BIOGAS:

GARBAGE POWER

LESSON PLAN | GRADES 6–8

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Approximately 72 billion pounds of food ends up in landfills and incinerators each year. When food decomposes, a colorless, odorless, and flammable gas called methane is produced. This isn't the only way that methane gets into the atmosphere. Methane is produced as the result of natural processes and human activities alike, including wetlands, oil and natural gas systems, agricultural activities, coal mining, wastewater treatment, and enteric fermentation, to name a few. Unfortunately, methane is a powerful greenhouse gas, trapping 28 times more heat than carbon dioxide, and human activities are putting more methane in the air than can be absorbed by natural sinks.

S1E4 (24 mins)

From Leftovers to Lifesavers

Leftovers become life-saving fuel with this backyard supercomposting system that is revolutionizing lives across the world.

But what if you could divert some of the methane being produced into something more useful? Methane is flammable and releases a lot of heat when it combusts, making it a useful resource for humans. One organization, HomeBiogas, has developed a backyard system that captures the methane released as food waste decomposes and turns it into cooking biogas and plant fertilizer. This "super composter" uses all organic matter, prevents additional methane from entering the atmosphere, and provides free renewable energy to empower people in remote and rural areas across the world.

OBJECTIVES

Lesson Time: 3 hr 25 mins+

Lesson Description: In this lesson, students will explore the "hidden power" of rotting food. Working primarily in small groups, they will set up a model to determine that methane and digestate is left behind after food rots. They will investigate and discuss the impacts of methane, both in the environment and as a renewable energy source called biogas. Finally, students will apply their knowledge by designing an experiment to determine how to increase biogas production, and provide feedback on other experiment designs.

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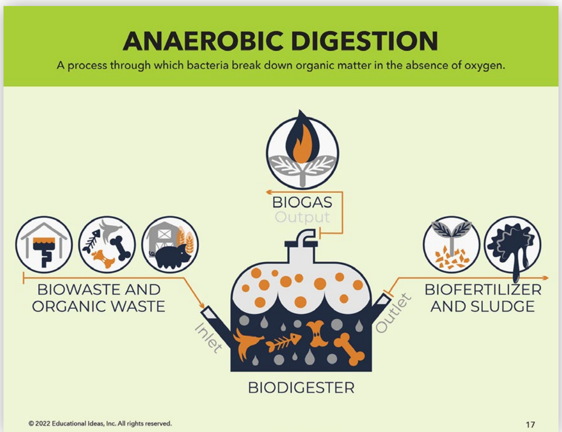
Students will:

- Students will create a model of a biogas generator to explore the products of decomposition.
- Students will learn about and discuss the impacts of biogas (methane) use on people and the environment.
- Students will identify variables that could impact biogas generation.
- Students will design an experiment to test the impact of different variables on biogas generation, and provide feedback on other experiment designs.



TO PREPARE

Per student group (Engage)
- 1-liter clear soda bottle
- balloon
- duct tape
- $\frac{1}{3}$cup raw vegetable scraps and grass
- $\frac{1}{3}$cup outdoor soil (not bagged)
- large Ziploc bag/bowl
- permanent marker
- funnel
- ruler
- string

Teacher demo (Engage)
- methane source
- balloon
- liquid dish soap
- plastic tubing
- flint/lighter
- water

Prior Knowledge:

- Students should have a basic understanding of decomposers and decomposition.
- Students should have a basic understanding of the scientific method.

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Vocabulary Words

Use the Vocabulary Slides to review these words and concepts as needed.

anaerobic digestion: a process through which bacteria break down organic matter in the absence of oxygen

biogas: a renewable fuel produced by the breakdown of organic matter such as food scraps and animal waste

biogas generator/biogas digester: a structure used to produce biogas

decomposer: an organism that breaks down organic matter for energy and nutrients

digestate: a nutrient-rich substance produced from anaerobic digestion that can be used as a fertilizer

methane: a colorless, odorless, flammable greenhouse gas; can be used as a fuel

Cross Curricular Lesson Suggestions

Math: Students use EIA's Natural Gas Data Reports to practice statistical analysis and graphing of data. For example, students can create a graph comparing the price of natural gas over time to the production, or by comparing the consumption of natural gas to the production, and then look for trends. Does the data show more production than consumption or vice versa? What are the implications of this data? Will the price of natural gas rise due to demand?

ELA/Art: Create a poster campaign focused on encouraging the use of biogas. Students should include the benefits and advantages of the technology as well as address any concerns.

Social Studies: Students research and discuss the proposed Agricultural Environmental Stewardship Act (S-2542), including the summary and press release of the bill. How would the bill positively impact the environment and farmers? What are the negative impacts of the bill? Would you support this bill, and why?

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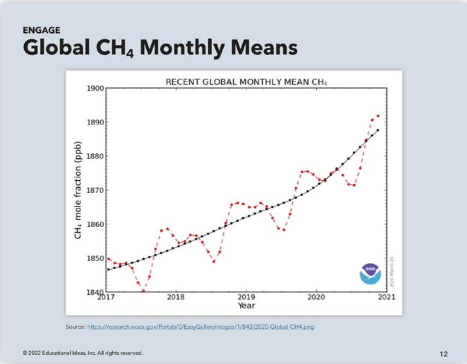
ENGAGE

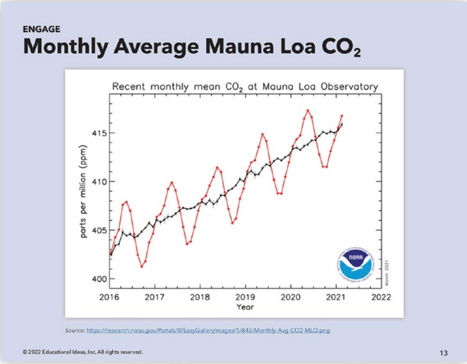
20 mins

Ancillary Materials: Whole Group Photo, Global CH_4 Monthly Means graph, Global CO_2 Monthly Averages graph, Methane Fact Sheet

Display the photo of rotting food. Tell students that 72 billion pounds of food ends up in landfills and incinerators each year, and that doesn't even include the food people throw out in their homes or at BBQs and parties. As the food decomposes, it creates methane, a greenhouse gas. Engage students in a whole group discussion with the following prompt:

- What do you know about the term "greenhouse gas"? *(Students should know that a greenhouse gas traps heat in the atmosphere. Students likely know that carbon dioxide is a greenhouse gas. Consult the "Greenhouse Effect" lesson plan if students are completely unfamiliar with this phenomena.)*
- Have you ever heard of methane? What do you know about it? *(Do not confirm or deny any student ideas at this time.)*





Display NOAA's Global CH_4 Monthly Means graph. Highlight graph features as needed, including the differences between the black and red lines and the measurement unit of ppb (parts per billion), to ensure student understanding. Display NOAA's Global CO_2 Monthly Averages graph and highlight the measurement unit of ppm (parts per million). Ask students to explain the differences in units, ensuring they understand that ppm is a thousand times greater than ppb. Divide students into small groups and distribute a set of graphs to each. Ask groups to discuss the following prompts, then share with the class:

- What trends do you notice in each graph? Are there any similarities or differences between the two? *(Students should notice that both CO_2 and CH_4 emissions increase. They may point out that CO_2 emissions increase more steadily than CH_4 emissions, and that there are always more CO_2 emissions than CH_4, due to the different measurement units.)*

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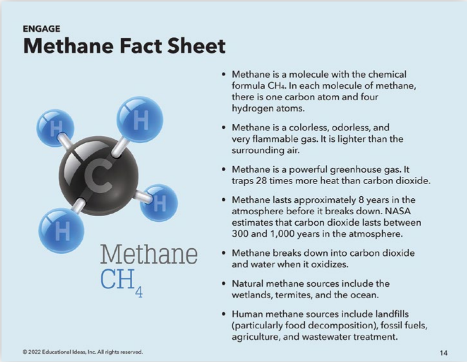
- As scientists, we know that greenhouse gas emissions trap more heat on Earth. After looking at the data, which set of greenhouse gas data is most concerning to you? Why? *(Accept any student answer at this point; students will likely argue that CO_2 data is more concerning because there is more CO_2 in the atmosphere.)*



After groups share their ideas, distribute a copy of Methane Fact Sheet to students. Ask students to read the fact sheet, return to their small groups, and discuss the following prompts:

- After reading the methane fact sheet, has your opinion about the most worrying greenhouse gas changed? Explain your thinking.
- Brainstorm ways that humans could prevent methane from entering the environment. *(Students should consider human methane sources listed in their fact sheet, including landfills/food decomposition, fossil fuels, agriculture, and wastewater treatment.)* Is there any way that methane could actually be useful to humans?

Note: The purpose of the last set of questions is to engage students with the content and reflect on changes to thinking when new information is presented. There is no "right" answer as to which greenhouse gas is more concerning; instead, focus on ensuring students are using relevant evidence to support their claims. Students might recognize from the fact sheet that methane's flammability means it could be useful to humans, but do not confirm or deny any student ideas at this point.

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EXPLORE

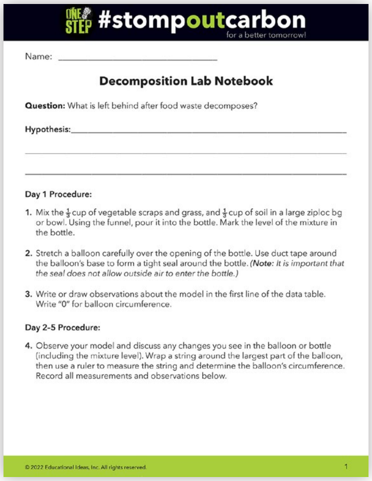
Ancillary Materials: Decomposition Lab Notebook

Supplies (per group): 1-liter clear soda bottle, balloon; duct tape, $\frac{1}{3}$ cup raw vegetable scraps, $\frac{1}{3}$ cup outdoor soil (not bagged), large Ziploc bag/bowl, permanent marker, funnel, ruler, string

Supplies (for teacher demo): methane source, balloon, liquid dish soap, plastic tubing, flint/lighter, water

Day 1: Set-up (15–20 minutes)

Explain to students that they will create a model in small groups to determine what is left behind after food is decomposed. Distribute Decomposition Lab Notebooks to students and ask them to record their hypothesis. Suggested procedure: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Name: ____________________

Decomposition Lab Notebook

Question: What is left behind after food waste decomposes?

Hypothesis: ____________________

Day 1 Procedure:

1. Mix the $\frac{1}{3}$ cup of vegetable scraps and grass, and $\frac{1}{3}$ cup of soil in a large ziploc bg or bowl. Using the funnel, pour it into the bottle. Mark the level of the mixture in the bottle.
2. Stretch a balloon carefully over the opening of the bottle. Use duct tape around the balloon's base to form a tight seal around the bottle. (*Note: It is important that the seal does not allow outside air to enter the bottle.*)
3. Write or draw observations about the model in the first line of the data table. Write "0" for balloon circumference.

Day 2-5 Procedure:

4. Observe your model and discuss any changes you see in the balloon or bottle (including the mixture level). Wrap a string around the largest part of the balloon, then use a ruler to measure the string and determine the balloon's circumference. Record all measurements and observations below.

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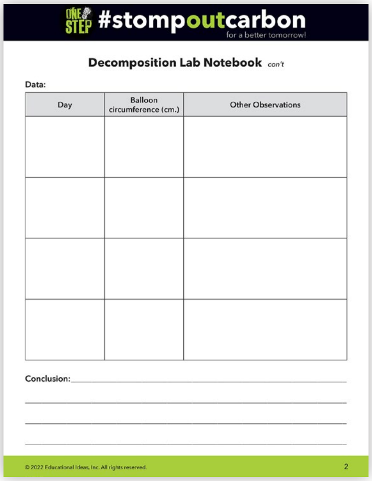
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Decomposition Lab Notebook con't

Data:

Day	Balloon circumference (cm.)	Other Observations

Conclusion: ____________________

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1. Mix the $\frac{1}{3}$ cup of vegetable scraps and grass, and $\frac{1}{3}$ cup of soil in a large ziploc bag or bowl. Using the funnel, pour it into the bottle. Mark the level of the mixture in the bottle.
2. Stretch a balloon carefully over the opening of the bottle. Use duct tape around the balloon's base to form a tight seal around the bottle. *(**Note:** It is important that the seal does not allow air to enter or leave the bottle.)*
3. Students write or draw observations about the model in their lab notebooks.

