Smithsonian | SCIENCE *for Global Goals*

STARTING WITH SUSTAINABILITY

LESSON SET

ACTIVITIES + INVESTIGATIONS
COMMUNITY RESEARCH TOOLS
MULTIMEDIA EXTENSIONS
SCIENCE READINGS
FOR YOUTH AGES 11-18

ssec.si.edu/global-goals

Smithsonian | SCIENCE *for Global Goals*

welcome

Welcome to this Starting with Sustainability Lesson Set. This lesson set includes educator and youth-facing lessons and supplemental materials that are inspired by the United Nations Sustainable Development Goals and draw on content from the Smithsonian Science for Global Goals guide series, found at **https://ssec.si.edu/global-goals.**

Smithsonian Science for Global Goals uses a *Discover*, *Understand*, *Act* framework to guide youth from ideas about real-world problems to actions. The Discover section contextualizes global issues within local communities by encouraging young people to recognize their existing knowledge. In the Understand section, youth gather data on real-world problems through natural and social science research. Finally, youth apply their learning through self-determined actions to help solve problems for their local and global communities.

DISCOVER
How do human activities produce greenhouse gases?

UNDERSTAND
How do greenhouse gases connect to climate change?

ACT
How can I change the way I use energy to help the climate?

Essential Understanding: Human activities, often related to energy use, are increasing greenhouse gas emissions and changing the climate. I can work with others to help solve this problem and create a more sustainable climate future.
Topics: Energy, Climate change, Emissions, Greenhouse gases, Research, Community
Target Population: Youth, ages 11 to 18
Estimated Time: At least 90 minutes to complete the lesson set

Lesson Set Resource Page:
ssec.si.edu/sustainability-lesson-set-energy-climate

- Full Lesson Slides
- Connections with Standards
- Activity + Investigations instructions
- Worksheets
- Printables

Discover: Educator Overview

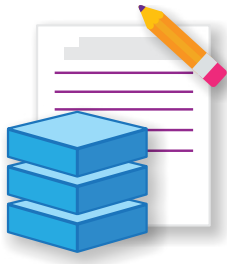
Learning Objective:

Students will be able to analyze climate data, explain the relationship between atmospheric change and human activities, and communicate information about climate change data to others.

Activity Overview:

- **Discover Reading (optional):** A 1-page reading and data analysis activity on the connection between fossil fuel use, carbon dioxide emissions, and rising temperatures.
  Estimated Time: 15 minutes
- **Discover Investigation:** A prediction activity where students generate and check ideas about greenhouse gas production and its causes. In an optional activity they explore daily habits that produce greenhouse gases.
  Estimated Time: 15–35 minutes
- **Discover Investigation Extension (optional):** Students can extend their learning by exploring ways to communicate science to their community and creatively designing science communications using the data shared during the Discover Reading and Investigation.
  Estimated Time: 15 minutes + art creation time

Materials List



- Paper
- Pen or pencil
- Colored pencils
- Art supplies (optional, for extension)

Discover Resources:

ssec.si.edu/sustainability-lesson-set-energy-climate

1. Discover Activity slides
2. GHG Prediction Worksheet
3. My Energy Reflection slides
4. Climate Data and Art Communication slides

