WIND GENERATORS

Overview:

In this lesson, students work in teams to design blades for a classroom wind turbine. Students choose one variable to investigate, then design and test blades. Students measure voltage and amperage then calculate total power produced by the turbine. Students graph classroom data and investigate the wind potential for their own community.

Objectives:

The student will:
- formulate a hypothesis about how blade shape and angle impact the performance of a wind turbine;
- design blades for a model wind turbine to test the hypothesis; and
- measure the voltage and current produced by two separate tests to determine power generation potential.

Alaska High School Graduation Qualifying Exam Performance Standards Addressed:

M2.3.1 Estimate and measure various dimensions to a specified degree of accuracy.

M2.4.2 Estimate and convert measurements between different systems.

M2.2.3 Use a variety of measuring tools; describe the attribute(s) they measure.

M2.3.4 Describe and apply the relationships between dimensions of geometric figures to solve problems using indirect measurement; describe and apply the concepts of rate and scale.

M6.3.1 Collect, analyze, and display data in a variety of visual displays including frequency distributions, circle graphs, histograms, and scatter plots.

M7.2.2 Select and apply a variety of strategies including making a table, chart or list, drawing pictures, making a model, and comparing with previous experience to solve problems.

M10.3.1 Apply mathematical skills and processes to science and humanities.

M10.3.2 Apply mathematical skills and processes to situations with peers and community

Targeted Alaska Grade Level Expectations:

Science

[11] SA1.1 The student develops an understanding of the processes of science by asking questions, predicting, observing, describing, measuring, classifying, making generalizations, analyzing data, developing models, inferring, and communicating.

[11] SB2.1 The student demonstrates an understanding of how energy can be transformed, transferred, and conserved by demonstrating energy (e.g., nuclear, electromagnetic, chemical, mechanical, thermal) transfers and transformations by comparing useful energy to total energy (entropy) (L)

Vocabulary:

drag – the forces that oppose the motion of an object

driveshaft – the mechanical component that transfers the rotary motion of wind turbine blades to other components of the system including gears and/or generators

gear ratio – the relationship between the numbers of teeth on two meshed gears

nacelle – housing that protects all the power-generating parts of a wind turbine

pitch – refers to the angle between the turbine blade and the oncoming flow of air; adjusting the pitch of the blades will change the rotation speed and therefore the amount of power generated

swept area – the area of the circle made by the spinning blades of a turbine

WIND GENERATORS

Whole Picture:

Wind power is the fastest growing renewable energy in the world. It utilizes a turbine that spins, converting the kinetic energy of the wind to mechanical energy of the spinning hub, driveshaft, and gears to electrical energy in the generator. Most wind turbines use gears to multiply the electrical output. This is accomplished by using gears with different numbers of teeth. When the larger gear (on the wind turbine) makes one full revolution, the smaller gear (on the generator) has to spin faster to keep up. Large commercial turbines may have a gear ratio of 100:1. In this scenario, the generator would spin 100 times for each revolution of the turbine blades. A generator essentially consists of a coiled conductor in a magnetic field. The faster the coils rotate near the magnet, the more electrons will be pushed along (the more electricity will be produced).

People have been using wind energy for thousands of years. Perhaps the most well known and earliest use of wind power was to propel boats, but as early as 200 B.C. people were using windmills to pump water and grind grain. Athabascan people have long used the wind when hunting moose, trapping and traveling, especially in the winter months. A good moose hunter would always travel against the wind when tracking moose in winter so the animal would not detect the hunter. Trappers and other travelers would have to be aware of the wind when heading out on a long trip. If you traveled with the wind, it would be an easier trip.

Alaska has abundant wind resources, especially in the western parts of the state and along its extensive coastline. Alaska's first wind farm is located in Kotzebue and has been producing power since 1997. Alaska currently has 20 communities with wind power systems. The community of Kodiak leads the state in renewable energy with 9% of its electricity generated from wind and 80% from hydropower.

Wind turbines can vary in size from small-scale residential models to large commercial models that produce upwards of 1 MW or more. The challenges of using wind energy include the intermittency of wind, environmental impacts (especially on birds), durability (in a tough Arctic climate), and limited technical or maintenance support (especially in rural areas).

