

WASTE TO WATTS

Overview:

In this lesson, students build a calorimeter, test the energy content in various edible nuts and investigate biomass as an alternative energy source for Alaska communities through three case studies.

Objectives:

The student will:

- build a simple calorimeter and test the energy content of various edible nuts;
- calculate the calories, per gram, released during the combustion of various nuts and graph the results;
- consider the feasibility of biomass as an energy source; and
- examine three case studies featuring Alaska communities using biomass energy.

Targeted Alaska Grade Level Expectations:

- [7-8] SA1.1 The student demonstrates an understanding of the processes of science by asking questions, predicting, observing, describing, measuring, classifying, making generalizations, inferring, and communicating.
- [7] SA1.2 The student demonstrates an understanding of the processes of science by collaborating to design and conduct simple repeatable investigations, in order to record, analyze (i.e. range, mean, median, mode), interpret data, and present findings.
- [8] SA1.2 The student demonstrates an understanding of the processes of science by collaborating to design and conduct repeatable investigations, in order to record, analyze (i.e. range, mean, median, mode), interpret data, and present findings.
- [8] SB2.1 The student demonstrates an understanding of how energy can be transformed, transferred, and conserved by identifying the initial source and resulting change in forms of energy in common phenomena (e.g. sun to tree to wood to stove to cabin heat).

Vocabulary:

biomass – all living and recently living things

calorie – the amount of heat required to raise the temperature of one gram of water by 1°C

calorimeter – a device used to measure energy content by calculating the heat required for a chemical reaction

joule – a unit of energy equal to 1/3,600 watt hour (equal to burning a 1 watt light bulb for one second)

nonrenewable energy source – a mineral energy source that is in limited supply, such as fossil fuels (gas, oil, and coal) and nuclear fuel

renewable energy source – an energy source that can be replenished in a short period of time (solar, wind, geothermal, tidal)

watt – a unit of power; equivalent to one joule per second

watt hour – a measure of electrical energy equivalent to consuming one watt for one hour

Whole Picture:

Biomass is a renewable energy source that includes all living and recently living things. Biomass energy is created by the combustion of carbon-based matter. The energy in biomass comes from the sun. Plants convert radiant energy into chemical energy through photosynthesis and store this energy as glucose. When we burn biomass, we use this stored energy to produce heat.

Alaska Native people have been using biomass fuels for heat and light for thousands of years; the most common source is wood. Other forms of biomass energy include biofuels made from fermented plant material (such as ethanol made from corn), solid waste (garbage and animal waste), and landfill gas (capturing the methane released during decomposition).

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Interior Alaska has extensive biomass resources including wood, sawmill waste, fish byproducts and municipal waste (garbage, especially paper and wood products). Conventional timber as well as fast growing shrubs like willows and alders can be cultivated and harvested for power generation and/or heating. On average, 1.5 million acres of forested land in Alaska is adversely affected by wildfires and beetles each year. Some of this wood is salvageable as biomass fuel.

Biomass is currently being used in Alaska communities to generate electricity and heat. It may become a more feasible energy option as the cost of oil and gas continues to rise, especially in rural communities.

We use a variety of units of measure for power and energy such as calories, joules, watts and BTUs. Many people are familiar with calories as a unit of food energy. A calorie is actually a unit of heat. It approximates the energy needed to increase the temperature of one gram of water by 1°C. Its use is largely archaic, having been replaced by the joule. However, it remains in use as a unit of food energy. The calories seen on food labels are actually "large calories," "kilogram calories" or simply "food calories." One large calorie is 1,000 calories. It approximates the energy needed to raise the temperature of one kilogram of water by 1°C.

A joule is a unit of power in the International System of Units. It is equivalent to the work required to produce one watt of power for one second. Watts are a unit of power that is equivalent to one joule/second. A calorie is equal to 4.19 joules.

Watts are a unit of power per unit time. One watt equals one joule per second. Power output and consumption (of engines, motors, heaters, etc.) is often expressed in kilowatts (1,000 watts). Electric companies often bill consumers in kilowatt hours. One kilowatt hour is equivalent to 1,000 watt hours or 3,600 joules. Using a 60 watt light bulb for one hour uses 60 watt hours or 0.06 kilowatt hours of electricity.