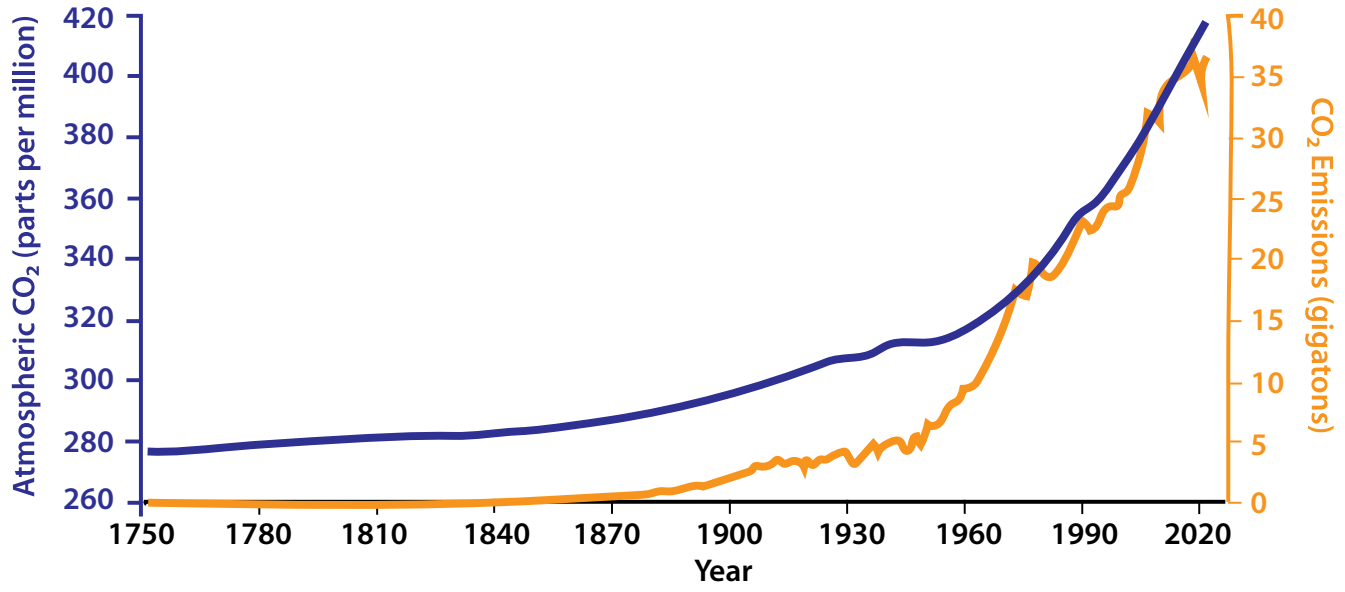
Discover Reading (optional):
From Fossil Fuels to Climate Change

A fossil fuel is an energy source that formed millions of years ago. Common fossil fuels include petroleum (oil), natural gas, and coal. When fossil fuels are burned, they release a lot of energy that can be used to do things such as power a car, create electricity, or heat a home. The carbon in fossil fuels has been locked away from Earth's atmosphere for millions of years. However, over the past 150 years or so, people have started using many fossil fuels as sources of energy. Burning fossil fuels emits (or releases) carbon dioxide (CO_2) and other gases into the atmosphere, where they trap heat and warm the global climate.

Examine the graph showing atmospheric CO_2 (blue line) and CO_2 emissions (orange line) between the years 1750 and 2020 and answer these questions.

- What do you notice about the amount of CO_2 emissions and atmospheric CO_2 from 1750 to 2020?
- What do you think might be the relationship between CO_2 emissions and atmospheric CO_2?