Materials:

- ALTurbine Wind Energy Full Kit (from KidWind®), including ALTurbine user guide
- Household fan with a diameter of at least 14"-18"
- Anemometer
- ¼" dowels (100 pack from KidWind®) NOTE: This is in addition to the 25 dowels included in the kit.
- Balsa wood (3" x 18" x 3/32")—6-10 per group. NOTE: This is in addition to the five sheets included in the kit.
- Hot glue gun (1 per group)
- Alligator clips (1 red, 1 black) NOTE: This is in addition to the set included with the kit.
- Wire strippers
- Protractor (1 per group). NOTE: This is in addition to the one provided in the kit.
- Scissors (1 pair per group)
- DIGITAL LECTURE: "Chief Robert Charlie Talks About Wind"
- TEACHER INFORMATION SHEET: "Wind Energy Lab"
- STUDENT LAB: "Wind Energy"
- STUDENT INFORMATION SHEET: "*Power Lab* from *Alaska Magazine*." (NOTE: Also available in text form at: http://www.onlinedigitalpubs.com/display_article.php?id=386781)

Activity Preparation:

1. Review the ALTurbine Wind Energy Full Kit and assemble as directed. You may choose to do this with a small group of students. Take some time to become familiar with the kit. This lesson does not use all of the components in the kit. Please visit http://learn.kidwind.org/teach for extension lessons and more detailed information.
2. Cut balsa wood if necessary. Pieces should be approximately 3" x 18" x 3/32" and should be uniform.

WIND GENERATORS

3. Carefully review how to use the multimeter and how to measure voltage and amperage. Practice attaching the turbine, multimeter and LED bulb if necessary. Refer to the ALTurbine user guide for more information.

Activity Procedure:

1. Pass out STUDENT LAB: "Wind Energy" and explain that you will investigate wind energy. Ask students what they know or have heard about wind energy. How does it work? Where are wind turbines located?Use the ALTurbine to explain how a wind turbine transfers the kinetic energy of wind to electrical energy that can power our homes, schools and businesses. Students can follow along on the diagram on page one of the student lab.
2. Explain that there are many factors that influence the power produced by wind generators. Ask students to suggest as many factors as they can. These factors include: location/wind conditions of an area, height of the tower, blade design and gear ratio (size of gears used). This lab will investigate one factor—blade design.
3. Ask students to brainstorm some elements of wind turbine design. Keep a list on the white board. See TEACHER INFORMATION SHEET: "Wind Energy Lab" for suggestions. Students will work in groups to investigate just one of these elements.
4. Set up the fan. The fan should be directly in line with the wind turbine, approximately one meter away. Mark the floor or table with a small piece of tape to ensure all student groups put the turbine in the same location.
5. Turn on the fan (to high speed, if applicable). Allow the fan to run for about 60 seconds. Ask a student volunteer to take a reading with the anemometer. Be sure your reading is in meters per second (m/s). Students should record this value as the wind velocity in both trials.
6. Instruct students to begin STUDENT LAB: "Wind Energy." Remind students to check their experiment design with you before proceeding. Provide safety guidelines for using the hot glue guns and be sure students understand how to use the multimeter. (See teacher information sheet for more information.)
7. Be aware that this lab may take more then one class period depending on the number of student groups that need to test their blades. Students should watch DIGITAL LECTURE: "Chief Robert Charlie Talks About Wind" and read the article, "Power Lab" while they are waiting for their turn.
8. After students have completed the lab, review the data analysis and conclusion sections. As a wrap up, ask students if they have ever seen wind turbines in Alaska. Do they work? Review some challenges and benefits.

Extension Ideas:

1. Collect a variety of household materials to use to design blades. Suggestions include: disposable pie plates, styrofoam bowls, paper/plastic cups, etc.
2. Experiment with other components of the ALTurbine kit. Try changing the gear ratio or hooking up an additional generator. (You will need an additional bracket for this. Generators can be attached in series to boost voltage or in parallel to boost amperage.) Try charging the capacitor. For more information and ideas, refer to the ALTurbine manual or the KidWind Project website (http://learn.kidwind.org/).
3. For a more fun and visual assessment of the efficiency of the student-designed blades, try pumping water with the water pump or by attaching the weightlifter accessories (plastic cup, spool, string).