Day 2–4: Data Collection (10–15 minutes)

4. The following day, students revisit the models and discuss any changes they see, including the mixture level. Each group wraps a string around the balloon to measure its circumference. Record all measurements and observations in lab notebooks.
5. Repeat Step 4 each day.

Day 5: Final Data Collection, Discussion, Teacher Demonstration (30–35 minutes)

6. Repeat Step 4.

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After students complete their final observations, engage them in a whole group discussion with the following prompts:

- Describe what happened in your model throughout the week. Why did that happen?
- How would the results differ if there was a hole in the balloon? How would those differences impact the environment?
- Describe what's left behind after food rots. Do you think either of these things left behind are useful, and why? *(Students should recognize that methane and a brownish sludge is left behind after food rots. Tell students that this sludge is called digestate.)*

Teacher Demo: Methane Bubbles:

Note: The following demonstration requires a methane source, and will show the flammability of methane by igniting methane bubbles. Most school laboratories use methane gas in their chemistry rooms, and it burns very quickly so there is very little risk to the teacher if done properly. This can be done in a fume hood or outside in a well-ventilated area. If it's not possible to perform this demonstration in front of students, consider finding a "methane bubbles demonstration" video to show students and discuss.

Explain to students they will observe a demonstration to determine if methane is flammable. Suggested demonstration procedure:

- Using a balloon pre-filled with methane gas, transfer some of the gas to a beaker filled with soapy water via plastic tubing.
- Submerge one hand into the soapy water solution and capture the gas filled bubbles to ensure that the bubbles have a surface to stick to.
- Using a flint or lighter, carefully light the bubble solution on your hand. The bubbles will burn very quickly and then extinguish themselves. Be careful not to touch anything else during this step. *(**Note:** This step should be done in a fume hood or in a well-ventilated area. Do not allow students to light the match or interact with the fire and be certain to have a fire blanket nearby in case of emergency).*

Ask students to discuss the following prompts in small groups, then share with the class:

- Methane is very flammable. How might this be useful to humans?
- What might be some potential dangers of methane?

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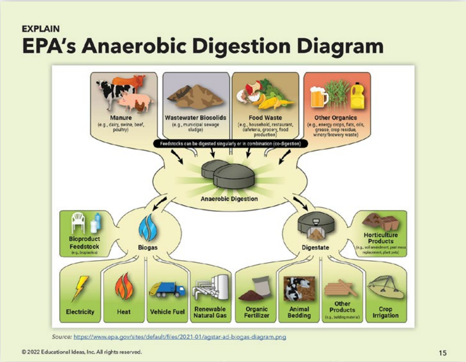
EXPLAIN

30–35 mins

Ancillary Materials: Vocabulary Slides

Watch the video "From Leftovers to Lifesavers" as a class. Use the Vocabulary Slides as necessary to review vocabulary or concepts. Engage students in a whole group discussion with the following prompts:

- Discuss your reaction to the HomeBiogas system. How does it impact people living in rural areas? What about the environment?
- Display the EPA's Anaerobic Digestion Diagram. Discuss the following prompts:



  - ➥ This diagram shows a larger scale biogas digester used on farms. Does this process require oxygen? *(Students should realize that, no matter the size, anaerobic digestion does not require oxygen.)*
  - ➥ How are the products of anaerobic digestion useful to farmers?
  - ➥ Anaerobic digestion results in the creation of carbon dioxide, another greenhouse gas. Explain why using this process is better than allowing organic material to rot naturally. *(Students should recognize that anaerobic digestion naturally releases both methane and carbon dioxide into the environment, and that methane is 28 times more effective at trapping heat than carbon dioxide.)*
- What are the advantages and disadvantages of using biogas? *(Consider giving students time to review HomeBiogas System's Advantages and Disadvantages of Using Biogas page to supplement the discussion.)*
- Vermont runs a program called "Cow Power," in which electricity customers can elect to pay a small increase to directly support farms producing biogas. Brainstorm other ways that the government or organizations can encourage biogas use and production.

Optional Extension: Methane Tracker

Ask students to explore NOAA's Carbon Tracker (CH_4) and discuss insights with the class. Highlight the maps showing Natural CH_4 Flux in North America and Agriculture and Waste Flux in North America.

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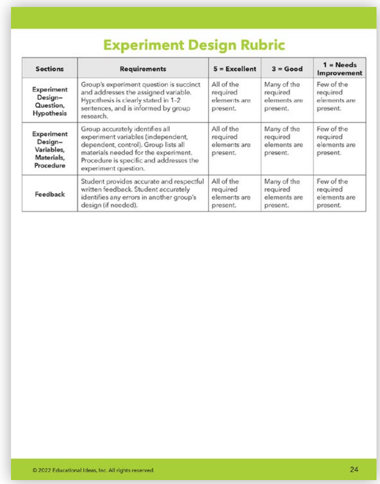
ELABORATE

60 mins

Ask students to discuss the following prompt in small groups, then share with the class:

- Do you think it's possible to alter the biogas generator model to create more methane? Brainstorm different variables (factors) that might impact how much biogas is created in a system.

As groups share different variables that might impact biogas production, record ideas on chart paper or another location students can see. Push students to consider variables like food type, amount, temperature, the presence of soil. After students share, choose one variable and model how to create an experiment question to test the variable. *(**Note:** Based on students' experiences, consider asking them to create the experiment question rather than modeling the process.)*



Experiment Design Rubric

Sections	Requirements	5 = Excellent	3 = Good	1 = Needs Improvement
Experiment Design–Question, Hypothesis	Group's experiment question is succinct and addresses the assigned variable. Hypothesis is clearly stated in 1-2 sentences, and is informed by group research.	All of the required elements are present.	Many of the required elements are present.	Few of the required elements are present.
Experiment Design–Variables, Materials, Procedure	Group accurately identifies all experiment variables (independent, dependent, control). Group lists all materials needed for the experiment. Procedure is specific and addresses the experiment question.	All of the required elements are present.	Many of the required elements are present.	Few of the required elements are present.
Feedback	Student provides accurate and respectful written feedback. Student accurately identifies any errors in another group's design (if needed).	All of the required elements are present.	Many of the required elements are present.	Few of the required elements are present.

