

2022
EDITION



Next Generation Climate

Grades 6-8



Lesson 2: What factors have caused the rise in the global temperature over the last century?

Looking into the causes



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| <i>Age Level</i> | Grades 6-8 |
| <i>Time Needed</i> | Three 50 minute class periods |
| <i>Materials</i> | <p>Human Impact cards (1 set) Lesson 2 Worksheet 1: Claim, Evidence, Reasoning (1 for each student) Evidence Figure Set (1 set of 10 for each group) Evidence Figure Set Descriptions (1 set) Lesson 2 Worksheet 2: Discussion Diamond (1 for each student) Separating Human and Natural Influences on Climate figure A large open area and chalk Small bag labeled ‘What do humans do?’</p> |
| <i>Vocabulary</i> | <p>greenhouse effect: A phenomenon in which the atmosphere of a planet traps radiation emitted by its sun, caused by gases such as carbon dioxide, water vapor, and methane that allow incoming sunlight to pass through but retain heat radiated back from the planet’s surface.</p> <p>greenhouse gas: gases which allow direct sunlight to reach Earth’s surface, but absorb the infrared energy (heat) that is reradiated to the atmosphere. These gases include: water vapor, carbon dioxide, methane, nitrous oxide, among others. Also referred to as heat-trapping gases.</p> <p>cumulative: increasing or increased in quantity</p> <p>atmosphere: the mixture of gases that surrounds earth; the air</p> <p>carbon dioxide: CO₂, is the primary greenhouse gas emitted through human activities</p> <p>emissions: the act of producing or sending out something (such as energy or gas) from a source</p> <p>carbon sink: anything that absorbs more carbon than it releases (trees, ocean)</p> |
| <i>Student Learning Outcomes</i> | <ul style="list-style-type: none"> • Students will be able to construct an argument, compare and critique multiple arguments, and analyze or interpret the facts presented. • Students will be able to investigate how temperature increase impacts and changes the atmospheric conditions. • Students will be able to demonstrate the greenhouse effect by showing how carbon dioxide and other greenhouse gases in the atmosphere trap heat and insulate the Earth. • Students will be able to determine how human population increase and per-capita consumption are contributing to the rise in the global temperature and the concentration of greenhouse gases in the atmosphere. • Students will be able to distinguish between the greenhouse effect and climate change. |
| <i>Performance Expectation(s) addressed</i> | <p>MS-ESS3-4. Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth’s system.</p> <p>MS-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.</p> |
| <i>Educator Prep</i> | <p>Greenhouse Effect Game:</p> <ul style="list-style-type: none"> • Print <i>Human Impacts Cards</i> and create ‘What do humans do?’ bag. • Find a large, open area for game play, preferably outside. Draw two concentric circles on the ground, one about 4 feet in diameter, and a larger one about 30 feet in diameter. The smaller circle represents the Earth and the larger one represents Earth’s atmosphere (for 15-30 students). • Read the information about CER (Claim, Evidence, Reasoning) in the beginning of the curriculum guide. This will provide you will an understanding of how to implement and assess this form of argumentation. • Make copies of the <i>Evidence Figure Set</i> and <i>Descriptions (if using)</i> for each group. • Make copies of the <i>Lesson 2 Activity: Claim, Evidence, Reasoning</i> worksheet for each student. • Make copies of the <i>Discussion Diamond</i> Worksheet for each student. |

Lesson 2: What factors have caused the rise in the global temperature over the last century?

Looking into the causes

Background Information

In this lesson, students will learn about the factors that are causing the climate to change. Students will be able to differentiate between natural and human causes that are happening around the world.

When discussing climate change, one of the most important concepts to understand is the greenhouse effect (see vocabulary section). The following is a list of important facts about the greenhouse effect and our atmosphere.

1. The earth's atmosphere has greenhouse gases which absorb and reflect the sun's radiation and keep the earth a habitable environment.
2. Some of the common greenhouse gases include carbon dioxide, methane, nitrous oxide, and water vapor.
3. Carbon dioxide is measured in parts per million (ppm) and reached 400 ppm in 2015. This is the highest that carbon dioxide levels have been in recorded history. Furthermore, with ice core data, we can tell carbon dioxide levels have not been that high in 800,000 years.
4. The burning of fossil fuels and other human activities release carbon dioxide into the atmosphere. Fossil fuels are burned in the process of electricity production, industrial processes, driving vehicles, and more.
5. The increase in global temperatures is a result of the increase in carbon dioxide and other greenhouse gases in our atmosphere, predominantly from humans burning fossil fuels. Scientists refer to this change in temperature which is influencing our climate system, as climate change.

The [temperature change] of the past 50 years is due primarily to human-induced increases in heattrapping gases. Human 'fingerprints' also have been identified in many other aspects of the climate system, including changes in ocean heat content, precipitation, atmospheric moisture, and Arctic sea ice.

- U.S. Global Change Research

The climate has always been changing. There are many factors influencing the climate. Changes in the earth's orbit and the tilt of the axis are examples of major influences. Others include changes in volcanic and solar activity. The current changes in earth's temperature are alarming because climate scientists know what the earth should be doing, based on where the earth is at in those cycles of orbital variation and other factors. Only when human effects are taken into account does the actual temperature data match.

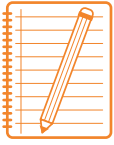
Students will be participating in a game in this lesson that will help them understand how the greenhouse effect keeps the planet warm, but also is causing our atmosphere to warm too quickly. The following is a list of things the students should learn during the game:

- a. There are gases in the atmosphere (CO₂, methane, nitrous oxide, etc.).
- b. These gases have different properties (lifetime, percentages).
- c. These gases are keeping Earth habitable.
- d. The greenhouse effect is not as simple as one gas. It is a cumulative effect of many gases and the amounts of those gases.
- e. The natural greenhouse effect is being enhanced by the increase in CO₂, causing a rise in global temperature. This enhanced greenhouse effect is referred to as climate change.

In this lesson educators have the opportunity to assess how the modeling activities (the game), the analogies (the cake) and the mathematical models (graphs) develop and change student mental models.

Lesson 2: What factors have caused the rise in the global temperature over the last century?

Looking into the causes



Journal Assignment

By the end of this lesson students will have a detailed picture of the greenhouse effect and statements about the *Human and Natural Influences on Climate* graph.

Activity Description

Introduction:

1. Refer back to the figure that was assembled in Lesson 1: Global Land and Ocean Temperature Anomalies graph. Discuss why the graph looks like it does. What things have happened in the past 135 years that could cause the global temperature changes that you see? Make a list of items (keep it accessible because students will need to come back to it at the end of this lesson).
2. Watch the following video about carbon dioxide, the greenhouse effect, and heat-trapping gases: <http://www.climategen.org/ngconline>. After the video, ask students to reflect in their journals on the questions:
 - a. Why is the greenhouse effect important?
 - b. Why is CO₂ important?
 - c. What is the relationship between CO₂ and the greenhouse effect?
3. Use the following analogy to explain what can happen if the ingredients to the atmosphere are changed. Cake as weather: “Let’s say a storm (weather) is like a cake. A storm has a specific set of ingredients, which the atmosphere provides. If we don’t have the ingredients, we are not going to make a cake. A storm needs air masses to collide and rise, allowing water to condense and fall out as rain. A cake needs a combination of flour, eggs, butter and sugar. Now what happens if we change the ingredients slightly? Say we use whole wheat flour, which makes the cake more dense. Or we use more sugar, which makes it sweeter. We will still make a cake, but it will be different. Changing the ingredients doesn’t change the fact that you are making a cake, just how it turns out. This is what climate change does. Climate change doesn’t make the storm (or cake), but it changes the ingredients! The cake will turn out a bit different.”

Activity 1: The Greenhouse Effect Game

Teacher Instructions: This activity will help students make a model of the atmosphere and will facilitate discussion. Students will illustrate a diagram of the greenhouse effect throughout the game. In the student’s drawings there will need to be arrows representing where light, heat, energy, etc. are coming from. As a teacher, these are things you should not instruct your students to do, but highlight as you review their work and as they improve their diagrams after each round of game play. “How did you show movement? Heat? Light? Amount?” Encourage them, “I like how you used arrows to show direction/amount/etc.” The game will work best with 15-30 students.

Setup (see Background Information)

1. Have students each make two notecards. One says HEAT and the other LIGHT.
2. Before going outside, have students draw a diagram of the greenhouse effect in their journals. Be sure they label what they draw, even if it is only a few things. They need to bring their journals outside to draw after each round of the game.
3. Take students outside to play the game. Explain that the smaller circle represents the Earth and the larger one represents Earth’s atmosphere. Have students place their ‘heat’ cards in a pile on the Earth.
 - Misconception Alert: Explain to students that the size to atmosphere is not to scale. In real life the Earth’s diameter is 7,917 miles and the atmosphere reaches about 800 miles above the Earth. A good analogy would be a peach. The flesh would represent the earth and the skin would represent the atmosphere.

Lesson 2: What factors have caused the rise in the global temperature over the last century?

Looking into the causes



Play (Take it Outside)

Round 1: Natural greenhouse effect.