Answers to STUDENT WORKSHEET: Wind Turbine

Data:

Answers will vary.

Data Analysis:

1. Answers will vary.

WIND GENERATORS

2. Answers will vary.
3. Answers will vary.
4. Answers will vary.

Conclusion:

1. Answers will vary.
2. Answers will vary, but should show an understanding of the factors that affect the total power. These factors all relate to lift and drag. For example, blades that are longer will produce a greater swept area, and so have the potential to produce greater are; however, they also may produce more drag. The more blades you use, the greater the potential power produced, but the greater the drag. The tips of the blades travel much faster than the base, so thin, narrow tips create less drag.

3–4. Answers will vary but should indicate an understanding that factors that increase lift and decrease drag will increase both voltage and current.

5. Answers will vary, but most wind turbines are not very efficient at capturing the total power available in the wind. If you were able to capture 100% of the energy available in the wind, you would stop the wind. (Of course, you could not literally stop the wind, but instead the wind would flow around the obstruction.)
6. Generally the windiest parts of Alaska are along the coast, especially in western Alaska and along mountain ranges (Healy, Delta).
7. the north wind
8. Answers will vary slightly based on individual experience, but should include the idea that you should hunt moose according to the wind. You should travel against the wind so that the moose does not smell you.
9. Answers will vary slightly based on individual experience but should include the idea that traveling with the wind can make your trip easier and faster (for you and your dog team).

Major Elements of Wind Turbine Blade Design:

- **Material**—Consider strength and weight (suggested standard: 3/32″ balsa wood).
- **Diameter of swept area (length of blades)**—Blades that are too short will not be able to get moving fast enough to generate power. As blades get longer, weight and drag will increase (suggested standard: 3″ x 18″ x 3/32″ balsa wood).
- **Number of Blades**—More blades provide more torque (twisting force), but slower speed. Two-bladed designs are very fast and easy to build, but can suffer from imbalanced forces on the blades. Three-bladed designs are very common and are generally a very good choice (suggested standard: 3 blades).
- **Shape**—Blades are usually wider at the base and narrower at the tips, since the area swept by the base of the blades is much smaller than that of the tips. The taper also adds strength to the base where stress is highest. Wide or heavy tips will add a lot of drag (suggested standard: 3″ x 18″ x 3/32″ rectangle).
- **Pitch & Twist**— Pitch refers to the angle between the blade and the oncoming flow of air. Adjusting the pitch of the blades will change the rotation speed and therefore the amount of power generated. Pitch can dramatically affect power output (suggested standard: consistent 5° pitch on all blades).

  There are also advantages to having a twist, although this can be challenging to do. Generally, more pitch at the base improves startup and efficiency, and less pitch at the tips improves high-speed performance (suggested standard: no twist).

Suggestions for testing elements of wind turbine blade design: Students should choose only one element of blade design to investigate. All other elements should remain constant. For example, they may choose to investigate the number of blades. In this case, all other aspects of the blades (shape, length, material, pitch, twist) should remain constant. If you would like students to be able to compare data amongst groups, choose a standard for each element. Suggestions are listed above.

Notes on the Multimeter: A multimeter is a device capable of measuring voltage, current and resistance. Make sure you connect the multimeter leads to the correct ports. The red lead should be connected to the center port (VΩMA) and the black lead should be connected to the left-side port (COM). Please see the ALTurbine user manual for more detail. Do not forget to turn the multimeter off when you are finished!

To measure voltage: Simply use the alligator clips to attach the wires from the generator to the multimeter. Color does not matter. Set the multimeter to 20 v in DC voltage. (DC voltage is indicated by a "V" followed by two lines, a solid line above a dotted line.) Voltage is measuring how fast the generator is spinning. The faster it spins, the higher the voltage. Typical blades will produce 1-2 volts. Very well designed blades may generate up to four volts.

