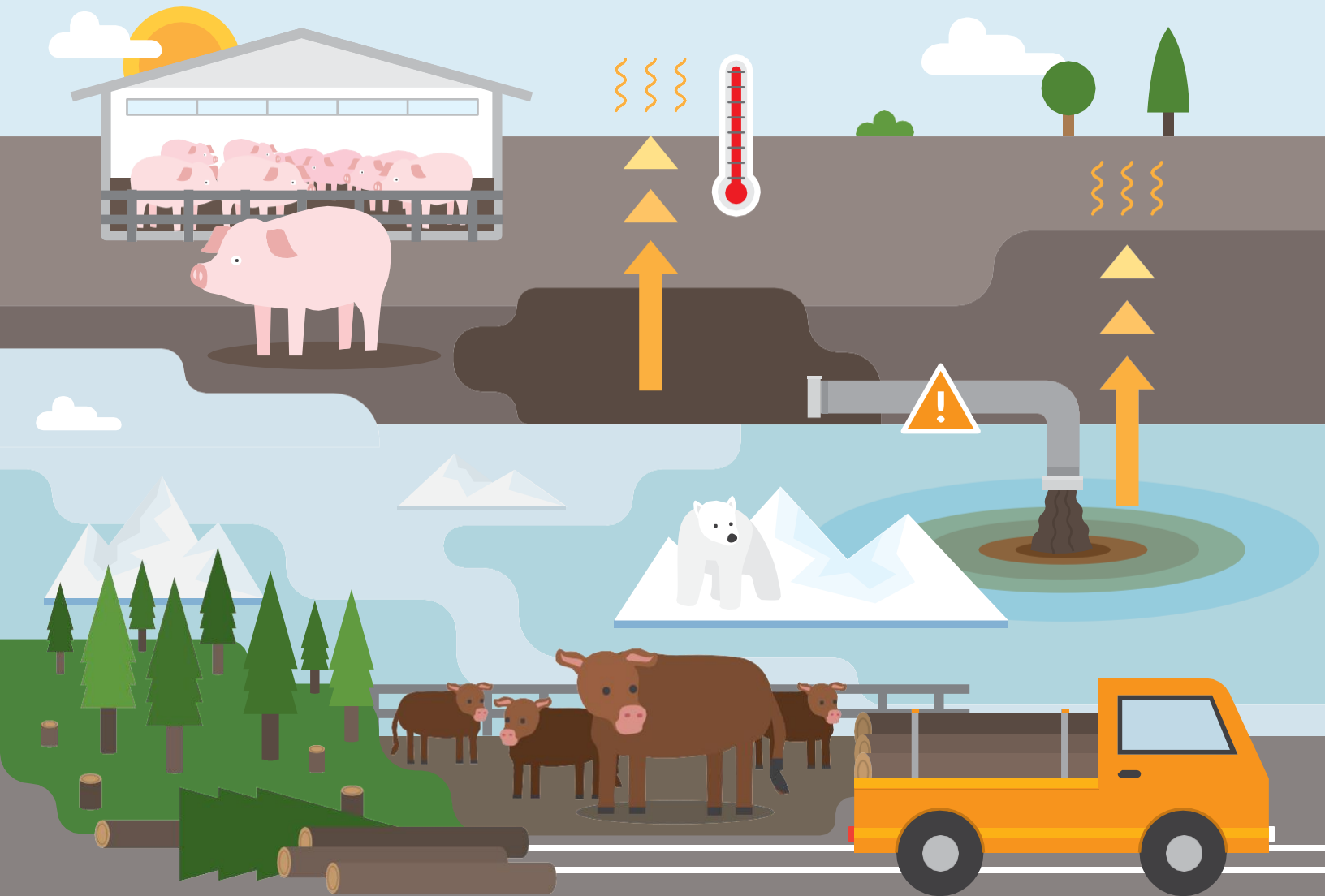


## Food Production & CO<sub>2</sub> Equivalents: Creating a Computational Simulation

*“For the first time [in history], we concluded anthropogenic warming has had an influence on many physical and biological systems.”*

— Cynthia Rosenzweig, NASA’s Goddard Institute for Space Studies



### Overview

Global warming can be attributed to an increase in greenhouse gas production. Many people assume that this increase primarily results from the burning of fossil fuels, but the agricultural industry is actually a major contributor. In this lesson, students will compare the carbon footprint of different types of foods to explore where greenhouse gases are coming from and which foods produce the most emissions.

- Students will use carbon dioxide equivalents (CO<sub>2</sub>e) to compare the amount of greenhouse gases released from different processes during food production.
- Students will use a spreadsheet to graph data to compare the CO<sub>2</sub>e for plant-based and animal-based food production.
- Students will use a formula to calculate the number of miles driven by a typical car for 1 kg of different types of food.

**Essential Questions:**

- How can we compare how much greenhouse gas emissions are created by different processes, specifically in food production?
- How does the production of different foods impact global warming?

**Lesson Time:**

Section 1 = 50 minutes  
 Section 2 = 50 minutes  
 Section 3 = 50 minutes

**Student Learning Objectives:**

Students will be able to...

- Interpret data relating plant-based farming and animal farming with corresponding CO<sub>2</sub> equivalents
- Identify the differences in amount of CO<sub>2</sub>e produced during plant-based and animal-based food production
- Investigate the relationship between farming and global warming
- Simulate the equivalent number of miles driven to produce 1 kg of different types of foods
- Consider ways to reduce CO<sub>2</sub>e emissions related to food production

**Resources\*:**

- **Article:** How Feed Production and Manure Generate Greenhouse Gases and Harm the Environment
- **PowerPoint:** Sources of Greenhouse Gases <https://www.dropbox.com/s/exy0zoidwwhv0oo/Sources%20of%20Greenhouse%20Gases.ppt?dl=0>
- **Student Handout:** Food Production and CO<sub>2</sub> Equivalents
- **Student Handout:** How Feed Production and Manure Generate Greenhouse Gases and Harm the Environment
- **Student Handout:** Sources of Greenhouse Gases
- **Student Handout:** Terms and Definitions
- **Teacher Key:** Food Production and CO<sub>2</sub> Equivalents
- **Teacher Key:** Sources of Greenhouse Gases
- **Video:** *Causes and Effects of Climate Change* - National Geographic (3:04): [https://www.youtube.com/watch?v=G4H1N\\_yXBIA](https://www.youtube.com/watch?v=G4H1N_yXBIA)

\*(If clicking a link does not work, please copy and paste the link into a web browser.)

**Materials:**

- An object or objects that are about 1 kg (examples: a 1 kg weight, a pineapple, a liter of water, or a small laptop)
- Access to YouTube\*\*

\*\* If Internet access in school is not available, YouTube Premium is a resource that allows you to download a video when you have WiFi/Internet access and then be able to play the video when you do not have WiFi/Internet access.

**Next Generation Science Standards\*\*\***

**HS-ESS3-3** Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.

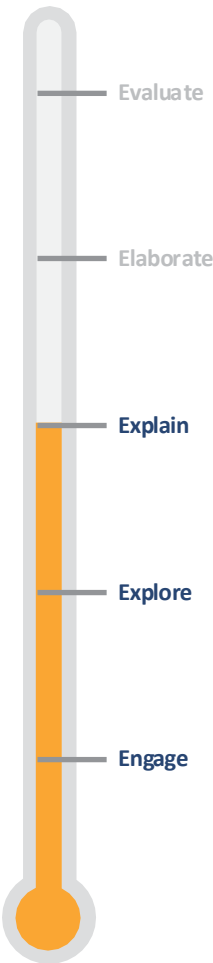
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p><b>Using Mathematics and Computational Thinking</b>                      Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.</p> <ul style="list-style-type: none"> <li>• Create a computational model or simulation of a phenomenon, designed device, process, or system.</li> </ul>	<p><b>ESS3.C: Human Impacts on Earth Systems</b></p> <ul style="list-style-type: none"> <li>• The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources.</li> </ul>	<p><b>Stability and Change</b></p> <ul style="list-style-type: none"> <li>• Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.</li> </ul> <hr/> <p style="text-align: center;"><b>Connections to Engineering, Technology, and Applications of Science</b></p> <p><b>Influence of Science, Engineering, and Technology on Society and the Natural World</b></p> <ul style="list-style-type: none"> <li>• Modern civilization depends on major technological systems.</li> <li>• New technologies can have deep impacts on society and the environment, including some that were not anticipated.</li> </ul> <hr/> <p style="text-align: center;"><b>Connections to Nature of Science</b></p> <p><b>Science is a Human Endeavor</b></p> <ul style="list-style-type: none"> <li>• Science is a result of human endeavors, imagination, and creativity.</li> </ul>

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**References:** (If clicking a link does not work, please copy and paste the link into a web browser.)

