Water + Energy Classroom Activity

Activity Overview

Only 2.5% of Earth's water is fresh and even then, only 1% is surface water we can easily access. Water treatment plants use microbes to break down organic material enabling us to recycle water over and over. **In this activity, students will examine how anaerobic digestion breaks down bio-solids into fertilizer and biogas that is used as a source of energy.** They will then identify places in their community that could benefit from recycling solid waste. As an extension, students will adapt or design their own self-sufficient device or system.

Target Audience: Middle School Students

Activity Duration: 45-60 minute class session

Essential Questions

- How do microbes break down organic bio-solids anaerobically?
- What are the products of the microbial digestion of organic material and how are these products used?
- Which areas in the community can benefit the most from recycling solid waste?
- What factors must be considered when adapting or designing a self-sufficient device or system?

Objectives

Students will:

- Describe the process of anaerobic digestion using a diagram.
- Present and defend ideas for places in the community that can benefit from recycling solid waste.
- Design or adapt a self-sufficient system that converts biodegradable material into renewable energy.

National Standards

ESS3.C: Human Impacts on Earth Systems
Typically, as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.

ETS1.B: Developing Possible Solutions
There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.

ITEEA 13: Students will develop the abilities to assess the impact of products and systems.

Materials

- Computers or other devices with internet access
- Chart paper or large Post-It paper
- Markers (various colors)
- Copies of “Four-Square Chart” graphic organizer
- Copies of “Water Reclaiming Design Challenge” prompt
- Copies of NGSS “Engineering Design Process” template

Procedure

1) Write the following guiding question on chart paper or a board, “How do microbes break down organic bio-solids?” If needed, clarify with students that bio-solids are sewage sludge. Invite students to watch the video to look for evidence to answer the question.

2) Invite students to share their responses to the guiding questions and lead students in a class discussion of the use of microbes in anaerobic digestion. This process is highlighted in the video.

   Clarify the following key points:
   - Biosolid waste is converted to a rich soil product and methane is harnessed as a power source.
   - Each digester can process millions of gallons of sludge.

- Tiny microbes digest the organic matter yielding methane gas, which is burned to boil water, which then creates steam that turns a turbine to generate power and heat.
- The bio-fertilizer is transported and applied directly to agricultural land that is used to grow crops for animal feed.

3) Direct students to work in groups to create a process diagram for the anaerobic digestion of biosolids on chart paper.

   Invite students to focus on the following key aspects:
   - Process of breaking down organic materials
   - The products of anaerobic digestion
   - How the products are used

   Suggested resources:
   How anaerobic digestion works and what it can do for you:
   https://www.epa.gov/anaerobic-digestion
   http://water.usgs.gov/edu/wwvisit.html

   Guide students in identifying the following key ideas, such as:
   - In the absence of air, microorganisms break down organic material through a series of biological processes.
     - Initially, bacterial hydrolysis releases organic polymers (amino acids)/carbohydrates (sugars) and makes them readily available for other bacteria to convert into hydrogen, organic-based acids, and ammonia.
     - Lastly, microorganisms transform these products into gaseous products (biogases), including carbon dioxide, methane, water vapor, and small quantities of other gases.
   - The CO_2 and other gases are expelled leaving methane, which is the primary component of natural gas.
   - Removing hydrogen sulfide refines the biogas and it is used to power engines, supply homes, fuel furnaces, etc. The biogas also may be purified further for use as compressed biomethane fuel for vehicles.
   - In addition, a nutrient-rich solid/liquid mixture is filtered and used as fertilizer for crops.

4) Four Corners Activity - Ask the class to move to one of four corners of the room based on the following sectors of the community that can benefit from recycling solid waste:

- Green Buildings (Residential and Commercial)
- Farms
- Watersheds
- Transportation (Hydrogen/Biomethane Fuels)

Instruct the class to apply what they learned to present/defend ideas on why that particular sector would benefit from recycling wastewater based on their research. Students can capture their ideas on one corner of the Four-Square chart. As each group presents, students will complete the other corners of the Four-Square Chart.

5) Following the presentations, engage students in a debriefing discussion. Collect students' completed Four-Square Chart (to serve as a graded Exit Slip).

