LAB 22

Lab Handout

Lab 22. Minimizing Carbon Emissions: What Type of Greenhouse Gas Emission Reduction Policy Will Different Regions of the World Need to Adopt to Prevent the Average Global Surface Temperature on Earth From Increasing by 2°C Between Now and the Year 2100?

Introduction

When sunlight first reaches Earth, some of it is either reflected back out into space or absorbed by the atmosphere. The rest of the sunlight travels to Earth's surface. The sunlight that travels through the atmosphere hits Earth's surface, and the energy from the sunlight increases the temperature of Earth's surface.

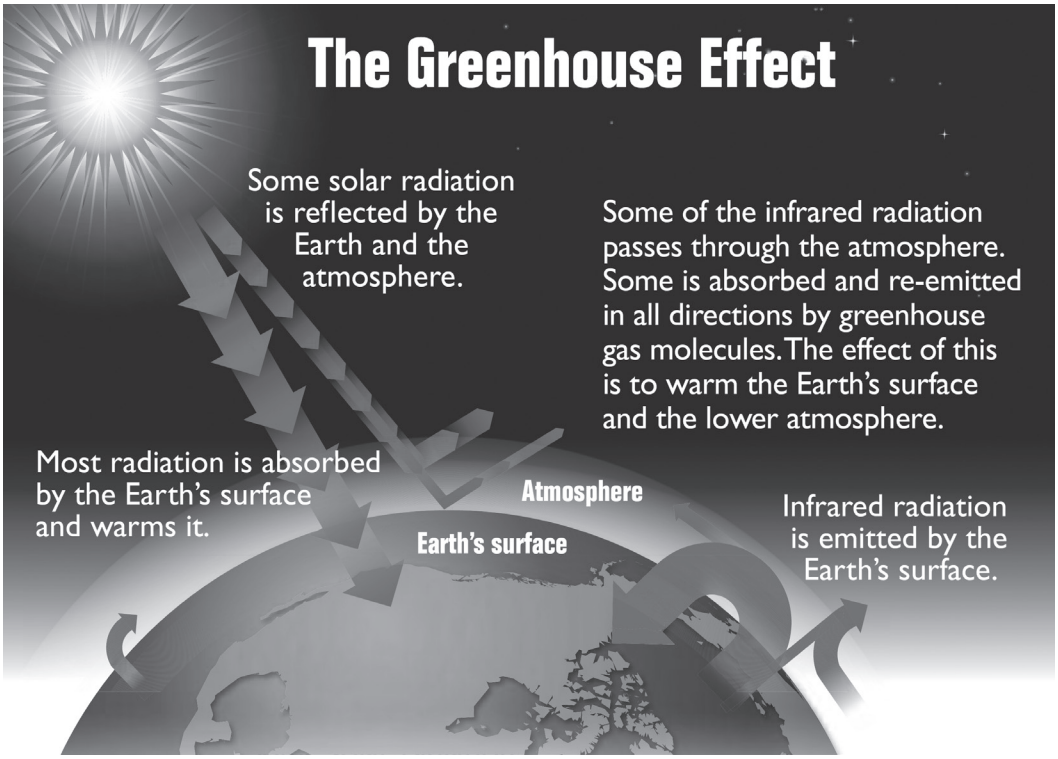
Earth's surface emits infrared radiation, and the amount of infrared radiation emitted by the surface increases at higher temperatures. The atmosphere traps some of this infrared radiation before it can escape into space. The trapped infrared radiation in the atmosphere helps keep the temperature of Earth warmer than it would be without the atmosphere. Scientists call the warming of the atmosphere that is caused by trapped infrared radiation the greenhouse effect. Many gases that are found naturally in Earth's atmosphere, including water vapor, carbon dioxide (CO_2), methane, nitrous oxide, and ozone, are called greenhouse gases because these gases trap infrared energy in the atmosphere (see Figure L22.1).

The amount of energy that enters and leaves the Earth system is directly related to the average global temperature of the Earth. The Earth system, which includes the surface and the atmosphere, currently absorbs an average of about 240 watts of solar power per square meter over the course of the year. The Earth system also emits about the same amount of infrared energy into space. The average global surface temperature, as a result, tends to be stable over time. However, if something was to change the amount of energy that enters or leaves this system, then the flow of energy would be unbalanced and the average global temperature would change in response. Therefore, any change to the Earth system that affects how much energy enters or leaves the system can cause a significant change in Earth's average global temperature.

