

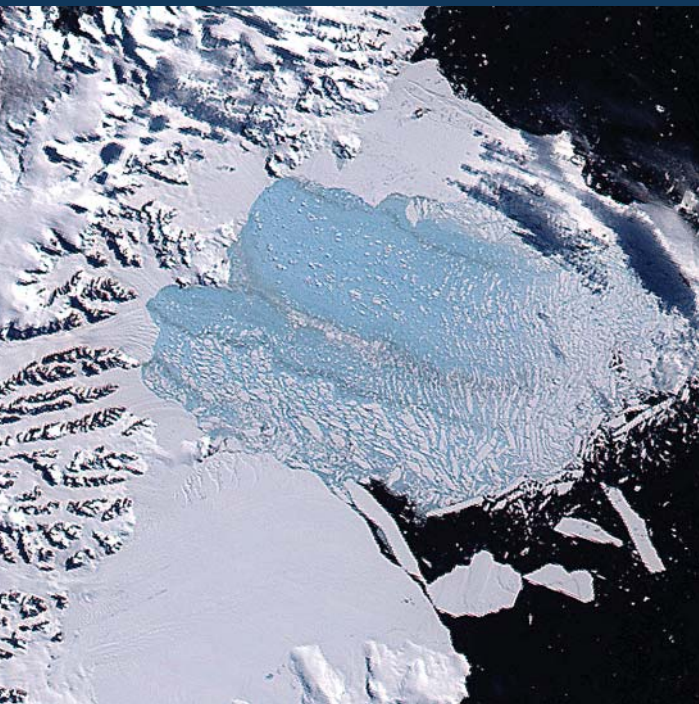


# CLIMATE CHANGE

## The Threat to Life and A New Energy Future

EDUCATOR'S GUIDE

[amnh.org/education/climatechange](http://amnh.org/education/climatechange)



### INSIDE:

- Suggestions to Help You **Come Prepared**
- **Essential Questions** for Student Inquiry
- Strategies for **Teaching in the Exhibition**
- Activities to Extend Learning **Back in the Classroom**
- **Map** of the Exhibition
- Correlation to **Standards**
- **Connections** to Other Museum Halls

# essential QUESTIONS

This exhibition explores how climate works, why it is warming, what the consequences might be, and how to address them. Use the Essential Questions below to connect the exhibition's themes to your curriculum.

## What is climate?

Climate is the long-term state of weather: the typical weather in a particular region over years. The Sun drives climate by warming the air, land, and sea. The oceans and atmosphere transport this heat from the tropics to the poles. In the short run, this transfer of energy creates weather (like a tornado or a sunny day); over the long run it creates climate (warm near the Equator, for example, or cold near the poles). The distribution of landmasses, the amount of ice cover, and the presence of life also play important roles in Earth's climate system.

## How does climate change?

In the past, temperatures at Earth's surface have risen and fallen naturally. Glacial periods alternated with shorter, warmer interglacial periods like the one we're in right now. However, temperatures remained within a range that has enabled life to survive and evolve for more than 3 billion years. That's because gases in the atmosphere, known as greenhouse gases, absorb heat emitted by Earth. Without this insulating blanket, the surface of Earth would actually be frozen. When the concentration of greenhouse gases in the atmosphere increases, more heat is trapped and Earth warms. Carbon dioxide (CO<sub>2</sub>) is the most significant of the greenhouse gases. Others include water vapor, methane, and nitrous oxide.

## How are people causing Earth's climate to change?

Over the last 100 years, human activity is causing global average temperatures to rise. In particular, the burning of fossil fuels (coal, oil, and natural gas) is releasing carbon that had been locked within Earth's geologic reservoir for millions of years. The burning of coal to generate electricity is the most significant source of this CO<sub>2</sub>. Deforestation also plays a part: trees remove CO<sub>2</sub> from the atmosphere through photosynthesis, and when trees burn, the carbon inside them rapidly turns into CO<sub>2</sub>. Since the Industrial Revolution at the end of the 18th century, concentrations of this greenhouse gas have grown faster and higher than at any time in the past 850,000 years (and probably much longer).

