

# METHANE MATTERS



Studies For Our Global Future

## introduction

**Methane (CH<sub>4</sub>)** is the main component in natural gas and responsible for about 20 percent of global warming. The atmospheric concentration of methane has risen more than 250 percent since pre-Industrial times, and while this concentration is much smaller than carbon dioxide (CO<sub>2</sub>), methane's heat-trapping properties are far greater – about 86 times as potent over a 20-year period.<sup>1</sup> One of the key biological processes that causes methane emissions is **anaerobic digestion**, the breakdown of plant materials in the absence of oxygen, as happens in swamps and inside cattle. Methane is also produced through certain human activities that have increased as our population has grown, including farming, ranching, mining, leaks from gas pipes, and solid waste production. **Anthropogenic**, or human-caused, methane emissions represent 60 percent of all CH<sub>4</sub> emissions and are increasing faster than any time since record keeping began in the 1980s.<sup>2</sup> Because CH<sub>4</sub> has a relatively shorter lifetime in the atmosphere than CO<sub>2</sub> (10 years as compared to 300+ years), efforts to reduce methane emissions can go a long way to preventing higher global temperatures.

**Vocabulary:** anaerobic digestion, anthropogenic, enteric fermentation, global warming, greenhouse gas, methane

## materials

### Part 1

- Student Worksheet
- Graph paper

### Part 2

- Student Assignment Sheet (provided)

## Part 1: People and Methane

### procedure

1. Distribute the Student Worksheet and a sheet of graph paper to each student. Allow them time to work through the questions and graphing exercises, either individually or in pairs. Consider answering Question #1 as a class to introduce students to the open-ended nature of the questions. They may then work independently beginning with Question #2.

### concept

Production of methane, a greenhouse gas, can be linked directly to human activity.

### objectives

Students will be able to:

- Identify ways in which human activity affects atmospheric methane concentrations.
- Graph world population and atmospheric methane over time and explore the relationship.
- Research and report on mitigation strategies for different sources of human-caused methane.

### subjects

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

### skills

Understanding cause and effect, graphing and analyzing data, interpreting line graphs, obtaining, evaluating and communicating information

### method

Through graphing and guided questioning students examine the cause and effect relationship between human activities and methane production. They then research and prepare presentations on methane mitigation projects.

2. Review the Worksheet answers as a class.

### Answers to Student Worksheet

See Answer Key

## discussion questions

1. What do you think caused these increases in methane levels over the past 240 years?

*All the causes have not been pinpointed, but the increases coincide with such important historical events as the colonization and clearing of the Americas, the Industrial Revolution, and an eight-fold increase in human population.*

2. If present trends continue, what would you predict for the year 2050?

*A larger global population and a higher level of atmospheric methane.*

3. What might change these present trends?

*Stabilizing human population growth and reducing activities which cause methane production (see answer to Question #1 on the Student Worksheet for examples). Also, the implementation of new technologies that could capture and repurpose the methane, keeping it from escaping into the atmosphere.*

4. Do you think some regions of the world bear more responsibility for reducing methane emissions than others? Why or why not?

*Answers will vary. Looking at the bar graph, students may reasonably conclude that all regions of the world contribute to methane emissions, but in different ways and different amounts.*

## Part 2: Methane Mitigation

### procedure

1. Distribute the Student Assignment Sheet and decide whether students should work on it individually or in pairs.
2. Provide students with appropriate parameters for their research, slide show development, and presentation. For example, provide guidance on the number of slides, application (PowerPoint, Google Slides, etc.), number of sites they should check for their research, and amount of time they should spend on the assignment.
3. After reviewing students' finished slide shows, you could select several for presentation to the entire class.

### assessment

Review completed Student Worksheets and evaluate the quality of their presentations from the Student Assignment.

## follow-up activities

1. Students go to [EPA's Flight tool](#) to explore the **greenhouse gas** (GHG) emissions in their community, city, or state. You can have students filter GHG data in a variety of ways, including by facility, industry, location, or gas. Have students specifically look at methane emissions in their area and the sectors that are responsible. As a class, discuss the sectors or types of facilities that produce the most methane emissions in your area and how they think facilities reduce their greenhouse gas emissions.
2. When most people think of greenhouse gases, they only think of carbon dioxide and may not realize the significance of methane and other GHGs. Have student create a short public service announcement (PSA) that educates about an action that individuals can take to help reduce methane emissions. This could be in any media (e.g. short video for social media, print ad, etc.).

