TOP

EXPLORATION 3: BIOENERGY

Phenomenon

Bioenergy includes methane produced by fermentation of animal and plant waste, and combustion of plant waste and wood are examples of renewable resources that can be used to produce energy. Although fermentation and burning of organic material releases carbon dioxide, methane is approximately 30 times more destructive as a greenhouse gas than carbon dioxide is.

Guiding Question

How can methane gas be produced efficiently from organic waste?

Overview

The use of bioenergy as a renewable resource is controversial in Germany, the European Union, and countries outside Europe. Small-scale production of biogas using animal waste and silage (crop waste) provides farm households with a reliable source of gas for cooking and heating. When scaled up, bioenergy has unintended negative social and environmental impacts. In Europe there is limited land available for farming. Shifting agricultural production from food to fuel crops raises concerns about food security. Further concerns arise from the environmental impacts of monoculture (growth of a single type of plant). Monoculture has large-scale impacts on ecosystems, pollinator species, and soil degradation. More research is needed before bioenergy can become a significant source of renewable energy in Germany.

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However, biogas produced from compost and animal waste is considered sustainable because it is producing power from waste that would otherwise be discarded.

It is important to distinguish between renewable and sustainable energy resources. Sustainable means meeting the needs of the current generation without sacrificing the needs of the future, and future generations. This means, that while some bioenergies like ethanol, are renewable, some are not sustainable because of environmental concerns like monoculture and food security. However, biogas from compost and animal waste is sustainable because it produces power from waste that would otherwise just be discarded. Biogas from compost or animal waste also does not take away from valuable and limited agricultural land.

Arriving at the education center, you walk past the wind turbine structure with a new appreciation of the technology involved in electricity generation using wind power. Your group settles into picnic tables for a bioenergy investigation.

Maja begins, “You will need the bioenergy section of your notes organizer. Turn to your partner. What does bioenergy mean?” Maja waits as partners discuss a definition. “Do I have a volunteer?”

Your partner, Alex, raises his hand. Maja says, “Go ahead.”

Alex says, “We think bioenergy is energy made by living things.”

“Okay. Let’s build on the idea. What are living things made of?” Maja asks.

Kendra volunteers to answer. “The basic elements of life are carbon, hydrogen, oxygen, nitrogen, and sulfur.”

Stephen adds, “Living things are organic because they contain carbon from cell processes.”

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You add, “Living things use carbon dioxide or release carbon dioxide as part of their cell processes.”

Maja summarizes student ideas. “Living things are made of cells that carry out life processes producing waste. Plant photosynthesis uses carbon dioxide and water to make sugar and releases oxygen as waste. Plant and animal respiration uses sugar and oxygen and releases carbon dioxide and water as waste.” She continues, “What happens when living things that are made of carbon, hydrogen, oxygen, nitrogen, and sulfur die?”

Kendra answers, “They decompose.”

“Who agrees?” Maja asks. Seeing everyone nod or raise a hand, Maja looks at Kendra, “Everyone agrees with you. I do too. Here in Feldheim, we use anaerobic decomposition of organic matter to heat our homes. Anaerobic means without oxygen.”

Carla wrinkles her nose, “Doesn’t that stink?”

“Yes. We need to control the decomposition in an anaerobic digester.” Maja responds. “Let’s use a model to understand how the process works. Please work with a partner.”

Maja holds up a clear plastic soda bottle. “This will be the digestion chamber.” Each pair of students takes a bottle from the bin at the end of the table.

“So now we need something to be digested. There are some vegetable peels in the bucket on the table. Take a few and chop them up a little with one of the knives from the rack.”

Maja and your chaperone supervise the shredding of the vegetable scraps, instructing each pair to add enough scraps to the bottle to fill it about a quarter to a third of the way.

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“Now we have the dead organic matter for digestion. What do we need to do for the digestion by anaerobic fermentation?”

“Fungi?” “Worms?” “Bacteria?”