## How do we study global climate?

Climate is enormously complex, and scientists have yet to understand how the system operates as a whole. Observations of present-day temperatures and greenhouse gas concentrations made by thermometers, ocean buoys, and satellites are key. Scientists also study the geologic record—information preserved in tree rings, fossil corals, glacial deposits, deep-sea sediments, and glacial ice—to understand how climate has changed in the past. Computer models based on all these observations help them understand what the future may hold.

## How does climate change affect our world?

All living things, from penguins to palm trees, survive only within a particular set of environmental conditions. Even a small change can upset the delicate balance in which species coexist. For example, changing ocean chemistry may kill the coral animals that create tropical reefs. These disturbances ripple through the web that connects all living things, threatening Earth's biodiversity in countless ways. The increase in average global temperatures may also intensify extreme weather events such as droughts and severe storms.



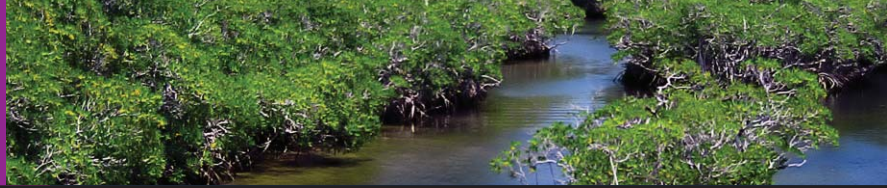
Warmer ocean waters could make storms more powerful.

## How could climate change affect human society?

While we can use technology to modify our surroundings, humans are not immune to the effects of climate change. Society could be at serious risk. For example, droughts could disrupt agriculture, causing starvation. Storm surges and rising sea levels could displace the hundreds of millions of people who live on or near seacoasts. Changes in temperatures and the distribution of rainfall could lead to disease outbreaks. The kind of social and economic upheaval that disrupts societies could result. We don't know what's going to happen, but we do have the power to act.

## What can we do to address climate change?

The decisions we make affect Earth's climate. These decisions are made at all levels: by individuals, communities, and countries. As individuals, we can use less energy in our homes, schools, and workplaces; recycle and reuse; buy locally grown produce; build energy-efficient "green" buildings; drive less; and reduce our energy use in countless other ways. On a broader scale, governments can encourage the development of non-fossil fuel-based energy sources like solar, wind, and nuclear power; investigate strategies to remove CO<sub>2</sub> from the atmosphere; and support sustainable development. While there is no single way to address climate change, people and communities acting together can reduce CO<sub>2</sub> emissions. Not acting is the riskiest course of all.



## Useful Terms & Concepts

**adaptation:** the adjustment of living things to environmental conditions. Human adaptation to climate change includes altering the way we grow crops, build homes, consume energy, and manage natural resources.

**carbon cycle:** the constant movement of carbon through living things, rocks, the oceans, and the atmosphere

**carbon dioxide (CO<sub>2</sub>):** a colorless, odorless gas that is naturally present in the atmosphere

**climate:** the average long-term weather (commonly years) in a particular region

**climate models:** computer programs that enable scientists to investigate the many factors at work in Earth's climate system. By manipulating variables such as the amount of CO<sub>2</sub> in the atmosphere, scientists try to understand how the climate will respond.

**fossil fuels:** coal, oil, and natural gas, which formed from the remains of organisms that lived millions of years ago

**global warming:** an increase in the average temperature at Earth's surface caused by the buildup of greenhouse gases in the atmosphere

**greenhouse effect:** the process by which an atmosphere warms a planet. This takes place when gases allow sunshine to pass through the atmosphere but absorb the heat that radiates back from the surface, keeping it warm.

**greenhouse gases:** gases that increase global temperatures by absorbing the radiation emitted by Earth's surface. Carbon dioxide is the most important greenhouse gas as far as climate change is concerned. Other greenhouse gases include water vapor, methane, and nitrous oxide.