To measure current: To accurately measure amperage, you will need to connect a "load" (or something to draw power) in series. Use the wire strippers to expose the ends of the small LED bulb. Connect one continuous circuit from the turbine output wires, to the multimeter, to the LED bulb, and back to the turbine. Use the alligator clips to attach multimeter probes, LED wires and the turbine output wires. Set the multimeter to "200 m" in DC amperage. (DC amperage is indicated by an "A" followed by two lines, a solid line above a dotted line. This reading will be in milliamps, and so students will need to convert milliamps to amps.) Typical blades will produce 100-300 milliamps. Well-designed blades will produce up to 400 milliamps. If the LED bulb does not light, try reversing the turbine output wires and try again. Current measures the volume of electrons through the wire. The strength of the current relates to the torque or force of the blades.

A Note on Turbine Efficiency: The efficiency of wind turbines is limited by what is called Betz law. Simply put, if you capture 100% of the energy available in the wind, you stop the wind. (Of course, you couldn't literally stop the wind, but instead the wind will flow around the obstruction.) The Betz limit defines 59.6% as the best compromise between stopping the wind and forcing it around a turbine. Most turbines capture an average of 35% of the energy available in wind.

NAME: ____________________________

WIND ENERGY

Wind power is the fastest growing renewable energy in the world. As of 2008 the U.S. leads the world in the amount of electricity generated with wind power. However, wind power still only represents about 1% of our energy consumption.

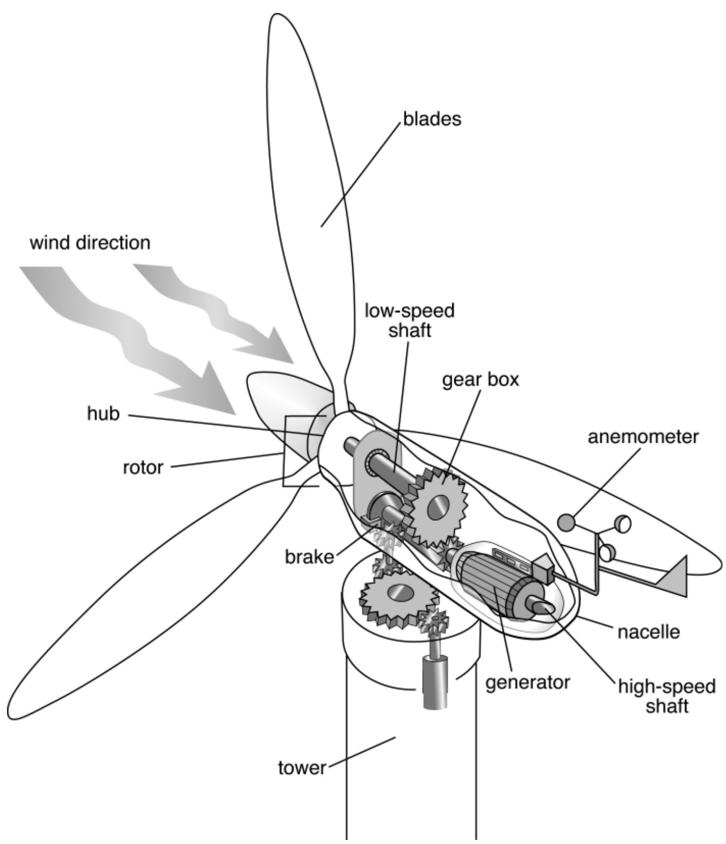
Wind turbines transfer the kinetic energy of wind into electrical energy that we can use. Wind speed increases with altitude, so turbines are usually located atop **towers** at least 60 feet tall. The **rotor** and **nacelle** sit atop the tower. The rotor consists of the **blades** and the hub. The **nacelle** is the housing that protects all the power-generating parts of the turbine.

How does it work? As the wind blows, the rotor blades turn. This turns the **low-speed shaft**, which turns the **gears**, the **high-speed shaft** and finally the **generator**. Generators contain a conductor (such as copper) inside a magnetic field. The rotary motion of the wind generator spins the conductor inside the magnetic field, creating a flow of electrons.

Most wind turbines use gears to increase the electrical output of the generator. This is accomplished by using gears with different numbers of teeth. When the larger gear (on the wind turbine) makes one full revolution, the smaller gear (on the generator) has to spin faster to keep up.