Climate scientists agree that human activities have led to an increase in the concentration of greenhouse gases found in the atmosphere (IPCC 2013). The greenhouse gas that has increased the most is carbon dioxide. Plants and animals release CO_2 into the atmosphere as a waste product of respiration. Plants also absorb CO_2 from the atmosphere for

FIGURE L22.1

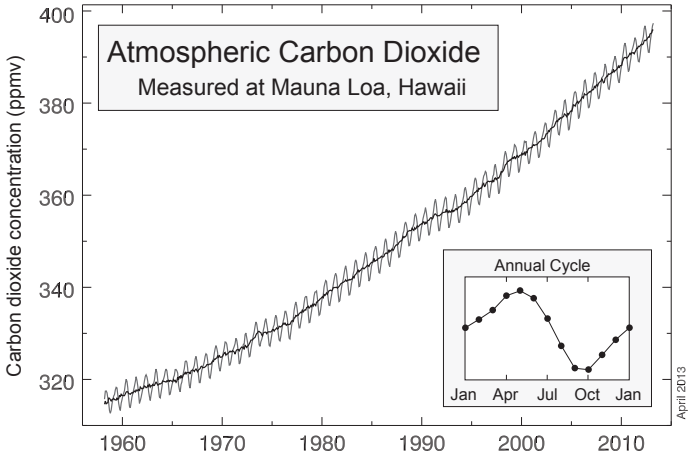
The greenhouse effect



photosynthesis. People, however, also add CO_2 to the atmosphere when they burn fossil fuels for energy. This energy is used for electricity; as fuel for cars, planes, or boats; for heating and cooling homes; and for industrial manufacturing. The concentration of CO_2 in the atmosphere increased from about 320 parts per million (ppm) to almost 390 ppm between 1960 and 2010 (see Figure L22.2). The increase in greenhouse gas emissions such as CO_2 has led to an increase in the greenhouse effect of the atmosphere. The increased greenhouse effect has caused the average global surface temperature to increase approximately 0.8°C (1.4°F) since 1880.

FIGURE L22.2

Concentration of carbon dioxide in the atmosphere between 1960 and 2010; measurements recorded at Mauna Loa, Hawaii (the levels at this site are considered representative of global carbon dioxide levels)



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Greenhouse gas concentrations in the atmosphere will continue to increase unless the billions of tons of greenhouse gas that people add to the atmosphere each year decreases substantially. Even if greenhouse emissions were to stop completely, atmospheric greenhouse gas concentrations will continue to remain elevated for hundreds of years because many greenhouse gases stay in the atmosphere for long periods of time. Moreover, if the concentration of greenhouse gases found in the current atmosphere remained steady (which would require a dramatic reduction in current greenhouse gas emissions), surface air temperatures will continue to increase. This is because the oceans, which store heat, take many decades to fully respond to changes in greenhouse gas concentrations. The oceans will therefore continue to have an impact on global climate over the next several decades to hundreds of years.

The Intergovernmental Panel on Climate Change (IPCC), which is the leading international body for the assessment of change in global climate, expects the Earth's average temperature to increase by at least 4.5°C (8.1°F) by the year 2100 (IPCC 2013). This substantial increase in average global temperature will reduce ice and snow cover, change precipitation patterns across the globe, raise sea level, increase the acidity of the oceans, and shift the characteristics of many different natural habitats. These changes will have an impact on our food supply, water resources, infrastructure, and health. Many people are therefore examining different ways to reduce the amount of CO_2 that is released into the atmosphere or to find ways to remove more CO_2 from the atmosphere to help prevent this substantial increase in average global temperature. The current goal is for various regions of the world to identify and enact CO_2 emission reduction policies that will prevent the average global surface temperature from increasing by more than 2°C (3.6°F) before the year 2100.

Your Task

Use what you know about the greenhouse effect, systems and system models, and stability and change to develop a plan to minimize human impact on climate. Your goal is to identify a greenhouse gas emission reduction plan for six different regions of the world that will, when enacted together, prevent the average global surface temperature of Earth from increasing by more than 2°C until the year 2100. The plan you will develop for each region must include recommendations for when the greenhouse gas emissions in the region will need to stop increasing, when the greenhouse gas emissions will need to start decreasing in that region, and the annual greenhouse gas emission reduction rate for that the region. Each plan will also need to include recommendations for a policy that will dictate how much deforestation will need to be reduced in that region by 2050 and how much effort should go into creating new forests in that region starting in 2016.