- Choose two students to be CO₂ molecules, and place them anywhere in the Earth's "atmosphere." Once they are in the atmosphere they cannot move their feet. The other students are sunlight (energy) from the sun — standing outside of the atmosphere.
- The object of the game is for the sunlight to enter the atmosphere, tag the Earth, exchange their 'light' card for a 'heat' card, and then escape the atmosphere without getting tagged by a CO₂ molecule. Students can only be tagged once they become heat (after they tag the earth and exchange their cards). This simulation recreates the greenhouse effect: energy from the sun is trapped as heat by CO₂ and other gases in the atmosphere. Sunlight who are tagged must stay standing still in the atmosphere. Those who avoid being tagged bounce back out of the atmosphere into space. The round lasts approximately 30 seconds.
- After the first round, have the escaped sunlight form a circle around the atmosphere to check how much heat has been trapped by greenhouse gases. During the first round, most of the energy will have escaped the atmosphere because CO₂ levels are low. Discuss how this may affect the temperature of the planet. Remind students that a certain amount of CO₂ is necessary to keep the planet consistently warm enough to support life. Before continuing the game, clear all the trapped sunlight (heat) out of the atmosphere.
- After round one, give students several minutes to add or change their diagrams and give them time to journal about what they learned about the greenhouse effect. What would they change about their initial diagram?

Round 2: Human enhanced greenhouse effect.

- Increase the number of CO₂ molecules in the atmosphere. Do this by reaching into the "What do humans do?" bag and pulling out an action card (for this round, include only cards that add CO₂ to the atmosphere). Follow the directions on the card and play again. Give time to journal and draw after round 2.

Round 3: Slowing down the greenhouse effect.

- Put all of the action cards in the bag so that CO₂ levels will increase and decrease based on the actions taken. Discuss what happens with each draw (2-3 cards). Some cards will not increase or decrease CO₂ levels. Riding your bike instead of driving will not add CO₂, but it won't take away CO₂ either. (Students will learn about mitigation in Lesson 5.)
- Give time to journal and draw after round 3. How did students' idea of the greenhouse effect change throughout the game? What conclusions can be drawn?

Activity 1: Wrap-up

Have a discussion about how energy from the sun gets trapped in the Earth's atmosphere. Discuss how human actions, particularly burning fossil fuels, can enhance the greenhouse effect by putting more CO₂ into the atmosphere. This increase in CO₂ which is increasing global temperature is referred to as climate change. The game should demonstrate that when you increase the amount of CO₂, more heat gets trapped (illustrated by the students that were tagged in the atmosphere) and the Earth's temperature increases. The action cards demonstrate how even small-scale actions can affect the amount of greenhouse gas that we emit to the atmosphere. The game can be a springboard into a variety of other explorations such as researching alternative energy sources, discussing sustainable lifestyles, and examining the various solutions humans can take part in. Use the following questions for a wrap-up discussion:

- How was this game like the atmosphere/not like the atmosphere?
- What makes the game an accurate or inaccurate model of the atmosphere?
- How did your diagram change throughout the game? What did you learn during the game?
- How did you show things moving around? How did you show quantity? How did you show that light changes to heat?

Lesson 2: What factors have caused the rise in the global temperature over the last century?

Looking into the causes

Activity 2: Claim, Evidence, Reasoning

1. Introduction: When asked about climate change, most people are able to give an opinion such as, “I believe...”. This activity is going to help students get away from saying “I believe...” and instead say, “Based on the data...”. To accomplish this change of thinking students will be using an argumentation strategy known as Claim, Evidence, Reasoning (see information at beginning of curriculum for explanation and help implementing CER).
2. Students will be working in small groups to read figures from various sources to help answer the question: What is causing the global average temperature on Earth to increase? Based on what they know already, students will make a claim, collect evidence, and build an argument based on their analysis of the figures.
 - a. Put students in groups of 3-4. Hand out a set of Evidence Figures for each group and a Claim, Evidence, Reasoning worksheet for each student. In their groups, students will study each figure and write a brief summary statement of what is being shown. What is the main concept or point being conveyed by the figure? Be sure to use the example format for your answers.
 - b. Using the information you summarized, make a claim that answers the question: What is causing the global average temperature on Earth to increase? (Ex: Global temperatures have risen over the past century because there are more hot air balloons.)
 - c. Give evidence to support your claim. Provide scientific data from the figures and data you were given. Include specific pieces of data. Students will also think about data they feel is missing.
 - d. Give reasoning to explain why your evidence supports your claim. Why is your evidence important? Describe what it means that Earth’s temperature is rising and why your evidence allowed you to determine that the Earth is warming because of those reasons.
 - e. After giving evidence and reasoning, would you revise your claim? Is there more info that you need? Write a statement about how you would revise your claim.

Note: Teachers may decide to share the explanatory information given in the Evidence Figure Set Descriptions with students after they have made their own interpretations. Or you can print off the figures with the descriptions from our website: www.climategen.org/ngconline
3. When students are finished with their worksheets, put students into groups of 5. Pass out the Discussion Diamond worksheet. “What is causing a rise in global temperatures?” Each group member will present their claim and evidence. The other group members will write the claim and the lines of evidence provided in one triangle. Students should develop two clarifying questions based on their notes and ask the presenter. By the end of the presentations, students will each have a summary of the claims and evidence.

Conclusion

1. Show the *Separating Human and Natural Influences on Climate* figure to your students on page 52 or by visiting Figure 2.3 on the website: <https://nca2014.globalchange.gov/report/our-changing-climate/observed-change>
2. In their notebooks, ask students to write their interpretation of the figure. What do each of the lines/colors mean? What are the contributing factors to those lines? Thinking about the other figures you reviewed, what connections can you make to this figure? Bring out the list of items that were discussed in the introduction activity.
 - a. Figure Description: Observed global average changes (black line), model simulations using only changes in natural factors (solar and volcanic) in green, and model simulations with the addition of human-induced emissions (blue). Climate changes since 1950 cannot be explained by natural factors or variability, and can only be explained by human factors.
3. Invite groups to share their explanation of the figure and the connections they made.

Lesson 2: What factors have caused the rise in the global temperature over the last century?

Looking into the causes

Extensions

1. Visit Climate Generation's *Our Changing Climate* curriculum for grades 6-12 for three readings: The Structure of the Atmosphere, Heat-Trapping Gases in the Atmosphere, and The Greenhouse Effect at http://curriculum.climategen.org/2015/OCC_6-12_L1_AtmosphereReadings.pdf. These will help students understand more about the greenhouse effect and heat-trapping gases.
2. Ask students to pursue a line of evidence for the increase in global temperatures that interests them and find some authentic data they can graph themselves and present to their peers. Sources of data that relate to climate change include:

NOAA Earth Monitoring — <https://gml.noaa.gov/>

CoCoRaHs — <http://www.cocorahs.org/ViewData/>

National Centers for Environmental Information — <https://www.ncei.noaa.gov/products>

NASA Data — <http://data.giss.nasa.gov/>

Globe Phenology Data — <http://www.globe.gov/globe-data/visualize-and-retrieve-data>

References

The Greenhouse Effect Game was adapted with permission from Green Teacher #70, Summer 2003. Subscriptions to this non-profit magazine are available from www.greenteacher.com or by calling toll free 1-888-804-1486.

Activity 2: Claim, Evidence, Reasoning was adapted with permission from Barry Golden. Original article (Generating arguments about climate change) from *Science Scope*, 2012.

CER Worksheet Adapted from Katherine L. McNeill and Dean M. Martin's article in *Science & Children*, 4/ 2011

Cake as weather analogy adapted from Angus Ferraro:

<https://angusferraro.wordpress.com/2012/11/19/storms-are-like-cake-analogies-for-weather-and-climate/>

Carbon dioxide video credit: courtesy of NASA and the National Science Foundation.

Humans drive cars.
Every gallon of gas puts 18.8 lbs
of CO₂ into the atmosphere.

Add four CO₂ molecules

Humans ride bikes. Riding a bike is
the most energy efficient form of
transportation and it's free!

DON'T add two CO₂ molecules

Humans cut down trees.
Trees remove CO₂ from the
atmosphere during photosynthesis.
Fewer trees means more CO₂.

Add two CO₂ molecules

Humans create energy
efficient technology.

DON'T add two CO₂ molecules

Humans drive more cars.
In 1906 Ford built the Model T car.
Between 1906 and 1927 15 million
cars were sold. Today, an estimated
500 million are in use worldwide.

Add four CO₂ molecules

Humans plant trees.
Trees remove CO₂ from the
atmosphere during photosynthesis.
More trees means less atmospheric CO₂.

Remove two CO₂ molecules

Humans burn trash.
Burning waste puts CO₂ into the
atmosphere along with other pollutants.

Add two CO₂ molecules

Humans recycle.
Recycling saves energy,
reducing our use of fossil fuels.