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Environmental Working Group. *EWG's quick tips for reducing your diet's climate footprint*. (2022). [https://www.ewg.org/sites/default/files/2022-04/EWG\\_TipSheet\\_Meat-Climate\\_CO2.pdf](https://www.ewg.org/sites/default/files/2022-04/EWG_TipSheet_Meat-Climate_CO2.pdf)

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United States Environmental Protection Agency. (2025). *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2023*. EPA 430-R-25-003. <https://library.edf.org/AssetLink/145ky510ew61fk1tq5c2klp5kq5yp33j.pdf>

**Notes:**

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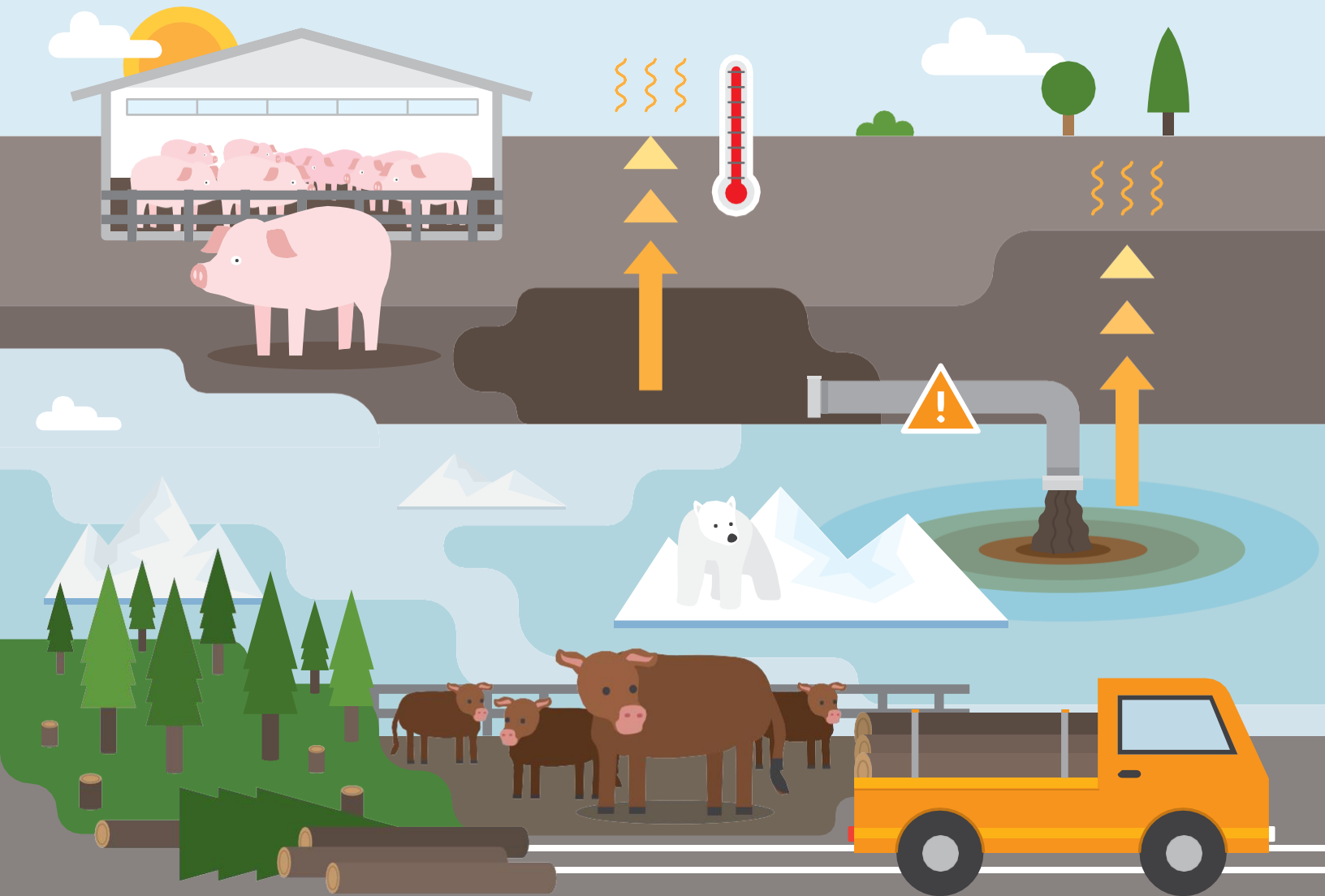
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## Food Production & CO<sub>2</sub> Equivalents: Creating a Computational Simulation

*“For the first time [in history], we concluded anthropogenic warming has had an influence on many physical and biological systems.”*

— Cynthia Rosenzweig, NASA’s Goddard Institute for Space Studies



### Overview

Global warming can be attributed to an increase in greenhouse gas production. Many people assume that this increase primarily results from the burning of fossil fuels, but the agricultural industry is actually a major contributor. In this lesson, students will compare the carbon footprint of different types of foods to explore where greenhouse gases are coming from and which foods produce the most emissions.

- Students will use carbon dioxide equivalents (CO<sub>2</sub>e) to compare the amount of greenhouse gases released from different processes during food production.
- Students will use a spreadsheet to graph data to compare the CO<sub>2</sub>e for plant-based and animal-based food production.
- Students will use a formula to calculate the number of miles driven by a typical car for 1 kg of different types of food.

**Essential Questions:**

- How can we compare how much greenhouse gas emissions are created by different processes, specifically in food production?
- How does the production of different foods impact global warming?

**Resources:**

- **Student Handout:** Food Production and CO<sub>2</sub> Equivalents
- **Student Handout:** Terms and Definitions
- **Teacher Key: Food Production and CO<sub>2</sub> Equivalents**

**Lesson Time:**

Section 1 = 50 minutes  
 Section 2 = 50 minutes  
 Section 3 = 50 minutes

**Materials:**

- Access to a computer spreadsheet program (such as Excel or Google Sheets)

**Student Learning Objectives:**

Students will be able to...

- Interpret data relating plant-based farming and animal farming with corresponding CO<sub>2</sub> equivalents
- Identify the differences in amount of CO<sub>2</sub>e produced during plant-based and animal-based food production
- Investigate the relationship between farming and global warming
- Simulate the equivalent number of miles driven to produce 1 kg of different types of foods
- Consider ways to reduce CO<sub>2</sub>e emissions related to food production

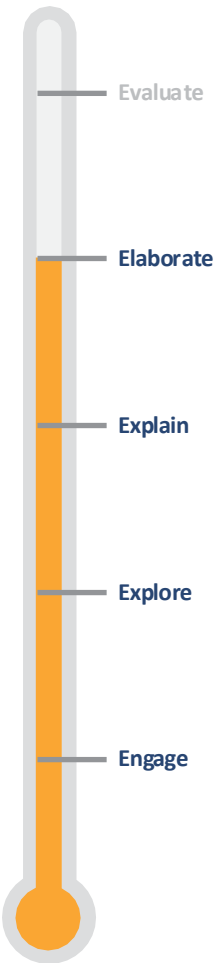
**Next Generation Science Standards\***

**HS-ESS3-3** Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p><b>Using Mathematics and Computational Thinking</b>                      Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.</p> <ul style="list-style-type: none"> <li>• Create a computational model or simulation of a phenomenon, designed device, process, or system.</li> </ul>	<p><b>ESS3.C: Human Impacts on Earth Systems</b></p> <ul style="list-style-type: none"> <li>• The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources.</li> </ul>	<p><b>Stability and Change</b></p> <ul style="list-style-type: none"> <li>• Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.</li> </ul> <hr/> <p><b>Connections to Engineering, Technology, and Applications of Science</b></p> <p><b>Influence of Science, Engineering, and Technology on Society and the Natural World</b></p> <ul style="list-style-type: none"> <li>• Modern civilization depends on major technological systems.</li> <li>• New technologies can have deep impacts on society and the environment, including some that were not anticipated.</li> </ul> <hr/> <p><b>Connections to Nature of Science</b></p> <p><b>Science is a Human Endeavor</b></p> <ul style="list-style-type: none"> <li>• Science is a result of human endeavors, imagination, and creativity.</li> </ul>