BTUs (British Thermal Units) are often used to rate heating and cooling systems like wood stoves, grills and air conditioners. Like the calorie, the BTU is a traditional unit of measure that is largely archaic in scientific contexts. One BTU is approximately equal to the heat energy needed to raise the temperature of one pound of water by one degree Fahrenheit. One pound of dry wood contains about 7,000 BTUs.

Materials:

- 12-ounce soda pop cans (two per group)
- Safety glasses (one pair per student)
- Digital scale (one per group)
- Oven mitt (one per group)
- Scissors (one pair per group)
- Shelled pecans, almonds, cashews, walnuts, peanuts or other edible nuts (enough for each group to have a variety of types)
- Paper fasteners (at least 1.5 inches long, 5-10 per group)
- Thermometer (with probes or small enough to fit in the opening of a soda can, one per group)
- 100 mL graduated cylinder (one per group)
- Thumbtack (one per group)
- Water (room temperature, 100 mL per group)
- Long tweezers (at least 6 inches, one per group)
- Aluminum foil (3-inch square, per group)
- Hot pad to protect desk/table (one per group)
- Grill lighter
- Needle-nose pliers (for optional class demonstration)
- STUDENT LAB: "Biomass Energy"
- STUDENT WORKSHEET: "Biomass: Three Alaskan Case Studies"

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Activity Preparation:

1. Carefully review procedure.

NOTE: This experiment involves cutting up an aluminum can and burning nuts. The nuts will produce a significant amount of heat and some smoke. Use discretion to determine if it is better to conduct the lab as a class demonstration or in small groups.

Teachers may want to choose a location with some ventilation (at least a window that can be opened.) Each nut will take approximately five minutes to burn. Large nuts like Brazil nuts can take up to 10-15 minutes. If time is limited, each group could test one kind of nut and then the class can share data.

2. Be prepared to clearly review safety precautions. Calorimeters need to be placed on a stable surface. While in use, the bottom will become hot. Use discretion to determine whether students are allowed to use the lighter, or whether you will light the nuts for them. Consider safety and the time available and decide if you will pre-cut the windows in the soda cans. Do not discard the squares of aluminum!
3. Decide if/how you will use the STUDENT WORKSHEET: "Biomass: Three Alaska Case Studies." You may choose to use them along with the student lab, as homework or as a follow-up later on.

Activity Procedure:

1. Ask students how they think their ancestors stayed warm during long Alaska winters. (People have been burning organic fuels like wood and animal fat for thousands of years.)
2. Introduce students to the terms "biomass" and "biofuels." What does the prefix "bio" mean? (The root word bio means "life," and so biomass means a total mass of living or once living material; biofuel refers to a fuel made directly from living matter.) Although wood is still the most common biomass resource in Alaska, we have many other resources. Ask students to brainstorm Alaska's biomass resources. Keep a list on the white board and provide hints as needed. (Students may mention fish oil, burning garbage, wood scraps and sawdust, fast-growing shrubs, capturing landfill gases, biodiesel made from used vegetable oil, etc.)
3. Explain more Alaska communities are again looking to biomass as an energy source. Ask students why they think this is? (The cost of oil and gas continues to rise making energy costs in rural Alaska among the highest in the nation.)
4. Explain today's lab will focus on biomass as an energy source. Students will measure the energy available through combustion of a plant product (nuts). Remind students that energy comes in many forms and can change form. Ask students where the energy in the nuts came from. It is originally from the sun. This radiant energy was captured via photosynthesis by the plants that grew the nuts and is stored as potential chemical energy in the cells of the plant. This energy is released as light (radiant) and heat (thermal) energy when we burn the nut.

OPTIONAL CLASS DEMONSTRATION (to accompany this discussion): Hold a cracker, potato chip or other available snack food with the needle nose pliers. Light with the grill lighter and allow to burn as you discuss the energy available through the combustion of plant products. If time allows, compare various snack foods. Be aware that oily foods like potato chips will produce smoke. Choose a location with appropriate ventilation.