DON'T add two CO₂ molecules

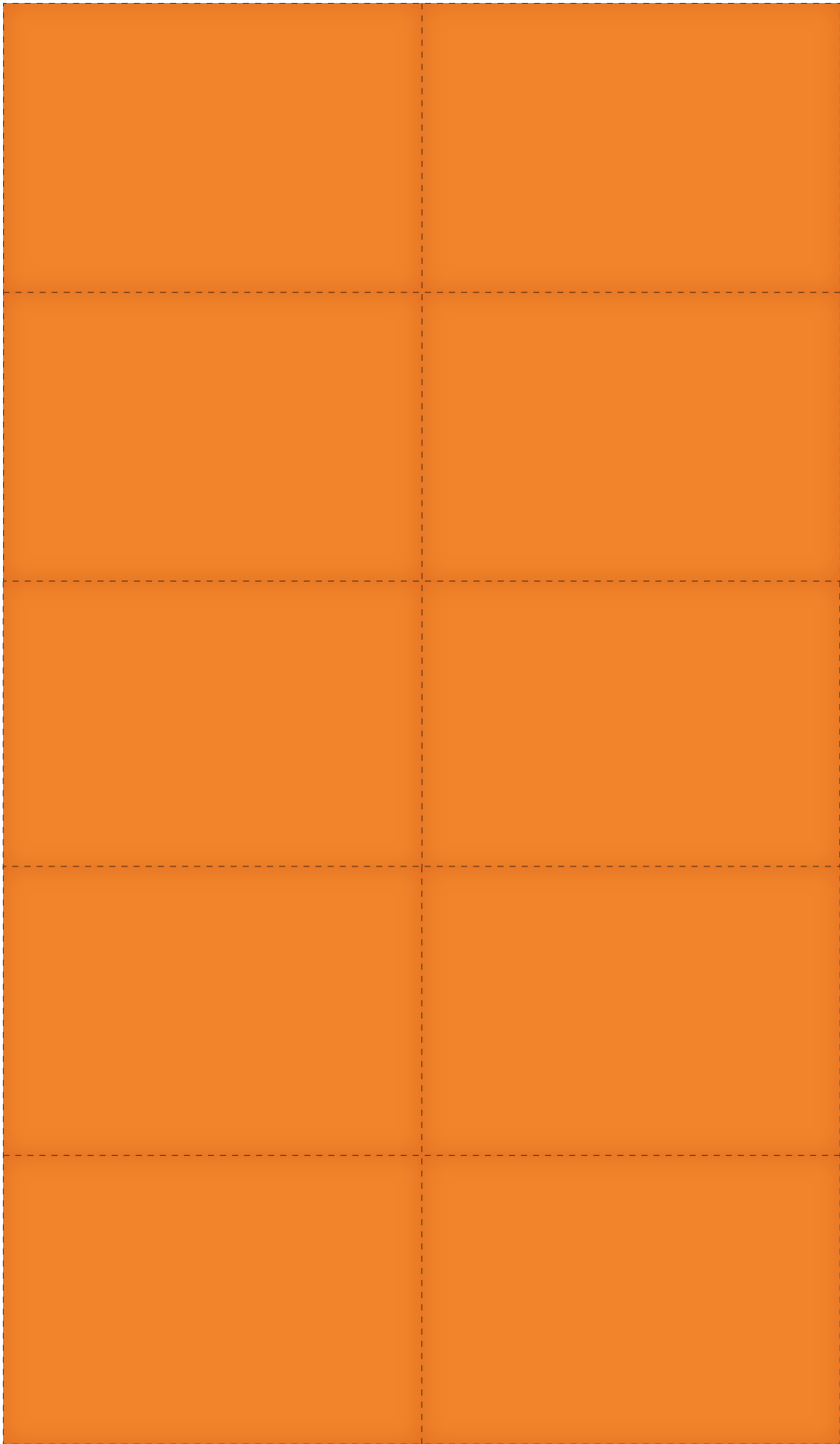
Agriculture activities (N₂O)
Pesticides and unsustainable
farming practices increase
nitrous oxide into the atmosphere.

Add two CO₂ molecules

Humans use wind and solar.
Renewable energy doesn't add
CO₂ or other greenhouse
gases to the atmosphere.

DON'T add two CO₂ molecules





Student Worksheet: Claim, Evidence, Reasoning

In this activity you will write a claim to answer the question: What is causing the global average temperature on Earth to increase?

A. For each figure, write a brief summary statement of what is being shown. What is the main concept or point being conveyed by the figure? Be sure to use the example format for your answers.

Ex) Figure 5 shows the carbon emissions from burning coal, oil, gas, and producing cement from 1850 to 2012. All areas are showing an overall increase in emissions with the total carbon emissions totaling over 8,000 million metric tons.

1. Graph Title: _____

Summary

2. Graph Title: _____

Summary:

3. Graph Title: _____

Summary

4. Graph Title: _____

Summary



5. Graph Title:
Summary

6. Graph Title:
Summary

7. Graph Title:
Summary

8. Graph Title:
Summary:



9. Graph Title: _____
Summary

10. Graph Title: _____
Summary



B. Using the information you collected, make a claim to answer the question: What is causing the global average temperature on Earth to increase? Ex) Global temperatures have risen over the past century because there are more hot air balloons. (Use the underlined part of the statement to start your claim.)

Claim:

C. Give evidence to support your claim. Provide scientific data from the graphs and figures you were given. Include specific pieces of data.

Evidence:

D. Is there any information you feel like you're missing? Explain.

E. Give reasoning to explain why your evidence supports your claim. Why is your evidence important? Describe what it means that Earth's temperature is rising and why your evidence allowed you to determine that the Earth is warming because of those reasons.

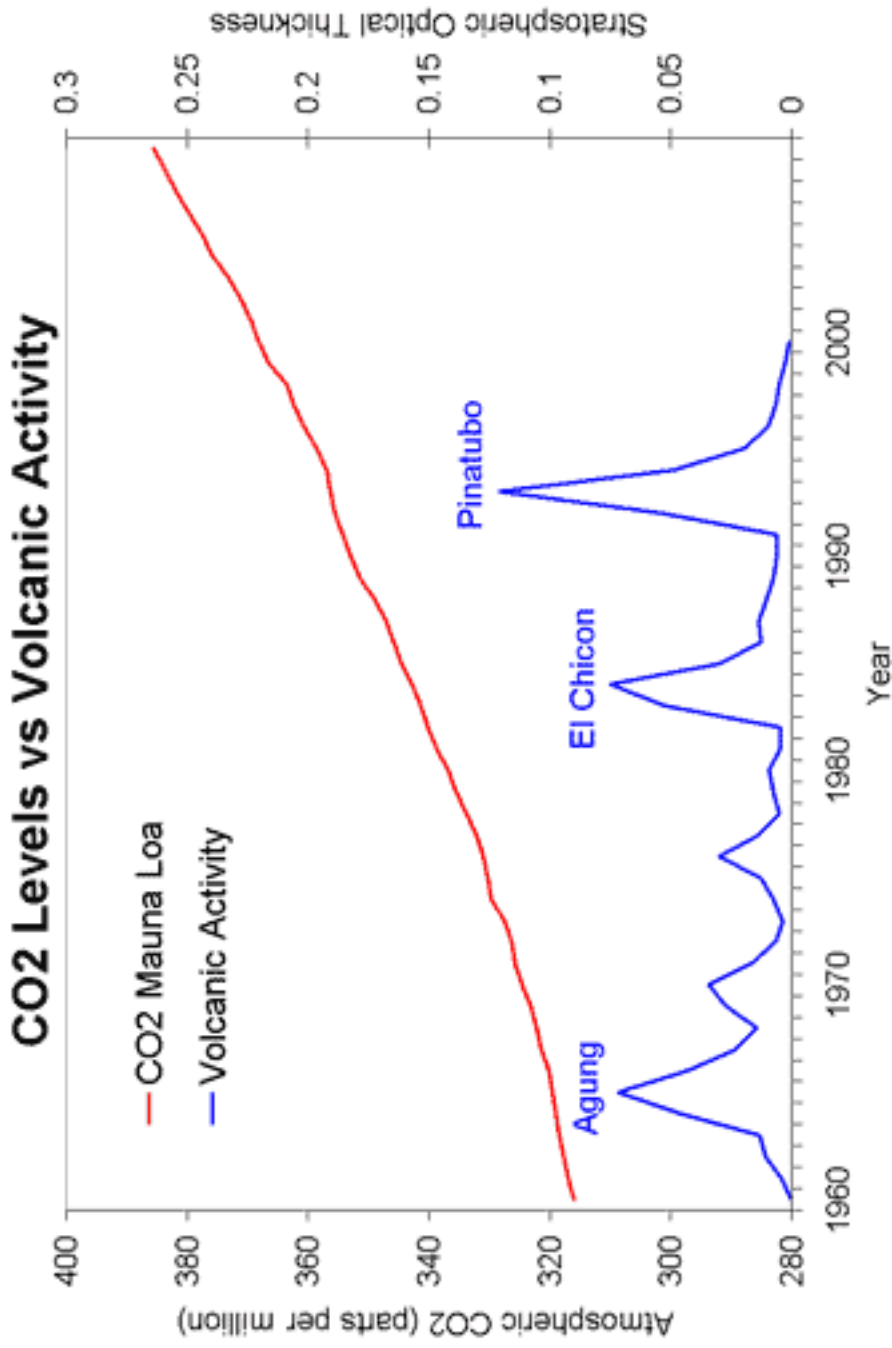
Reasoning:

F. After giving evidence and reasoning, would you revise your claim? Is there more info that you need?

Revise:



Figure 1 – CO₂ Levels vs. Volcanic Activity



Note: Stratospheric Optical Thickness is the measure of aerosols (e.g., urban haze, smoke particles, desert dust, sea salt) distributed within a column of air from the instrument (Earth's surface) to the top of the atmosphere.