**methane (CH<sub>4</sub>):** a colorless, odorless, flammable gas produced by a variety of natural sources, including microorganisms, cattle, and termites

**nitrous oxide (N<sub>2</sub>O):** a colorless gas or liquid produced by the combustion of fossil fuel

**paleoclimate:** the past climate, before humans started measuring and recording it

**parts per million (ppm):** units used to measure concentrations of trace gases. Values refer to the number of specified molecules contained in 1 million molecules of dry air.

**permafrost:** the permanently frozen layer of soil beneath the surface in cold regions

**photosynthesis:** the process by which green plants use sunlight to synthesize food from CO<sub>2</sub> and water. Photosynthesis releases oxygen into the atmosphere.

**respiration:** the process within living cells that releases CO<sub>2</sub> and water when organic compounds combine with oxygen and break down

**water cycle:** the cycling of water among oceans and lakes, land, living organisms, and the atmosphere

**water vapor:** the gaseous state of water

**weather:** the state of the atmosphere at a particular place and time

## Come Prepared

Before your visit, review the **Essential Questions** to see how the exhibition's educational themes connect to your curriculum. Identify what you'd like your students to learn from *Climate Change*, and how they could continue learning back in the classroom.

**There are many ways to explore the *Climate Change* exhibition:**

- You (and your class chaperones) can use the **Teaching in the Exhibition** section of this guide as you move through the gallery with students.
- You can create student worksheets using the **Teaching in the Exhibition** section.
- Students can use copies of the enclosed **Student Worksheets** as they explore the exhibition independently.
- You can distribute copies of the **Map of the Exhibition** to chaperones and/or students, and let them choose their own paths.

After you leave *Climate Change*, or the next time you visit, you and your students can explore the exhibition's themes elsewhere in the Museum. Refer to the inserts: **Connections to Other Museum Halls** and **Explore the Gottesman Hall of Planet Earth**.

**Visit [amnh.org/education/climatechange](http://amnh.org/education/climatechange) for:**

- information on field trips, reservations, lunchrooms, and other useful tips to help plan your visit
- free resources, including activities and references
- a link to the *Climate Change* exhibition website

## Correlation to Standards

Your visit to the *Climate Change* exhibition can be correlated to the standards listed below. Visit [amnh.org/resources/rfl/web/climatechangeguide/standards.html](http://amnh.org/resources/rfl/web/climatechangeguide/standards.html) for a full listing of relevant NYS Science Core Curriculum Standards and NYC Scope & Sequence.

### National Science Education Standards

**All grades** • A1: Abilities necessary to do scientific inquiry • A2: Understanding about scientific inquiry • E1: Abilities of technological design • E2: Understanding about science and technology • G1: Science as human endeavor

**K–4** • C1: The characteristics of organisms • C3: Organisms and environments • D1: Properties of Earth materials • D3: Changes in Earth and sky • F3: Types of resources • F4: Changes in environments • F5: Science and technology in local challenges

**5–8** • C1: Structure and function in living systems • C3: Regulation and behavior • C4: Populations and ecosystems • C5: Diversity and adaptations of organisms • D1: Structure of the Earth system • D2: Earth's history • F2: Populations, resources, and environments • F3: Natural hazards • F4: Risks and benefits • F5: Science and technology in society • G3: History of science

**9–12** • C4: Interdependence of organisms • C5: Behavior of organisms • D1: Energy in the Earth system • D2: Geochemical cycles • D3: Origin and evolution of the Earth system • F2: Population growth • F3: Natural resources • F4: Environmental quality • F5: Natural and human-induced hazards • F5: Science and technology in local, national, and global challenges • G3: Historical perspectives

# TEACHING in the exhibition

The *Climate Change* exhibition uses interactives, models, videos, and more to engage all learning styles. The eight areas below are labeled on the Map of the Exhibition.