5. Distribute STUDENT LAB SHEET: "Biomass Energy" and provide instructions for completing the lab in small groups or as a class demonstration. Allow time to carefully review the safety considerations mentioned in the Activity Preparation section.
6. When all groups are finished, share data on the white board (if necessary), review results and answers to questions.
7. If applicable, distribute STUDENT WORKSHEET: "Biomass: Three Alaska Case Studies."

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Extension Ideas:

1. Try burning other food items in the calorimeter (including snack foods and leftovers from student lunches!) Oily foods work particularly well. How do these compare to nuts? Graph results.
2. Contact one of the communities featured in STUDENT WORKSHEET: "Biomass: Three Alaska Case Studies." Find out more about the project's successes and challenges.

Answers to STUDENT LAB SHEET: "Biomass Energy"

1. *Answers will vary.*
2. *Answers will vary.*
3. *Answers will vary.*
4. *Answers will vary.*
5. *the size (mass) of the sample and the oil content of the nut*
6. *the oil content of the nut*
7. *Responses will vary, but students should recognize the energy released from nuts is very small compared to the energy we use each day. Alaska communities would need to import a very large quantity of nuts, which is not economical.*
8. *Responses may vary but may include timber, shrubs (such as alder and willow), animal waste (from dog yards or farm animals), paper/cardboard, wood byproducts (sawdust, saw mill scraps), food scraps, fish oil, fish scraps, etc.*
9. *D*
10. *energy content (by calculating the heat required for a chemical reaction)*
11. *calorie*
12. *You would need spruce poles measuring 14.4 feet in length.*

diameter = $2r$	24 feet = $2r$	$r = 12$ feet	
$s = \sqrt{(r^2 + h^2)}$	$s = \sqrt{(12^2 + 8^2)}$	$s = \sqrt{208}$	$s = 14.4$ feet

13. *You would need 542.6 ft² of birch bark to cover the structure.*

surface area = $\pi \cdot r \cdot s$
surface area = $3.14 \cdot 12 \text{ feet} \cdot 14.4 \text{ feet} = 542.6 \text{ ft}^2$

Answers to STUDENT WORKSHEET: "Biomass: Three Alaska Case Studies"

1. *Answers will vary but may include: creating local jobs, reducing the risk of wildfire close to the community, using a renewable energy source, reducing the cost of fuel used, decreasing carbon emissions and reducing dependence on imported fuel.*
2. *Answers will vary but may include: high initial investment (very expensive to buy), may require special expertise to maintain equipment, could deplete nearby forests.*
3. *Answers will vary.*

BIOMASS ENERGY

NAME: _____

Directions:

A calorimeter is a device used to measure energy content by calculating the heat required for a chemical reaction. Follow the directions below to build a calorimeter and use it to measure the biomass energy available through the combustion of different nuts. (Do not eat the nuts!)

Testable Question:

What kinds of nuts contain the most stored heat energy?

Prediction:

Predict which nuts will produce the greatest and smallest change in water temperature when burned in the calorimeter.

Greatest change in water temperature (most energy released): _____

Smallest change in water temperature (least energy released): _____

Materials:

- 12-ounce soda pop can (2)
- Digital scale
- Safety glasses
- Scissors
- A variety of shelled nuts
- Paper fasteners (5-10)
- Thermometer
- 100 mL graduated cylinder
- Thumbtack
- Water (room temperature)
- Oven mitt
- Tweezers
- Aluminum foil (3-inch square)
- Hot pad



Experiment:

Build the calorimeter:

1. Measure 100 mL of water in the graduated cylinder and carefully pour it into one can.
2. Carefully cut a window (approximately 3.5 inches tall by 2 inches wide) out of the side of the second can (close to the bottom), if your teacher has not already done this for you.
3. On the opposite side of the window, use a thumbtack to poke a small hole approximately 1-2 inches from the bottom. Insert a paper fastener into the hole and spread the arms slightly. This will be the platform for the nuts to sit on.
4. Place the can with the water on top of the can with the window. Be sure to place your calorimeter on the hot pad in a safe place where it will not be bumped or knocked over.