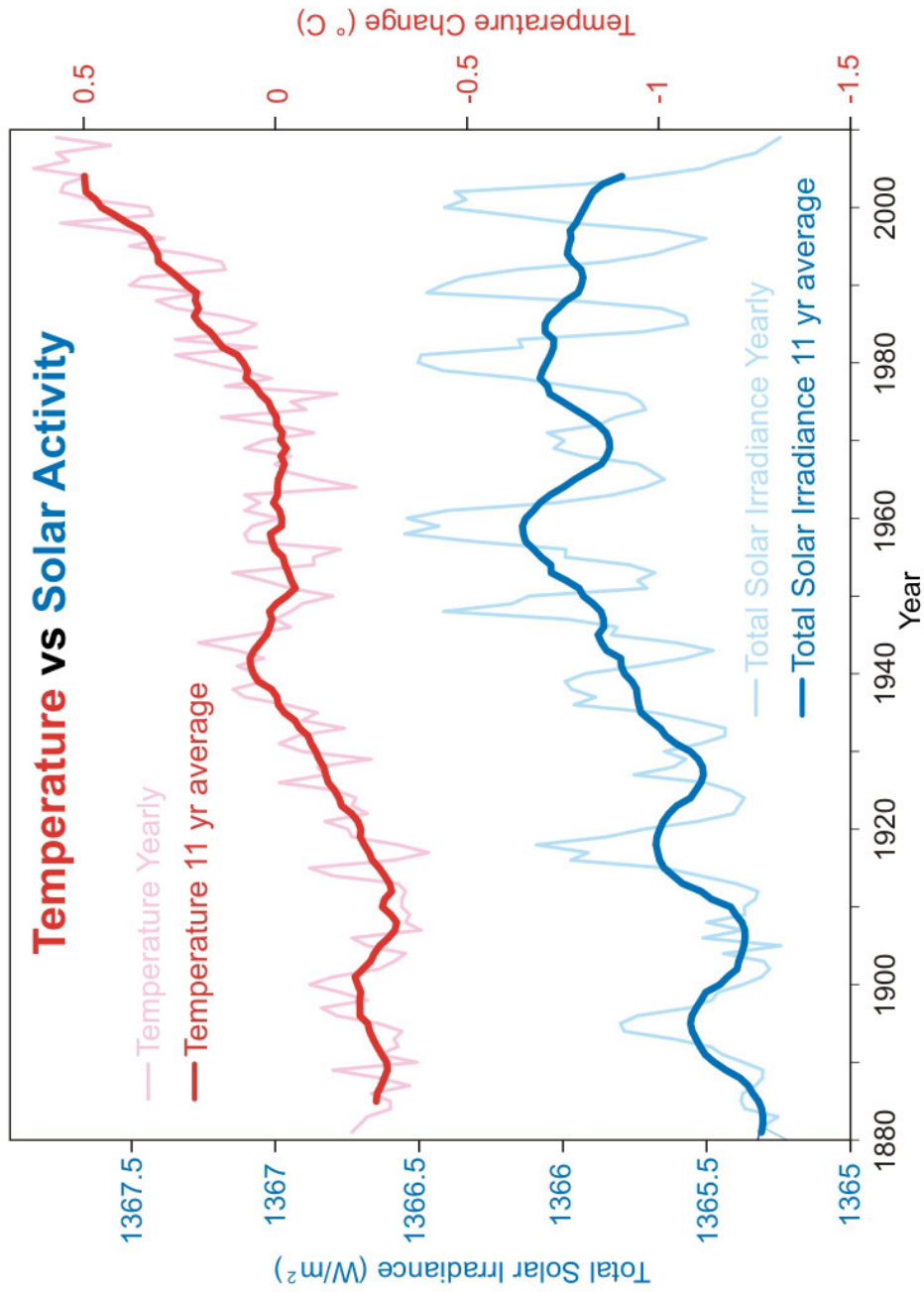
Skeptical Science. (2015). *Do volcanoes emit more CO₂ than humans?* Retrieved from www.skepticalscience.com/print.php?r=50

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Figure 2 — Temperature vs. Solar Activity



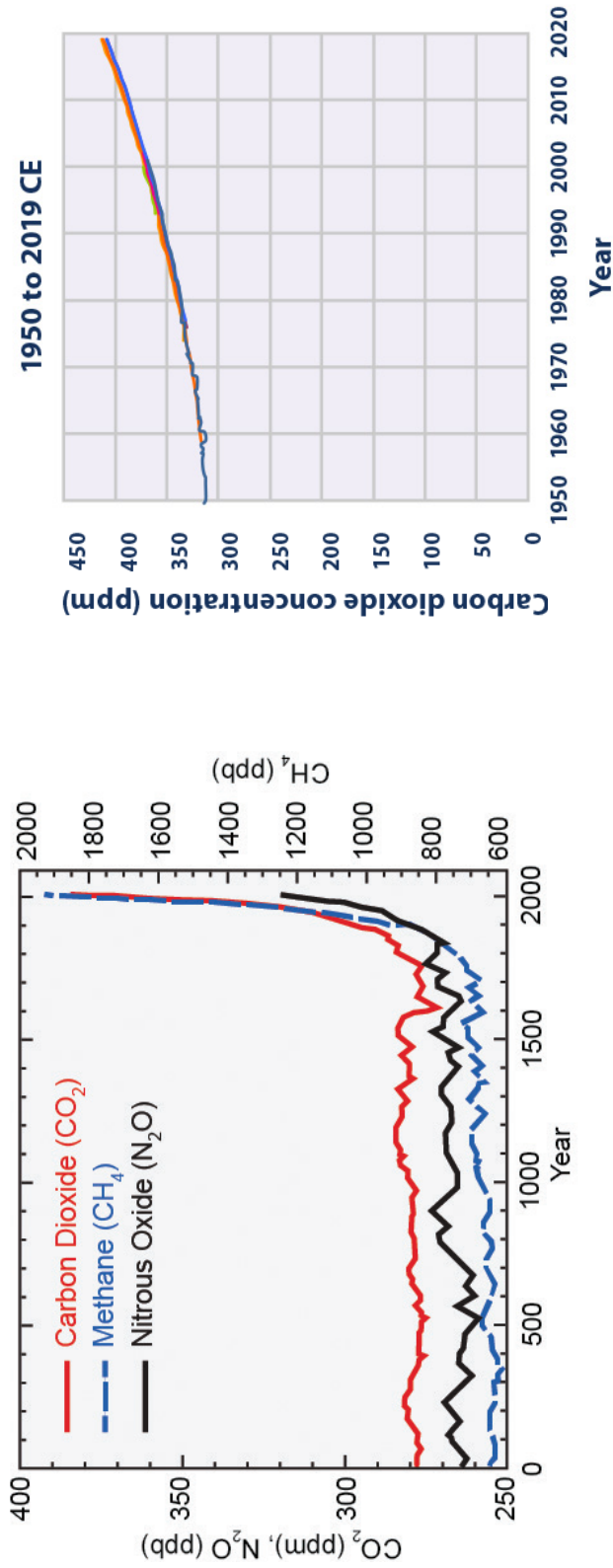
Note: Total Solar Irradiance is the power per unit area produced by the Sun.

Skeptical Science. (2015). *Sun & climate: moving in opposite directions.*

Retrieved from <https://www.skepticalscience.com/solar-activity-sunspots-global-warming.htm>

Skeptical Science Graphics by Skeptical Science is licensed under a [Creative Commons Attribution 3.0 Unported License](#).

Figure 3 – Heat-Trapping Gas Levels



National Climate Assessment and Development Advisory Committee. (2014). *Climate Science Supplement*.

Retrieved from <http://nca2014.globalchange.gov/report/appendices/climate-science-supplement>

Source: Adapted from: Climate Change 2013: The Physical Science Basis

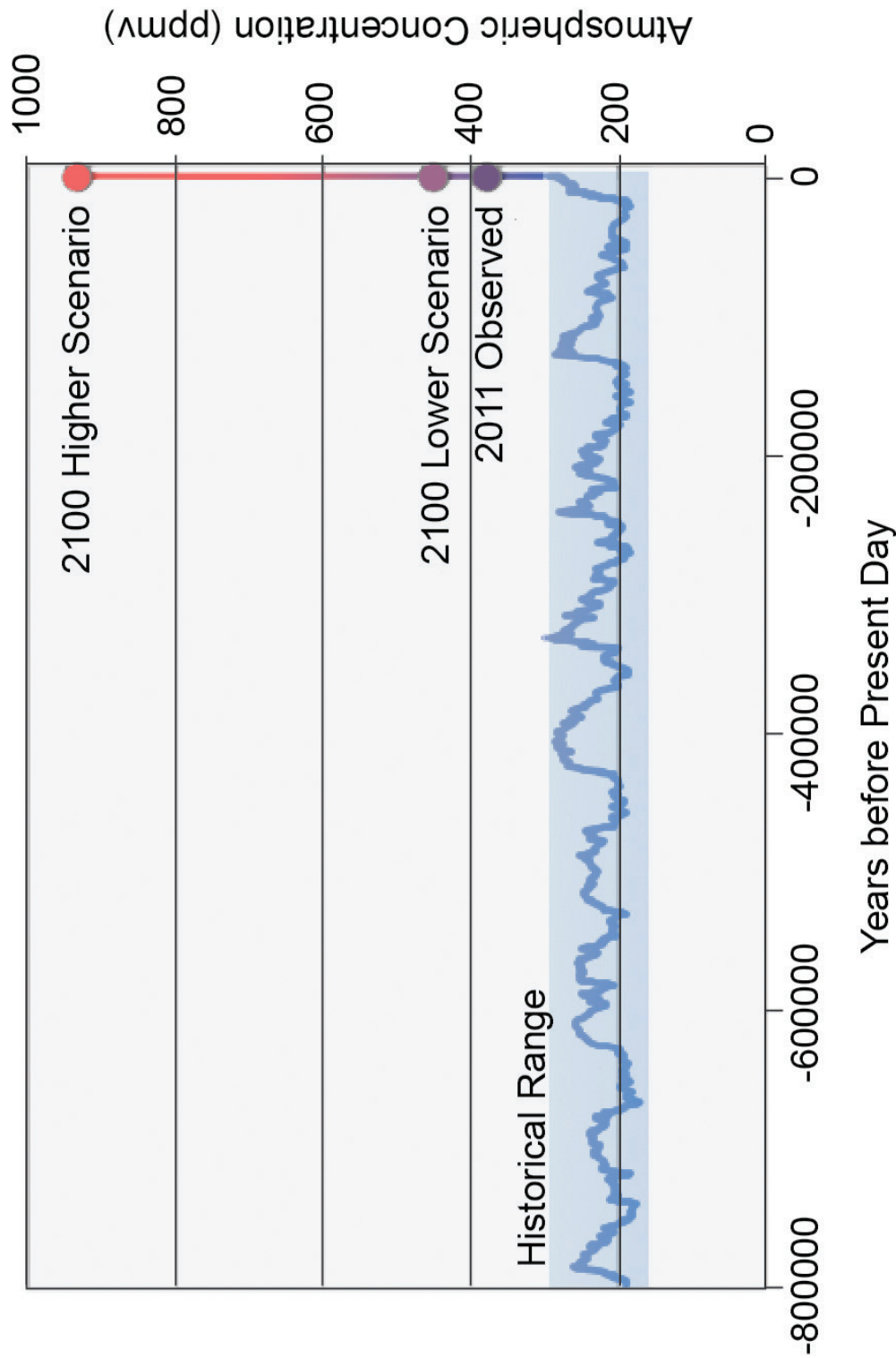
Data source: Compilation of eight underlying datasets. See www.epa.gov/climate-indicators for specific information.