## 1. Introduction

**OVERVIEW:** This area charts the dramatic rise of atmospheric carbon dioxide (CO<sub>2</sub>) over the past 400 years and its link with industrial activity and population growth.

**EXPLORATION:**

- **“400 Years of CO<sub>2</sub>” graph:** Invite students to make connections between technology, energy use, world population, the size of the world economy, and the rise in Earth’s atmospheric CO<sub>2</sub> levels since the year 1600.
- **Coal basket, steam engine, light bulb, and computer:** Students can explore these objects to infer how technological innovations have changed our way of life. Have students focus on the steam engine, which launched the Industrial Revolution.

**GUIDING QUESTIONS:**

- Why is atmospheric CO<sub>2</sub> on the rise?
- How are different kinds of machines powered?
- How have different kinds of carbon-based technologies affected human societies?

## 2. Climate Change Today

**OVERVIEW:** This area explains how the burning of fossil fuels to generate energy releases CO<sub>2</sub> into the atmosphere, and that this is causing Earth’s climate to warm.

**EXPLORATION:**

- **“Greenhouse Effect” wall:** Invite students to investigate how greenhouse gases keep our planet livable.
- **Model of a metric ton of coal:** Students can explore the connection between energy use (electricity), the burning of coal, and CO<sub>2</sub> emissions.

**GUIDING QUESTIONS:**

- How do greenhouse gases affect Earth’s atmosphere?
- What human activities are causing the atmosphere to warm?



Oil—when refined into gasoline and diesel fuel—powers nearly all of the world’s cars and trucks.

## 3. Making a Difference

**OVERVIEW:** Conserving energy is essential, and there are many ways for individuals to go about it. This area describes changes that can make a difference—if many act.

**EXPLORATION:**

- **“What Can You Do?” wall:** Invite students to explore all the different ways in which individuals can save energy and consume less—at home, at school, and at work.
- **“Solutions” digital interactive:** Students can envision the multiplier effect of an individual action when thousands or millions of people join in.
- **“The Built Environment” wall:** Students can explore the energy-efficient components of a building or community.
- **“Everyday Actions” wall:** Have students examine how energy conservation and efficiency can help reduce CO<sub>2</sub> emissions. Help them understand that individual actions are only one part of the solution.

**GUIDING QUESTIONS:**

- What can you do to conserve energy and reduce CO<sub>2</sub> in the atmosphere?
- How could you and others work together to broaden the effect of your actions?

## 4. Changing Atmosphere

**OVERVIEW:** This area explains how scientists know that Earth’s atmosphere is changing, and some of the expected effects.

**EXPLORATION:**

- **“Weather vs. Climate” wall:** Ask students to distinguish between weather and climate through photos and a Q&A.
- **Weather journals & thermometer:** Students can explore the tools that scientists use to observe climate and weather.
- **“Air Temperatures Are Rising” graph & ice core sample:** Students can examine the evidence for rising air temperatures and levels of CO<sub>2</sub> emissions.
- **“Uneven Heating” hands-on interactive:** Invite students to find out why Earth is warmer at the Equator than at the poles.
- **“How Climate Works: Atmosphere” globe:** Students can choose animations about the role of clouds and storms.

**GUIDING QUESTIONS:**

- What’s the difference between weather and climate?
- What are some ways in which climate change affects weather?
- What’s the evidence that Earth’s atmosphere is changing?
- What are some of the consequences of a warming atmosphere?

## 5. Changing Ice

**OVERVIEW:** Ice is melting at the poles, and glaciers are shrinking. This area describes the present and possible future impact upon the world around us.

### EXPLORATION:

- **“Flooded City” model:** Students can observe the effect of rising sea level on Manhattan.
- **Brain coral:** Invite students to examine a marine fossil, found well above sea level, as evidence of past climate change.
- **“How Climate Works: Ice” globe:** Students can choose animations about sea ice and snow cover across the seasons.
- **Polar bear diorama:** Students can explore how life in the Arctic is being disrupted.
- **“Bouncing Back” hands-on interactive:** Invite students to learn about the albedo effect.