The guiding question of this investigation is, ***What type of greenhouse gas emission reduction policy will different regions of the world need to adopt to prevent the average global surface temperature on Earth from increasing by 2°C between now and the year 2100?***

Materials

You will use an online simulation called C-ROADS (Climate Rapid Overview and Decision Support) that helps people understand the long-term climate impacts of actions that reduce greenhouse gas emissions; the simulation is available at *www.climateinteractive.org/tools/c-roads*.

Safety Precautions

Follow all normal lab safety rules.

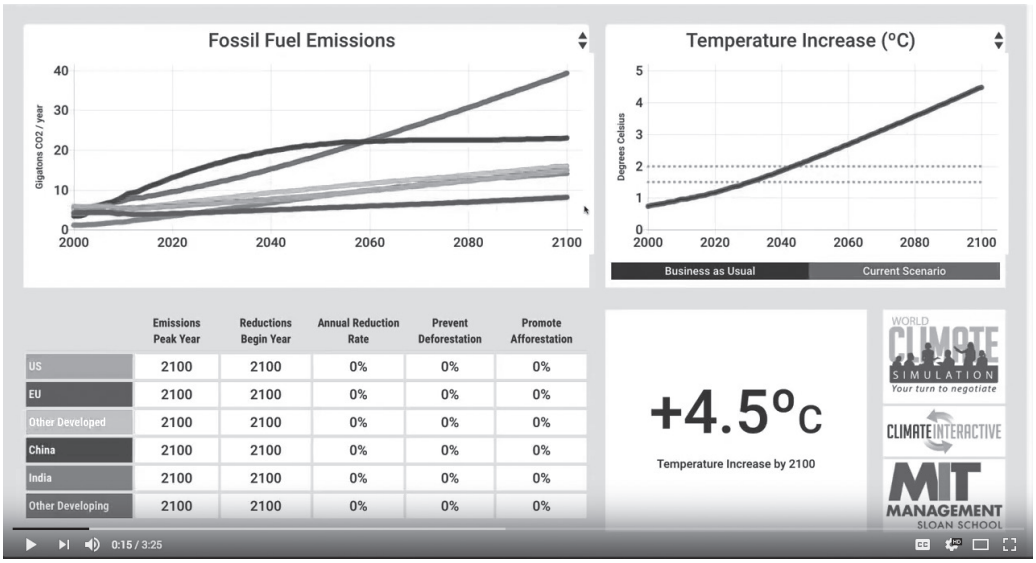
Investigation Proposal Required? ☐ Yes ☐ No

Getting Started

You can use C-ROADS (see Figure L22.3) to test strategies for tackling climate change. The online simulation allows users to visualize the impact of adopting different emission reduction policies in different regions of the world. This model is useful because it allows users to see and understand the gap between a proposed policy (such as reducing deforestation in a region by 10% a year) and what actually needs to happen to stabilize the concentration of greenhouse gases in the atmosphere and prevent an increase in average global surface temperature. C-ROADS therefore offers you a way to test different policies.

FIGURE L22.3

Screenshot of C-ROADS simulation



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The first step in this investigation is to develop a greenhouse gas emission reduction policy for different regions of the world and then see how these policies, when enacted together, will affect the average global surface temperature over time. *C-ROADS* allows you to create greenhouse gas emission reduction policies for (1) the United States, (2) the European Union, (3) Other Developed Countries (e.g., Japan, Russia, Australia, Korea), (4) China, (5) India, and (6) Other Developing Countries (e.g., nations in Africa, South America, Central America, and the Middle East). The policy you create for each region will need to include

- the year that greenhouse gas emissions will *stop increasing* in the region (emission peak year),
- the year that greenhouse gas emission will *start decreasing* in the region (reduction begin year),
- the rate at which each region *decreases* emission each year (annual reduction rate),
- the rate at which deforestation will *decrease* in the region each year (reduce deforestation), and
- the rate at which new forests will *added* in the region each year (promote afforestation).

You can set values for these five aspects of a greenhouse gas emission reduction policy for the six different regions in *C-ROADS* using the table in the lower-left corner of the simulation. You can then examine how your choices will affect the fossil fuel emissions in each region over time (graph in the upper-left corner) and the average global temperature over time (graph in the upper-right corner). The box in the lower-right corner also tells you how much the average global temperature will change between now and 2100.