Test the nuts:

5. Determine the mass of the first nut with the digital scale. Record the type of nut and its mass in the data table.
6. Use the thermometer to take the start temperature of the water in the top can. Record it in the data table.
7. Place the square of aluminum foil over the hole in the top soda can (to act as a lid).
8. Carefully place the nut on the paper fastener in the lower can.
9. As directed by your teacher, you or your teacher will light the nut. Allow it to burn.
10. Do not touch the calorimeter as the nut is burning! It will be hot. If the nut falls off the fastener, use the tweezers to carefully put it back on.
11. When the nut has been consumed (and the fire goes out) take the end temperature. Record it in the data table. CAUTION: The bottom will be hot!
12. Calculate the temperature change in ° Celsius. If necessary, convert both the start and end temperature to Celsius before calculating the temperature change. (Do not simply convert the temperature change!) Round to the nearest whole number.
13. Use the formula provided to calculate the calories released. Record in the data table.
14. Divide the calories released by the original mass of the nut to get the calories released per gram. Record in the data table.
15. Repeat the process for each nut.

Graph your results:

16. Create a bar graph of your results:
 - Put the type of nut on the x-axis. Label the axis.
 - Put the calories per gram on the y-axis. Label the axis and be sure to include the units in your label.
 - Give your graph a title on the line provided.

Data

Type of Nut	Mass of Nut (g)	Volume of Water (mL)	Mass of Water (g)	Start Temp. (°C)	End Temp. (°C)	Temp. Change (°C)	Calories (cal)	Calories per Gram (cal/g)

Use the following formulas in your calculations:

- The formula for converting temperatures from Fahrenheit to Celsius is:

$$^{\circ}\text{Celsius} = \frac{5}{9} \times (^{\circ}\text{Fahrenheit} - 32)$$

- The formula for converting volume of water to mass is:

$$1 \text{ milliliter (mL) water} = 1 \text{ gram (g) of water.}$$

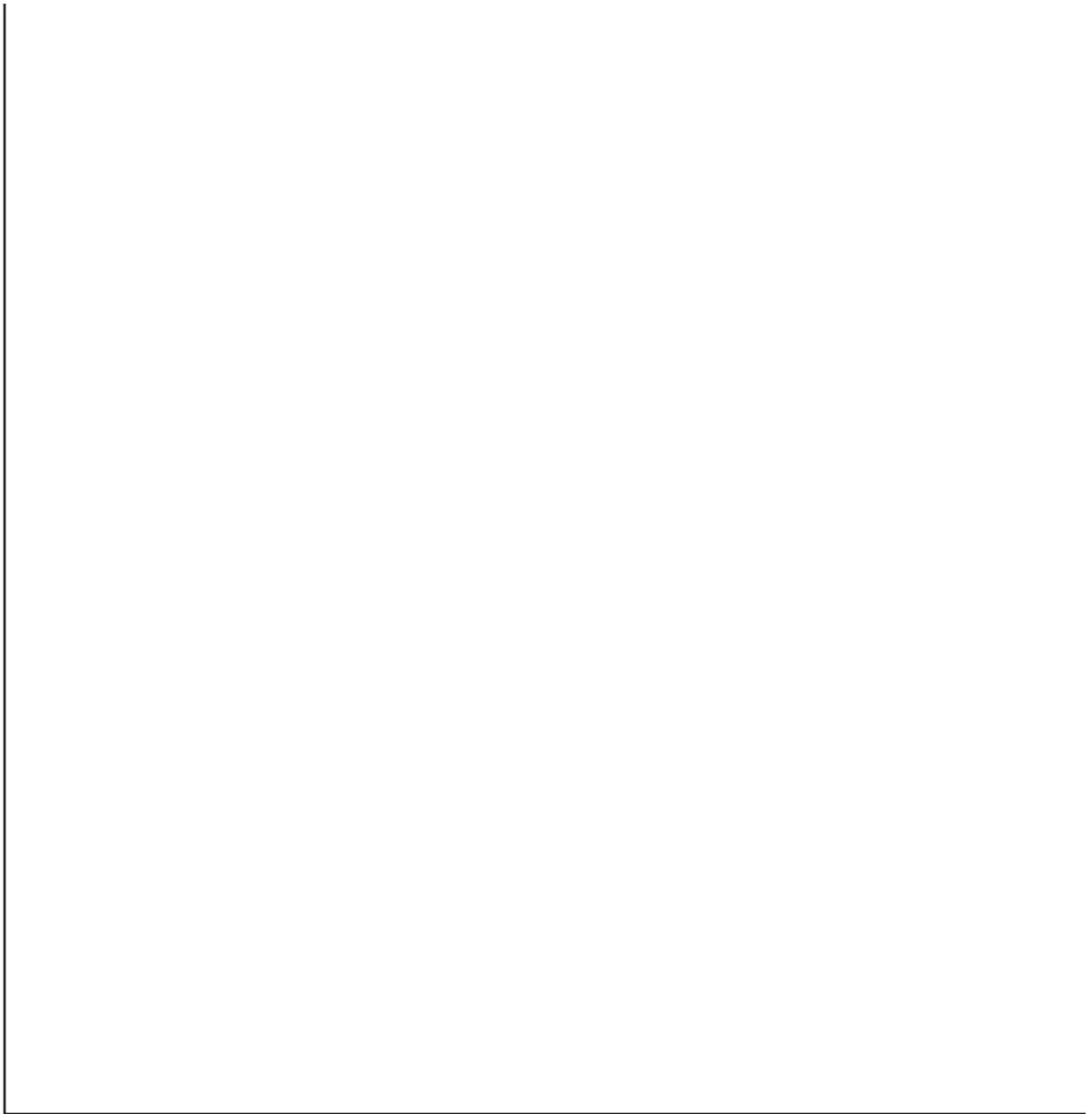
- A calorie is the amount of heat required to raise one gram of water by 1° Celsius, so:

$$\text{calories} = \text{mass of water (g)} \times \text{temperature change (}^{\circ}\text{C)}.$$

- The formula for calculating calories per gram is:

$$\text{calories per gram} = \text{calories} / \text{mass of nut}$$

BIOMASS ENERGY



BIOMASS ENERGY

Data Analysis:

1. Which type of nut produced the most heat (measured in calories)? _____
2. Which type of nut produced the least heat (measured in calories)? _____
3. Which type of nut produced the most heat per gram? _____
4. Which type of nut produced the least heat per gram? _____
5. What factors do you think contributed to the nut that produced the most heat?

6. What factors do you think contributed to the nut that produced the most heat per gram?

Conclusion:

7. Do you think burning nuts would be a good source of energy for your community? Why or why not?

8. What biomass energy resources are available in your community?

Review:

9. Biomass can be:
A) trees
B) food scraps
C) paper
D) A, B, and C
10. A calorimeter measures _____.
11. A _____ is the amount of heat required to raise one gram of water by 1° Celsius.

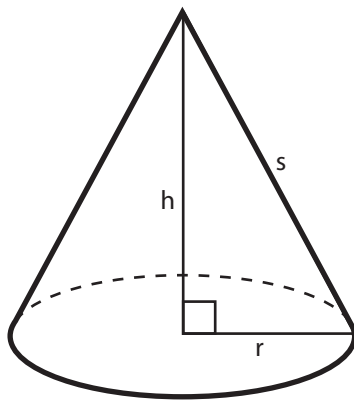
Biomass and Alaska Native Culture:

Alaska Native people have used biomass as a source of heat and light for thousands of years. Athabascan people built sod shelters with a central fire pit. The houses were usually constructed of spruce poles fastened with willow. The willow also provided a place to insert moss for insulation. The structure was covered with birch bark for weatherproofing. Finally, they added about two feet of dirt around the base of the structure to keep out drafts and covered the doorway with a bear hide with full fur.

Families maintained the fire in the center of the sod house to provide heat, light and a means of cooking food. Wood and small animal bones were burned. Smoke escaped through the vent in the top.

—Information provided by Chief Robert Charlie.