The shrinking Arctic ice cap is forcing some polar bears to forage for food near human settlements.

### GUIDING QUESTIONS:

- How will melting ice affect our world?
- What role do seasonal changes in snow and ice cover play in Earth’s climate?
- Why is the Arctic so sensitive to climate change?

## 6. Changing Ocean

**OVERVIEW:** The ocean plays a vital role in climate by storing heat and carbon. This area explains the effects of higher CO<sub>2</sub> levels and warming temperatures on marine systems.

### EXPLORATION:

- **“How Climate Works: Ocean” globe:** Students can choose animations showing the ocean’s role in the climate system.
- **Buoy & ocean glider:** Students can examine the tools that climate scientists use to collect data in the ocean.
- **Sediment core sample:** Have students consider what geological evidence of past climate suggests about future changes.
- **“Tiny Ocean Organisms Have a Big Impact” display:** Students can explore how microorganisms affect the ocean’s carbon uptake.

### GUIDING QUESTIONS:

- How do scientists study ocean temperature and chemistry?
- Why is the ocean so important to Earth’s climate?
- How might changing conditions affect marine ecosystems?

## 7. Changing Land

**OVERVIEW:** This area explores the effect of climate change on land. Droughts and floods may become more common, with consequences for ecosystems and human society.

### EXPLORATION:

- **“How Climate Works: Land” globe:** Students can choose animations about how climatic variations affect land conditions.
- **“Ecosystems & Climate Change” dioramas:** Students can investigate the many ways in which the warming climate may affect biodiversity.
- **Tree ring samples & hands-on interactive:** Invite students to move a magnifier to explore the evidence of past climate changes recorded in tree rings.

### GUIDING QUESTIONS:

- Why will both droughts and floods become more common?
- What are some of the ways that climate change is affecting organisms?

## 8. A New Energy Future

**OVERVIEW:** This area describes options for meeting the world’s increasing demand for energy while reducing CO<sub>2</sub> emissions.

### EXPLORATION:

- **Wall panels and objects about “clean” energy sources that could meet future needs:** Students can explore different ways to generate electricity, which include solar, wind, water, geothermal, and nuclear power.
- **Theater:** Students can watch this video to discover how experts are thinking about the issue of climate change.
- **Leave Your Message:** Encourage students to comment on the issues and challenges of climate change.

### GUIDING QUESTIONS:

- Why is “clean” electricity key to solving climate change?
- What do you think governments like ours should do?

Using panels like these to capture solar energy produces no greenhouse gases or pollution.



Answer Key to the Guiding Questions: [amnh.org/resources/rfl/web/climatechangeguide/questions.html](https://amnh.org/resources/rfl/web/climatechangeguide/questions.html)

# back in the **CLASSROOM**

## Discuss the Exhibition

Use these conversation starters to build on what your students learned at the Museum:

- What did you learn about climate change that surprised you?
- How does climate change affect the world around us?
- How could your life change as our planet warms?
- What did you learn about our energy use? What would your life be like with less electricity?
- How do your actions affect how much energy you use? What could you do to save energy and lower CO<sub>2</sub> emissions?



Simple acts like switching to energy-saver light bulbs reduce energy consumption and CO<sub>2</sub> emissions.

## Classroom Activities

**Energy Conservation:** Have students list ways in which they can save energy and lower CO<sub>2</sub> emissions. For ideas, visit **Be an Energy Saver** ([amnh.org/ology/energysaver](http://amnh.org/ology/energysaver)). As an extension, have students brainstorm ways to encourage their schoolmates, friends, and families to join the effort. How could students promote the program (e.g., a campaign with flyers, posters, school assembly presentations, and/or letters to local politicians or businesspeople)?

**Energy Conservation in School:** Ask students to survey how your school uses energy. Brainstorm energy-saving strategies (e.g., switching to Energy Star products, keeping thermostat settings lower in the winter and higher in the summer, car pooling). Encourage them to present the report to your principal.