The gear ratio is the relationship between the number of teeth on the gears. Large commercial turbines may have a gear ratio of 100:1. In this scenario, the generator would spin 100 times for each revolution of the turbine blades. Many wind turbines also have multiple braking systems that allow the turbine to be slowed in extreme wind conditions, or stopped in case of emergencies or service needs.

Alaska has abundant wind resources, especially in the western parts of the state and along its extensive coastline. Alaska's oldest wind farm is located in Kotzebue. It has been producing power since 1997.



Basic Parts of a Wind Turbine

NAME: ______________________________

WIND ENERGY

Directions:

Work in groups to complete the following lab.

In this lab you will work in teams to design and test blades for a classroom wind turbine. You should choose one independent variable to test. The dependent variable is the power produced by the wind turbine. Your hypothesis should predict how changing the independent variable will affect the dependent variable.

Testable Question:

What blade characteristics affect the power produced by a wind turbine?

Materials:

- ¼" dowels (6-10)
- balsa wood 3" x 18" x 3/32" (6-10 pieces)
- Protractor
- Hot glue gun
- Scissors

Procedure:

1. Choose one element of wind turbine blade design to investigate. List this as your independent variable.

   The independent variable I will test: ______________________________.

   Hypothesis: IF ______________________________,

   THEN the power produced by the wind turbine will ______________________________.

2. Create your research plan. This will describe how your group will investigate the independent variable you choose to test. Remember to keep all other elements of the blades constant. You will conduct two trials. For each trial, identify the elements of the blade design, fill in the blanks and draw your blade in the boxes provided.

   STOP! Ask your teacher to approve your research plan before you begin construction!

3. Construct your blades. Work slowly and carefully as you cut the balsa wood or it will crack. Attach each blade to a dowel with the hot glue gun. Draw your blades for each trial in the box provided.
4. Test your first set of blades.
   a. Place your first set of blades into the hub of the KidWind® ALTurbine.
   b. Place the turbine about one meter from the fan. Be sure the turbine is directly in line with the airflow from the fan.
   c. Turn on the fan and allow it to run for about 30 seconds.
   d. **To measure voltage:** Use the alligator clips to attach the multimeter to the turbine output wires. Color does not matter. Set the multimeter to 20 in DC voltage. (DC voltage is indicated by a "V" followed by two lines, a solid line above a dotted line.) Allow it to run for about 30 seconds. Record the highest number you see on the line marked "Volts (V)" under "Trial 1."
   e. **To measure current:** To measure current, you will need to connect a "load" (or something to draw power) in a series. Use the alligator clips to connect one continuous circuit from the turbine output wires, to the multimeter, to the LED bulb, and back to the turbine. Start by setting the multimeter to "10 A" in DC amperage. (DC amperage is indicated by an "A" followed by two lines, a solid line above a dotted line.) Allow it to run for about 30 seconds. Record the highest number you see on the line marked "Amps (I)" under "Trial 1."
5. Repeat steps a-e for Trial 2. Be careful to change only the one variable you are testing.

NAME: ______________________________

WIND ENERGY

Data:

Trial 1:

Material ______________________________

Length of Blades ______________________________

Number of Blades ______________________________

Shape ______________________________

Pitch ______________________________

Twist ______________________________

Volts (V) ______________________________

Amps (I) ______________________________

Wind velocity (v) ______________________________

Trial 2:

Material ______________________________

Length of Blades ______________________________

Number of Blades ______________________________

Shape ______________________________

Pitch ______________________________

Twist ______________________________

Volts (V) ______________________________

Amps (I) ______________________________

Wind velocity (v) ______________________________

NAME: ______________________________

WIND ENERGY

Data Analysis:

1. Calculate the actual power produced by the wind turbine after each trial. Power (P) is equal to voltage (V) multiplied by current (I): P = V x I. Power is measured in watts.

   Trial 1 produced __________________________ watts.