“Fungi are decomposers, but they are not what we need for anaerobic fermentation. Worms will eat the scraps and digest them into castings, but that isn’t anaerobic fermentation. We need bacteria.” Maja puts a container of organic soil and compost mixture on the table. “Roll up a sheet of paper into a funnel. Put the funnel into the mouth of the bottle. Now add three or four teaspoons of soil to the bottle.”

When everyone finishes adding soil to the food scraps, Maja continues. “The bacteria in the soil will break down the vegetable peels, but we still need something if we are to make methane through anaerobic digestion.”

“Seeing the puzzled looks on your faces,” Maja adds, “we need nitrogen. In our biogas system we use pig manure. However, today we will use beef stock cubes. Crush the stock cube and add it to your bottle.”

You crush a stock cube and add it to the bottle as Alex steadies the paper funnel. “The stock cube provides minerals that encourage the bacteria to eat and digest the food scraps,” Maja explains. “Now that everyone is ready, we will add some water and get the fermentation started.”

“How much water?” You ask.

Maja replies, “Enough to make a liquid mixture. Probably 120 milliliters, but it depends on how much soil you added.” After all the groups have added water to their bottles, Maja says, “Put the cap on the bottle and shake it up a little.”

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“Last step, take the cap of the bottle and place your balloon over the mouth of the bottle. This will capture the methane from anaerobic fermentation.” While groups complete the step, Maja opens a box. “Anaerobic fermentation takes more time than we have. Normally, I could send you back to school with your bottle. However, because you are traveling, your bottles will stay here.” Maja smiles and says, “I don’t think your hotel would like to host a biogas experiment. To show you the final results, we started an experiment last week. Tell me what evidence you see that fermentation took place?”

“The balloon is bigger.” “The mixture looks different.” “There are almost no food scraps.”

“Yes. That can be used as evidence. Now we need to prove that the gas in the balloon is methane.” Your chaperone assists Maja as Maja removes the balloon from the bottle. Pinching the neck of the balloon tightly, she attaches it to a glass tube. Your chaperone strikes a match while Maja releases her pressure on the neck of the balloon. The escaping gas ignites into a blue flame.

“Methane!” Maja explains, as you and your group members react with surprise and excitement.

When the flame dies out, Maja asks you to take out your organizers. “Methane is a hydrocarbon gas. This means it is made of carbon and hydrogen. When it burns, it combines with oxygen to make carbon dioxide and water. Sometimes biogas is used directly in place of natural gas for heating or cooking. In Feldheim, we use biogas to make steam heat to generate electricity and heat.”

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"Feldheim has been producing biogas since 2008. The agricultural cooperative supplies 8,600 cubic meters of manure, 9,590 tons of corn, and 209 tons of wholegrain cereal. From these raw materials, the plant generates 4 million kilowatt hours of electricity per year. All the electricity feeds into the public grid" (Neue Energien Forum Feldheim, n.d.).

Maja continues, "The heat produced during power generation is distributed through our district heating grid. The district heating grid serves local homes, the livestock farm, and businesses. Because our village is self-sufficient for heating energy, we save 68,420 gallons of heating oil each year. In addition to the economic and environmental benefits of the electricity we sell and the heating oil we don't buy, each year 15,500 cubic meters of fertilizer is produced as a by-product of electricity generation. The fertilizer can go back to the agricultural cooperative" (Neue Energien Forum Feldheim, n.d.).

"During the winter, temperatures can become too cold for efficient operation of the biogas plant. During such periods, electricity and heat can be produced using solid biomass in the form of wood chips and firewood. Here in Germany, biomass is gaining popularity. The biomass used in Feldheim comes from thinning of local woodlands. Using the wood from forest and woodland management is a sustainable resource practice that conserves energy associated with extraction of fossil fuels."

"Feldheim is a small village. By having our own heating grid, a central boiler can replace individual boilers. Environmental impacts of waste gases from steam or heat production can be more efficiently controlled by having one central boiler system instead of multiple individual systems."

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