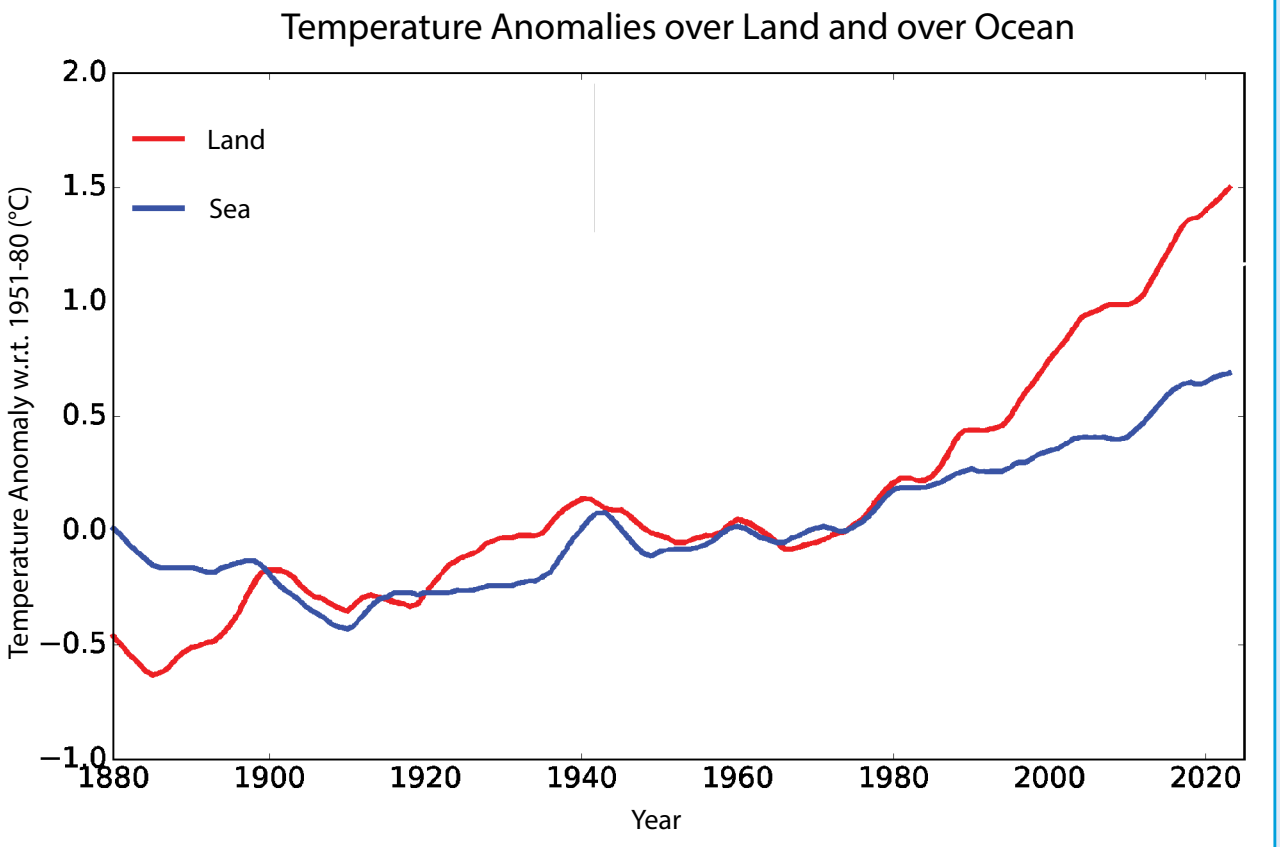
Global Atmospheric Carbon Dioxide Compared to Annual Emissions (1751-2022)



Discover Reading (Continued)

Next, examine this graph showing the anomalies in Earth's temperature over the land and over the ocean since 1880. An anomaly is something that is different than expected. For example, if the average yearly temperature in a place was 20°C, but one year the average was 21°C, that would be an anomaly of 1°C.

- What do you notice about the global temperatures since 1880?
- What do you think might be the relationship between rising atmospheric CO_2 from the first graph and rising global temperature anomalies from the second?



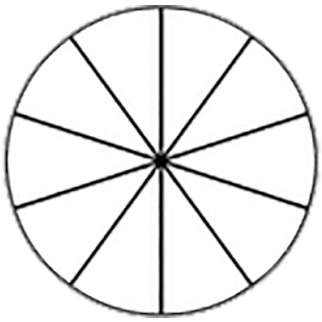
Community Connection

What do you wonder about changes in your community now or in the future related to changing emissions and climate?

Discover Investigation:
How do human activities produce greenhouse gases?

Greenhouse gases (GHGs) are gases that trap energy from the sun and warm the atmosphere. Carbon dioxide is one GHG, but there are others, too, such as methane. Some GHGs in the atmosphere are produced by human activities, others through natural processes.

1. By yourself or with others, make a prediction. Use the worksheet or create a pie chart like the one shown here to represent 100 percent of global GHGs being added to the atmosphere. Draw ten segments. Each segment shows 10% of the total. Then use two different colors to show what percentage of current global GHG additions to the atmosphere you think are human-caused and what percentage are created through natural processes. The answers are at the bottom of the page. How close were your predictions?



   Resource: GHG Prediction Worksheet
2. Now use a similar pie chart to make another GHG prediction. The major human economic sectors that produce GHGs are agriculture, electric power, transportation, industry, and commercial and residential buildings. If the full pie chart is 100% of GHGs produced by human activities, what percentage do you think each activity contributes?
3. Turn to a partner and discuss:
   a. Which of the human activities that produce GHGs do you think are related to energy use?
   b. Which could you influence?
4. If you have time, you can investigate your energy use further.

   Resource: My Energy Reflection slides

GHG Prediction Answers:
Human-Caused or Natural Processes Pie Chart: 45% Natural Processes; 55% Human Activities
Sectors of Human Activities Pie Chart: 11% Agriculture; 25% Electric Power; 28% Transportation, 23% Industry; 13% Commercial and Residential Buildings

Discover Extension (optional):

Apply your learning to your community!