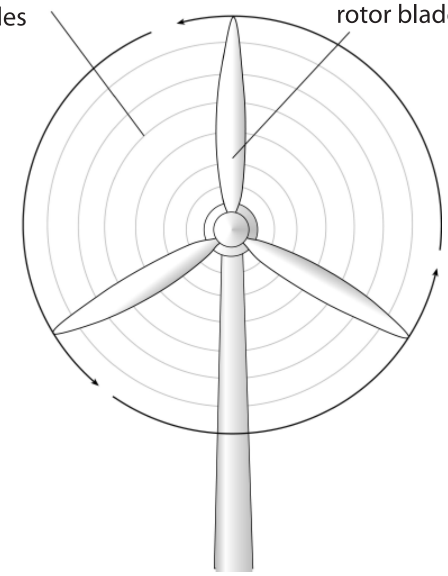
   Trial 2 produced __________________________ watts.

2. The power produced by a wind turbine is directly related to the ***swept area*** of its rotor blades. The swept area is the area of the circle made by the spinning rotor blades. The length of the rotor blades is the radius (*r*) of the circle.

   Calculate the swept area of your turbine. If you varied the length of your blades, you will need to calculate the swept area for each trial. If the length of your blades remained constant, you can use the same value for both trials.

   First convert the length of each blade from inches to centimeters.

   1 inch = 2.54 centimeters



   Then calculate the swept area (*A*): $A = \pi \cdot r^2$

   $\pi = 3.14$

   Swept Area of Turbine for Trial 1 _________________________ m^2.

   Swept Area of Turbine for Trial 2 __________________________ m^2.

NAME: ______________________________

WIND ENERGY

3. How much power is in the wind?

   Total power available (P) = (density of air · swept area · wind velocity) ÷ 2

   $P = (\rho \cdot A \cdot v^3) \div 2$

   air density (ρ) at room temperature (20° C) = 1.21 kg/m^3.

   Total power available for turbine, Trial 1 ________________________ watts.

   Total power available for turbine, Trial 2 ________________________ watts.

4. Calculate the percent efficiency of each trial.

   Percent efficiency = (total power produced ÷ total power available) · 100

   Percent efficiency for turbine, Trial 1 ________________________ %.

   Percent efficiency for turbine, Trial 2 ________________________ %.

NAME: ______________________________

WIND ENERGY

Conclusion:

Directions: Watch the DIGITAL LECTURE: Chief Robert Charlie Talks About Wind. Answer the following questions based on the lecture and your lab results.

1. What independent variable did you test? ____

2. Which of your trials produced more power? What factors do you think affected this result?

 ____
 ____
 ____

3. Voltage is a measure of how fast the turbine is spinning the generator. What factors do you think would increase voltage? What factors do you think would decrease voltage?

 ____
 ____
 ____

4. Current is a measure of the flow of electrons through the wire. The strength of the current relates to the torque or force of the blades. What factors do you think would increase current? What factors do you think would decrease current?

 ____
 ____
 ____

5. Describe the efficiency of each of your trials. Which one was more efficient at capturing the total power found in the wind? Why? What would happen if a wind turbine captured 100% of the total power available in the wind?

 ____
 ____
 ____

6. What geographic regions of Alaska do you think have the greatest wind energy potential? Why?

 ____
 ____
 ____

NAME: ______________________________

WIND ENERGY

7. According to Chief Robert Charlie, what is the coldest of all winds? ______________________________

8. Use information from Chief Robert Charlie's lecture as well as your own experience to describe how paying attention to the direction of the wind can help a moose hunter.

____

____

____

____

____

9. Use information from Chief Robert Charlie's lecture as well as your own experience to describe how wind can help a person traveling by snow machine or dog team.

____

____

____

____

____

"POWER LAB" REPRINT FROM *ALASKA MAGAZINE*, JUNE 2010

The following *Alaska Magazine* article has been reprinted with permission from Kaylene Johnson.

POWER LAB

Known for its oil, Alaska could become a leader in alternative energy technologies

By **Kaylene Johnson**

Reindeer graze the flats below the Banner Wind Project, Alaska's largest wind farm, outside Nome.

(THIS PAGE) ANDREW C. JOHNSON/ALASKAPHOTOGRAPHICS.COM
(PREVIOUS SPREAD) DARYL PEDERSON/ALASKASTOCK.COM

Tom Waldrip doesn't consider himself an environmentalist or, as he calls it, a "do-gooder." He's just fed up with the expensive, unreliable energy he uses to power his home 22 miles from downtown Juneau. So in true pioneering spirit, he is building a hydrogen system that he says will reliably heat his home.