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## Activities: Section 2



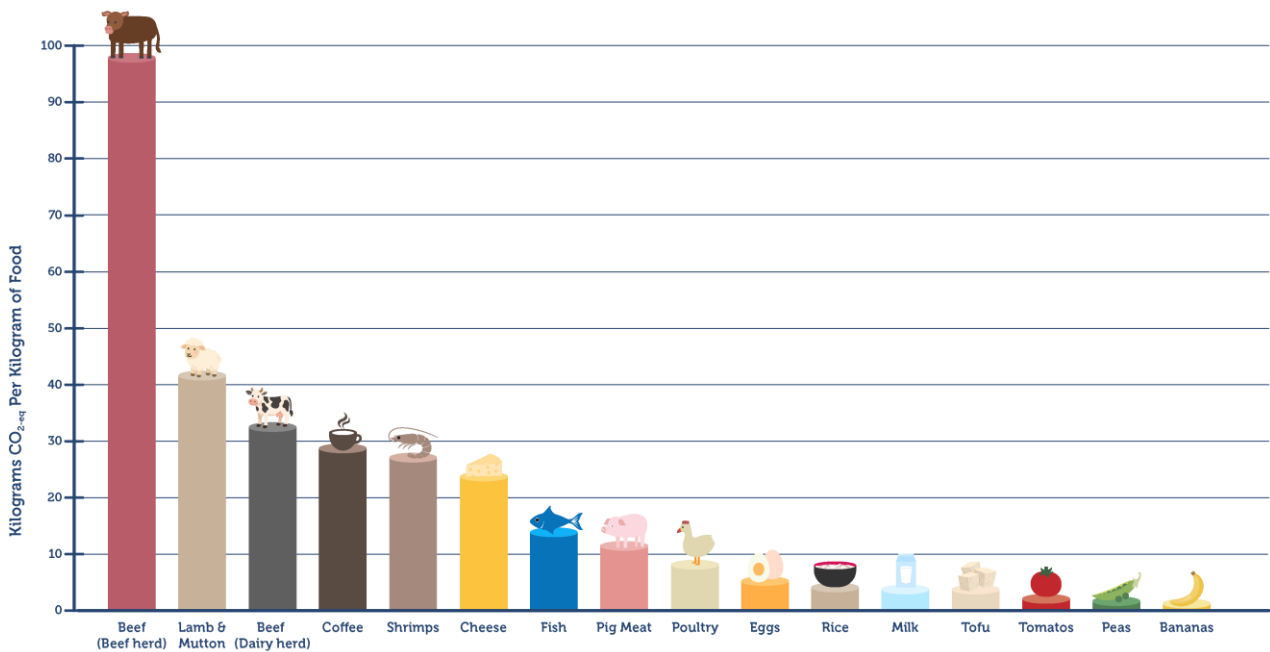
### Elaborate: What foods are responsible for the most CO<sub>2</sub> emissions? (20 minutes)

Tell students that they will find a data table with the amount of CO<sub>2</sub> equivalent (CO<sub>2</sub>e) associated with the production of different foods on the second page of their **Food Production and CO<sub>2</sub> Equivalents** handout. They will then use a spreadsheet program, such as Excel or Google Sheets, to create a graph that will enable them to compare the CO<sub>2</sub> footprints of different foods (see sample bar graph below).

Note: Refer to the teacher key, **Food Production and CO<sub>2</sub> Equivalents**, for answers to the calculation and graphing portion of the student handout.

1. Students should open a spreadsheet in Excel, Google Sheets, or another graphing program.
2. Students will then copy and paste (or type in) the two columns of data from Data Set 1, comparing kg CO<sub>2</sub>e released per 1 kg of consumed food.
3. Students will then sort the data to see a trend. (Students may try sorting by one column and then the other to see which makes more sense. In this case, sorting by kg CO<sub>2</sub>e is more appropriate.)
4. Students should then determine the best type of graph to represent their data. (They will do this by selecting their data and creating a chart or graph. In Google Sheets, charts or graphs can be located under the "Insert" tab.) In this case, a bar graph is most appropriate.
5. Students should come up with an appropriate title for their bar graph.

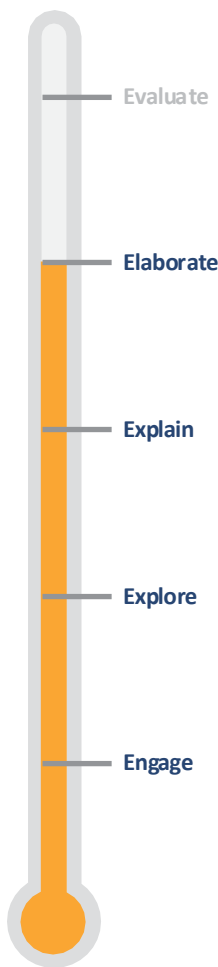
### Kilograms of CO<sub>2-eq</sub> Per Kilogram of Food



Sources: Our World in Data (2018), Poore and Nemecek (2018)



## Breaking Down the Data (5 minutes)



1. Ask students, is there a difference between producing food from plants and producing food from animals? If so, what is the difference?

The difference is that animal-based food production releases dramatically more CO<sub>2</sub> than plant-based food production.

2. What is the relationship between animal-based food production and global warming?

Global warming is a result of an increase in the amount of greenhouse gases, like CO<sub>2</sub>, in the atmosphere. Animal-based food production requires a lot of energy and produces a large amount of greenhouse gases, therefore contributing to the warming of the planet.

**References:** (If clicking a link does not work, please copy and paste the link into a web browser.)

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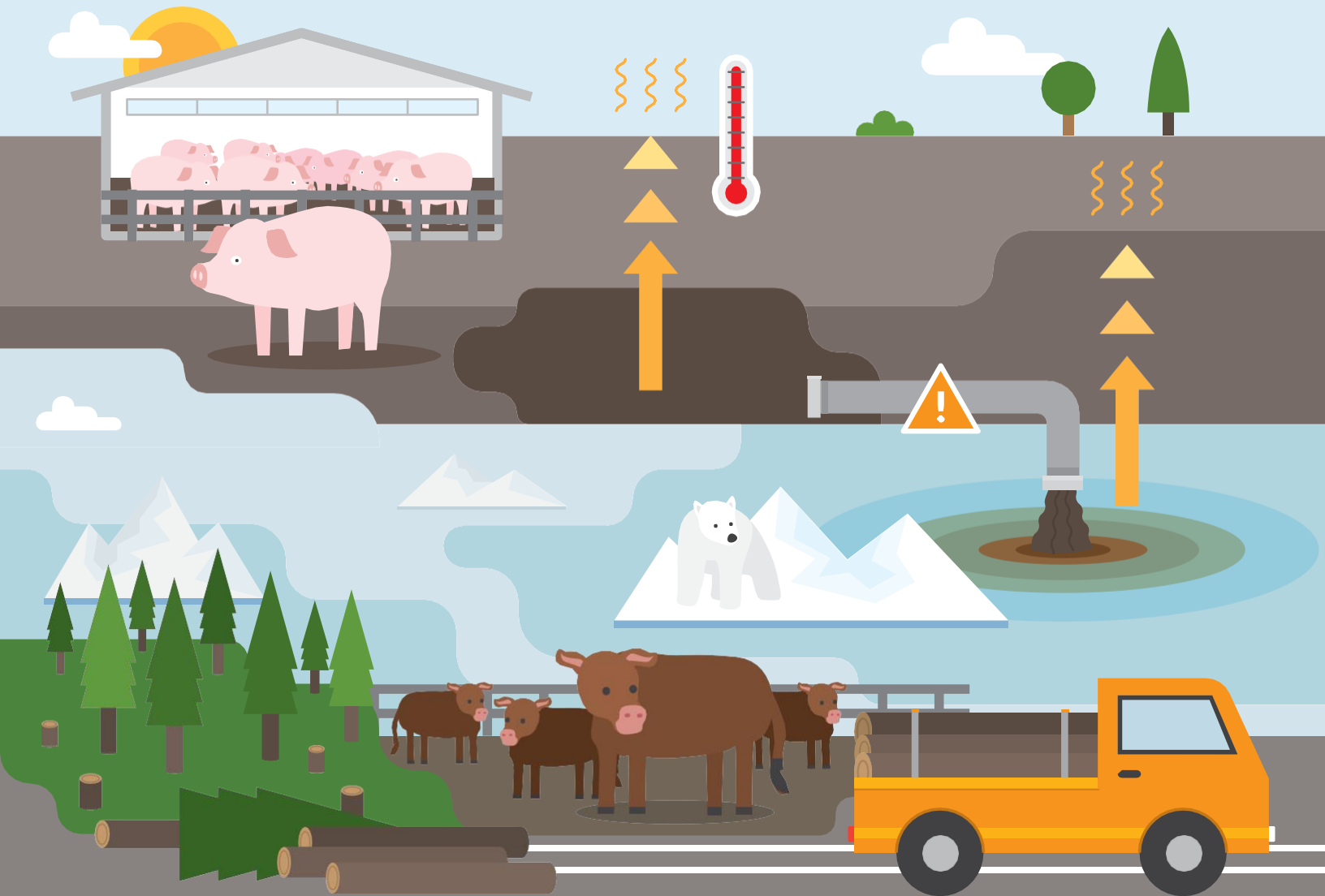
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**Lesson Time:**

Section 1 = 50 minutes

Section 2 = 50 minutes

Section 3 = 50 minutes

**Student Learning Objectives:**

Students will be able to...