One you have developed an initial policy for each region and tested how these policies, when enacted together, will affect fossil fuel emissions and average global temperature over time, you can then begin to modify each of your proposed policies to make your overall plan more effective. Your goal for this step of the investigation is to determine how your proposed policies for each region will need to be changed to close the gap between what you are proposing and what actually needs to happen to prevent a 2°C increase in average global surface temperature between now and 2100. As you modify your greenhouse gas emission policies, think about the following questions to help guide the changes you will make:

- What are the components of the system and how do they interact with each other?
- When is this system stable and under which conditions does it change?
- Which factor(s) might control the rate of change in this system?
- What scale or scales should you use to when you take measurements?

The last step in your investigation will be to identify the potential challenges and consequences that are associated with putting a proposed greenhouse gas emission reduction policy into action. This is important because policies affect the lives of people. For example, what are the consequences of a policy that requires an immediate 20% reduction in fossil fuel emissions for the people in a region that relies on coal or oil as an energy source? Will the people in that region be able to get to work? Heat their homes? Will they lose their jobs? You must also consider what is ethical and what is fair in terms of any proposed policy. For example, is it ethical or fair for people who live in a country in South America to have to cut greenhouse gas emissions at the same rate as people who live in the United States? You will therefore need to take into account these issues to ensure that your proposed greenhouse gas emission reduction policy is valid and acceptable. You can include information about any political, economic, or social issues you considered as you developed and evaluated your policy as part of your justification of your evidence.

Connections to the Nature of Scientific Knowledge and Scientific Inquiry

As you work through your investigation, be sure to think about

- how models are used as tools for reasoning about natural phenomena, and
- the types of questions that scientists can investigate.

Initial Argument

Once your group has finished collecting and analyzing your data, your group will need to develop an initial argument. Your initial argument needs to include a claim, evidence to support your claim, and a justification of the evidence. The *claim* is your group's answer to the guiding question. The *evidence* is an analysis and interpretation of your data. Finally, the *justification* of the evidence is why your group thinks the evidence matters. The justification of the evidence is important because scientists can use different kinds of evidence to support their claims. Your group will create your initial argument on a whiteboard. Your whiteboard should include all the information shown in Figure L22.4.

FIGURE L22.4
Argument presentation on a whiteboard

The Guiding Question:	
Our Claim:	
Our Evidence:	Our Justification of the Evidence:

Argumentation Session

The argumentation session allows all of the groups to share their arguments. One or two members of each group will stay at the lab station to share that group's argument, while the other members of the group go to the other lab stations to listen to and critique the other arguments. This is similar to what scientists do when they propose, support, evaluate, and refine new ideas during a

poster session at a conference. If you are presenting your group's argument, your goal is to share your ideas and answer questions. You should also keep a record of the critiques and suggestions made by your classmates so you can use this feedback to make your initial argument stronger. You can keep track of specific critiques and suggestions for improvement that your classmates mention in the space below.

Critiques of our initial argument and suggestions for improvement:

If you are critiquing your classmates' arguments, your goal is to look for mistakes in their arguments and offer suggestions for improvement so these mistakes can be fixed. You should look for ways to make your initial argument stronger by looking for things that the other groups did well. You can keep track of interesting ideas that you see and hear during the argumentation in the space below. You can also use this space to keep track of any questions that you will need to discuss with your team.

Interesting ideas from other groups or questions to take back to my group:

Once the argumentation session is complete, you will have a chance to meet with your group and revise your initial argument. Your group might need to gather more data or design a way to test one or more alternative claims as part of this process. Remember, your goal at this stage of the investigation is to develop the best argument possible.

Report

Once you have completed your research, you will need to prepare an *investigation report* that consists of three sections. Each section should provide an answer for the following questions:

1. What question were you trying to answer and why?
2. What did you do to answer your question and why?
3. What is your argument?

Your report should answer these questions in two pages or less. You should write your report using a word processing application (such as Word, Pages, or Google Docs), if possible, to make it easier for you to edit and revise it later. You should embed any diagrams, figures, or tables into the document. Be sure to write in a persuasive style; you are trying to convince others that your claim is acceptable or valid.

Reference

Intergovernmental Panel on Climate Change (IPCC). 2013. *Climate change 2013: The physical science basis. Working Group I contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge, England: Cambridge University Press.