Retrieved from: <https://www.epa.gov/climate-indicators/climate-change-indicators-atmospheric-concentrations-greenhouse-gases#ref5>





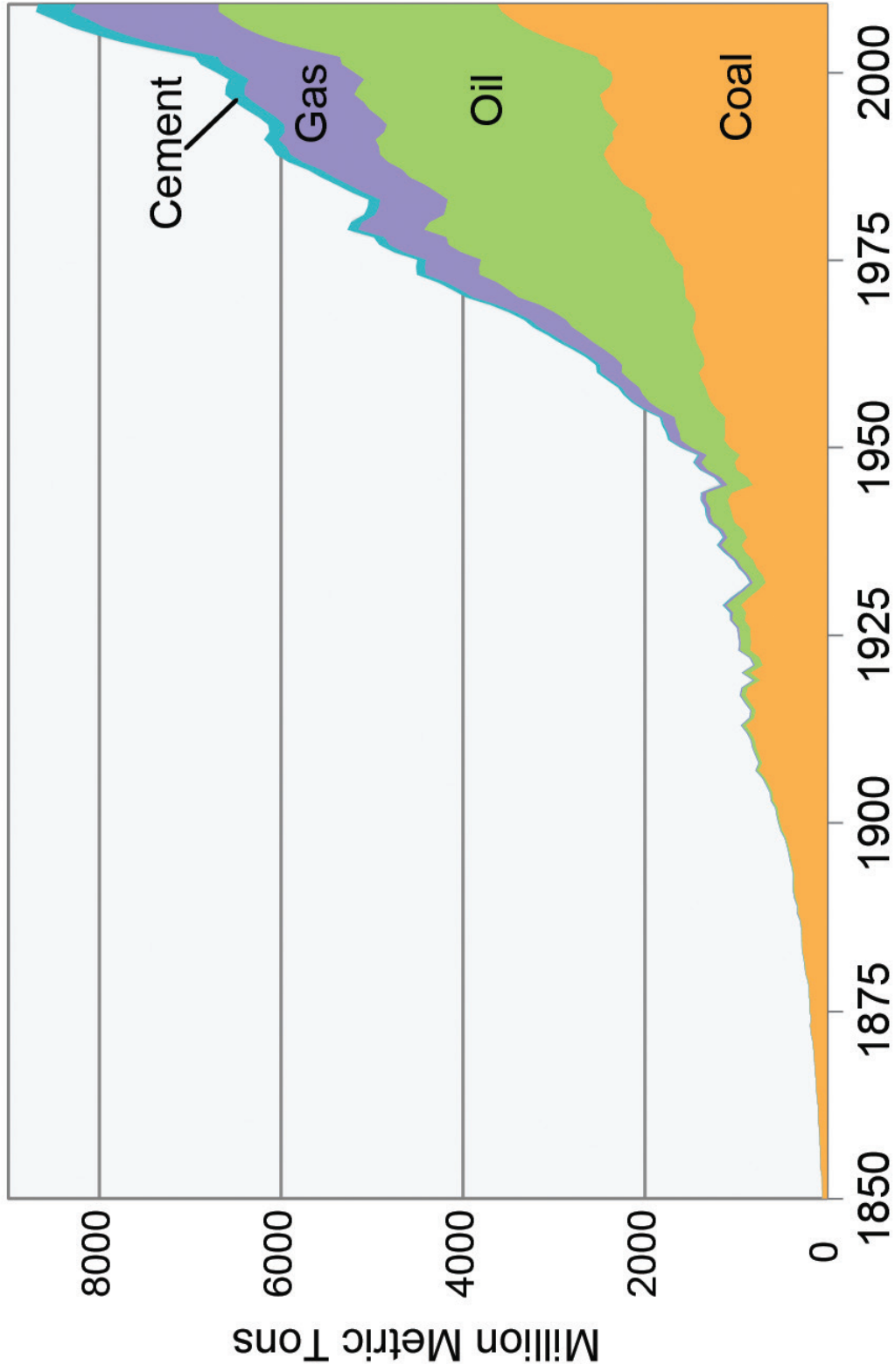
Figure 4 – Atmospheric Carbon Dioxide Levels



National Climate Assessment and Development Advisory Committee. (2014). *Climate Science Supplement*. Retrieved from <http://nca2014.globalchange.gov/report/appendices/climate-science-supplement>

Source: Katharine Hayhoe, Texas Tech University

Figure 5 — Carbon Emissions in the Industrial Age

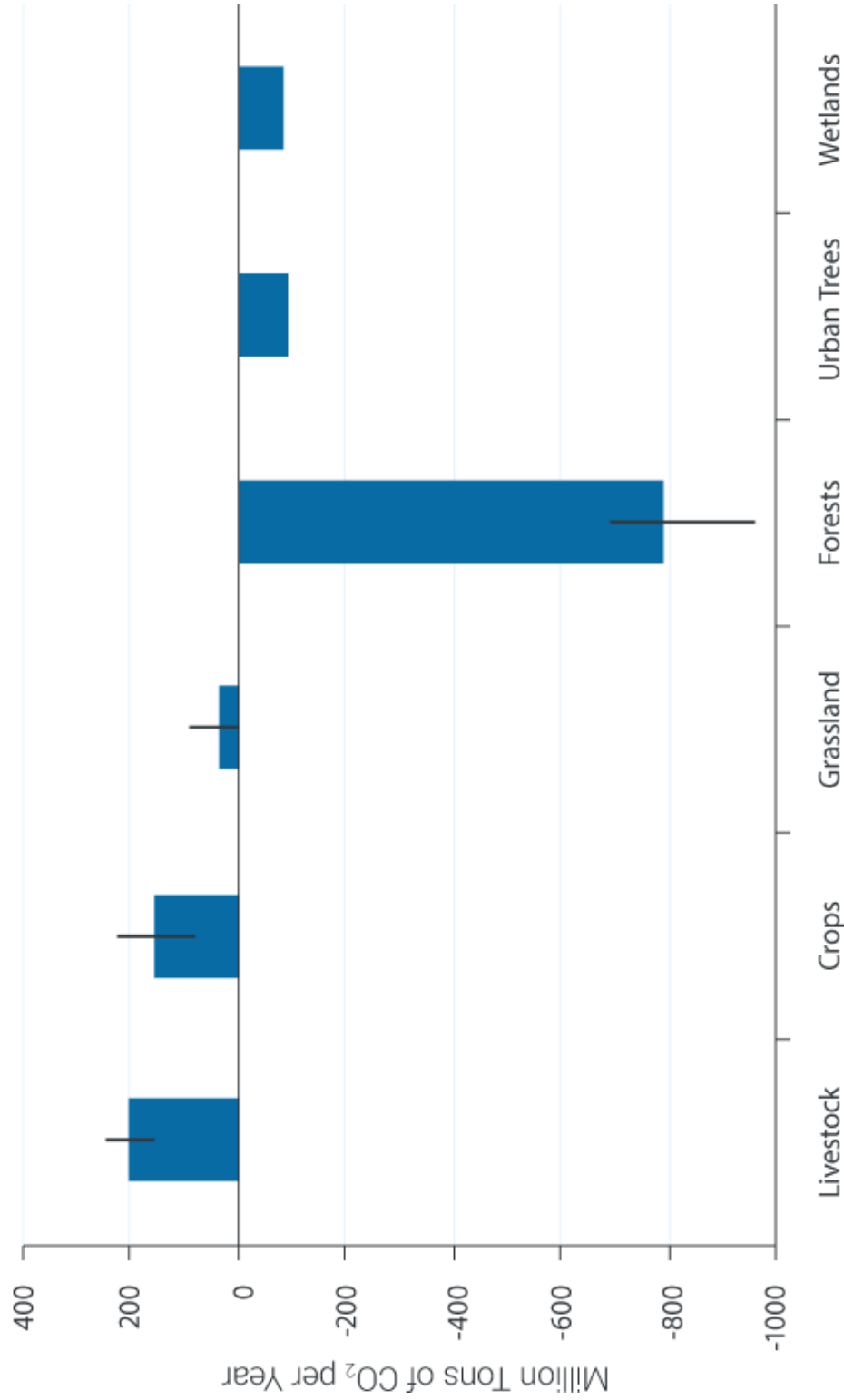


National Climate Assessment and Development Advisory Committee. (2014). *Climate Science Supplement*. Retrieved from <http://nca2014.globalchange.gov/report/appendices/climate-science-supplement>
(Source: Katharine Hayhoe, Texas Tech University)