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- Simulate the equivalent number of miles driven to produce 1 kg of different types of foods
- Consider ways to reduce CO<sub>2</sub>e emissions related to food production

**Materials:**

- Sticky notes, one for each student

**Resources\*:**

- **Article:** Impossible Foods to Supersize Production of Lab-Grown Burger  
<https://www.cnet.com/news/impossible-foods-ramps-up-production-of-its-lab-grown-hamburger/>
- **Article:** Less Beef, Less Carbon: Americans Shrink Their Diet-Related Carbon Footprint by 10 Percent Between 2005 and 2014 (Pages 1 & 2 only)  
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- **Article:** Millennials Are Driving The Worldwide Shift Away From Meat  
<https://www.forbes.com/sites/michaelpellmanrowland/2018/03/23/millennials-move-away-from-meat/#3e253cdaa4a4>
- **Student Activity:** Sticky Note Exercise
- **Student Handout:** Impossible Foods to Supersize Production of Lab-Grown Burger
- **Student Handout:** Less Beef, Less Carbon: Americans Shrink Their Diet-Related Carbon Footprint by 10 Percent Between 2005 and 2014
- **Student Handout:** Millennials Are Driving The Worldwide Shift Away From Meat
- **Student Handout:** Terms and Definitions

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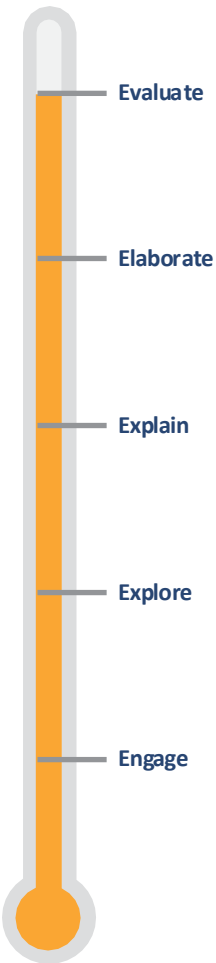
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## Evaluate: What are some solutions? (40 minutes)



One solution to the problem of global warming is eating less or no meat. Give each student a copy of **Less Beef, Less Carbon: Americans Shrink Their Diet-Related Carbon Footprint by 10 Percent Between 2005 and 2014** (pages 1 & 2 only), a report conducted by the Natural Resources Defense Council (NRDC), as well as a copy of the accompanying handout. Give students seven minutes to read the article and answer the questions before going over the answers as a class. (Note: Students may reference their **Terms and Definitions** handout as they read each article for this lesson.)

1. Between 2005 and 2014, the amount of beef that Americans cut out of their diet brought down carbon emissions equivalent to the annual tailpipe emissions for how many cars?

39 million cars

2. How could pollution (carbon emissions) be reduced even more?

If Americans decreased their consumption of other carbon-intensive products including other meats, milk, cheese, butter, and yogurt, pollution could be further reduced.

3. What food in the American diet contributes the most to climate-warming pollution?

Beef

Next, have students read the article, **Impossible Foods to Supersize Production of Lab Grown Burger**, which discusses how people’s desire to reduce how much meat they consume has inspired a growing market in the development of meatless, plant-based foods that mimic the taste of meat and other animal-based foods.

Note: The term, lab-grown meat, is also used to describe the production of meat through the process of dividing muscle cell tissues from an animal in a lab environment. This article specifically is speaking to a plant-based burger, not a burger that is grown from the cells of a cow.

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Give students ten minutes to read this article and answer the questions on the accompanying handout before going over the answers as a class.

1. What “secret ingredient” is in these burgers to make them seem more like meat?

“Heme” (leghemoglobin) is what makes animal blood red, and it’s found in all living things, including plants. When Impossible Burgers cook in a pan, they secrete a pinkish juice that resembles blood, and they also give off the smell of charred meat.

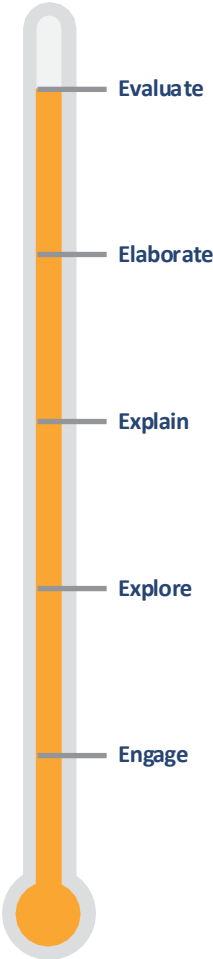
2. How are plant-based hamburgers better for the environment than burgers that come from cows?

Impossible Foods says producing one of its burgers requires only a quarter of the water and 5 percent of the land that making a burger from a cow requires. Also, the process to produce the Impossible Burger emits only 13 percent of the greenhouse gases that the production of a burger from a cow emits.

3. If your favorite burger restaurant offered the Impossible Burger, would you eat it? Why or why not?

Answers will vary.

Note: Hampton Creek (referred to in article) is now called Just.



Now distribute a copy of the article, **Millennials Are Driving The Worldwide Shift Away From Meat** to each student, and give students another ten minutes to read this article and answer the questions on the corresponding handout before going over the answers as a class.

1. What three things do millennials often think about when they choose what to eat?

The source of their food, animal welfare issues, and environmental impacts

2. Name one health concern associated with eating processed meats like bacon and ham.

Answers may include: Processed meats (like bacon and ham) have been linked to cancer. Animal products are linked to an increase in the risk of heart disease.

3. Name two things that companies are doing as a result of the growing demand for plant-based food options.

Answers may include: Companies like Cargill are investing in more plant-based food options. Start-up companies are working on lab-grown meat production. Retailers like Walmart are demanding more plant-based foods from food suppliers to sell in their stores.

Finally, as a class, ask students: Given what you now know about the production of animal-based foods and plant-based foods, what are some ways humans could reduce the amount of carbon dioxide we release when producing food for the world?

Students may list:

- Eating no meat (following a vegetarian or vegan diet), which would result in the highest reduction of CO<sub>2</sub> by far
- Eating less meat (Meatless Mondays\*)
- Other ideas

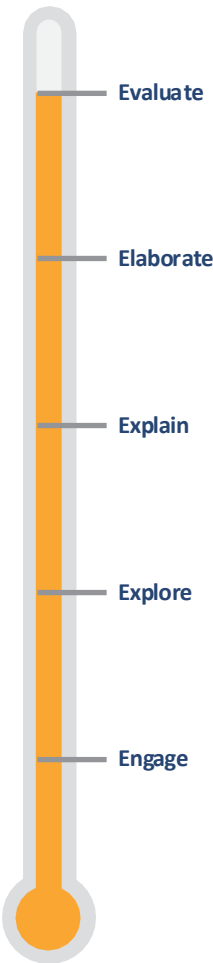
\* Meatless Monday is a non-profit initiative started in 2003 by the Monday Campaigns and the Center for a Livable Future (CLF) at the Johns Hopkins Bloomberg School of Public Health. The initiative's goal is to reduce meat consumption to improve personal health and the health of the planet. For more information: <https://www.meatlessmonday.com/>. (If clicking a link does not work, please copy and paste the link into a web browser.)



### Closure: Student Sticky Note Exercise (5-10 minutes)

Please refer to **Student Activity: Sticky Note Exercise** for detailed instructions. Each student will write 1-2 sentences on a sticky note about what they consider to be the most important thing they learned in this lesson. The sticky notes should be completed anonymously. Students will then post their sticky notes on a board or wall and engage in a brief class discussion.

Time Permitting: Have the students group together sticky notes with similar ideas. Then ask students to come up with a title to describe each group of sticky notes. Finally, add titles to each group of sticky notes using an additional sticky note.



