural Skills
- 21st Century Themes
    - Environmental Literacy
    - Global Awareness
- Critical Thinking Skills
    - Analyzing
    - Applying
    - Evaluating
- Science and Engineering Practices
    - Analyzing and interpreting data
    - Engaging in argument from evidence
    - Using mathematics and computational thinking

National Standards, Principles, and Practices

COMMON CORE STATE STANDARDS FOR ENGLISH LANGUAGE ARTS & LITERACY

- **CCSS.ELA-LITERACY.WHST.6-8.1.B:**

Support claim(s) with logical reasoning and relevant, accurate data and evidence that demonstrate an understanding of the topic or text, using credible sources.

NEXT GENERATION SCIENCE STANDARDS

• **Crosscutting Concept 1:**
Patterns
• **MS. Earth and Human Activity:**
MS-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.
• **Science and Engineering Practice 4:**
Analyzing and interpreting data
• **Science and Engineering Practice 5:**
Using mathematics and computational thinking
• **Science and Engineering Practice 7:**
Engaging in argument from evidence

Preparation

BACKGROUND & VOCABULARY

Background Information

In the United States and across the world, a variety of different sectors contribute to carbon emissions. Burning fossil fuels for electricity, heat, and transportation are some of the biggest carbon sources, with manufacturing and agriculture playing a smaller role. Although many of these sectors are increasing efficiency, demand for energy around the world is growing quickly, often outpacing these gains.

Mean, median, and range are numbers used to summarize information about groups of observations; for this reason, they are called 'descriptive statistics.' To calculate the mean, divide the sum of all observations in a list by the number of observations. To find the median, choose the middle observation in an ordered list, or average the two middle observations if there are an even number of observations. To calculate the range, subtract the smallest observation in a list from the largest. These three descriptive statistics are useful for working with large amounts of data, in particular, to describe and compare the average observation or the spread of observations in two groups.

Prior Knowledge

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Recommended Prior Activities

- None

Vocabulary

Term	Part of Speech	Definition
carbon dioxide	*noun*	greenhouse gas produced by animals during respiration and used by plants during photosynthesis. Carbon dioxide is also the byproduct of burning fossil fuels.
carbon emission	*noun*	carbon compound (such as carbon dioxide) released into the atmosphere, often through human activity such as the burning of fossil fuels such as coal or gas.
carbon sink	*noun*	area or ecosystem that absorbs more carbon dioxide than it releases.
carbon source	*noun*	process, area, or ecosystem that releases more carbon dioxide than it absorbs.
climate change	*noun*	gradual changes in all the interconnected weather elements on our planet.
global warming	*noun*	increase in the average temperature of the Earth's air and oceans.

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