The connection between human activities, GHGs, and climate can feel abstract or unfamiliar for some people. One way to help people think about this relationship is through different types of communication.

1. Think quietly to yourself, what makes you think about or remember data? Sometimes people engage with data through formal information sources, such as academic articles, newspapers, or textbooks. Other times it may be from more informal sources, such as social media posts, videos, artwork, drama, songs, or many other methods of communication.
2. If you have time, explore an example of using art to communicate climate data.

   Resource: Climate Data and Art Communication slides
3. Choose one or more charts you examined in the Discover Reading or Investigation. You can also use art to communicate data.
4. Create a piece of visual art or another method of communication to share this data with your community in an engaging way.
5. Discuss with a partner or your team: Why is communication style so important when you are trying to share information?
6. Examine the mood board below:
   a. When you think about the way your community's activities affect the climate right now, which of the mood board symbols best shows how you feel?
   b. When you think about a future where people find a way to no longer negatively affect the climate, which of mood board symbols best shows how you feel?

MOODBOARD

Notes:

Understand: Educator Overview

Learning Objective:

Students will be able to explain the impact of the changing climate on their community and the mechanism for how increased GHGs leads to increased heat.

Activity Overview:

- **Understand Reading (optional):** A 1-page reading on the impacts of the changing climate and an opportunity to connect to challenges in your community.
  Estimated Time: 15 minutes
- **Understand Investigation:** A hands-on science activity where students can either play a game or create a model to understand how GHGs trap heat in the atmosphere and then reflect on ways to reduce GHGs.
  Estimated Time: 20–30 minutes
- **Understand Investigation Extension (optional):** Students can extend their learning by using climate data from multiple fields to analyze climate trends.
  Estimated Time: 20 minutes

Materials List

- Student-identified photos of community climate challenges (optional)
- Paper
- Pen or pencil
- Materials for modeling activities (see Greenhouse Gases Model slides for details)

Understand Resources:

ssec.si.edu/sustainability-lesson-set-energy-climate

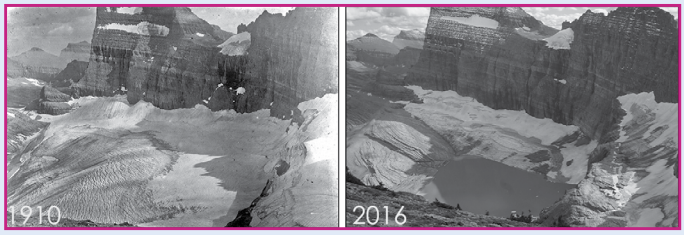
1. Understand Activity slides
2. Earth's Energy System Game slides
3. Greenhouse Gases Model slides
4. Climate Change Data Worksheet
5. Climate Data by Field slides

Understand Reading (optional):
Impacts of a Changing Climate

Temperature affects our daily life and many things about our communities. The air temperature outside can be an important part of many decisions you make. Even though the temperature may change every day for you, each place has a climate, which includes a range of how hot and cold it gets at your location.

Humans are adding a lot of greenhouse gases to the atmosphere, often by burning fossil fuels. Greenhouse gases in the atmosphere, such as carbon dioxide, trap energy from the sun that reaches Earth. Increasing greenhouse gases means additional heat stays on Earth. This increases average global air temperatures. This means it may not be hotter every day, but on average the temperature is increasing. Higher air temperatures can be uncomfortable to live with. They also can melt currently frozen parts of the Earth, such as glaciers and permafrost.

Examine the two photos. **Notice:** What is different about the two photos?



Think: What do you think caused the change between 1910 and 2016?

Wonder: What do you think might happen next?

There are other effects of a changing climate. Extreme weather is becoming more common. Warming air means a warming ocean. A warming ocean means more water evaporates into the air, changing weather patterns. Hurricanes and typhoons are becoming more powerful.

Precipitation patterns are changing, with some places having long periods of drought. Drought is often linked to wildfires. Other places have increasing rain or snow, leading to flooding.