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Explain to students that they will work in small groups to research and design an experiment to test how one variable impacts biogas production, and then share their design with others for feedback. Assign each group one variable from the student-generated list (assuming each variable can be feasibly tested in the classroom), or allow groups to self-select their variable. Give students time to research their variable in order to make an informed hypothesis. Review the rubric and answer student questions as needed. Suggested design requirements:

- Experiment question
- Informed hypothesis (based on Internet research)
- Independent, dependent, and control variables *(Review "Experiment Design" found in the Vocabulary Slides to review these terms as needed.)*
- Materials list
- Procedure

Note: *Based on your student's familiarity with experiment design, consider providing students with a guide to support students. See the 4–5 lesson plan for an example guide.*

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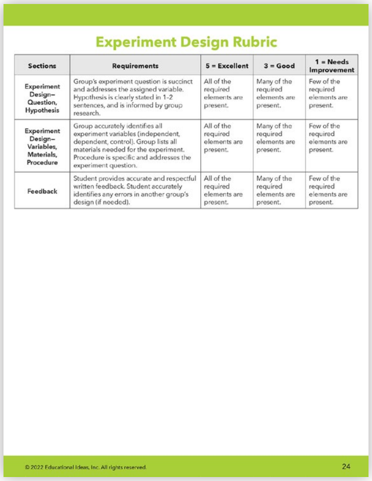
Ancillary Materials: Student Feedback Card

Poster Gallery Walk: Each group will present their experiment design poster in a Gallery Walk format. Each student should write feedback to at least one other group by using a Student Feedback Card. Give groups 10 minutes to update their design based on feedback, then submit to the teacher. Use the rubric to assess students' final posters.



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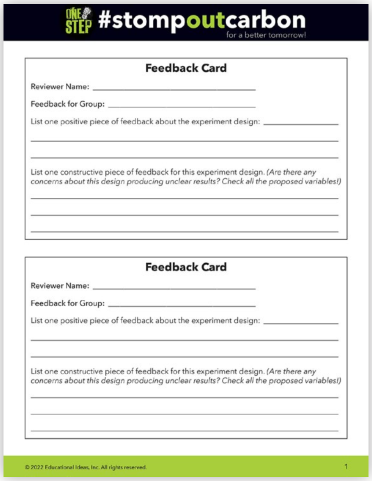

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Feedback Card

Reviewer Name: ____________

Feedback for Group: ____________

List one positive piece of feedback about the experiment design: ____________

List one constructive piece of feedback for this experiment design. *(Are there any concerns about this design producing unclear results? Check all the proposed variables!)*

Feedback Card

Reviewer Name: ____________

Feedback for Group: ____________

List one positive piece of feedback about the experiment design: ____________

List one constructive piece of feedback for this experiment design. *(Are there any concerns about this design producing unclear results? Check all the proposed variables!)*

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Optional Extension: Conduct Biogas Experiment: It is highly suggested to provide students with materials to conduct the biogas experiments they designed in order to increase student buy-in. If you choose to do this, set aside 5–10 minutes of class each day for students to gather data after they set up the experiment. Groups can also briefly present their results to the class.

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rotting food

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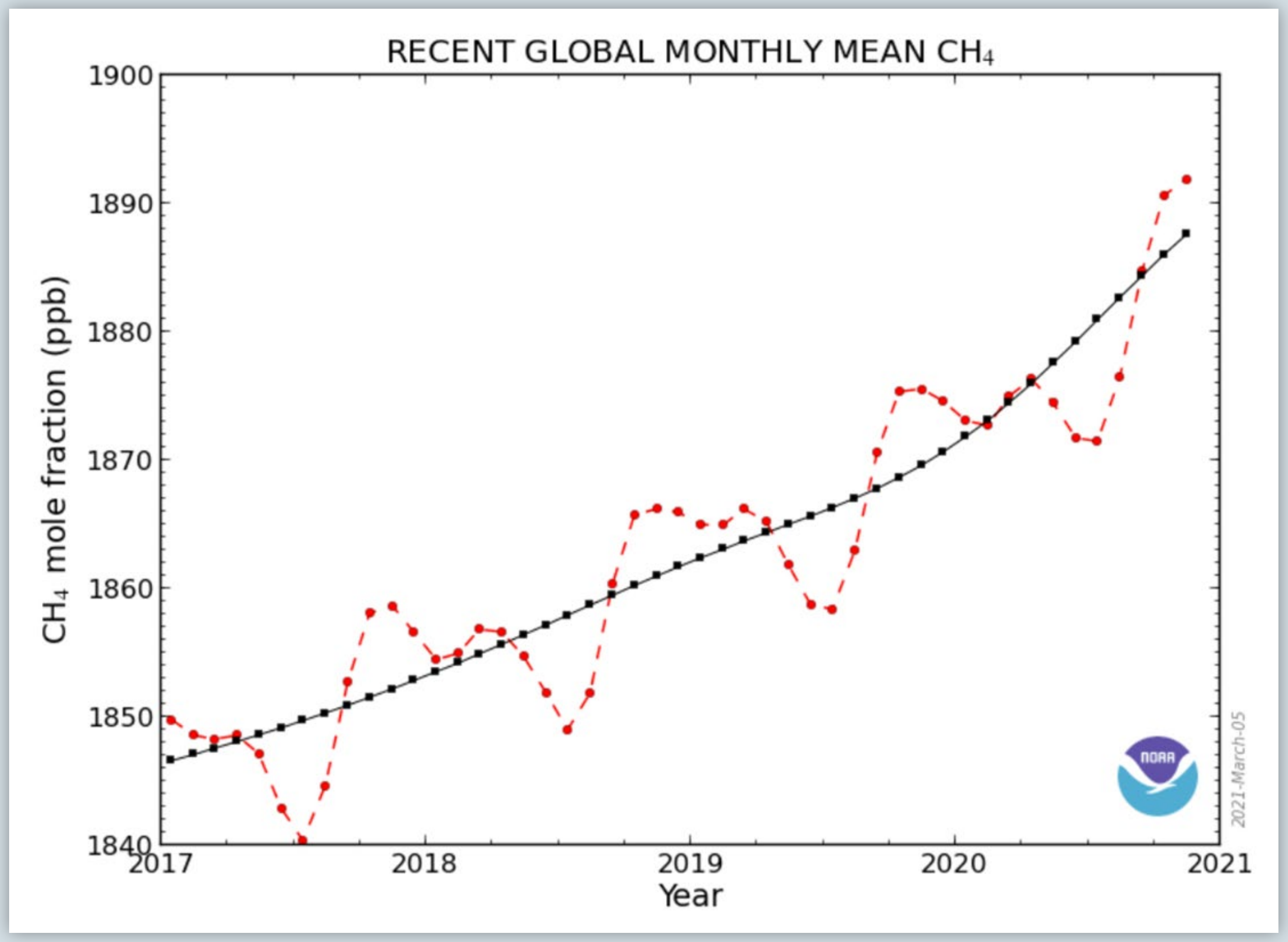
ENGAGE