Adapted with permission from the Climate Protection Institute. The original, "Human Activity and Methane Production," appears in *Global Warming Activities for High School Science Classes* by Dorothy Rosenthal and Richard Golden, Climate Protection Institute, Oakland, CA, 1991.

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<sup>1</sup>Jackson, R.B., et. al. (2020, July 15). Increasing anthropogenic methane emissions arise equally from agricultural and fossil fuel sources. *Environmental Research Letters*. Vol. 15. No. 7.

<sup>2</sup>United Nations Economic Commission for Europe. (n.d.). *The Challenge*. UNECE. Retrieved from <https://unece.org/challenge>

# METHANE MATTERS | student worksheet

Name: \_\_\_\_\_ Date: \_\_\_\_\_

Methane (CH<sub>4</sub>), our most abundant hydrocarbon (often called natural gas) is a very efficient absorber of infrared radiation and accounts for 20 percent of greenhouse gas emissions. Ice bubble analysis has shown that methane concentration held steady for most of the last 10,000 years. About 300 years ago the level began to rise, and 100 years ago it began to soar. This is attributed to the **anthropogenic**, or human-caused, sources of methane as opposed to the naturally occurring sources.

The concentration of methane gas in the atmosphere has increased more than 250 percent since pre-Industrial times, dwarfing the 50 percent increase in the concentration of carbon dioxide (CO<sub>2</sub>). CO<sub>2</sub> is the only greenhouse gas responsible for a larger share of global warming than methane. However, methane is a more powerful greenhouse gas than CO<sub>2</sub>; one ton of methane has the same warming effect as 21 tons of CO<sub>2</sub> with 86 times the warming effect over a 20-year timespan.

1. Below is a list of sources of methane in order of volume produced – highest to lowest.

- wetlands, swamps
- livestock (**enteric fermentation**\* and manure)
- oil and gas industry (extraction, processing, and distribution)
- landfills and wastewater
- coal mining
- rice cultivation (rice paddies)
- biomass burning (including forests and savannas)
- termites and other insects
- methane hydrates (crystals found in sea-floor sediments) and organic matter in arctic permafrost

\*Enteric fermentation is the digestive process in ruminant animals (cattle, buffalo, sheep, goats, and camels) where microbes break down food. Methane is released as a byproduct of this process when the animals belch.

Which of the above are anthropogenic sources of methane? Which do you consider natural sources of methane? Explain your selections.

2. Natural sources of methane could also be impacted by human activities. The permafrost of tundra regions and of polar ocean sediments contain vast quantities of methane trapped by frozen water molecules. What may happen if, partly due to the increase in atmospheric methane and other greenhouse gases, the environment gets warmer and the frozen water melts?
3. Cattle, goats, and sheep emit methane as they digest grass and other fibrous plants. Each head of beef cattle in the U.S. belches out about 0.4 pounds of methane per pound of beef it yields. Add the  $\text{CO}_2$  released from fuels burned in animal farming, and every pound of steak has the same greenhouse warming effect as a 30-mile drive in a typical U.S. car. Livestock account for one-third of all human-caused methane emissions.
- a. According to the U.S. Department of Agriculture, people in the U.S. consume an average of 58 pounds of beef per year. If each pound of beef contributes 0.4 pounds of methane, how many pounds of methane does this contribute per person?
- b. What, if anything, could be done to reduce cattle's contribution to climate change?

4. On graph paper, construct a chart with the years 1780 - 2020 C.E. along the x-axis, “world population (in billions)” written along the right y-axis, and “methane concentration (ppm)” written along the left y-axis. Using the data below, construct two line graphs on your chart: one showing world population growth over time and the other showing the amount of atmospheric methane over time.

Year	Methane (ppm)	World Population (in billions)
1780	0.71	0.84
1820	0.75	1.08
1860	0.79	1.29
1900	0.87	1.58
1940	1.05	2.30
1980	1.48	4.45
2020	1.89	7.80

Sources: Methanelevels.org; worldpopulationhistory.org

- a. What appears to be the relationship between human population and methane concentrations in the atmosphere?
- b. What do you think is the reason for this relationship? Does the graph, alone, establish a causal relationship?

