HOW CAN PEOPLE CONSERVE NATURAL RESOURCES?

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

On successful completion of this lesson, students will be able to:

- 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.

Alaska Standards

Alaska Science Standards / Grade Level Expectations

[6] 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.

[6] SB 2.1 The student demonstrates an understanding of how energy can be transformed, transferred and conserved by recognizing that energy can exist in many forms (i.e. heat, light, chemical, electrical, mechanical).

Alaska Mathematics Standards

6.SP.5. Summarize numerical data sets in relation to their context, such as by:

a. Reporting the number of observations (occurrences).
b. Describing the nature of the attribute under investigation, including how it was measured and its units of measurement.
c. Giving quantitative measures of center (median and/or mean) and variability (interquartile range), as well as describing any overall pattern and any outliers with reference to the context in which the data were gathered.
d. Relating the choice of measures of center and variability to the shape of the data distribution and the context in which the data were gathered.

Alaska Cultural Standards

[B] Culturally-knowledgeable students are able to build on the knowledge and skills of the local cultural community as a foundation from which to achieve personal and academic success throughout life. Students who meet this cultural standard are able to:

[B.2] identify appropriate forms of technology and anticipate the consequences of their use for improving the quality of life in the community.

Bering Strait School District Scope & Sequence

M.S. Sequence 7.10 Natural Resources

M.S. Sequence 8.3 Energy

Materials

- 12-ounce soda cans (two per group)
- Water (room temperature)
- Safety glasses (one pair per student)
- Protective gloves (two pairs per group)
- Utility knife (one per group)
- Thumbtack (one per group)
- Paper fasteners (at least 1.5 inches long, one per group)
- Bag of shelled pecans
- Bag of shelled walnuts
- Can of shelled almonds
- Can of shelled cashews
- Digital Scale (one per group)
- Thermometer (small enough to fit in the soda can, one per group)
- 100 mL graduated cylinder (one per group)
- Forceps (at least 6 inches long, one per group)
- Aluminum foil (3-inch square, one per group)
- Aluminum foil (4x12-inch strip, two per group
- Silicone hot pad (one per group)
- Grill lighter (one per group)
- Large plastic cups (two per group)
- STUDENT WORKSHEET: "Biomass Energy Lab"
- STUDENT WORKSHEET: "Biomass: Three Alaska Case Studies"

Multimedia

REACH Multimedia 4-6: "Conserving Electricity"
Available at: www.k12reach.org

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Additional Resources

Glencoe Life Science Ch 23
Glencoe Earth Science Ch 18
Glencoe Physical Science Ch 5

Activity Preparations

1. Carefully review procedure. Note that this experiment involves cutting up an aluminum can and burning nuts. You will need to determine that no students are allergic to nuts. (Other foods may be substituted.) This lesson is set up for the lab to be done in small groups, but use your own discretion to determine if it is better to conduct the lab as a class demonstration. Consider safety and the time available and decide if you will precut the holes in the soda cans. You should also determine whether you will allow students to use the lighter, or whether you will light the nuts for them. The nuts will produce heat and smoke. You will want to choose a location with some ventilation (if you do not have access to a ventilation hood, make sure the room has a window that can be opened and a fan to circulate the air out the window.) Each nut will take approximately five minutes to burn. Larger nuts may take up to 10-15 minutes to burn. If time is limited, each group could test one kind of nut and then share their data with the class. If time allows, have each group test each type of nut twice.
2. Plan ahead and have students collect aluminum cans; you will need two cans for each group. You will also need a water source, preferably a jug of room temperature water. The plastic cups will help minimize the students trips between the water and their lab station.
3. Be prepared to clearly review safety precautions.

   For cutting aluminum cans:

   a. Only the students wearing protective gloves should touch the cans; students should take turns.
   b. Each group will need two cans, one as is, and one with a rectangular "window" cut into it. (See illustration on the STUDENT WORKSHEET.) Use the utility knife to poke four slits in the can, marking the corners of a rectangle, approximately 3 inches tall by 2 inches wide. Use the utility knife (or a scissors) to cut lines connecting the holes you created.
   c. Use caution when discarding scraps of aluminum.