"I'm just tired of dealing with it," Waldrip said.

When an avalanche took out the power lines between the Snettisham hydroelectric power plant and Juneau in 2008, Waldrip's electric bill spiked from $100 a month to $500 because Juneau fuels its backup system with high-priced diesel fuels. Waldrip's wife raises chickens and rabbits, so the couple sat in the dark next to the woodstove, using the limited electricity they could afford on infrared lights to keep their baby chicks warm.

Between avalanches and windstorms, they average five or six power outages a year.

"I don't want to worry about oil prices or about avalanches anymore," Waldrip said. "Now I'm doing something to alleviate the problem."

Waldrip's dilemma is common across Alaska. In rural areas of the state, some households are spending up to 40 percent of their income on fuel oil, prompting some extended families to move in together to conserve.

In the more populated Railbelt region of the state, known reserves of natural gas are dwindling. Estimates of the gas accessible in Cook Inlet provide for about 10 years at current consumption levels. A gas pipeline from the North Slope is being discussed but wouldn't be up and running for several more years.

Renewable energy offers important solutions to Alaska's energy problems, said Chris Rose, executive director of the Renewable Energy of Alaska Project, a group that helps create public policy to foster renewable energy in Alaska.

"We have the best renewable resources in the country. What we need is a vision for the next 50 years, a roadmap of where we're going."

Rose said Iceland is a good example of visionary progress; nearly 100 percent of its heat and electricity is derived from geothermal and hydro resources. The only fossil fuel used in the small island nation, with the population of Anchorage and the latitude of Fairbanks, is for boats and automobiles.

Alaska is rich in geothermal, wind, solar, wave, tidal, hydro and biomass resources, and some believe the state could become an exporter of renewable energy technologies.

"We're a smart people in this nation," Rose said. "There's no reason Alaska can't lead the way in advancing renewable energy technology around the world."

Some Alaskans have installed their own renewable energy sources, like this solar array near Fairbanks.

SUN AND WIND

THERE ARE OBVIOUS PROS—long summer days—and cons—long winter nights—to using solar energy in Alaska. However, in the right location with either a battery bank or some other backup energy source, experts say solar energy can work here. What's more, solar energy systems require little maintenance, they're quiet and they have long lifespans.

George Menard sees the benefits of solar energy. He started Invertech Alaska in 1985 to sell and service small-scale renewable energy systems. Quantum leaps in technology have made solar and wind power more affordable and more efficient in the past 25 years, and with the high cost of diesel, Menard said inquiries about his solar and wind energy systems more than doubled in the past year.

Menard installed a solar system at Denali West Lodge in 2004. One hundred miles from the nearest road on the edge of Denali National Park and Preserve, the lodge went from running a diesel generator around the clock to firing it up twice a month, saving nearly $1,000 a month in fuel costs.

THE SUN PROVIDES MORE ENERGY IN **ONE HOUR** THAN WHAT IS USED BY THE EARTH'S POPULATION IN ONE YEAR.

Carol Schlentner, one of the lodge's owners, said the conversion to solar power has been nothing but positive.

"We have no contamination of soil since there's no spillage of diesel fuel, no left-over oil drums which cannot be easily recycled when you live off the road system," she said. "My only lament is that we have so much leftover energy in March, April and May. If there was a way we could save it, we would never even have to use our little 2-kilowatt diesel generator."

Wind is also abundant in many parts of the state, and wind turbines are gaining popularity

"POWER LAB" REPRINT FROM *ALASKA MAGAZINE*, JUNE 2010

in many rural communities. Kotzebue Electric Association first demonstrated the value of wind power when it installed three wind turbines in 1997. Since then, the wind farm has added 11 turbines that account for 7 percent of the co-op's annual electricity production.

The Alaska Village Electric Cooperative also uses wind energy to help power the villages of Toksook Bay, Kasigluk, Selawik, Savoonga, Hooper Bay, Chevak, Gambell, Mekoryuk and Wales. The success of AVEC's wind-diesel energy program has garnered national and international attention, and engineers and officials from 12 countries have toured AVEC's hybrid wind-diesel power generation facility in Kasigluk. Local residents are being trained to perform maintenance and repairs on the wind-diesel facilities, saving villages the expense of flying in a technician.