Optional Extension

Challenge students to adapt/design a self-sufficient device for reclaiming wastewater. Ask students to address the prompt (shown on page 7) using the Engineering Design Process Template to guide their thinking. Make sure students include the following components in their report:

- Precise definition and solution to the problem
- A drawing of the prototype to be built (including relevant materials)
- Tests of the prototype
- Evaluation of the results and ways to achieve an optimal design

Resources

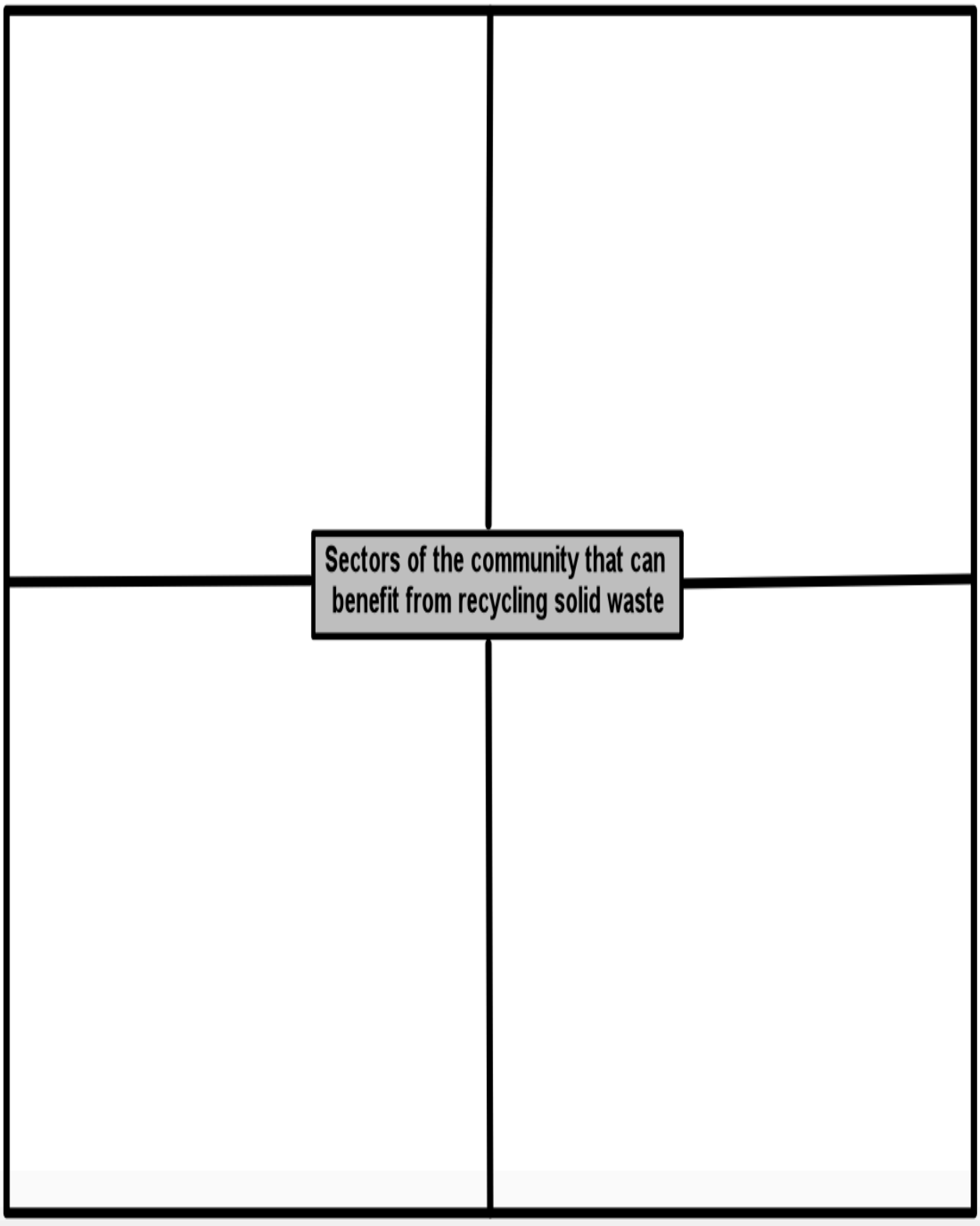
AgSTAR Biogas Recovery in the Agriculture Sector:
https://www.epa.gov/agstar

Innovations in nanotechnology for water treatment:
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4294021/

Step-by-step guide to primary treatment process of wastewater:
http://water.usgs.gov/edu/wwvisit.html

Includes glossary of terms and international examples of cost-effective sanitation and wastewater management:
http://www.wecf.eu/download/2010/03/guidancepaperengl.pdf

FOUR-SQUARE CHART



WATER RECLAIMING DESIGN CHALLENGE

Name: _____

You are part of an engineering team tasked with designing a "Tiny House" that will function off-grid and reduce its owner's carbon footprint. Your specific role within the engineering team is to design a self-sufficient device that reclaims gray wastewater (non-sewage wastewater that comes from bathroom sinks, kitchen sinks, showers, and washing machines).

Make sure to include the following components in your report:

Define the Problem Precisely and Develop a Solution (Research-Based)

_____
_____
_____
_____
_____
_____
_____

Attach a Drawing of your Prototype (on the back) and List Relevant Materials

_____
_____
_____

Describe How You Will Test Your Device

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_____
_____
_____
_____

Evaluate the Results – How Will You Achieve an Optimal Design?

_____
_____
_____
_____