   For burning nuts:

   a. Again, only the students wearing protective gloves should touch the calorimeter; students should take turns.
   b. Review fire safety procedures: students should know the locations of the fire alarm and fire extinguisher, what to do should the teacher need to use the fire extinguisher, and how to evacuate the building.

   c. Have cold water and first aid available if someone should burn themselves.
   d. Students should not inhale smoke from the fires.
   e. Calorimeters need to be placed on a stable surface. While in use, the bottom will become hot. Students should use the hot pad to protect the desk/table and the protective gloves to protect their hands.
4. Make copies of the STUDENT WORKSHEET: "Biomass Energy Lab". 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.

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, such as wood or nuts. The energy in biomass comes from the sun. Plants convert the sun's radiant energy into chemical energy through photosynthesis and store this energy as glucose. When we burn biomass, we change this stored energy into 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 (paper garbage and animal waste), and landfill gas (capturing the methane released during decomposition).

Interior Alaska has extensive biomass resources including wood, sawmill waste, fish byproducts and municipal waste (the paper and wood products in garbage). 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 biomass appliances become more efficient, and the cost of oil and gas continue to rise, especially in rural communities.

Additionally, wind and wind-diesel hybrid systems are starting to be used in more and more communities in Alaska. The Alaska Village Electric Cooperative has installed wind-diesel systems in 10 of the 55 villages it serves, with more slated to be installed in the future. Much of coastal Alaska is rated as "excellent" for utilizing wind resources.

Vocabulary

Biomass all living and recently living things

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 (emphasize paper products, fumes from other garbage items can be toxic), wood scraps and sawdust, fast-growing shrubs, capturing landfill gases, biodiesel made from used vegetable oil, etc.
3. Review that oil/fuel is a nonrenewable natural resource. Using fuel for heating homes is expensive and is contributing to the depletion of the resource. Explain more Alaska communities are again looking to biomass, wind, geothermal and other alternatives as an energy source. Ask students why they think this is? (Again, oil is a natural resource that is not renewable. Although there are fluctuations in price, the trend is that the price will go up as the resource becomes depleted.)
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.
5. 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.
6. Distribute STUDENT WORKSHEET: "Biomass Energy Lab" 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.
7. When all groups are finished, share data on the white board (if necessary), review results and answers to questions.
8. If applicable, distribute STUDENT WORKSHEET: "Biomass: Three Alaska Case Studies."

Extension Activity

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? You could also try burning wood chips, and compare the energy stored in cured firewood versus wet firewood. Graph results.

References

Alaska Energy Wiki; Accessed 4/2/15 http://energy-alaska.wikidot.com/biomass

Renewable Energy Alaska Project; Accessed 4/2/15, http://alaskarenewableenergy.org/why-renewable-energy-is-important/alaskas-resources/biomass/

"From Wood Waste to Renewable Energy", Accessed 4/2/15, http://www.wflccenter.org/news_pdf/295_pdf.pdf

"New wood energy project keeps Tok School warm" From the Fairbanks Daily News-Miner, December 6, 2010, Accessed 4/2/15 http://www.newsminer.com/view/full_story/10544325/article-Tok-School-burns-biomass-in-big-boiler?instance=home_news_window_left_top_2

WHAT ARE NATURAL RESOURCES?

Answers

Biomass Energy

1. answers will vary
2. answers will vary
3. answers will vary
4. answers will vary
5. 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.
6. 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.

Three Alaska Case Studies

1. The Tanana Washeteria Garn® Boiler is a wood stove located inside a 280,000 gallon water tank. The water absorbs and then stores the heat. It heats the buildings by piping the heated water through a system of pipes in the floor.
2. 85%
3. a. 40 acres, 1/3 of amount they want to clear.

   b. 1200 acres over 30 years.
4. The school will save $125,000 annually.
5. Answers will vary. Many homes in Alaska use wood to supplement fuel dependent boilers and furnaces. Some communities have started using wind to produce electricity for homes and businesses.

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STUDENT WORKSHEET: 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 per gram?

Prediction:

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

a. Greatest change in water temperature per gram burned (most energy released): ___________
b. Smallest change in water temperature per gram burned (least energy released): ___________

Materials:

- 12-ounce soda cans (two)
- Water (room temperature)
- Safety glasses (one pair per studer
- Protective gloves (two pairs per gr
- Utility knife
- Thumbtack
- Paper fastener (at least 1.5 inches)
- Shelled pecans
- Shelled walnuts
- Shelled almonds
- Shelled cashews
- Digital Scale
- Thermometer
- 100 mL graduated cylinder
- Forceps

- Aluminum foil (one 3-inch square)
- Aluminum foil (two 4x12-inch strips)
- Silicone hot pad
- Grill lighter
- Large plastic cups (two)

Gather Materials:

Gather all materials. Fill one of the plastic cups with water. The other cup will be for emptying the used water into.