Using the formulas provided below, complete the following word problems. Round to the nearest tenth and show your work.



$$\text{diameter} = 2r$$

$$s = \sqrt{r^2 + h^2}$$

$$\text{surface area of a cone} = \pi \cdot r \cdot s$$

$$\pi = 3.14$$

12. You would like to build an Athabascan sod house that is 24 feet in diameter and 8 feet tall at the center. What size spruce poles do you need to cut?

13. How much birch bark would you need to collect in order to weatherproof your sod house?

BIOMASS: THREE ALASKA CASE STUDIES

NAME: _____

CASE STUDY ONE: The Tanana Washeteria*Adapted from the Alaska Center for Energy & Power*

The washeteria in Tanana is more than a place where local residents can do laundry and take a shower. It is an example of using local, sustainable resources to save energy and money.

In 2007, the Interior Alaska community installed two wood-fired Garn® Boilers to heat the washeteria and other buildings nearby. [A wood-fired Garn® Boiler is a wood stove located inside a water tank. The water absorbs and then stores the heat. This type of system can be used to heat multiple buildings by piping the heated water through a system of pipes in the floor.]

By stoking each boiler with wood just a few times during the day, the system produces enough BTUs to heat the buildings and the 280,000-gallon water storage tank. Use of heating oil has dropped by 30%, saving the community tens of thousands of dollars each year. Solar panels were also installed on the roof of the washeteria to help reduce electricity costs.

The city obtains wood for the boilers by paying local woodcutters \$250 per cord. The community used to buy diesel fuel and that money would leave the village. Now it has created an economic opportunity for residents that keeps the money local. There are plans to expand the system with three larger wood-fired boilers to heat tribal buildings and the senior citizen center.

CASE STUDY TWO: The Craig Schools & Swimming Pool*Adapted from the Alaska Center for Energy & Power*

Craig is a fishing village of 1,400 people located in southeast Alaska. In 2004 they looked at the heating bills for the local schools and swimming pool, and knew they needed to make a change. The boilers used 20,000 gallons of diesel and 40,000 gallons of propane annually. The monthly fuel bill for the three buildings was over \$10,000.

Craig is located in a forested area, so woody biomass is a plentiful resource and a local sawmill is able to supply tons of wood chips. In 2008, with support from the U.S. Department of Agriculture and Alaska Energy Authority, Craig installed a wood-fired heating system they hoped would save them money and reduce the amount of fossil fuels they needed.

It is too early to know the exact economic impact of the wood-fired system, but so far it has displaced 85% of the diesel and propane. With a price tag of \$1.5 million, the system will pay for itself in twelve years by using a resource that grows in the town's backyard.

A BTU (British Thermal Unit) is a unit of measure used to describe the amount of energy a fuel contains (similar to how an inch or a mile is used to express distance). BTUs are also used to rate heat-generating devices like wood stoves. One BTU is equal to the heat energy needed to raise the temperature of one pound of water by one degree Fahrenheit. One pound of dry wood contains about 7,000 BTUs. Propane contains about 15,000 BTUs per pound, while charcoal contains about 9,000 BTUs per pound.

BIOMASS: THREE ALASKA CASE STUDIES

CASE STUDY THREE: The Tok School

Adapted from the Alaska Department of Natural Resources Division of Forestry



The Alaska Division of Forestry (DOF) is working on two problems at the same time in the community of Tok: protecting the town from wild fires and high energy costs. The DOF Tok-area staff, U.S. Fish & Wildlife Service and a local contractor are working together to thin dense stands of trees around the school. The wood chips will be used in a wood-fired (biomass) boiler system that is being planned to heat the school. It will replace the current oil-fired boiler and should reduce heating fuel costs for the building. The thinning project around the school will generate enough biomass to heat the Tok School for at least 1.5 years. The cooperators hope that this project will serve as a model for other small communities in Interior Alaska that are similarly threatened by wildlife and share the burden of high fuel costs.

Thinking Deeper:

1. Based on these stories, identify at least three benefits of using biomass energy.

2. Based on these stories, identify at least three drawbacks of using biomass energy.

3. Think about what biomass energy resources are available in your area and describe a building in your community that you think could use this energy. Why did you choose this resource and this location?