**References:** (If clicking a link does not work, please copy and paste the link into a web browser.)

Center for Sustainable Systems, University of Michigan. (2025). *Carbon footprint factsheet*. Pub No. CSS09-05. <https://css.umich.edu/publications/factsheets/sustainability-indicators/carbon-footprint-factsheet>

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**Notes:**

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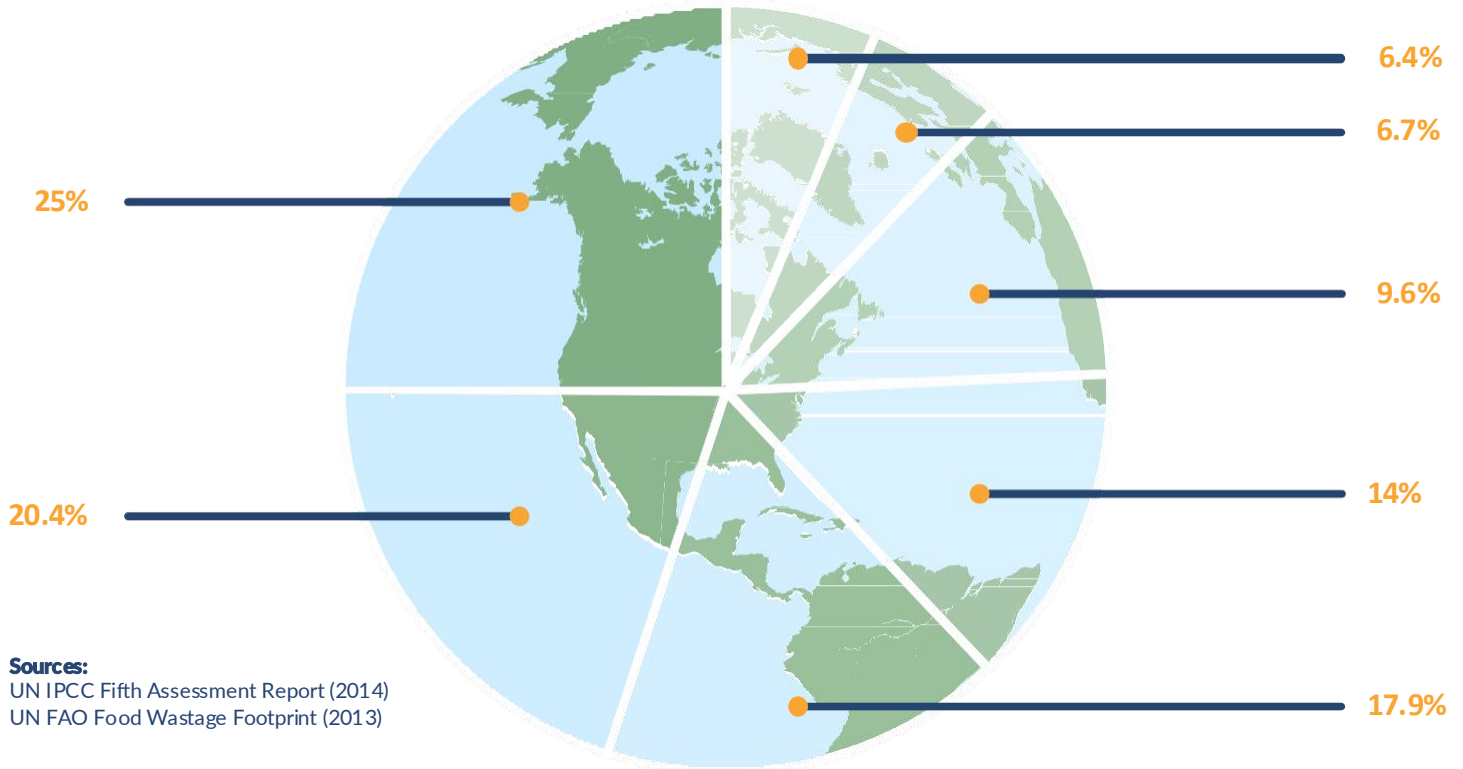
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# Sources of Greenhouse Gases








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

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

Which source is responsible for each percentage of greenhouse gas emissions created on our planet? Fill in the blanks.

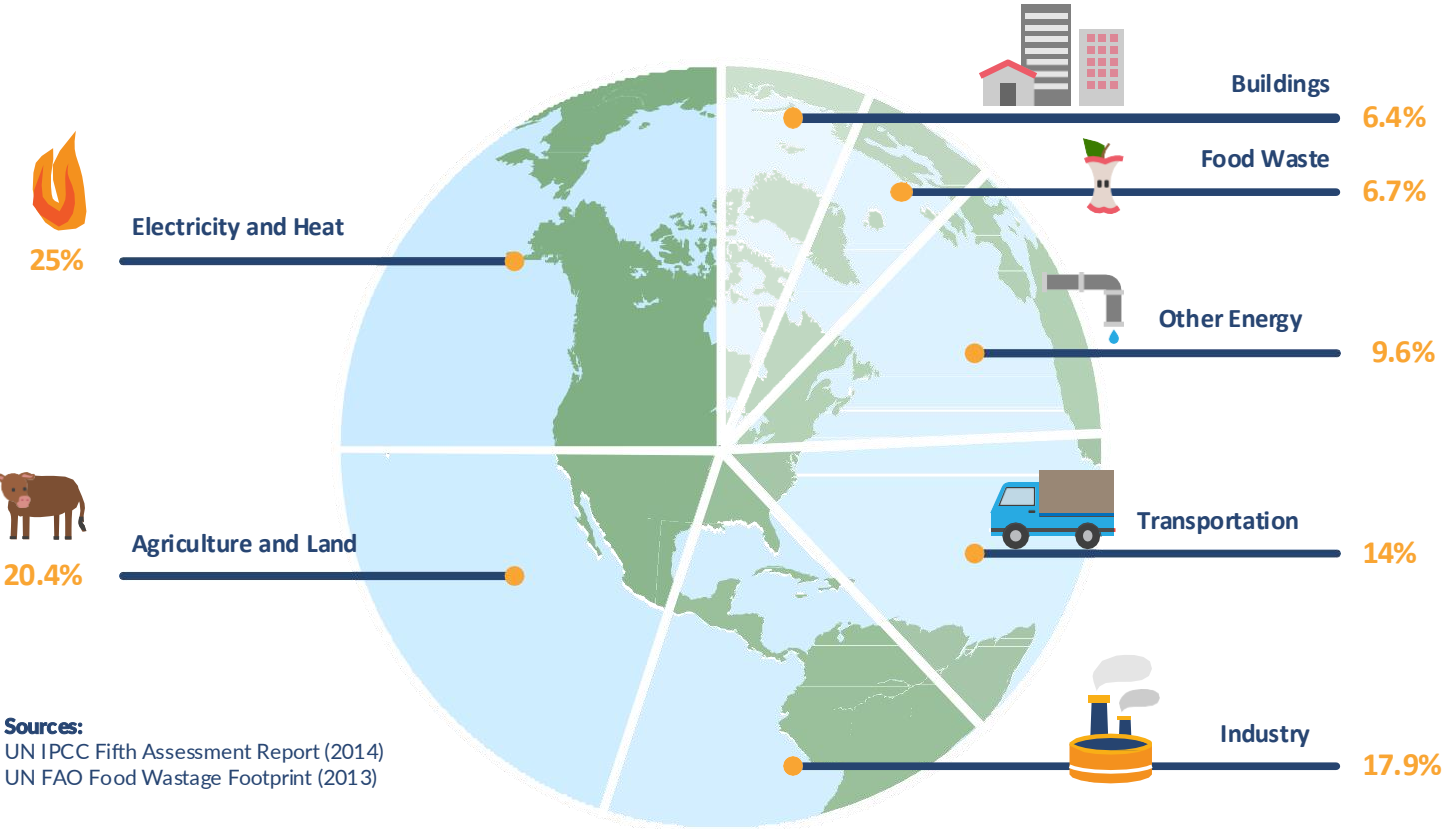


Sources:  
 UN IPCC Fifth Assessment Report (2014)  
 UN FAO Food Wastage Footprint (2013)

- 
Agriculture and Land
- 
Buildings
- 
Electricity and Heat
- 
Food Waste
- 
Industry
- 
Transportation
- 
Other Energy

# Sources of Greenhouse Gases

Which source is responsible for each percentage of greenhouse gas emissions created on our planet? Fill in the blanks.



# Food Production and CO<sub>2</sub> Equivalents

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

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

## Introductory Question

Make a list of the different ways that the growing and production of food could release greenhouse gases such as carbon dioxide (CO<sub>2</sub>) or methane (CH<sub>4</sub>).

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## Background Information

Carbon dioxide and other greenhouse gases are produced by various processes, one of which is by burning gasoline when you drive a car. To know how much CO<sub>2</sub> is given off by driving a car, you can calculate how many kilograms of CO<sub>2</sub> are produced for X number of miles driven.