Safety:

All students in the group must wear safety glasses. Only the students wearing the protective gloves may handle the calorimeter materials (cans, utility knife, and grill lighter). Take turns wearing the gloves for different tasks throughout the lab.

Experiment:

Build the calorimeter:

1. Wrap one of the cans with a strip of tin foil to provide extra insulation. Measure 100 mL of water in the graduated cylinder and carefully pour it into this can.
2. Carefully cut a window (approximately 3 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. Following your teacher's directions, use the utility knife to poke 4 slits in the can where the corners of the window will be. Then cut out the sides of the window.
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. Loosely wrap the second can with a strip of tin foil, leaving a space to access the paper fastener with the forceps and the grill lighter.
5. 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:

6. Determine the mass of the first nut with the digital scale. Record the type of nut and its mass in grams in the data table.
7. Use the thermometer to take the start temperature of the water in the top can in °Celsius. Record it in the data table.
8. Place the square of aluminum foil over the hole in the top soda can (to act as a lid).
9. Using the forceps, carefully place the nut on the paper fastener in the lower can.

10. As directed by your teacher, you or your teacher will light the nut. Hold the grill lighter below the nut until the nut begins to flame, then remove the grill lighter. Allow the nut to burn until the fire goes out.
11. Do not touch the calorimeter as the nut is burning! It will be hot. If the nut falls off the fastener, use the forceps to carefully put it back on.
12. When the nut has been consumed (only black ash is left), take the end temperature of the water in °Celsius. Record it in the data table. CAUTION: The bottom can will be hot!
13. Calculate the temperature change. Round to the nearest whole number.
14. Use the following formula provided to calculate the calories released.
    A calorie is the amount of heat required to raise one gram of water by 1° Celsius.

    The formula for converting volume of water to mass is:
    1 milliliter (mL) water = 1 gram (g) of water.

    So: calories = mass of water (g) x temperature change (°C).

    Record the number of calories in the data table. (Note that there are 100 calories in 1 Calorie with a capital "C", or Kilocalorie. Calories/Kilocalories are how energy is listed in the nutrition information on food packaging in the United States.)

15. Divide the calories released by the original mass of the nut to get the calories released per gram. Record in the data table.
16. Repeat the process for each nut. If time allows, test each type of nut twice. Use new water for each nut so the starting temperatures are similar.

Graph your Results:

1. 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.

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

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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?

Conclusion:

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

6. What types of biomass energy sources are available in your community?

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STUDENT WORKSHEET: 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.

A BTU (British Thermal Unit) is a unit of measure used to describe the amount of energy a fuel contains (similar to how inches or miles 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

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.

CASE STUDY THREE: The Tok School

Excerpt from an article by Molly Rettig for the Fairbanks Daily News-Miner, December 6, 2010

A new wood energy project in Tok has turned surrounding forests from a fire hazard into renewable fuel. The Tok School lit a new wood chip-fired boiler for the first time several weeks ago.

The 5.5-million-BTU steam boiler produces the school's heat, saving the school district thousands of dollars in heating fuel and saving forest managers untold costs fighting fires and eliminating waste wood. The school district plans to add a steam turbine generator to the system in May to produce 75 percent of its electricity.

"We're the first school in the state to be heated entirely by wood," said project manager and assistant superintendent Scott MacManus, who has been trying to spur wood energy in Tok for 10 years. "As far as I know, we'd be the first public school in the country to produce heat and power from biomass."

At the school's new biomass facility, trees and slash are fed into a Rotochopper grinder, processed into chips that resemble wood shavings, spit into a bin and carried by conveyor belt into the boiler, which is 17 feet tall, 6 feet wide and 12 feet long. Fuel comes from forest thinning projects, scraps and nearby sawmills.

The forest around the school has yielded enough biomass for the first year, according to Alaska Division of Forestry spokeswoman Maggie Rogers. Project leaders hope the system will be used as a model of energy independence for other school districts, communities and utilities.