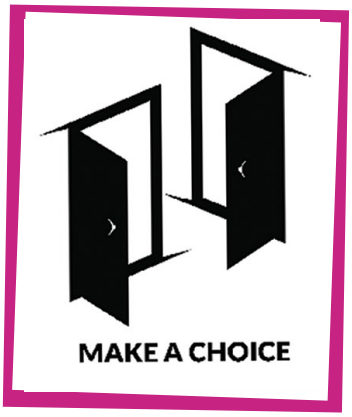
Community Connection

If you had to choose one photo to show the impact of climate challenges on your community, what would it be? If you can, find a photo and share it with a partner. Tell them why you think it is important.

Understand Investigation:
How do greenhouse gases connect to climate change?

Have you ever been in a greenhouse or a room with many windows? The glass often allows sunlight to enter and warm a space. Then the glass then traps some of the heat from the sunlight, leading to a higher temperature inside. GHGs act in a similar way to the glass. GHGs allow sunlight to stream through the atmosphere, but then trap some of the heat that would otherwise bounce back into outer space. Higher concentrations of GHGs mean higher temperatures on Earth. You can model this in two different ways during this activity.

1. Turn to a partner and try to explain your understanding of how a GHG traps more energy and warms the atmosphere. Do not worry if you find it difficult. You will now explore to understand it better.
2. Make a choice: You can choose to play a game or create a model to build your understanding of the relationship between the energy from the sun, GHG, and temperature. Choose between:
   a. A game to show what happens to energy from the sun that enters Earth's atmosphere.
      Resource: Earth's Energy System Game slides
   b. A model to show how GHG traps heat in the atmosphere, raising temperatures.
      Resource: Greenhouse Gases Model slides



3. Discuss as a team: Since increased GHG can increase global temperatures, you may be wondering how to limit GHG production. Governments, industries, scientists, and individuals can all contribute to this goal. Below are a few examples of potential actions to reduce GHG production. Which of the activities do you think would be easiest for you to implement? What else would you add to the list?
   - Set the thermostat several degrees higher in high temperatures or lower in low temperatures. This means you use less energy for cooling and heating.
   - Make different choices about items in your home that use energy. For example, you could switch to efficient light bulbs or appliances.
   - Take shorter showers or smaller baths.
   - Wash clothes with cold water.
   - Many other ideas!

Understand Extension (optional):
Research more!

Climate is like a giant puzzle. Scientists use data and information from many different areas to put the pieces together. Think of scientists as detectives, gathering clues from places like the sky, the ocean, and even deep in the Earth. They use special tools such as thermometers, satellites, and ice drills to collect data. This information comes from everywhere—weather stations on land, buoys in the ocean, and even ancient ice that holds secrets about the past. By bringing together all these pieces of the puzzle, scientists work as a team to understand how Earth's climate works and how it might be changing.

1. Divide your team into five groups, or do the whole activity together as a team. If you use groups, each group will examine data related to a different field. You will try to understand whether the data sets show similar trends.
2. Create a table like the one below and assign each group to one field.

   Resource: Climate Change Data Worksheet

Field	Type of Data	Evidence of a Changing Climate
Oceanographers		
Meteorologists		
Botanists		
Firefighters		
Economists		

3. Examine the data related to the field you are investigating. Fill in the table with the type of data and whether you think it shows evidence of a changing climate.

   Resource: Climate Data by Field slides

4. Discuss as a team:
   a. Is the evidence from the different groups telling a similar story about changes to the climate? What is the trend you notice?
   b. What other types of data would you want to have?
   c. Why do you think having multiple sets of data might be important in this situation?

Act: Educator Overview

Learning Objective:

Students will apply what they have learned by choosing and implementing actions to help solve a problem related to human activities, energy, and climate.

Activity Overview:

- **Act Reading (optional):** A 1-page reading about TEMPO, a collaboration between the Smithsonian Astrophysical Observatory and NASA.
  Estimated Time: 10 minutes
- **Act Investigation:** An activity where students build consensus around a group action and complete a detailed Action Plan.
  Estimated Time: 20 minutes
- **Act Investigation Extension (optional):** Students implement their Action Plan and evaluate which Smithsonian Science for Global Goals guide might best support their additional areas of interest.
  Estimated Time: 10 minutes + action implementation time

Materials List

- Paper
- Pen or pencil

Act Resources:

ssec.si.edu/sustainability-lesson-set-energy-climate

1. Act activity slides
2. Action Planner Worksheet
3. *Energy!* Community Research Guide
4. *Climate Resilience!* Community Research Guide
5. *Ocean!* Community Research Guide