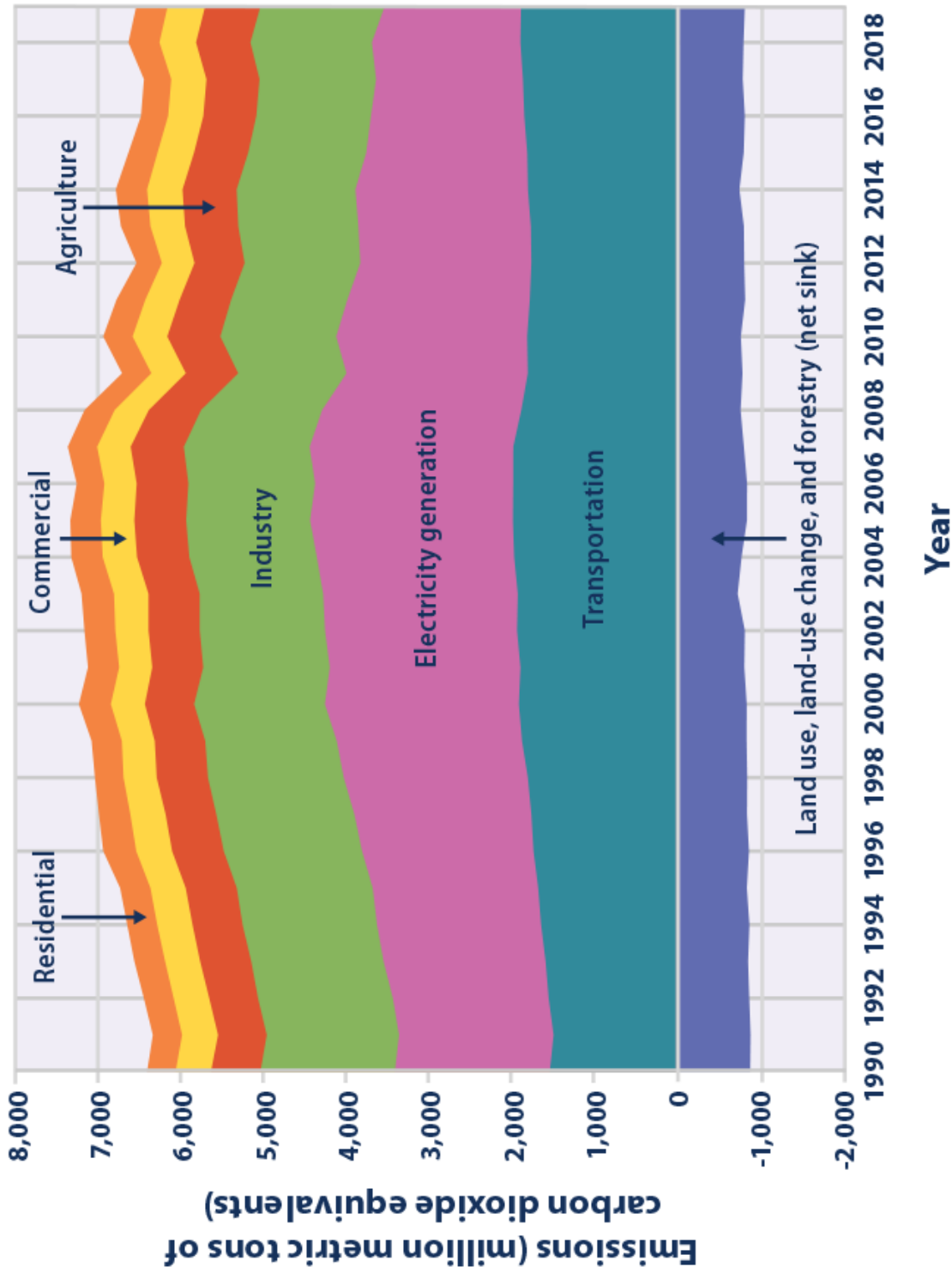


Figure 6 – Sources and Sinks in U.S. Agriculture and Forests



National Climate Assessment and Development Advisory Committee. (2014). *Mitigation*. Retrieved from <http://nca2014.globalchange.gov/report/response-strategies/mitigation#graphic-17171>

Figure 7 – U.S. Greenhouse Gas Emissions and Sinks by Economic Sector from 1990–2019



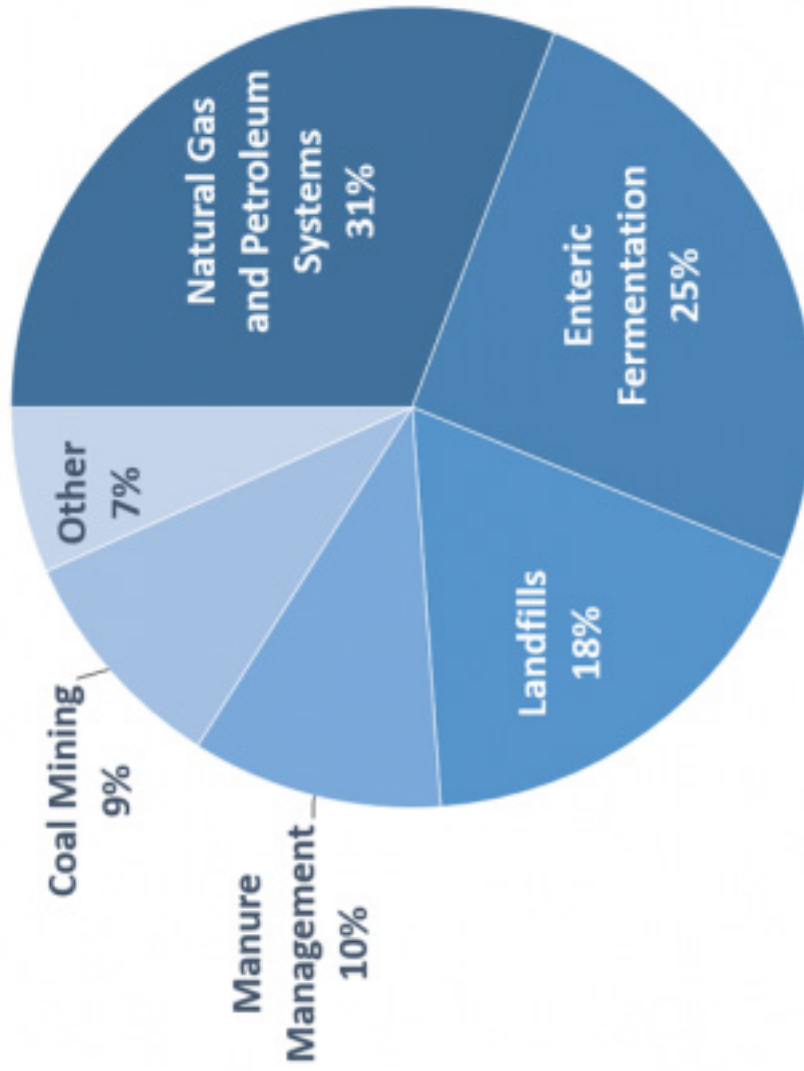
Data Source: U.S. EPA (U.S. Environmental Protection Agency). 2021. Inventory of U.S. greenhouse gas emissions and sinks: 1990–2019. EPA 430-R-21-005. www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks.

U.S. Environmental Protection Agency. (2021). *Climate Change Indicators in the United States*. Retrieved from <https://www.epa.gov/climate-indicators/climate-change-indicators-us-greenhouse-gas-emissions#ref5>





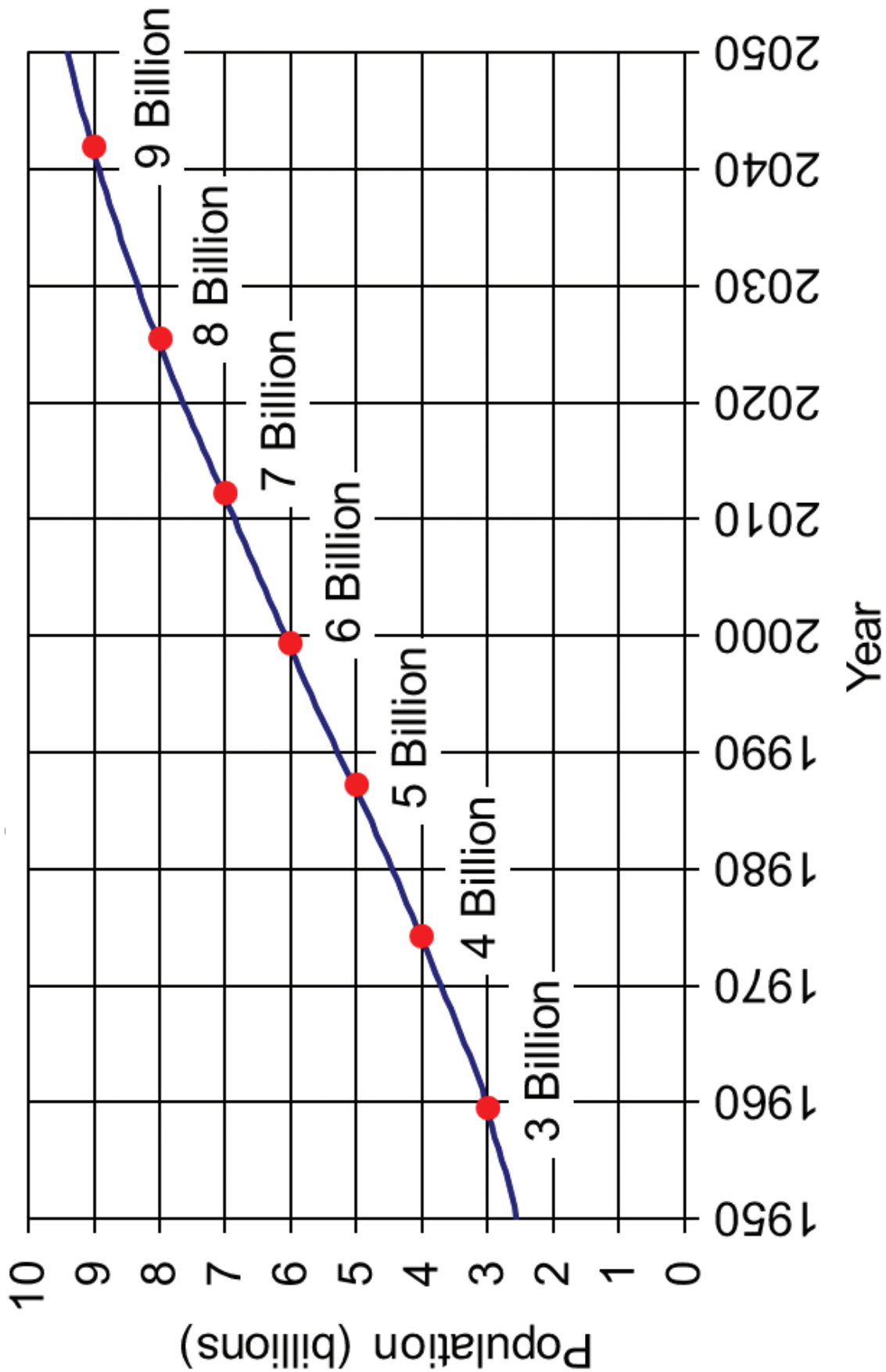
Figure 8 – U.S. Methane Emissions, by source



