GENERATING HEAT

EARTH matters
Studies For Our Global Future

introduction

Carbon dioxide (CO_2) is the primary **greenhouse gas** contributing to global **climate change**. A greenhouse gas is a gas that absorbs the sunlight that is reflected back towards space as infrared radiation (heat), trapping the heat in the atmosphere. This is known as the **greenhouse effect**. As the world's population grows, so does the impact of human activities, including the burning of **fossil fuels**. Over the past 250 years, such activities have raised carbon dioxide levels in the atmosphere to a level significantly higher than it has been for hundreds of thousands of years. The link between population growth and increasing **carbon dioxide emissions** becomes especially clear when observing graphic data, as the growth curves for both follow a similar path over the past few hundred years. Scientific evidence shows a correlation between high CO_2 levels in the atmosphere and rising global temperatures.

Vocabulary: carbon dioxide (CO_2), carbon dioxide emissions, climate change, fossil fuels, greenhouse effect, greenhouse gas

materials

- Student Worksheet
- Graph paper or access to a spreadsheet program (Microsoft Excel or Google Sheets)

procedure

1. Distribute the Student Worksheet, one per student, and allow them time to complete both parts. Students can either work individually or in pairs.

   Students may complete the graph by hand on graph paper, or they can create an electronic graph by copying the data into a spreadsheet. Steps for creating a graph in Excel and Google Sheets are provided on the Student Worksheet.

2. Review the Worksheet answers as a class.

Answers to Student Worksheet

See Answer Key

concept

Population growth, along with rapid industrialization over the past two centuries, has increased the world's carbon dioxide emissions significantly.

objectives

Students will be able to:

- Graph population and carbon dioxide emissions data over time.
- Identify the relationship between population growth and carbon dioxide emissions.

subjects

Environmental Science (General and AP), AP Human Geography, Geography, Algebra

skills

Graphing and analyzing data, interpreting line graphs

method

Students graph carbon dioxide emissions and population growth over time and discuss trends they observe.

discussion questions

1. Would it be possible for the two graphs to follow opposite paths? (Could one increase while the other decreases?)

   Yes. People's consumption, and thus their emissions, can grow without the population growing, or the population could grow while per capita energy use decreases and thus overall emissions remain the same or decrease.

2. China and India are the world's largest populations. Both countries are rapidly industrializing, creating greater affluence but also more CO_2 emissions. The United States, with a smaller population size and slower growth rate, is still the largest CO_2 emitter in the world per capita. Is it fair to ask developing countries to curb CO_2 emissions? Should the United States and other developed countries cut their emissions more to allow developing countries greater fossil fuel use than they've had in the past? Is there a strategy that would create an equitable balance of carbon use?

   Answers will vary. Students may suggest that such demands on developing countries are only reasonable as long as the U.S. is leading the way in reducing CO_2 emissions, or that as new technology is developed that is more eco-friendly, developing nations should use it. Carbon dioxide emissions trading systems can be seen as a way to prevent growth in emissions, or perhaps multilateral agreements such as the Paris Agreement.

assessment

Review students' completed graphs and monitor participation in the class discussion.

follow-up activity

Have students visit www.WorldPopulationHistory.org and analyze the changes they see using the CO_2 emissions overlay. Focusing on the years 1890, 1920, 1950, 1980, and 2010, students should note where in the world they see differences in emissions and intensity for the different time periods.

GENERATING HEAT | student worksheet

Name: _____ Date: _____

Year	Population (in millions)	CO_2 emissions (in millions of metric tons)
1750	790	11
1800	980	29
1850	1,260	198
1900	1,650	1,958
1950	2,520	5,977
2000	6,060	24,690
2050	9,700*	43,085*

Sources: Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory
*UN and U.S. Energy Information Administration

Graph the Trends

Using the table above, graph the population and carbon dioxide (CO_2) emissions for each year. Then answer the discussion questions below. You may use graphing paper, or a spreadsheet program (Microsoft Excel or Google Sheets), to create your graph.

<u>If using Excel 2013 or 2016, follow these steps:</u>

1. Copy the table above into Excel exactly as it is written. Then delete the two asterisks from the bottom row.

2. Highlight all of the data, including the three column headings, by clicking on Year in the upper left corner and dragging down to the cell "43,085."

3. Click the Insert tab on the Toolbar. There will be an area for charts in the middle of the toolbar, click the small arrow in the lower right hand corner of that area.

4. A pop-up box will appear. Click on the All Charts tab at the top.

5. Then click Line Charts, and choose the Line with Markers (the fourth chart from the left at the top). There will be three chart options, choose the second chart (the one with x-axis as years), and then click OK.

6. In order to get the secondary y-axis for the Population data, right click on the population line on your graph and click Format Data Series. (When you mouse over each line, text will appear that tells you which data set it represents.)

7. A pop-up will appear. Select Format Data Series..., and a sidebar will appear on the right of the screen. Under Series Options, Plot Series On, click Secondary Axis.

8. To label the x- and y-axis, click on either of the axis numbers, then click the Chart Elements button (it looks like a + sign). Select Axis Titles and replace the Axis Title labels on the graph with the appropriate label.