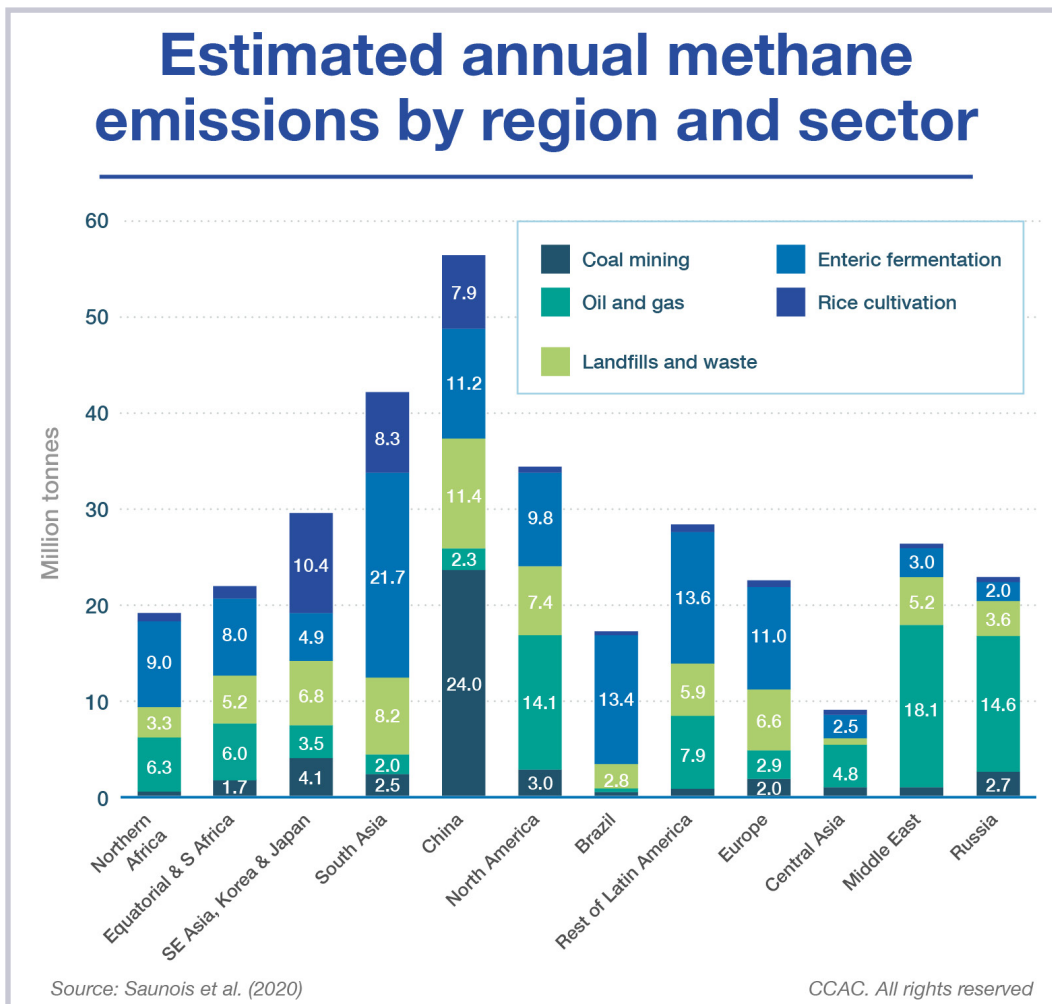
5. Leading sources of methane emissions vary among regions of the world. Use the stacked bar graph on the next page to answer the following questions:

- a. Which region emits the most methane from:
- coal mining?
  - oil and gas?
  - rice cultivation?
  - enteric fermentation?

b. What are the leading sources of emissions in North America?

c. What does the data suggest about where and how methane mitigation efforts would need to be implemented?

d. Did anything about the graph surprise you?



# METHANE MATTERS | student worksheet answer key

1. Which of the above are anthropogenic sources of methane? Which do you consider natural sources of methane? Explain your selections.