For example, a typical car releases 0.411kg of CO<sub>2</sub> for each mile you drive it. More efficient cars will give off less CO<sub>2</sub>; less efficient cars will give off more CO<sub>2</sub>.

**1. How many miles would you have to drive a typical car to give off 1 kilogram of CO<sub>2</sub>? (Hint: Use the conversion factor of 1 mile/0.411 kg CO<sub>2</sub>).**

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**2. What is the relationship between the release of CO<sub>2</sub> and other greenhouse gases into the atmosphere and global warming?**

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## Background Information Continued

The carbon dioxide equivalent (CO<sub>2</sub>e) is a way of expressing greenhouse gas emissions as a single number in order to show their global warming potential (Center for Sustainable Systems, University of Michigan, 2025). One way to compare how much CO<sub>2</sub> is given off by certain processes, like driving a car, to other processes, like food production, is to calculate the number of miles one would have to drive a car to produce the kilograms of CO<sub>2</sub>e created by a type of food. This is your next activity.

## Graphing Activity

In Data Set 1, you are given data for the CO<sub>2</sub> equivalent produced by different foods.

1. Open up a spreadsheet in Excel, Google Sheets, or another graphing program.
2. Copy and paste (or type in) Data Set 1, comparing kg CO<sub>2</sub>e released per 1 kg of consumed food.
3. Sort the data to see a trend. (Which column should you sort by?)
4. Determine the best type of graph to represent your data. Select your data and create a chart or graph. In Google Sheets, charts or graphs can be located under the "Insert" tab.
5. Come up with an appropriate title for your graph.

## Data Set 1.

1 kg Consumed Food	kg CO <sub>2</sub> e Produced by 1 kg of Consumed Food
Bananas	0.86
Beef (beef herd)	99
Beef (dairy herd)	33
Cheese	24
Coffee	29
Eggs	4.7
Fish (farmed)	14
Lamb & Mutton	40
Milk	3.2
Peas	0.98
Pig Meat	12
Poultry Meat	9.9
Rice	4.5
Shrimps (farmed)	27
Tofu	3.2
Tomatoes	2.1

**Source:** (If clicking a link does not work, please copy and paste the link into a web browser.)

Our World in Data. (n.d.). *Food: greenhouse gas emissions across the supply chain* [Chart]. Retrieved March 11, 2026, from <https://ourworldindata.org/grapher/food-emissions-supply-chain>

## Conclusions

**1. What foods release the least CO<sub>2</sub>e? What foods release the most CO<sub>2</sub>e? How much of a difference is there? Compare lamb and mutton, beef from beef herds, tofu, and tomato.**

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**2. How does this compare to driving a car? In other words, how many miles would you need to drive to give off the same amount of CO<sub>2</sub>e produced by different foods? You can determine this using your spreadsheet.**

- Make a new column entitled "Comparative Miles Driven".
- Use the following conversion factor: the kg CO<sub>2</sub>e for a specific food multiplied by the conversion factor of 1 mile/0.411 kg CO<sub>2</sub>. Notice how the kg CO<sub>2</sub>e cancels out to give you an answer in miles.
- Select the first data square in your new column. What formula could you type in to calculate the miles you would drive for each type of food? Use this formula for each food type.
- How many miles of driving difference is there between producing 1 kg of tofu vs. 1 kg of beef from beef herds?

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**3. Why do you think producing animal-based foods releases so many more greenhouse gases than producing plant-based foods? Give two reasons.**

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**4. Look at Table 1 on the next page. Underline all the items in column 1 that have to do specifically with growing plants. Circle all of the items in Column 1 that have to do specifically with producing animal-based foods like meat, dairy, and eggs. Explain how this exercise might help to answer question #3.**

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**Table 1. Sources of Primary Greenhouse Gas Emissions**

Item (Input/Output) Considered	Processes Included in Assessment	Sources of GHG Emissions for Inputs and Outputs
<b>Fertilizer for cover crops, plant-based foods and animal feed</b>	Production; transportation of fertilizer to farm; application to field	Electrical plant; natural gas for production; fuel combustion during transport
<b>Pesticides for cover crops, plant-based foods and animal feed</b>	Production; transportation of pesticide to farm; application to field	Electricity and fuel for production; fuel combustion during transport
<b>Lime, gypsum, sulfur and other soil additives - for cover crops, plant-based foods and animal feed</b>	Production; transportation of lime to farm; (application to field is included in feed category)	Electricity and fuel for production; fuel combustion during transport
<b>Irrigation water</b>	Withdrawal and distribution	Electricity
<b>Harvested crop</b>	Harvesting and decomposition	Fuel for farm equipment; N <sub>2</sub> O from post-harvest crop residues left on fields; N <sub>2</sub> O from legumes (nitrogen fixation) and crop residues.
<b>Animal feed (corn, soybean, alfalfa, etc.), rice and other crops</b>	Production (pre- and post-harvest for plant-based feeds); transportation to farm	CO <sub>2</sub> from urea (fertilizer); N <sub>2</sub> O from nitrogen-fertilizer emissions emanating from soil and water; CO <sub>2</sub> from lime application on soil; methane from rice production
<b>Other on-farm inputs</b>	Other on-farm activities to raise animals or grow crops	Electricity and fuel combustion
<b>Growing plants</b>	Plant growth	Carbon storage in the biomass of perennial species such as nut trees during growth and at maturity
<b>Maturing animal (during grazing and at the feedlot)</b>	Enteric fermentation (digestive process of ruminants) and manure management	CH <sub>4</sub> from enteric fermentation (adjusted for different kinds of feed); N <sub>2</sub> O and CH <sub>4</sub> emissions from manure management
<b>Slaughtered animal</b>	Transport of animal to slaughter facility; slaughter	Electricity used in slaughter process
<b>Packaged food</b>	Transportation of food to packaging facility; production of packaging materials; packaging process	Fuel for transport and electricity used in production of packaging materials as well as actual packaging of the food

<b>Food at retail</b>	Transportation from packaging facility to retail; freezing and refrigeration during transport and at retail	Electricity; hydrofluorocarbons leaked from refrigeration systems at retail
<b>Cooked food</b>	Cooking	Natural gas used for cooking
<b>Wasted food</b>	Transportation from home/ restaurant to landfill; food deposited in landfill	Fuel; CH <sub>4</sub> from food waste in landfills
<b>Aquaculture</b>	Electricity, water, feed, fertilizer (in some cases); transportation of inputs; fuel for boats	Electricity, water pumping, feed production, and transport

Table 1: Copyright © Environmental Working Group, [www.ewg.org](http://www.ewg.org).

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**Source:** (If clicking a link does not work, please copy and paste the link into a web browser.)

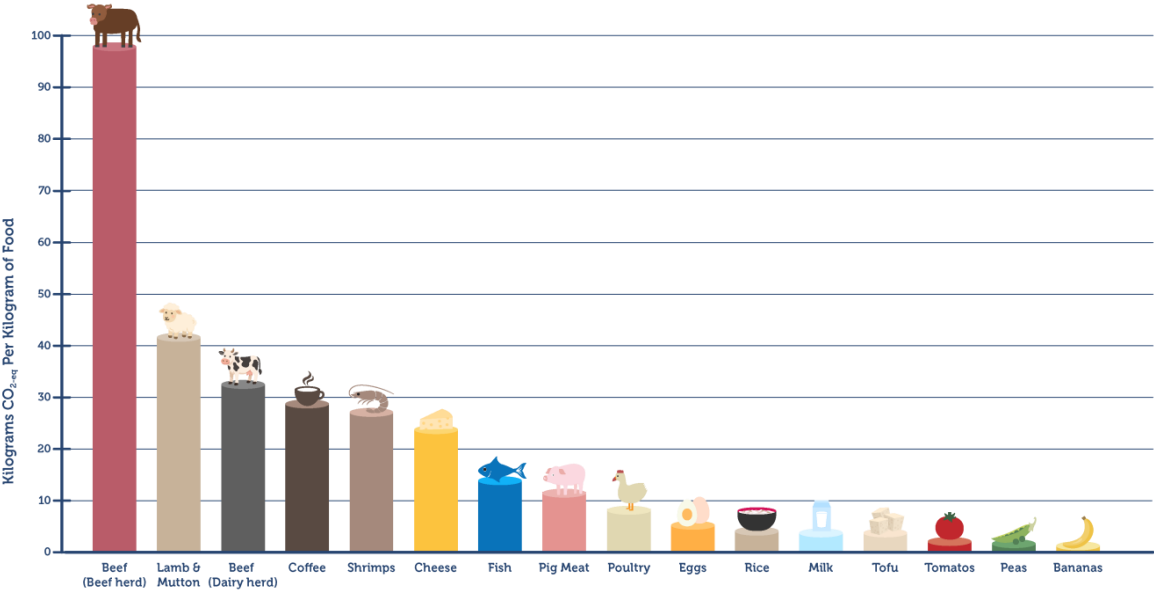
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[https://static.ewg.org/reports/2011/meateaters/pdf/report\\_ewg\\_meat\\_eaters\\_guide\\_to\\_health\\_and\\_climate\\_2011.pdf](https://static.ewg.org/reports/2011/meateaters/pdf/report_ewg_meat_eaters_guide_to_health_and_climate_2011.pdf)