**Imagining Solutions:** Review with students the various energy solutions from the exhibition ([amnh.org/climatechange](http://amnh.org/climatechange)). Point out that the demand for energy will continue to rise, and that we need to produce more “clean” energy to meet the need and to lower CO<sub>2</sub> emissions. Have student teams brainstorm innovations—from ideas to inventions, and individual actions to nationwide initiatives—that could address this energy dilemma.

## Online Resources

- **Climate Change exhibition:** [amnh.org/climatechange](http://amnh.org/climatechange)  
Access the exhibition text and images before or after your visit.
- **Climate Change for Educators:** [amnh.org/education/climatechange](http://amnh.org/education/climatechange)  
Find free online resources, including downloadable activities such as “Climate Change Circle of Consequences,” “Environmental Alphabet,” and “Using Solar Energy.”
- **Climate Change OLogy:** [amnh.org/ology/climatechange](http://amnh.org/ology/climatechange)  
Younger students can explore big ideas about climate change and energy use, find energy-saving tips, and build a terrarium.
- **Science Bulletins:** [amnh.org/sciencebulletins](http://amnh.org/sciencebulletins)  
Through videos and interactives, middle and high school students can learn about current research into melting ice and rising sea levels. Click on the “Climate Change” tab at the top right.
- **Environmental Protection Agency Personal Emission Calculator:** [epa.gov/climatechange/emissions/ind\\_calculator.html](http://epa.gov/climatechange/emissions/ind_calculator.html)  
Students can use this online calculator to estimate their or their family’s rate of greenhouse gas emissions.

## credits

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AMERICAN MUSEUM OF NATURAL HISTORY



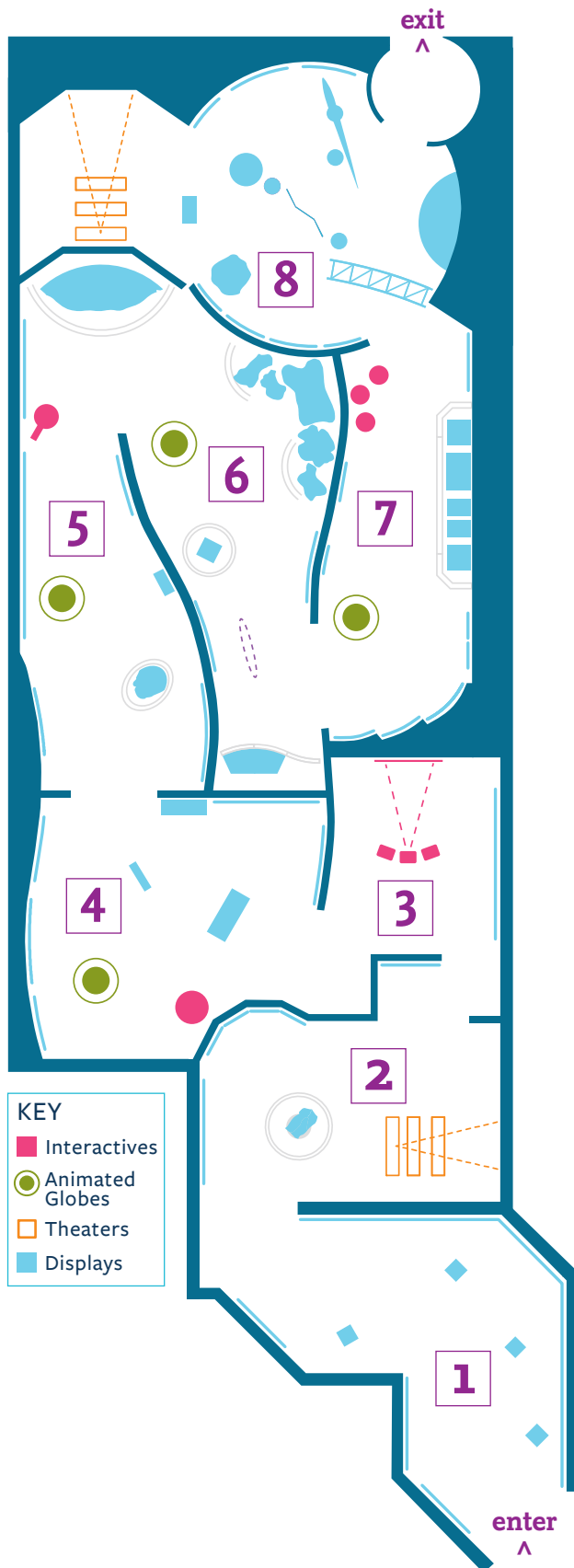
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# MAP of the exhibition