*Anthropogenic: Livestock – due to people eating meat*

*Oil and gas industry – human demand for fuel*

*Coal mining – human demand for fuel*

*Landfills and wastewater – creation and disposal of human waste*

*Rice cultivation – food staple for people around the world*

*Biomass and biofuel burning – clearing land to grow food and graze cattle; fuel source*

*Natural Sources: Wetlands – natural formations (except for rice paddies which have been cultivated)*

*Termites – wild species; digestion of plant matter produces methane*

*Methane hydrates “ice” and organic matter in permafrost – old geological formations in tundra, sea floors, etc.*

2. Natural sources of methane could also be impacted by human activities. The permafrost of tundra regions and of polar ocean sediments contain vast quantities of methane trapped by frozen water molecules. What may happen if, partly due to the increase in atmospheric methane and other greenhouse gases, the environment gets warmer and the frozen water melts?

*The melting of the frozen water and thawing ground will release methane into the atmosphere. Permafrost covers one-fourth of the Northern Hemisphere and stores great quantities of methane and carbon from millennia of decomposing organic matter beneath the frozen surface. As long as this organic matter remains frozen, it stays trapped in the permafrost. However, if it thaws, microbes will begin to eat the material, causing it to decay and releasing methane and carbon dioxide into the atmosphere.*

3. Cattle, goats, and sheep emit methane as they digest grass and other fibrous plants. Each head of beef cattle in the U.S. belches out about 0.4 pounds of methane per pound of beef it yields. Add the CO<sub>2</sub> released from fuels burned in animal farming, and every pound of steak has the same greenhouse warming effect as a 30-mile drive in a typical U.S. car. Livestock account for one-third of all human-caused methane emissions.

- a. According to the U.S. Department of Agriculture, people in the U.S. consume an average of 58 pounds of beef per year. If each pound of beef contributes 0.4 pounds of methane, how many pounds of methane does this contribute per person?

*23.2 lbs.*

*1 person = 58 lbs of beef*

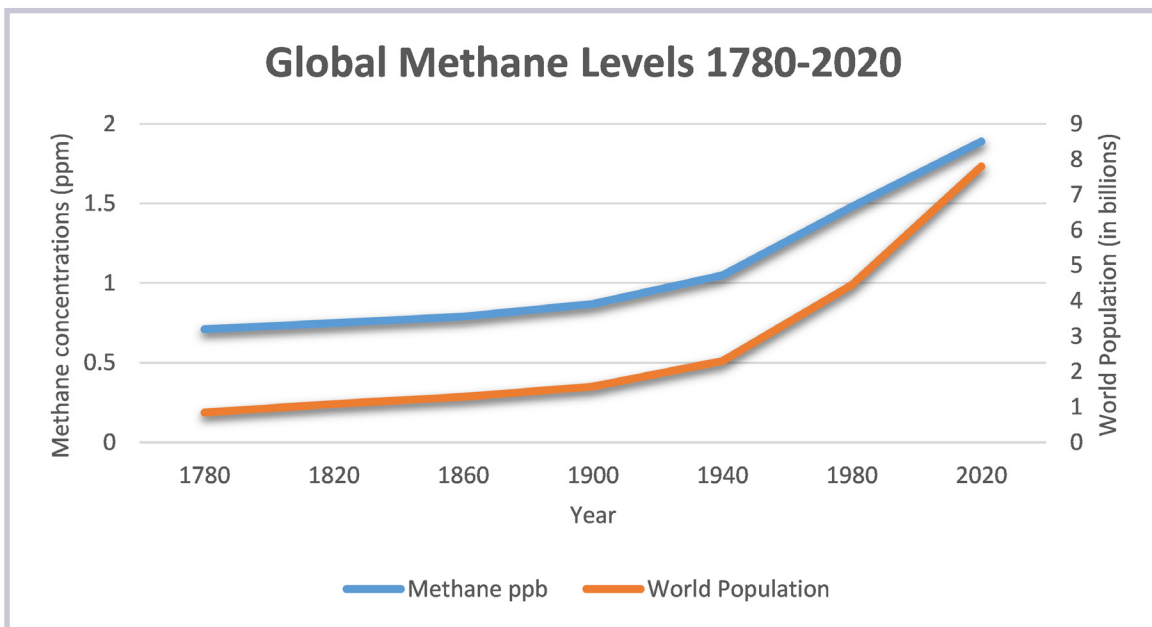
*58 lbs of beef x 0.4 lbs of methane = 23.2 lbs of methane from beef per person*

- b. What, if anything, could be done to reduce cattle's contribution to climate change?