Global CH_4 Monthly Means



Source: https://research.noaa.gov/Portals/0/EasyGalleryImages/1/843/2020-Global-CH4.png

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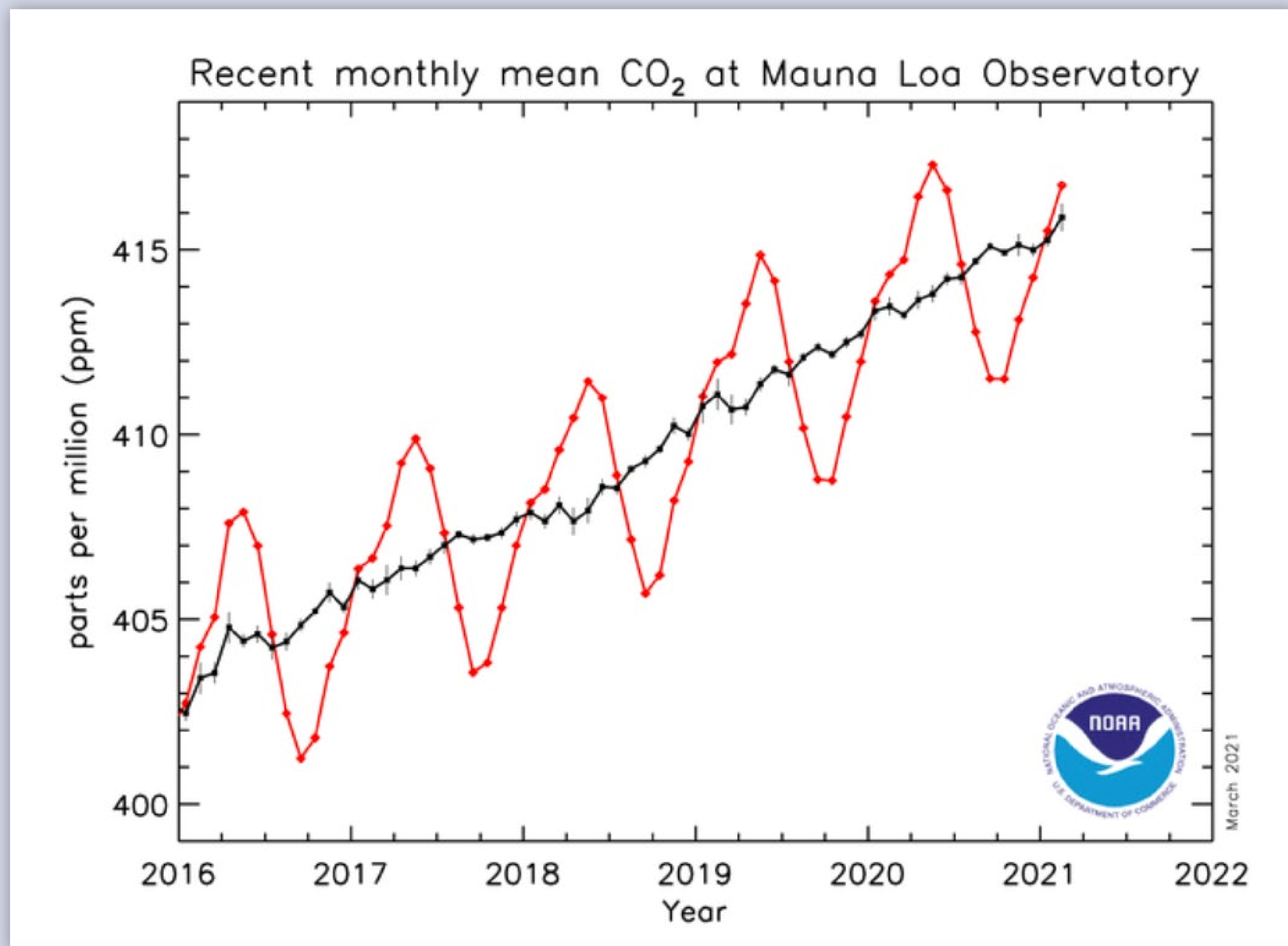
ENGAGE

Monthly Average Mauna Loa CO_2



Source: https://research.noaa.gov/Portals/0/EasyGalleryImages/1/843/Monthly-Avg-CO2-MLO.png

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ENGAGE

Methane Fact Sheet

- Methane is a molecule with the chemical formula CH_4. In each molecule of methane, there is one carbon atom and four hydrogen atoms.
- Methane is a colorless, odorless, and very flammable gas. It is lighter than the surrounding air.
- Methane is a powerful greenhouse gas. It traps 28 times more heat than carbon dioxide.
- Methane lasts approximately 8 years in the atmosphere before it breaks down. NASA estimates that carbon dioxide lasts between 300 and 1,000 years in the atmosphere.
- Methane breaks down into carbon dioxide and water when it oxidizes.
- Natural methane sources include the wetlands, termites, and the ocean.
- Human methane sources include landfills (particularly food decomposition), fossil fuels, agriculture, and wastewater treatment.