	A	B	C
1	<b>1 kg/2.2 lbs of Consumed Food</b>	<b>kg CO<sub>2</sub>e</b>	<b>Comparative Miles Driven*</b>
2	Bananas	0.86	2.09
3	Peas	0.98	2.38
4	Tomatoes	2.1	5.11
5	Milk	3.2	7.79
6	Tofu	3.2	7.79
7	Rice	4.5	10.95
8	Eggs	4.7	11.44
9	Poultry Meat	9.9	24.09
10	Pig Meat	12	29.2
11	Fish (farmed)	14	34.06
12	Cheese	24	58.39
13	Shrimps (farmed)	27	65.69
14	Coffee	29	70.56
15	Beef (dairy herd)	33	80.29
16	Lamb & Mutton	40	97.32
17	Beef (beef herd)	99	240.88

\*The formula for Comparative Miles Driven is the data from Column B (kg CO<sub>2</sub>e) multiplied by the conversion factor of 1 mile/0.411 kg to cancel out the kg CO<sub>2</sub>e. This is the same as dividing the data in Column B by 0.411. Example: for the first row, the formula would be B2/0.411. For the second row, the formula would be B3/0.411, and so on.

### Kilograms of CO<sub>2-eq</sub> Per Kilogram of Food



Sources: Our World in Data (2018), Poore and Nemecek (2018)

# Terms and Definitions

## General Lesson:

Term	Definition
Atmosphere	The mixture of gases that surrounds the earth <sup>6</sup>
Atom	The smallest particle of a chemical element that can exist <sup>6</sup>
Carbon Dioxide	A gas breathed out by people and animals from the lungs or produced by burning carbon <sup>6</sup>
Cesspool	A container for the temporary storage of liquid waste and sewage <sup>6</sup>
Climate	The regular pattern of weather conditions of a particular place <sup>6</sup>
Climate Change	Changes in the earth's weather, including changes in temperature, wind patterns, and rainfall, especially the increase in the temperature of the earth's atmosphere that is caused by the increase of particular gases, especially carbon dioxide <sup>6</sup>
Concentration	A lot of something in one place; the amount of substance in a liquid or in another substance <sup>6</sup>
Deforestation	The act of cutting down or burning the trees in an area <sup>6</sup>
Emit	To send out something such as light, heat, sound, gas, etc. <sup>6</sup>
Emission	The production or sending out of light, heat, gas, etc. <sup>6</sup>
Export	To sell and send goods to another country <sup>6</sup>

<b>Factory Farm</b>	A type of farm in which animals are kept inside in small spaces and are fed special food so that a large amount of meat, milk, eggs, etc. is produced as quickly and cheaply as possible <sup>6</sup>
<b>Fossil Fuels</b>	Fuel such as coal or oil that was formed over millions of years from the remains of animals or plants <sup>6</sup>
<b>Global Warming</b>	The increase in temperature of the earth's atmosphere that is caused by the increase of particular gases, especially carbon dioxide <sup>6</sup>
<b>Greenhouse Effect</b>	A phenomenon where gases allow sunlight to enter Earth's atmosphere but make it difficult for heat to escape <sup>5</sup>
<b>Hydrogen Sulfide</b>	A colorless, poisonous, flammable gas <sup>6</sup>
<b>Industry</b>	The production of goods from raw materials, especially in factories <sup>6</sup>
<b>Manure</b>	The waste matter from animals <sup>6</sup>
<b>Methane</b>	A gas without color or smell that burns easily and is used as fuel; natural gas consists mainly of methane <sup>6</sup>
<b>Microbe</b>	An extremely small living thing that you can only see under a microscope and that may cause disease <sup>6</sup>
<b>Molecule</b>	The smallest unit, consisting of a group of atoms, into which a substance can be divided without a change in its chemical nature
<b>Phenomenon</b>	A fact or an event in nature or society, especially one that is not fully understood <sup>6</sup>
<b>Regurgitate</b>	To bring food that has been swallowed back up into the mouth again <sup>6</sup>
<b>Ruminants</b>	Animals, such as cows and sheep, who bring back food from their stomachs into their mouths and chew it again <sup>6</sup>

**Article:**

How Feed Production and Manure Generate Greenhouse Gases - Environmental Working Group

Term	Definition
CAFO	A concentrated animal feeding operation <sup>6</sup>
Confined	(Of a space or an area) Small and surrounded by walls or sides <sup>6</sup>
Decompose	To be destroyed gradually by natural chemical processes <sup>6</sup>
Degraded	To degrade something is to make something become worse, especially in quality <sup>6</sup>
Federal	(Within a federal system, for example the US and Canada) Connected with national government rather than the local government of an individual state <sup>6</sup>
Fertilizer	A substance added to soil to make plants grow more successfully <sup>6</sup>
Generate	To produce or create something <sup>6</sup>
Irrigation	The practice of supplying water to an area of land through pipes or channels so that crops will grow <sup>6</sup>
Pesticide	A chemical used for killing pests, especially insects <sup>6</sup>
Reservoir	A natural or artificial lake where water is stored before it is taken by pipes to houses, etc. <sup>6</sup>
Runoff	Rain, water, or other liquid that runs off land into streams and rivers <sup>6</sup>
Subsidized	To subsidize somebody/something is to give money to somebody or an organization to help pay for something; to give a subsidy <sup>6</sup>

**Article:**

Impossible Foods to Supersize Production of Lab-Grown Burger - CNET

Term	Definition
Cohort	A group of people who share a common feature or aspect of behavior <sup>6</sup>
Faux	Artificial, but intended to look or seem real <sup>6</sup>
Lab-Grown Meat*	Lab-grown meat, also called cultured or cultivated meat, is grown from the cells of an animal [in a lab] without any need to slaughter an animal to obtain the meat <sup>2</sup>
Secrete	Secrete something (of part of the body or a plant) to produce a liquid substance <sup>6</sup>
Undiscerning	Unable to show good judgement about the quality of somebody/ something <sup>6</sup>

\*Note: The term "lab-grown meat" is used to describe the production of meat through the process of dividing muscle cell tissues from an animal in a lab environment. This article specifically is speaking to a plant-based burger, not a burger that is grown from the cells of a cow.

**Article:**

Millennials Are Driving The Worldwide Shift Away From Meat – Forbes.com

Term	Definition
<b>Blistering</b>	Done very fast or with great energy <sup>6</sup>
<b>Combat</b>	To struggle against or to strive to reduce or eliminate <sup>4</sup>
<b>Conscious</b>	Aware of something; noticing something <sup>6</sup>
<b>Cruelty-Free</b>	Developed or produced without testing on animals <sup>3</sup>
<b>Diversify</b>	To develop a wider range of products, interest, skills, etc. in order to be more successful or reduce risk <sup>6</sup>
<b>Entitlement</b>	A government system that provides financial support to a particular group of people <sup>6</sup>
<b>Environmental (Ecological) Footprint</b>	A measure of the amount of the earth's resources used by a person or a population that lives in a particular way <sup>6</sup>
<b>Flexitarian(ism)</b>	A person who sometimes eats meat or fish although they do not usually do so <sup>6</sup>
<b>Heart Disease</b>	An abnormal condition of the heart or of the heart and blood circulation <sup>4</sup>
<b>Lab-Grown Meat</b>	Lab-grown meat, also called cultured or cultivated meat, is grown from the cells of an animal [in a lab] without any need to slaughter an animal to obtain the meat <sup>2</sup>
<b>Meat-Free</b>	Food that is free of meat (animal flesh)
<b>Millennial</b>	A person born in the 1980s or 1990s <sup>4</sup>

<b>Organic</b>	Produced or practiced without using artificial chemicals <sup>6</sup>
<b>Pivot</b>	To turn on a central point <sup>1</sup>
<b>Plant-Based</b>	A diet based on foods derived from plants, including vegetables, whole grains, nuts, seeds, legumes, and fruits, but with no animal products
<b>Plant-Centric</b>	A diet centered around foods derived from plants, including vegetables, whole grains, nuts, seeds, legumes, and fruits
<b>(Be) Processed</b>	To treat raw material, food, etc. in order to change it, preserve it, etc. <sup>6</sup>
<b>Secular</b>	Not connected with spiritual or religious matters <sup>6</sup>
<b>Sustainable</b>	Involving the use of natural products and energy in a way that does not harm the environment <sup>6</sup>
<b>Vegan</b>	A person who does not eat any animal products such as meat, dairy, or eggs, or use animal products such as leather and wool <sup>6</sup>