*If individuals change their dietary habits and eat less beef, we could decrease the amount of cattle raised. Scientists have also been experimenting with additives to cattle feed (such as red seaweed) that could change the digestion process, resulting in less methane emitted when cattle belch.*



4.



- a. What appears to be the relationship between human population and methane concentrations in the atmosphere?

*There is a direct relationship. Both have been increasing steadily with substantial increases since the mid-20<sup>th</sup> century.*

- b. What do you think is the reason for this relationship? Does the graph, alone, establish a causal relationship?

*Students might hypothesize that human population growth leads to increased methane production, especially since most of the increase in methane appears to be from anthropogenic sources. The three major sources of anthropogenic methane – agriculture, energy, and waste – have all been impacted as the human population has grown. However, it is important to note that this graph shows a correlation, but not causation. A graph that also included data on steadily rising human activities in agriculture, energy, and waste – along with their rising methane emissions – would better establish a causal relationship.*

5. Leading sources of methane emissions vary among regions of the world. Use the stacked bar graph below to answer the following questions:

- a. Which region emits the most methane from:

- coal mining? *China*
- oil and gas? *Middle East*
- rice cultivation? *Southeast Asia, S. Korea, and Japan*
- enteric fermentation? *South Asia*

b. What are the leading sources of emissions in North America?

*Oil and gas industry; enteric fermentation*

c. What does the data suggest about where and how methane mitigation efforts would need to be implemented?

*Answers will vary. One of the key takeaways from the data is that a different mix of methane mitigation strategies will need to be used in different regions of the world, depending on the leading sources of methane.*

d. Did anything about the graph surprise you?

*Answers will vary.*

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<sup>1</sup>Global Methane Initiative. (2015, December). Global Methane Emissions and Mitigation Opportunities. [Fact sheet]. Retrieved from <https://www.globalmethane.org/documents/gmi-mitigation-factsheet.pdf>

<sup>2</sup>USDA, Economic Research Service. (n.d.). Food Availability (Per Capita) Data System. Retrieved July 12, 2021 from <https://www.ers.usda.gov/data-products/food-availability-per-capita-data-system/>

# METHANE MATTERS | student assignment sheet

*“Cutting methane is the strongest lever we have to slow climate change over the next 25 years and complements necessary efforts to reduce carbon dioxide. The benefits to society, economies, and the environment are numerous and far outweigh the cost. We need international cooperation to urgently reduce methane emissions as much as possible this decade.”*<sup>1</sup> Inger Anderson, Executive Director of the United Nations Environment Program

About 60 percent of global methane emissions are due to human activities. The main sources are oil/gas industries, agriculture (including fermentation, manure management, and rice cultivation), landfills, wastewater treatment, and emissions from coal mines. Fortunately, there are ways to make significant progress in cutting methane from all of these activities. Some are technological that could be implemented quickly. Others are behavioral changes that take more time and require global cooperation among individuals, governments, and industry.

Select one of the methane mitigation projects below from any of the three sectors. Conduct research and prepare a slide show that:

1. Describes the source of methane emissions.
2. Explains the technology or behavioral change that could reduce methane emissions, and by how much.
3. Identifies what progress has been made using this solution, and by whom. If it's a new technology, identifies who is working on it, and do they have the support of different stakeholders?
4. Makes a claim on the possible success of the solution.

## Agricultural sector:

- Cattle feed additives that reduce methane production
- Reducing global meat consumption, and thus the amount of livestock
- Draining rice field and applying straw offseason to reduce global methane emissions
- Preventing the burning of fields after harvests
- Biogas plants that capture the waste from anaerobic digesters used to process organic wastes, such as manure from farm animals

## Energy sector:

- Improving the detection and repair of methane leaks at oil and gas facilities and flooding abandoned coal mines that leak the gas
- Capturing methane from abandoned coal mines to use to generate electricity
- Switching from fossil fuels to renewable energy sources

## Waste sector:

- Diverting organic waste from landfills through separation/composting
- Disposing of organic matter in waste-to-energy facilities

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<sup>1</sup>UN Environment Programme. (2021, May 6). Global Assessment: Urgent steps must be taken to reduce methane emissions this decade. [Press release]. Retrieved from <https://www.unep.org/news-and-stories/press-release/global-assessment-urgent-steps-must-be-taken-reduce-methane>