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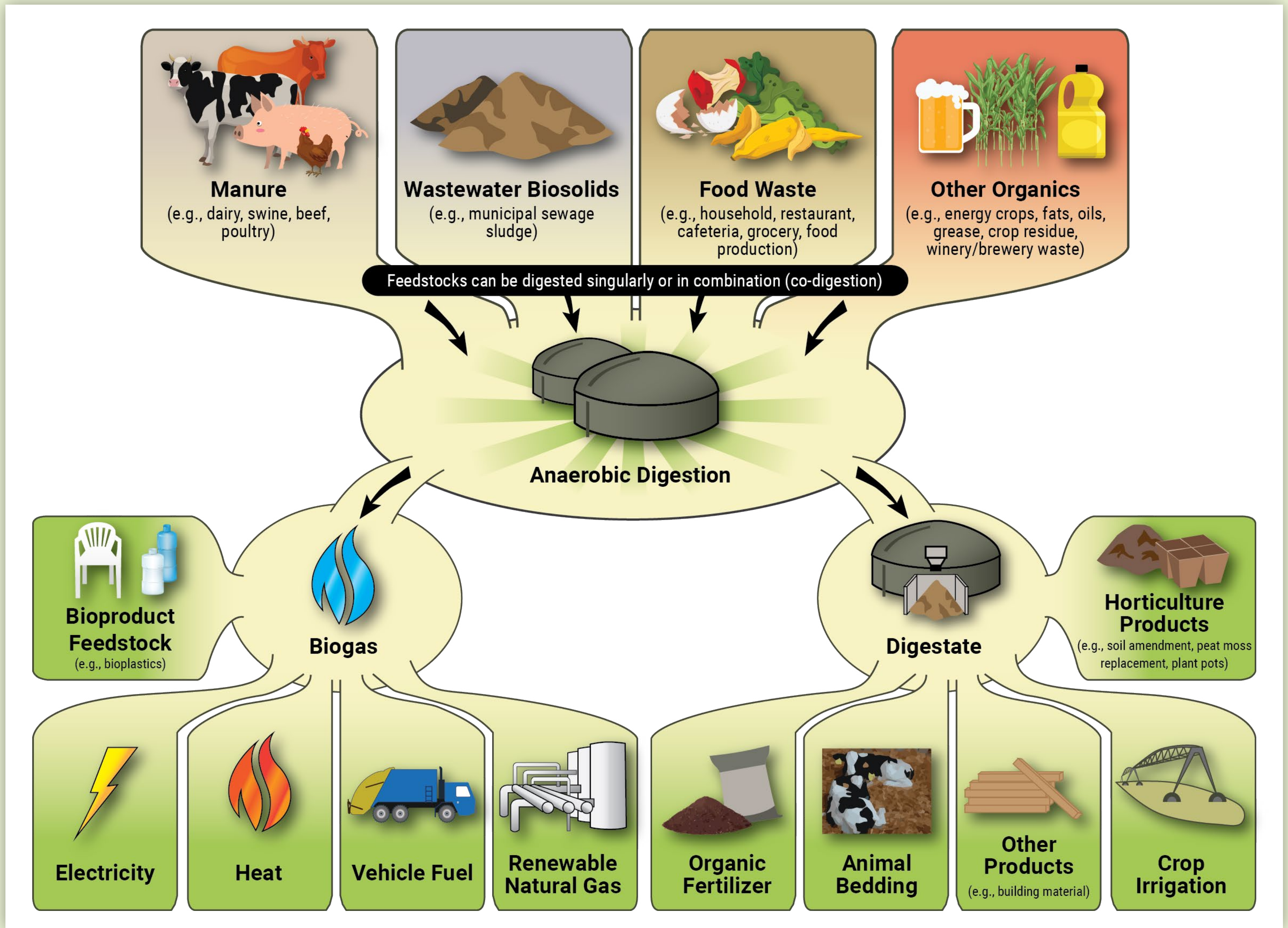
EXPLAIN

EPA's Anaerobic Digestion Diagram



Source: https://www.epa.gov/sites/default/files/2021-01/agstar-ad-biogas-diagram.png

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Vocabulary

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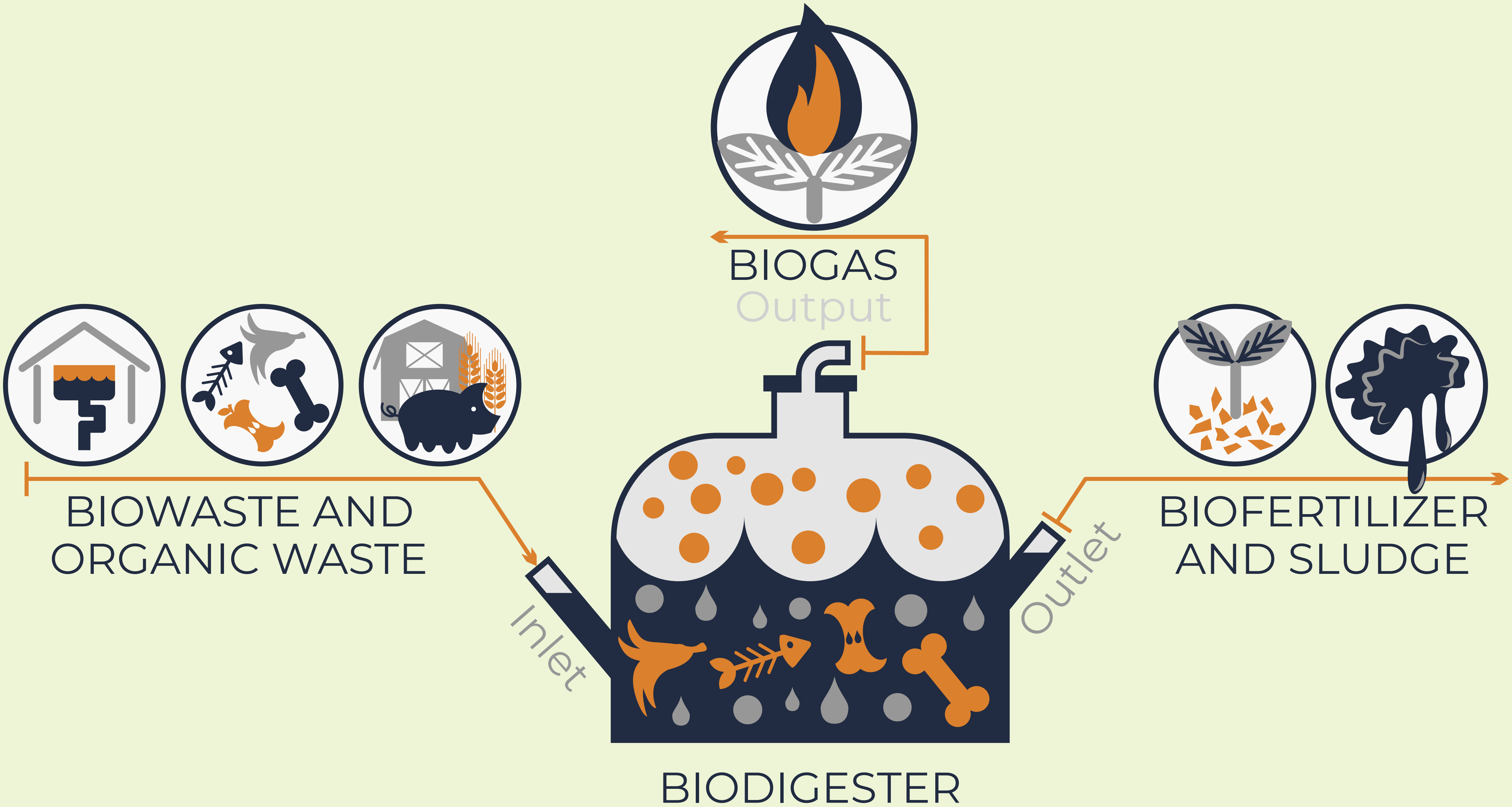
ANAEROBIC DIGESTION