**Article:**

**Less Beef, Less Carbon: Americans Shrink Their Diet-Related Carbon Footprint by 10% Between 2005 and 2014 – NRDC**

Term	Definition
<b>Carbon Footprint</b>	A measure of the amount of carbon dioxide that is produced by the daily activities of a person or company <sup>6</sup>
<b>Cumulatively</b>	In a way that increases in strength or importance each time something more or new is added <sup>6</sup>
<b>Impactful</b>	Having a major impact or effect <sup>6</sup>
<b>Pollutant</b>	A substance that pollutes something, especially air and water <sup>6</sup>
<b>Scrutiny</b>	Careful and thorough examination <sup>6</sup>

**References:** (If clicking a link does not work, please copy and paste the link into a web browser.)

<sup>1</sup> Collins Dictionary. (n.d.). Retrieved March 11, 2026, from: <https://www.collinsdictionary.com/us/>

<sup>2</sup> Farm Forward. (2023, April 27). *Lab-grown meat*. [https://www.farmforward.com/news/lab-grown-meat/?gad\\_source=1&gad\\_campaignid=16519203249&gbraid=0AAAAADudVfShFxbEsZ2ipMFenOP1nDVa&gclid=CjwKCAjw1N7NBhAoEiwAcPchp7RPNXAvN2a3hwMFD4N13tWGUmp95wmXTd1QfhUODemZACveExXixRoCnlwQAvD\\_BwE](https://www.farmforward.com/news/lab-grown-meat/?gad_source=1&gad_campaignid=16519203249&gbraid=0AAAAADudVfShFxbEsZ2ipMFenOP1nDVa&gclid=CjwKCAjw1N7NBhAoEiwAcPchp7RPNXAvN2a3hwMFD4N13tWGUmp95wmXTd1QfhUODemZACveExXixRoCnlwQAvD_BwE)

<sup>3</sup> Merriam-Webster. (n.d.) Retrieved March 11, 2026, from: <https://www.merriam-webster.com/dictionary/>

<sup>4</sup> Merriam-Webster Student Dictionary for Kids. (n.d.). Retrieved from: <https://www.merriam-webster.com/kids>

<sup>5</sup> National Geographic. (n.d.). *Greenhouse effect*. Retrieved March 11, 2026, from <https://education.nationalgeographic.org/resource/greenhouse-effect/>

<sup>6</sup> Oxford Learner's Dictionary. (n.d.). Oxford University Press. Retrieved March 11, 2026, from <https://www.oxfordlearnersdictionaries.com/us/>

# How Feed Production and Manure Generate Greenhouse Gases and Harm the Environment



## Feed Production

Most U.S. livestock are fattened on fishmeal, corn, soybean meal and other grains. Grain production, in particular, requires significant quantities of fertilizer, fuel, pesticides, water and land. It takes 149 million acres of cropland, 76 million kilos (167 million lbs) of pesticides and 7.7 billion kilos (17 billion lbs) of nitrogen fertilizer to grow this feed. Fertilizer applied to soil generates nitrous oxide (N<sub>2</sub>O), which has 300 times the warming effect of carbon dioxide. Irrigation pumps, tractors and other farm equipment also release carbon dioxide, but in relatively small amounts. Pesticides and fertilizers often end up in runoff that pollutes rivers, groundwater and oceans. Feed crops are heavily subsidized by taxpayers through the federal Farm Bill, to the tune of \$45 billion over the past 10 years. Fertilizer and pesticide production requires a significant amount of energy, but our model found that together they account for just 12 percent of the emissions from growing feed. The biggest impact is from the nitrous oxide emissions resulting from fertilizer application.

## Manure

Animal waste releases nitrous oxide and methane and pollutes our water and air, especially when it is concentrated. In 2007, U.S. livestock in confined feeding operations generated about 500 million tons of manure a year, three times the amount of human waste produced by the entire U.S. population (EPA 2007). Manure [management] is the fastest growing major source of methane, up [66 percent from 1990 to 2023 (EPA 2025)]. While manure is a valuable nutrient for plants, it can leach pollutants – including nitrogen, phosphorus, antibiotics and metals – into groundwater when storage facilities leak or too much is spread on farm fields. More than 34,000 miles of rivers and 216,000 acres of lakes and reservoirs in the U.S. have been degraded by waste from confined feeding operations (EPA 2009). Decomposing waste releases dust, smog odors and toxic gases, including ammonia and hydrogen sulfide, which degrade air quality and can cause itching, dizziness and discomfort to workers and nearby residents.

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**Sources:** (If clicking a link does not work, please copy and paste the link into a web browser.)

Hammerschlag, K. (2011, July). *Meat eater's guide to climate change and health*. Environmental Working Group.  
[https://static.ewg.org/reports/2011/meateaters/pdf/report\\_ewg\\_meat\\_eaters\\_guide\\_to\\_health\\_and\\_climate\\_2011.pdf](https://static.ewg.org/reports/2011/meateaters/pdf/report_ewg_meat_eaters_guide_to_health_and_climate_2011.pdf)

United States Environmental Protection Agency. (2025). *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2023*. EPA 430-R-25-003. <https://library.edf.org/AssetLink/145ky510ew61fk1tq5c2klp5kq5yp33j.pdf>

# Article Worksheet

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

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

**Article:** How Feed Production and Manure Generate Greenhouse Gases and Harm the Environment

**Author:** Environmental Working Group

**1. How does producing food for farm animals generate greenhouse gases and harm the environment?**

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**2. How does animal waste generate greenhouse gases and harm the environment?**

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**3. What is the fastest growing major source of methane?**

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# Article Worksheet

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

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

**Article:** Less Beef, Less Carbon: Americans Shrink Their Diet-Related Carbon Footprint by 10 Percent Between 2005 and 2014

**Author:** NRDC

**1. Between 2005 and 2014, the amount of beef that Americans cut out of their diet brought down carbon emissions equivalent to the annual tailpipe emissions for how many cars?**

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**2. How could pollution (carbon emissions) be reduced even more?**

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**3. What food in the American diet contributes the most to climate-warming pollution?**

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# Article Worksheet

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

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

**Article:** Impossible Foods to Supersize Production of Lab-Grown Burger

**Author:** Dara Kerr, CNET

**1. What "secret ingredient" is in these burgers to make them seem more like meat?**

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**2. How are plant-based hamburgers better for the environment than hamburgers made from cows?**

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**3. If your favorite burger restaurant offered the Impossible Burger, would you eat it? Why or why not?**

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# Article Worksheet

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

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

**Article:** Millennials Are Driving The Worldwide Shift Away From Meat

**Author:** Michael Pellman Rowland, Forbes.com

**1. What three things do millennials often think about when they choose what to eat?**

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**2. Name one health concern associated with eating processed meats like bacon and ham.**

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**3. Name two things that companies are doing as a result of the demand for plant-based options.**

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# Final Activity: Sticky Note Exercise

**Purpose:** Identify key student learning to assess lesson effectiveness

## 1. Requirements



### Time

5-10 minutes  
at end of session



### Materials

- One sticky note for each student
- Thin-line markers or pens



### Board or Wall Space

A place where students can post the sticky notes and the class can gather around to view them

## 2. Introduction

Inform the class that the final activity will have them reflect upon what they have learned throughout the lesson. **Ask each student to write 1-2 sentences on a sticky note about what they think is the most important thing they learned. Students should not write their names on the sticky notes.**

## 3. Individual Work Time (2 minutes)

## 4. Posting Sticky Notes (2 minutes)

Students should now post their sticky notes on the board/wall so that they can see what their fellow classmates learned as a whole. Inform the students that they do not have to post their sticky note if they prefer not to do so. Students should remain standing by the board/wall once they have posted their sticky notes.

## 5. Themes (up to 5 minutes)

Now, ask the class if they see similar concepts, facts, or comments referred to on the sticky notes. Encourage a brief discussion.

**Time Permitting:** Have the students group together sticky notes with similar ideas. Then ask students to come up with a title to describe each group of sticky notes. Finally, add titles to each group of sticky notes using an additional sticky note.

### Contact

Please feel free to contact us with any questions, feedback, or ideas by emailing [education@farmsanctuary.org](mailto:education@farmsanctuary.org).