9. Change the title of your graph to: CO_2 Emissions and Population Growth.

If using Google Sheets, follow these steps:

1. Copy the table above into Google Sheets exactly as it is written. Then delete the two asterisks from the bottom row.

2. Highlight all of the data, including the three column headings, by clicking on Year in the upper left corner and dragging down to the cell "43,085."

3. Click the Insert tab on the Toolbar. Select Chart. A chart will now appear, along with a sidebar on the right side of the screen.

4. In the Chart Editor side bar, click the Setup tab and use the Chart Type dropdown menu to select Line chart. Now designate the Years as the x-axis by selecting Year under "X-axis."

5. Still in the Setup tab, under Series, click on the three vertical circles next to Year and select Remove.

6. Click the Customize tab in the Chart Editor, then click Series. In the dropdown menu you'll see the two series (Population and CO_2 emissions). Click "Population" and then under the Axis dropdown select "Right axis." Click "CO_2 emissions" in the dropdown and select "Left axis" in the Axis dropdown.

7. Still in the Customize tab, scroll up to Chart & Axis Titles. For the Chart title, type in: CO_2 Emissions and Population Growth.

8. Add text for the vertical axes by selecting Axis Title from the dropdown and typing in the Title Text field. (Note: The left axis is the default "Vertical axis" and the right axis is listed as "Right vertical axis.")

Graph Analysis and Discussion (Use scratch paper to write your answers if you need more space.)

1. Is there a correlational relationship between population and CO_2 emissions? Is there a causal relationship?

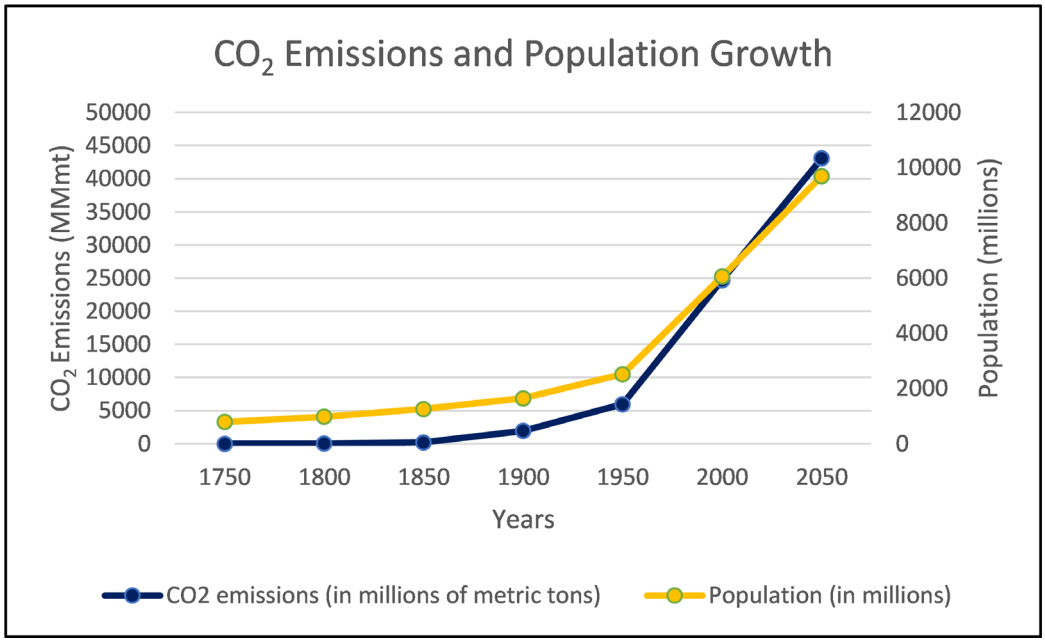
2. What do you think accounts for the growth in CO_2 emissions from 1750-2050?

3. Today, most of the world's population growth is occurring in the world's least developed countries. Do you think CO_2 emissions will increase with increasing population growth in these countries? Why or why not?

4. Based on the data you graphed and information you have read about climate change, what are some possible implications to communities and the environment by 2050?

GENERATING HEAT | student worksheet answer key

Graph the Trends



Graph Analysis and Discussion

1. Is there a correlational relationship between population and CO_2 emissions? Is there a causal relationship?

   Yes, there is a correlational relationship between population and CO_2 emissions – both have increased over time. From the graph alone, we cannot tell if there is causation.

2. What do you think accounts for the growth in CO_2 emissions from 1750-2050?

   As population increased, more people were using energy and the ways of producing this energy, such as by burning coal or oil, resulted in CO_2 emissions. Additionally, per capita use has increased with industrialization and increased technology and urbanization. Plants absorb carbon dioxide, so deforestation and urban sprawl have also increased the amount in the atmosphere.

3. Today, most of the world's population growth is occurring in the world's poorest countries. Do you think CO_2 emissions will increase with increasing population growth in these countries? Why or why not?

   It is likely. Even if these countries do not further industrialize, more people still means more cars and factories to emit CO_2. In all likelihood, however, many of these countries will further develop and industrialize, needing more energy per capita as well as more energy overall.

4. Based on the data you graphed and information you have read about climate change, what are some possible implications to communities and the environment by 2050?

   Answers will vary but may include: increases in sea level rise, ocean acidification, coastal flooding, more extreme weather events and drought conditions.