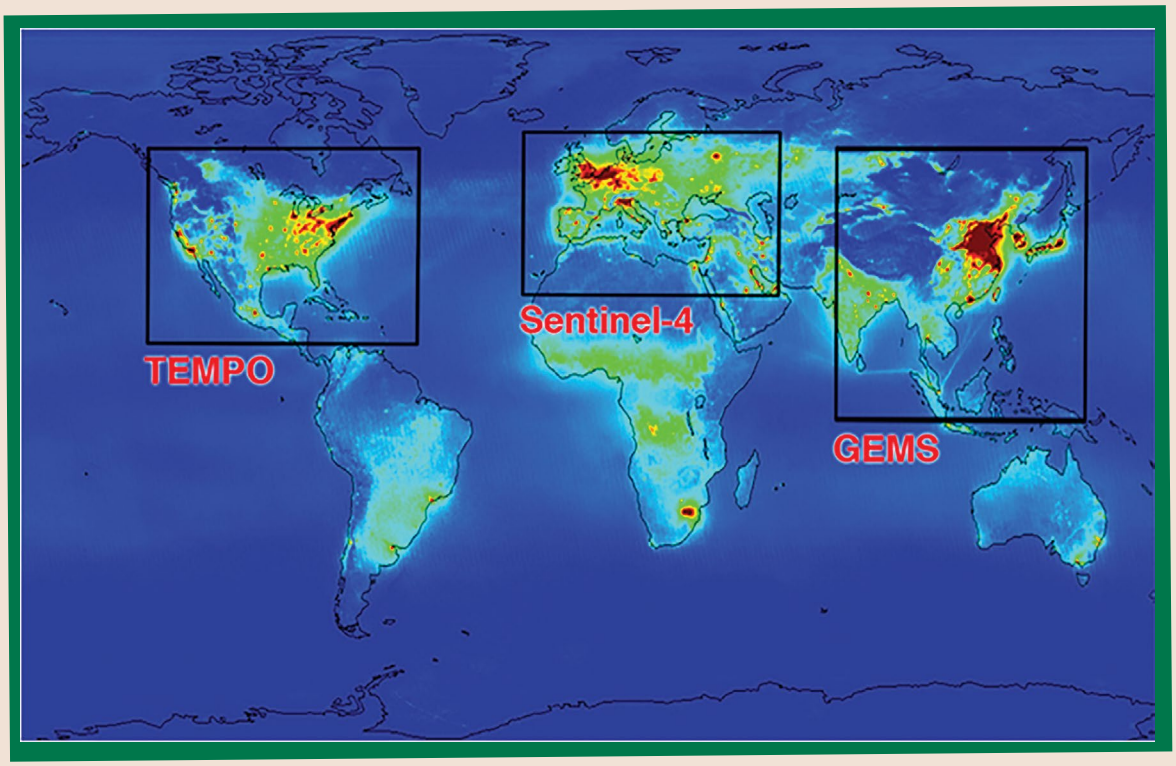
Act Reading (Optional): At the Smithsonian:
Monitoring Atmospheric Changes

Energy production is one of many things that adds greenhouse gases to the atmosphere. Smithsonian scientists are working to understand the details of where, when, and how atmospheric additions happen. The Tropospheric Emissions: Monitoring Pollution (TEMPO) mission is a collaboration between the Smithsonian Astrophysical Observatory and NASA. It monitors atmospheric additions from space, using a special tool called a spectrometer. In 2023 this tool caught a ride into space on a satellite, and is now up about 22,000 miles (about 35,000 kilometers) above Earth.

From up there, the boundaries of TEMPO's research site are North America, from the Atlantic Ocean to the Pacific Ocean, and from Mexico City to Canada. It will keep an eye on all the natural and human additions into the atmosphere. It can see things in the atmosphere, such as additions of gases from human activities. And it's good at seeing small areas of the atmosphere—much better than the technology we had before. The data from TEMPO will help scientists better understand where additions to the atmosphere come from. They'll share this information with everyone, so we all can know and decide what actions to take.