A process through which bacteria break down organic matter in the absence of oxygen.



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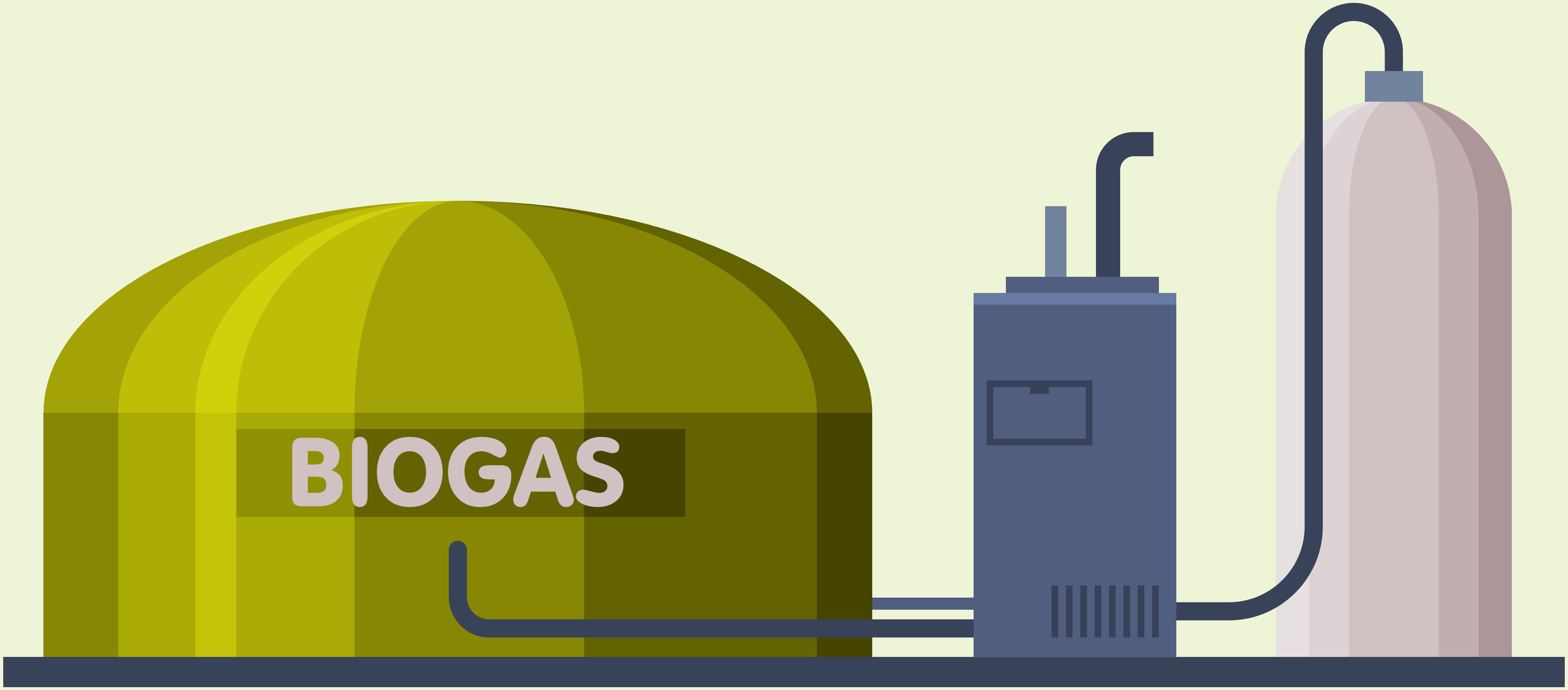
BIOGAS

A renewable fuel produced by the breakdown of organic matter such as food scraps and animal waste.



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BIOGAS GENERATOR/BIOGAS DIGESTER

A structure used to produce biogas.

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DECOMPOSER

An organism that breaks down organic matter for energy and nutrients.

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DIGESTATE

A nutrient-rich substance produced from anaerobic digestion that can be used as a fertilizer.

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METHANE

A colorless, odorless, flammable greenhouse gas; can be used as a fuel.