U.S. Environmental Protection Agency (2017). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2015.

U.S. Environmental Protection Agency. (2016). Overview of Greenhouse Gases. Retrieved from <https://www.epa.gov/ghgemissions/overview-greenhouse-gases>

Figure 9 — World Population: 1950-2050

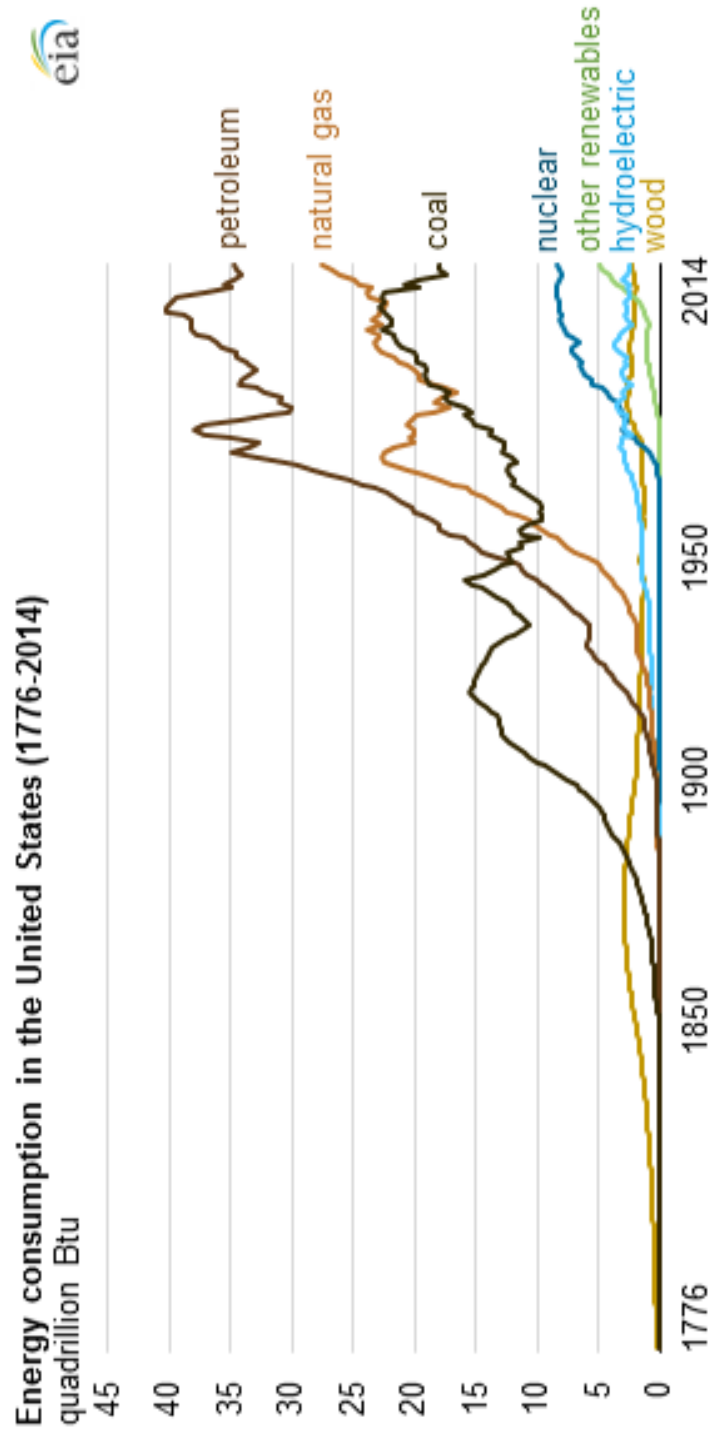


U.S. Census Bureau. (2015). *International Programs*.





Figure 10 – Energy Consumption in the United States (1776-2014)



U.S. Energy Information Agency. (2015). *Today in Energy*. Retrieved from <http://www.eia.gov/todayinenergy/detail.cfm?id=21912>. (Source: U.S. Energy Information Administration, Monthly Energy Review)

Evidence Figure Set Descriptions

1. CO₂ Levels vs. Volcanic Activity — Volcanoes emit CO₂ both on land and underwater. Underwater volcanoes have little effect on atmospheric CO₂ levels. Land volcanoes are estimated to emit 242 million tons of CO₂ per year. In contrast, humans are currently emitting around 29 billion tons of CO₂ per year. Human CO₂ emissions are over 100 times greater than volcanic CO₂ emissions. When comparing atmospheric CO₂ levels to volcanic activity, it is apparent that large volcanic eruptions have little impact on CO₂ levels.

2. Temperature vs. Solar Activity — Over the last 35 years the sun has shown a slight cooling trend. However global temperatures have been increasing. Since the sun and climate are going in opposite directions scientists conclude the sun cannot be the cause of recent climate change. The only way to blame the sun for the current rise in temperatures is by cherry picking the data. This is done by showing only past periods when sun and climate move together and ignoring the last few decades when the two are moving in opposite directions.

3. Heat-Trapping Gas Levels — Current atmospheric levels of carbon dioxide, methane, and nitrous oxide are notably higher than their pre-industrial (1750) averages. Air sampling from 1958 shows the steady increase in CO₂, which has been largely influenced by humans. The increases and decreases in the Carbon Dioxide graph is caused by seasonal changes in the Northern Hemisphere. As the leaves come out in the spring, they capture more CO₂ from the atmosphere. In the winter they lose their leaves and are not able to capture the CO₂ and therefore, the amount of CO₂ in the atmosphere goes up.

4. Atmospheric Carbon Dioxide Levels — Air bubbles trapped in ice cores can be examined to help scientists determine what the atmosphere was like many years ago. Ice core data goes back 800,000 years, and only recently has the CO₂ level increased to 400 parts per million (ppm). Before human activity, CO₂ levels fluctuated between 170 and 300 ppm. By 2100, additional emissions from human activities are projected to increase CO₂ levels to 420 ppm (Lower Scenario), which would require immediate and sharp emissions reductions. If we continue to increase our emissions, the Higher Scenario predicts that we will reach 935 ppm by 2100.

5. Carbon Emissions in the Industrial Age — This figure shows global carbon emissions from burning coal, oil, gas and producing cement. These emissions account for about 80% of the total emissions of carbon from human activities. Land-use changes (like cutting down forests) accounts for the other 20% of emissions in recent decades. Land-use changes increases total emissions because the carbon that was stored in a tree is released after the forests are cut down.

6. Sources and Sinks in U.S. Agriculture and Forests — This figure shows the annual average greenhouse gas emissions from land use including livestock and crop production, but does not include fossil fuels used in agricultural production. Forests are a significant “sink” that absorbs CO₂ from the atmosphere. Urban trees and wetlands are also sinks. As we cut down more and more forests, we are not only adding the carbon that was captured in the trees, but are also unable to capture any more carbon in the future. All values shown are for 2008, except wetlands, which are shown for 2003. (Black lines in graph represent uncertainty.)



Evidence Figure Set Descriptions (cont.)

7. U.S. Greenhouse Gas Emissions and Sinks by Economic Sector — This figure shows greenhouse gas emissions and sinks by source in the United States from 1990 - 2019. Notice how there are many more sources of emissions than sinks. In order to decrease emissions, the negative values must be closer to the positive values to cancel each other out.