Act Reading (Continued)

TEMPO went into space around the same time as two other satellites that have a research site over Europe (Sentinel 4) and a research site over Asia (GEMS) that also watch additions to the atmosphere. Together, they form a team to watch the atmosphere in different parts of the world. They focus on how things that are added to the atmosphere move between different parts of the world, like from North America to Europe or Asia, across the Atlantic and Pacific Oceans.



Community Connection

- What are some activities around you that you think would contribute to TEMPO results for your community?
- Why do you think monitoring activities such as TEMPO, Sentinel 4, and GEMs might be useful in fighting GHG emissions?

Act Investigation:

How can I change the way I use energy to help the climate?

Act

Now you will get ready to act. The first step toward action is deciding what problem you want to solve and the action you want to take to solve it. Then you can plan when and how you will act.

1. With your group, decide on the problem you want to help solve. This might be a problem such as lack of knowledge about data and climate change. Or it might be a problem related to changing energy use or other things that could reduce GHG. Or it could be another problem you noticed. Write down the problem either on the *Action Planner Worksheet* or on a separate piece of paper.

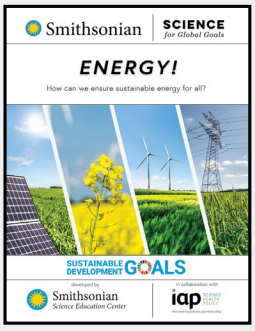
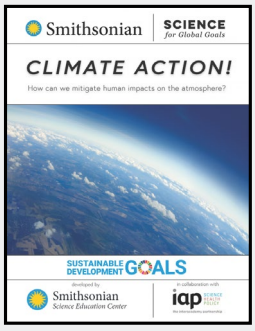
   Resource: Action Planner Worksheet
2. Using the worksheet or paper, list any actions you can think of that might help solve the problem. For example, maybe you want to communicate information to your friends or family in your community. Maybe you want to commit to using less energy by turning of the lights or taking shorter showers. List any actions that will help to solve your problem.
3. Write down the strengths your group has and how they could be used to improve the way people use energy in your community. For example,
   a. Are members of your group part of any groups that you could communicate with?
   b. Do members of your group have any special talents, such as art or music, that might be useful to capture people's attention?
   c. Are members of your group interested in science and engineering or other ways to try to find innovative solutions?
   d. Do group members have good planning or organization skills?
4. Pick an action based on the strengths of your group.
5. Write down your ideas to plan for your action. Be sure to think about:
   a. What will you need to do?
   b. How can you make sure everyone in your team is included?
   c. Are there other people you need to help you or give you permission?
   d. Where will your action take place?
   e. What materials will you need?
   f. What challenges should you be prepared for?
6. In order, list each step you need to do to complete this action.
7. Assign one or more steps to each person in your team.
8. Congratulations, you have planned your action!

Act Research Extension (optional):

Choose your path!

The time has come to act! You can use everything you have learned to take the first step toward making your community more aware of the energy they use and the impact on the climate.

1. With your teammates, implement your Action Plan. This may take some time. When you are finished, come back and complete this activity.
2. Think quietly about the action you took.
   - What went well?
   - What do you think could have gone better?
   - How would you change your action if you had to do it again?
3. Decide on how you want to learn more! The Community Research Guides listed here can help you explore different topics. Which topics interest you most?

		
Energy! Explore more about the use and sources of energy in your community.	*Climate Action!* Explore more about climate change and actions to address it.	*Ocean!* Explore more about ocean systems and their relationship with the climate.

4. As a group, pick a guide that you would like to use and start to explore together.

— — — — — — — — — — — — — — — — — — — —

MOODBOARD

How do you feel about your ability to communicate about energy, human activities, and the changing climate?

Notes:

Starting with Sustainability Lesson Set
Energy and the Climate

Smithsonian Science for Global Goals Development Team

Lesson Set Developers/Writers
Heidi Gibson, Andre Radloff, and Khadijah Thibodeaux

Douglas M. Lapp and Anne B. Keiser Director
Dr. Carol O'Donnell

Division Director
Dr. Brian Mandell

Global Goals Series Developers
Heidi Gibson
Andre Radloff
Logan Schmidt
Khadijah Thibodeaux

Project Manager
Hannah Osborn

Marketing & Communications Team
Carolina Gonzalez

Digital Media Team
Sofia Elian
Joao Victor Lucena

Publishing Assistant
Raymond Williams, III

Smithsonian Science Education Center Staff

Executive Office
Kate Echevarria
Johnny McInerney

Advancement & Partnerships
Denise Anderson
Inola Walston

Finance & Administration
Lisa Rogers, Division Director
Allison Gamble
Jasmine Rogers

