CE
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BRIGHT FUTURES

Bioreactor Water Heating

Lesson 3: Bioreactor Water Circulation System

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DESCRIPTION: Solar energy is available when the sun shines but energy can be supplemented at night by the decomposition energy in a bioreactor. In this activity we will experiment with the feasibility of using heated water in a bioreactor to circulate it through a water trough or pipe system to prevent it from freezing in the winter. This method will save money and natural resources for those who rely on water trough heaters to water livestock or those who use heat coil systems to make sure pipes do not freeze in winter months. This system could also be used as a radiant heating system throughout a shed or chicken coop to warm the shelter in winter.

GRADE LEVEL(S): 7th-12th grades

SUBJECT AREA(S): Physical Science, Energy Fundamentals; Sustainable energy, Solar/Renewable energy

ACTIVITY LENGTH: 3-4 class periods over a ~3-month timeline

LEARNING GOAL(S):

1. Students will examine the properties of solar water pumping systems using KidWind solar water pumps or similar water pumps.
2. Students will experiment with the properties of water and its limitations in circulating due to pump power and distance.
3. Students will evaluate the use of a heat sink/chiller in the circulation of water through the bioreactor.

NEXT GENERATION SCIENCE STANDARDS:
Students who demonstrate understanding can:

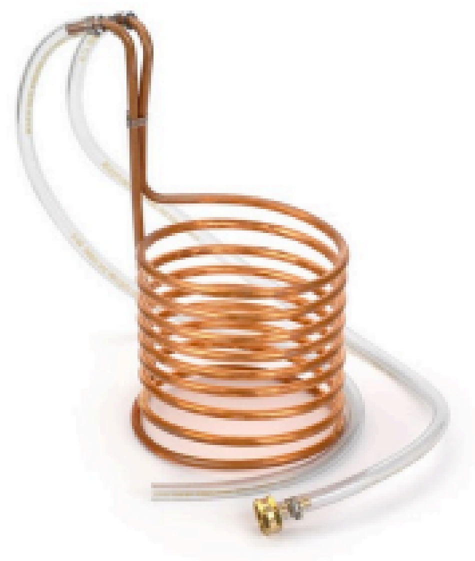
MS-PS3-3. Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.

MS-PS3-4. Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.

HS-PS3-3. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

Materials List

- 1-5 large bioreactors (compost piles) already in use.
- Wooden pallet composters or large 50-gallon trash cans may be used to create a composting bioreactor to use for experimentation.
- KidWind water pumps with tubing (class set).
    - Note that the operating voltage of these pumps is 3 Volts.
    - If you use batteries or solar panels, ensure that your circuit voltage does not exceed 3 Volts (e.g. 2 batteries in series). You can also do this portion of the activity with KidWind wind turbines from Vernier.
- At least (2) 1.5 V or (1) 3 V solar modules for water pump testing (or 2 batteries) per group
- 2-3 Water circulation systems that will act as heat exchangers for your bioreactor's energy to be distributed to another location (water trough).
- A **wort chiller** works very well and is relatively inexpensive.
- Plastic irrigation tubing available at local hardware stores
- Metal belt connectors or small zip ties can be used as connectors.
- Shovel/gloves/trowel



Wort Chiller

Vocabulary

- Passive solar energy
- Chemical energy
- heat sink
- radiant heating system
- bioreactor
- organic matter
- wort chiller

Lesson Details

Planning and Prep

Ideally this lesson is an extension to Lessons 1 and 2 (Passive Solar Water Heating and Bioreactor Water Heating). The background information in the previous lessons will aid both the teacher and the students with this lesson. This lesson requires a bioreactor: the best is established compost that is already releasing thermal energy. Ensure that your compost is active by monitoring the temperature in the middle of it. If temperatures are warm and especially if temperatures are rising, then you can be sure that your bioreactor's decomposition is happening properly. This lesson has three parts. First, students will test ideas and constraints with moving water by experimenting with small water pumps.

As an introductory or follow-on lesson, there is a great lesson on air pressure and water demonstration, found at: https://www.lsop.colostate.edu/wp-content/uploads/sites/6/2014/10/SuperlongStraw.pdf.

This is a great and engaging lesson that explains the limits of transporting water at different heights.

Students can determine how they want to circulate water throughout the compost pile.