## 1. Introduction



This area charts the dramatic rise of atmospheric carbon dioxide (CO<sub>2</sub>) over the past 400 years and its link with industrial activity and population growth.

## 2. Climate Change Today

This area explains how the burning of fossil fuels to generate energy releases CO<sub>2</sub> into the atmosphere, and that this is causing Earth's climate to warm.

## 3. Making a Difference



Conserving energy is essential, and there are many ways for individuals to go about it. This area describes changes that can make a difference—if many act.

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Ice is melting at the poles, and glaciers are shrinking. This area describes the present and possible future impact upon the world around us.

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The ocean plays a vital role in climate by storing heat and carbon. This area explains the effects of higher CO<sub>2</sub> levels and warming temperatures on marine systems.

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This area explores the effect of climate change on land. Droughts and floods may become more common, with consequences for ecosystems and human society.

## 8. A New Energy Future

This area describes options for meeting the world's increasing demand for energy while reducing CO<sub>2</sub> emissions.

# CONNECTIONS to other museum halls

Find out more about Earth’s climate system. Here are some good places to look throughout the Museum (all are on the first floor):



## Gotesman Hall of Planet Earth

- **“Earth Cycles” wall:** Examine diagrams of the rock, water, and carbon cycles to learn more about how carbon and energy are connected in these three Earth cycles.
- **“What Causes Climate and Climate Change?” wall:** The long panel on one side illustrates how solar energy circulates through the atmosphere, and the ocean-atmosphere connection. A video in the middle of the panel explains the dramatic effects of El Niño on weather patterns. Opposite, check out the different kinds of evidence of past climate change (an ice core, tree rings, glacial striations).

## North American Forests

- **“Giant Cactus Forest” and “Timberline in the Northern Rocky Mountains” dioramas:** Look at the ways in which the plants in these dioramas have adapted to their environments. What changes might a warmer climate bring to the timberline?
- **“Stories a Stump Can Tell” display:** Scientists study tree rings like the ones in this case for evidence of past climate. What factors besides climate can affect tree growth?

## Warburg Hall of New York State Environment

- **“Glaciation” display:** An ice sheet once covered much of New York State. What signs of glaciation can you find across the street on the rocks of Central Park?

## Hall of North American Mammals

- **“Bighorn Sheep” and “White Sheep” dioramas:** Climate change affects species in many different ways. How are animals in these dioramas adapted to their environments? How might they be affected by warming temperatures?
- **“Extinct American Mammals of the Ice Age” miniature dioramas** (on both sides of the main entrance): Explore regions of California and Alaska 15,000 years ago, when Earth’s average temperature was much cooler than it is now. Some of these animals have vanished, while others have near relatives living in the New World. Can you name any of those relatives? Where do they live today?

## Hall of Biodiversity

- **“Urbanization and Agriculture,” “Increasing Resource Demands,” “Deforestation,” and “Global Environmental Change” wall panels** (corridor behind the forest diorama): Examine examples of how human activities have altered global systems. Compare consumption patterns in the United States to those in other countries.

## Spitzer Hall of Human Origins

- **“Life During the Ice Age” display:** 15,000 years ago, humans coped with the cold in various ways. How might we change our clothing or housing, and even our ways of life, to adapt to a warmer world?