Professional Services
Dr. Amy D'Amico, Division Director
Addy Allred
Alexia Antunez-Hernandez
Katherine Blanchard
Katherine Fancher
Katie Gainsback
Grace Harnett
Dr. Hyunju Lee
Shellie Pick
Layla Sastry
Elle Satterthwaite
Amanda Tao
Sherrell Williams

Contributing Interns
Hailey Bowers
Aanila Kishwar Tarannum

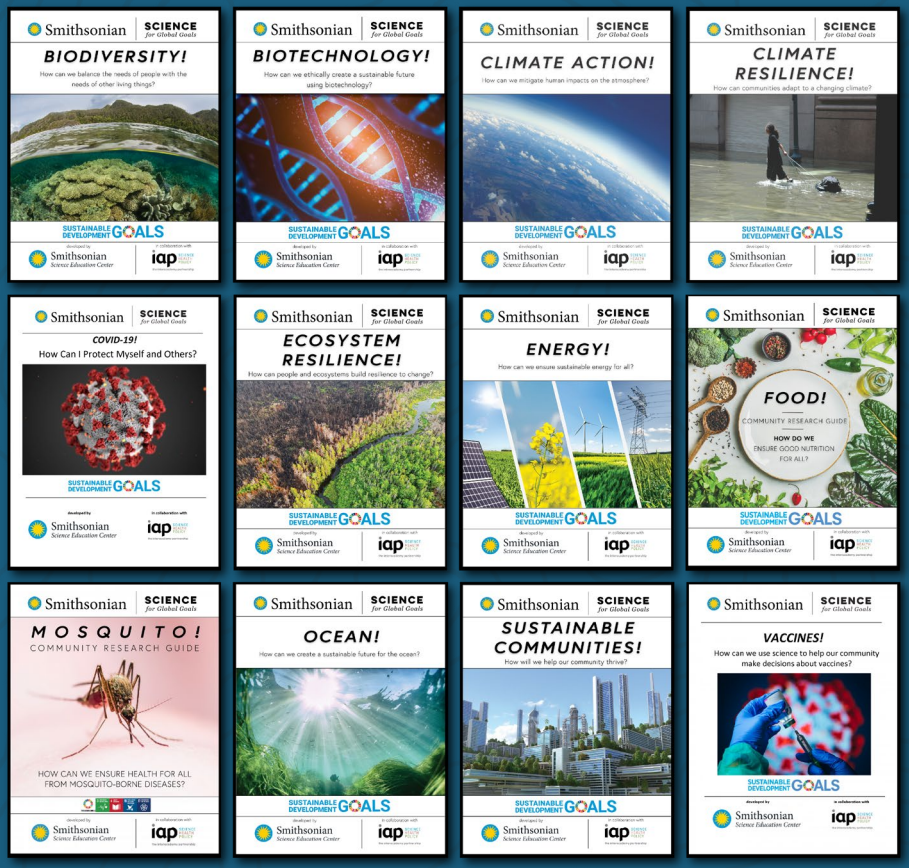
Image Credits:
All designs, icons, guide covers, and tables – Smithsonian Science Education Center
Atmospheric carbon graph – Smithsonian Science Education Center
Temperature anomalies graph – NASA/GISS/SISTEMP
Pie chart – Smithsonian Science Education Center
Glacier comparison – Elrod photo, U of M Collection; McKeon photo, USGS
Satellite coverage – Smithsonian Astrophysical Observatory

References:
NASA. "GISS Surface Temperature Analysis (GISTEMP v4) Temperature Anomalies over Land and Over Ocean reference." NASA. February 10, 2025. https://data.giss.nasa.gov/gistemp/

Lindsey, Rebecca. "Climate Change: Atmospheric Carbon Dioxide." NOAA Climate.gov. April 9, 2024. https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide

MAKE A CHOICE FOR THE FUTURE

Ready to learn more? Access the Smithsonian Science for Global Goals guides to discover, understand, and take action on sustainability issues in your community.



Smithsonian | SCIENCE *for Global Goals*

ssec.si.edu/global-goals