Student Background

Students participating in this lesson should be familiar with the following:

- Lesson 1: Bioreactor Water Heating
- Lesson 2: Compost Bioreactor Design
- Inquiry lab on using a straw and the limitation of heights water can be transported. • Importance of sustainable water heating and carbon footprints.
- Go over the diagram to show water flow and the connection of the plastic tubing • Basic circuit wiring (series and parallel circuits if using small and/or less than 3 V solar modules

Educator Background

Educators leading this lesson should be familiar with the following:

- Water transportation and air pressure:
    - **"Can you drink through a 30 foot straw?"** Little Shop of Physics at Colorado State University, Center for Multiscale Modeling of Atmospheric Processes https://www.lsop.colostate.edu/wp-content/uploads/sites/6/2014/10/SuperlongStraw.pdf
    - Veritasium. "World's Longest Vertical Straw" https://youtu.be/HUmZrtiXDik
- "Engineering with Renewable Energy: Solar Water Pumping Activity," by Jamie Repasky, located in this online resource library
- Bioreactors and composting
- Chemical energy released through composting and heat energy generation
- Background reading/videos/websites or other resources in Lessons 1 and 2.
- Diagram of the bioreactor and water flow.

Lesson Details

Part I: Solar Water Pumping

Students will use the KidWind water pumps to explore pumping water between two water vessels. The students can use inquiry learning to explore on their own or the teacher can use the lesson plan in this resource library created by Jamie Repasky, titled, "Engineering with Renewable Energy: Solar Water Pumping Activity."

Optional: Before or after the water pumping activity, do "Can you drink through a 30 foot straw?" activity.

Part II: System Design—Bioreactor Solar Water Circulation Heating System

After familiarizing themselves with water circulation through a water pump, the students will begin to design an experiment that will circulate water using solar energy throughout a bioreactor system that will heat the water as the pump circulates the water.

Part III: Design Experiment and Test Variables

The students will use a wort chiller or a coil of plastic tubing to expose the colder water to the thermal energy “generated” by the bioreactor. The students will design the experiment, but can test variables such as:

- speed of the circulating water
- length of the coiled plastic tubing
- size of the wort chiller

Students should also record the high temperature of the day for comparison. This value can be graphed next to the water temperatures.

Assessment

A rubric to assess the planning and execution of the student-led inquiry investigation is attached on the following page.

Lesson Extensions

This lesson is very open-ended and can be modified to go in many directions, Some ideas are:

- Create an inquiry lab on using different temperatures of water and circulating water of one temperature through water of another would help give the students an understanding of the concepts of circulating water and use of the water pump.
- Heating water for indoor radiant energy.
- Heating water for hot water usage in a classroom.
- Circulating water by wind turbine generated energy.

Assessment

A rubric to assess the planning and execution of the student-led inquiry investigation is provided below.

Inquiry and Analysis VALUE Rubric				
	Outstanding (4 pts)	**Proficient (3 pts)**	**Basic (2 pts)**	**Below Basic (1 pt)**
Existing Information Existing Knowledge, Research, and/or Views	Outstanding Synthesizes in-depth information from relevant sources representing various points of view/approaches.	Proficient Presents in-depth information from relevant sources representing various points of view/approaches.	Basic Presents information from relevant sources representing limited points of view/approaches.	Below Basic Presents information from irrelevant sources representing limited points of view/approaches.
Design Process	Outstanding All elements of the experiment are skillfully developed. Appropriate methodology or theoretical frameworks may be synthesized from across disciplines or from relevant subdisciplines.	Proficient Critical elements of the experiment are appropriately developed, however, more subtle elements are ignored or unaccounted for.	Basic Critical elements of the experiment are missing, incorrectly developed, or unfocused.	Below Basic Inquiry design demonstrates a misunderstanding of the experiment.
Analysis	Outstanding Organizes and synthesizes evidence to reveal insightful patterns, differences, or similarities related to focus.	Proficient Organizes evidence to reveal important patterns, differences, or similarities related to focus.	Basic Organizes evidence, but the organization is not effective in revealing important patterns, differences, or similarities.	Below Basic Lists evidence, but it is not organized and/or is unrelated to focus.
Conclusions	Outstanding States a conclusion that is a logical extrapolation from the inquiry findings.	Proficient States a conclusion focused solely on the inquiry findings. The conclusion arises specifically from and responds specifically to the inquiry findings.	Basic States a general conclusion that, because it is so general, also applies beyond the scope of the inquiry findings.	Below Basic States an ambiguous, illogical, or unsupportable conclusion from inquiry findings.
Limitations and Implications	Outstanding Insightfully discusses in detail relevant and supported limitations and implications.	Proficient Discusses relevant and supported limitations and implications.	Basic Presents relevant and supported limitations and implications.	Below Basic Presents limitations and implications, but they are possibly irrelevant and unsupported.