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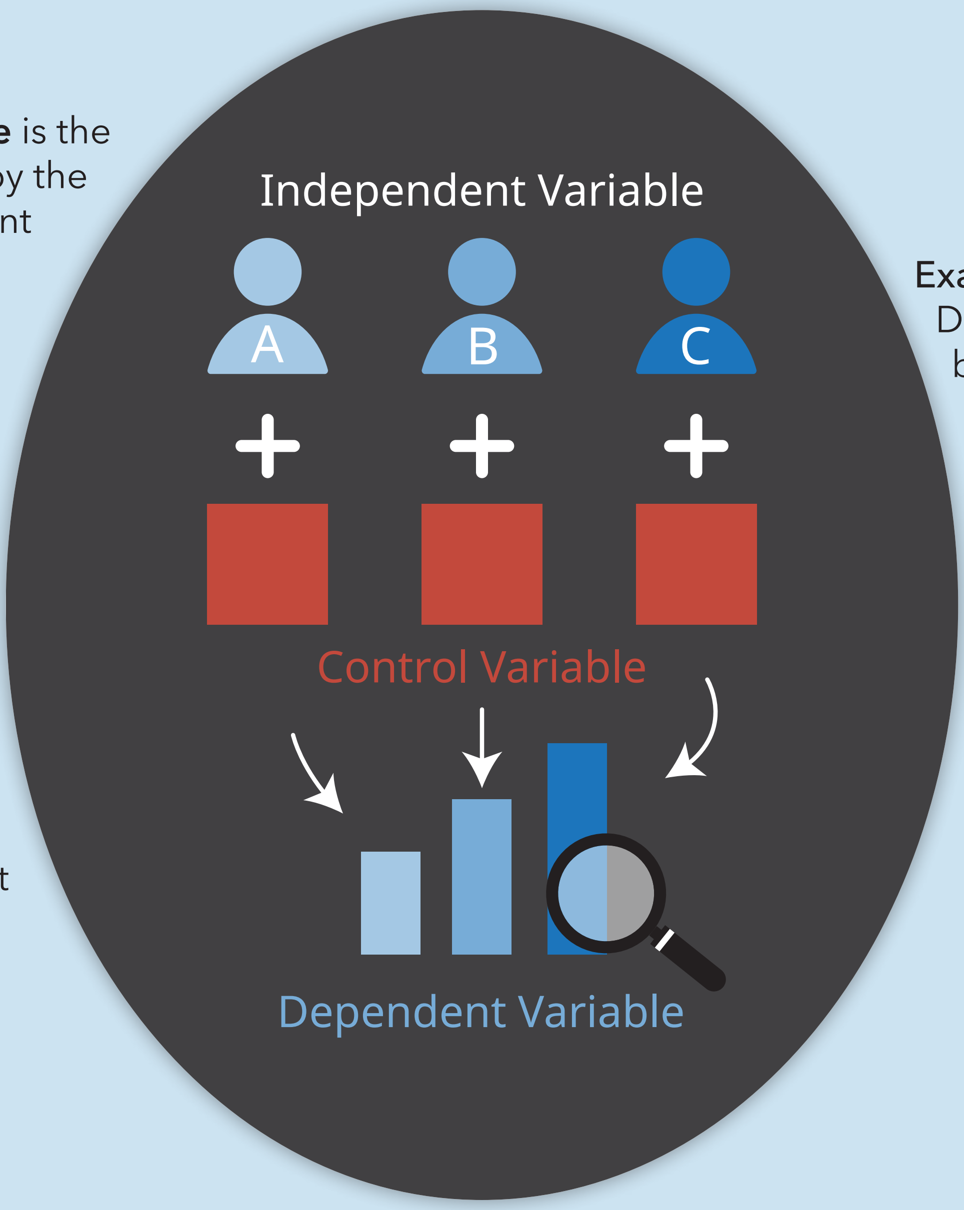
Experimental Design

- The **independent variable** is the variable that is changed by the experiment. An experiment can only include one independent variable.
- The **dependent variable** is the variable that changes as a result of the independent variable, and is sometimes known as the "outcome variable."
- The **control variables** are all variables that are kept the same throughout the experiment. Control variables ensure that the dependent variable is an accurate reflection of the independent variable.



Example Experiment Question:
Does temperature affect a bean plant's growth?

- **Independent variable:** temperature
- **Dependent variable:** the amount of growth
- **Control variables:** amount of sunlight and water plants receive, bean plant and soil type, etc.

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MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

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 systems.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Engaging in Argument from Evidence Constructing Explanations and Designing Solutions	**ESS3.C:** Human Impacts on Earth Systems	Cause and Effect **Connections to Engineering, Technology, and Applications of Science** Influence of Science, Engineering, and Technology on Society and the Natural World **Connections to Nature of Science** Science Addresses Questions About the Natural and Material World

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Student Materials

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Name: ________________________________

Decomposition Lab Notebook

Question: What is left behind after food waste decomposes?

Hypothesis:____

____

____

Day 1 Procedure:

1. Mix the $\frac{1}{3}$ cup of vegetable scraps and grass, and $\frac{1}{3}$ cup of soil in a large ziploc bag or bowl. Using the funnel, pour it into the bottle. Mark the level of the mixture in the bottle.

2. Stretch a balloon carefully over the opening of the bottle. Use duct tape around the balloon's base to form a tight seal around the bottle. *(**Note:** It is important that the seal does not allow outside air to enter the bottle.)*

3. Write or draw observations about the model in the first line of the data table. Write "0" for balloon circumference.

Day 2–5 Procedure:

4. Observe your model and discuss any changes you see in the balloon or bottle (including the mixture level). Wrap a string around the largest part of the balloon, then use a ruler to measure the string and determine the balloon's circumference. Record all measurements and observations below.

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Decomposition Lab Notebook *con't*

Data:

Day	Balloon circumference (cm.)	Other Observations

Conclusion:____

____

____

____

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Feedback Card

Reviewer Name: ______________________________

Feedback for Group: ______________________________

List one positive piece of feedback about the experiment design: ________________

____

____

List one constructive piece of feedback for this experiment design. *(Are there any concerns about this design producing unclear results? Check all the proposed variables!)*

____

____

____

Feedback Card

Reviewer Name: ______________________________

Feedback for Group: ______________________________

List one positive piece of feedback about the experiment design: ________________

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