The project was a partnership between the Division of Forestry, the Tok community, the Alaska Gateway School District and the Alaska Energy Authority and used research from University of Alaska Fairbanks and elsewhere. Funding came from a $3.2 million state renewable-energy grant as well as about $750,000 in grants from the Alaska Legislature. A long-term fuel contract is in the works between the state and the school district.

Turning hazardous fuel into energy

The project started nearly four years ago as a way to get rid of wood from forest-thinning projects and lessen fire danger. In the past 25 years, nearly 2 million acres in the area have burned, costing more than $60 million for fire suppression and causing six evacuations, according to the state.

"The fire history in Tok has basically demonstrated that Tok is going to burn unless we take action," said Jeff Hermanns, Tok area forester and a spearhead of the boiler project.

A recent wildfire protection plan recommended that 3,000 acres of black and white spruce forest in Tok be removed to make the community safer, including an area around the school, Hermanns said. Foresters usually try to sell or repurpose good wood, but the trees were junk wood, he said.

"Most of them aren't any bigger than three inches. Most people won't cut that tree for firewood. It's too small. You can't sell board out of it," Hermanns said.

Foresters thinned 100 acres of trees around the school and stacked them into decks. Then they set them on fire, a pricey and smoky last resort.

"All of those BTUs, all of that energy, just went up in smoke," Hermanns said. "By the school using this material, it's saving me a minimum of $1,000 an acre." Sending timber to the grinder is cheaper because foresters don't have to hand-limb every 3-inch tree, as with other treatments. It's also cleaner than burning the decks because the boiler emits no smoke and little pollution. The carbon emitted by the boiler is offset by the carbon absorbed during the life of the tree.

"The beauty of it all is that it grows back. It's carbon neutral and our foresters can finally manage our forest," said Dave Stancliff, vice president of the Tok Chamber of Commerce and partner in the project. It's also cheaper than wildfires, which cost between $10,000 and $20,000 per acre to fight near urban areas.

The boiler should burn 40 acres worth of wood per year, using only one-third of the area foresters want to clear in the boiler's 30-year life span.

Form follows fuel

Hermanns and MacManus decided on a wood chip model because it best fit the fuel source. "You have to go out and determine what your fuel is, and then design your project around it," said Hermanns.

The grinder was key. "It effectively turns a large volume of these non-merchantable, scrawny little spruce trees, these hazardous fuels, into usable fuels," he said. The grinder processes up to 40 trees at once. You don't need to dry, trim or treat the wood before burning it.

"It's what we call gut, feathers and all. You put the whole bird in the soup," Hermanns said.

The boiler is supposed to be as clean as burning heating fuel, and the school district will monitor its emissions. It burns at 2,000 degrees Fahrenheit and generates very little smoke, thanks to air that moves up through the wood chips and fans the flame.

"You're getting a super-efficient burn," Hermanns said. Any smoke is removed by an electrostatic precipitator, which electronically charges smoke particles out of the exhaust. "If you look at the stack today, all you would see is steam," Hermanns said.

School savings

Tok School spends more than $300,0000 annually on heating fuel and electricity, said school district superintendent Todd Poage. The boiler will save an estimated $125,000 per year on fuel, and the generator will further erode their bill.

The savings will go toward music and counseling programs, student activity funding, teacher training and other programs throughout the district, Poage said.

Students have been learning about fire science through the forest thinning and boiler projects and will visit the biomass facility when it is completed.

Administrators hope the project will inspire other communities in the district and the state to take advantage of local resources.

"This is a model I think that could be used in a lot of different villages," said assistant superintendent MacManus, who grew up in Ambler, a village outside of Kotzebue, where heating fuel runs $9 per gallon. "A lot of villages, Fort Yukon, McGrath, Galena, have access to biomass. Those communities should be able to heat themselves."

Villages without forests can consider other resources, like fish waste, peat, stream or wave power, project leaders said.

"That's the beauty of this. This system utilized a product that there is no use for in the Interior," Hermanns said.

Questions

1. Describe the Garn® Boiler used at the Tanana Washeteria.

2. The Craig boiler has displaced _________ % of the diesel and propane used by the local schools and swimming pool.

3. a. The Tok School boiler should burn ____________ acres of wood per year, using only _________ of the area foresters want to clear in the boiler's 30-year life span.

   b. How many acres of wood will the school burn in 30 years?

4. The Tok School will save an estimated _________________ dollars on per year on fuel.

5. In order to reduce the amount of fuel used in your home, or at your school, what type of alternative energy resources are used, or could be used?