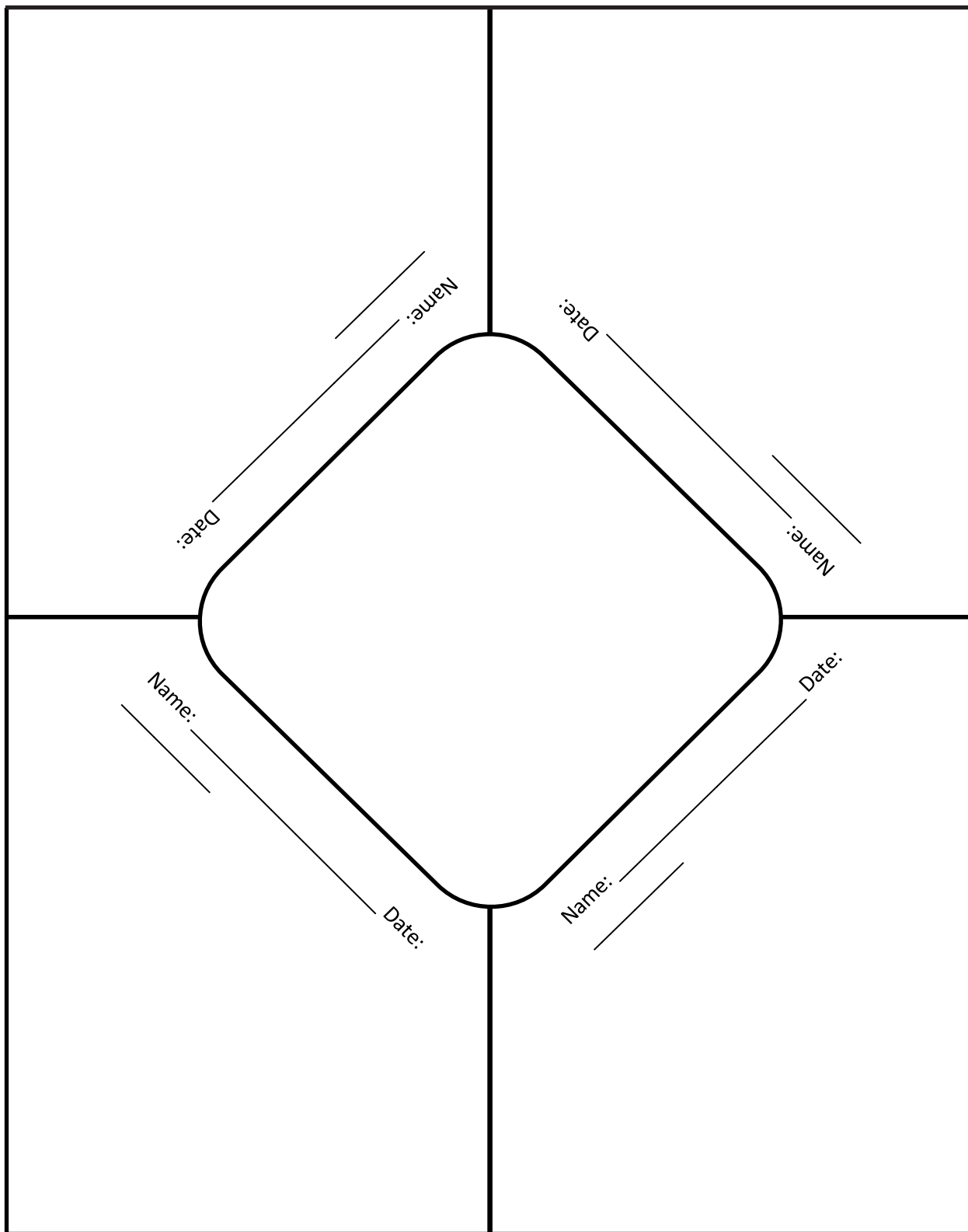
8. U.S. Methane Emissions — This pie chart shows the U.S. methane emissions by source. Methane (CH₄) is the second most prevalent greenhouse gas emitted in the United States from human activities. Methane accounts for about 10% of all U.S. greenhouse gas emissions. Methane is also emitted by natural sources, such as wetlands. Methane's lifetime in the atmosphere is much shorter than CO₂, but methane is a much stronger greenhouse gas. Globally, over 60% of total CH₄ emissions come from human activities. (Enteric fermentation is a process that takes place in the stomachs of livestock animals and leads to the animal passing gas and releasing methane.)

9. World Population: 1950-2050 — The world population increased from 3 billion in 1959 to 6 billion by 1999, a doubling that occurred over 40 years. The Census Bureau's latest projections imply that population growth will continue into the 21st century, although more slowly. The world population is projected to grow from 6 billion in 1999 to 9 billion by 2044, an increase of 50 percent that is expected to take 45 years.

10. Energy Consumption in the United States (1776-2014) — This graph shows the energy consumption of the U.S. from 1776 to 2014. Nonrenewable resources like coal, natural gas, and oil have created most of the energy for the U.S. over the nation's history. But new forms of energy— nuclear— and renewable forms of energy—wind, solar, geothermal, and biomass— have started to provide a larger share of the U.S. energy consumption. The total amount of energy consumed continues to rise overall because of increased population and consumption. Notes: a BTU (British Thermal Unit) is the quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit at a specified temperature.



Discussion Diamond Worksheet

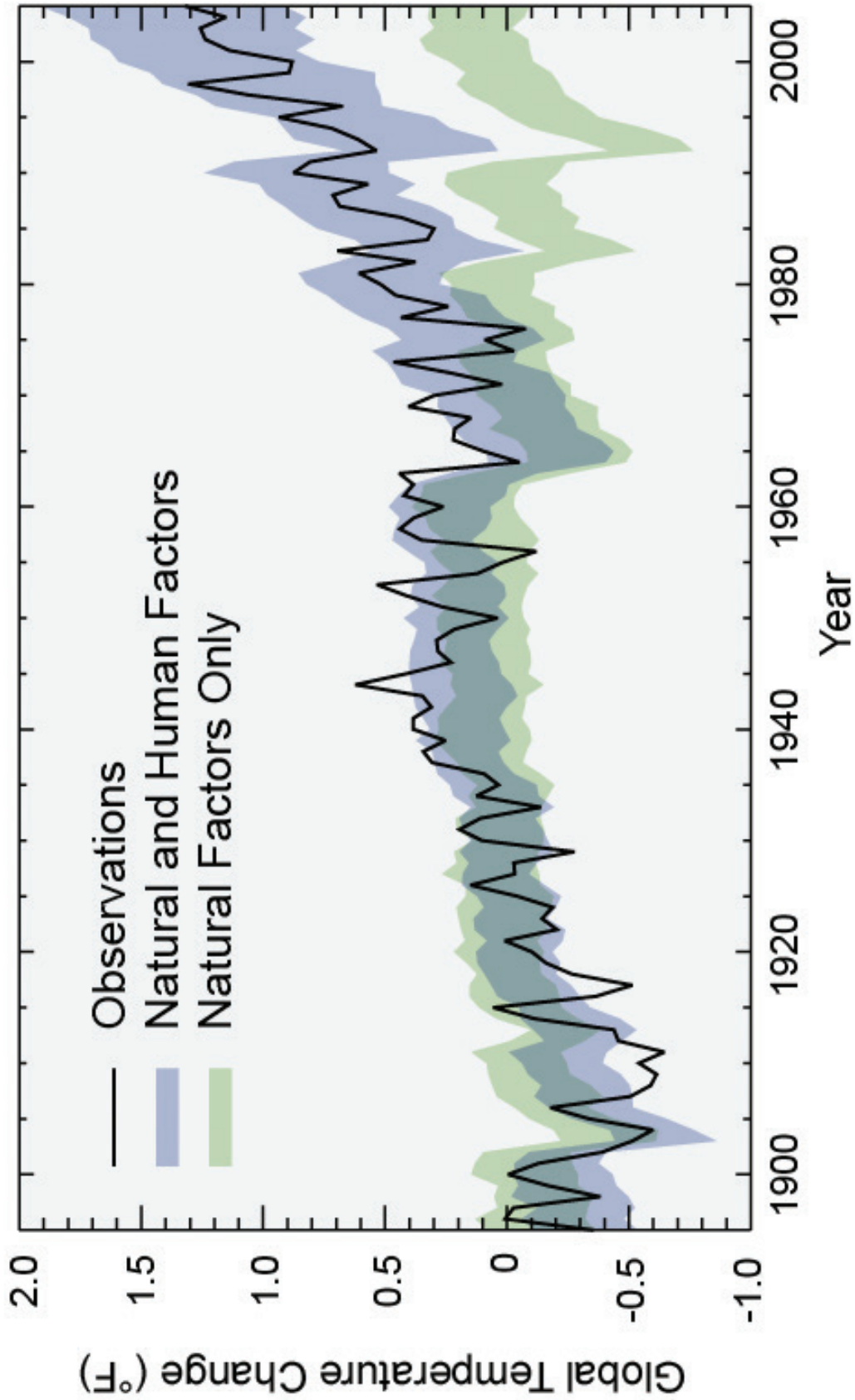


The diagram is a large square divided into four quadrants by a vertical and a horizontal line. In the center of the square is a diamond shape with rounded corners. Each of the four corners of the diamond is positioned at the intersection of the central lines and the outer square border. Each of these four corners contains a label: 'Name:' and 'Date:'. The labels are oriented diagonally, following the shape of the diamond's corners. Specifically, the top-left corner has 'Name:' above 'Date:', the top-right corner has 'Date:' above 'Name:', the bottom-left corner has 'Name:' above 'Date:', and the bottom-right corner has 'Date:' above 'Name:'.





Separating Human and Natural Influences on Climate



National Climate Assessment and Development Advisory Committee. (2014). *Observed Change*. Retrieved from <http://nca2014.globalchange.gov/report/our-changing-climate/observed-change>
(Figure source: adapted from Huber and Knutti)