"We are enthusiastic about the successes we have seen and hope that wind can play a meaningful role in many of our villages," said Meera Kohler, AVEC's president and chief executive officer.

The community of Kodiak plans to meet 95 percent of its energy needs through renewable energy by 2020. Kodiak Electric Association generates 80 percent of its energy from hydropower and recently spent $21.5 million on three large wind turbines that began operating on Pillar Mountain in 2009. Experts estimate that wind energy will save Kodiak 800,000 gallons of fuel and $2 million annually.

"We decided we couldn't afford to wait," said Stosh Anderson, a KEA board member. "We're going to spend the money either way; we'll either spend it on fuel or on capital investments. This will help keep electric rates stable and not subject to the whims of the world hydrocarbon market."

And a wind farm on Fire Island, in Cook Inlet just offshore from Anchorage, will soon capture enough wind energy to offset the natural gas demands of as many as 19,500 homes in Southcentral Alaska. The 36-turbine, 54-megawatt plant, scheduled to go online in 2011, will help conserve Cook Inlet's gas reserves. According to Jim Jager, a spokesman for Cook Inlet Region Inc., which is building the farm, one advantage to renewable energy projects such as the one on Fire Island is that it can be up and running in three to five years, compared to a minimum of 15 years to build the hydroelectric dams proposed in the Susitna Valley north of Anchorage, or the seven years for a proposed pipeline to bring North Slope natural gas to Southcentral.

ALASKA'S ALTERNATIVE ENERGY POTENTIAL

FIRE ISLAND
36-TURBINE
54-MEGAWATT
POWER PLANT
WILL POWER
19,500 HOMES

ALASKA IS HOME TO MORE THAN

40
ACTIVE VOLCANOES
AND

100
HOT SPRINGS

DRILLING FOR HEAT

CHENA HOT SPRINGS RESORT, nestled among rolling hills along the Chena River 60 miles northeast of Fairbanks, has made international news in recent years. Miles from the nearest power grid, it runs off a 400-kilowatt geothermal electric power plant built there in 2006 using geothermally heated water to generate electricity. The plant powers the entire resort, including a year-round greenhouse and an absorption chiller to keep an ice museum chilled on 90-degree summer days.

Alaska has more than 40 active volcanoes and more than 100 hot springs that could be tapped in this manner to generate electricity, and rural communities close to these resources are paying close attention to Chena Hot Springs' success. Private developers are investigating geothermal prospects in several locations, but the resource presents a challenge.

"Geothermal is one of the most difficult renewable resources to tap; it's like drilling for oil or gas," said Nick Goodman, chief executive officer of TDX Power, a company looking at developing geothermal power in Manley Hot Springs. "But once you secure a good source, it's great. Unlike solar or wind, it produces power all the time."

Mount Spurr, within view of Anchorage, is 40 miles from a transmission grid, making it a promising site for a large-scale geothermal plant. Ormat Technologies Inc., one of the world's largest developers of geothermal power, has been researching the feasibility of developing a power plant near the volcano.

"What we're looking for is the best heat, the best permeability in the earth's crust, and the best fluid," said Paul Thomsen, Ormat's director of business development and policy.

In addition, the U.S. Department of Energy recently granted $12 million to Naknek Electric Association to develop a geothermal energy project and $4.6 million to the University of Alaska Fairbanks to explore geothermal resources at Pilgrim Hot Springs, northeast of Nome.

WATER POWER

THE TECHNOLOGY NEEDED TO HARNESS the power of tides and waves is younger than its wind and geothermal counterparts, but the outlook is just as promising. The advantages to tidal power are its predictability and, because water is almost 1,000 times denser than air, the amount of energy it could

TOP PHOTO: PATRICK J. ENDRES/ALASKAPHOTOGRAPHICS.COM, BOTTOM PHOTO: COURTESY YUKON RIVER INTER-TRIBAL WATERSHED COUNCIL

"POWER LAB" REPRINT FROM *ALASKA MAGAZINE*, JUNE 2010

Chena Hot Springs resort, miles from the nearest power grid, runs off a 400-kilowatt geothermal electric power plant that powers the entire resort, including a year-round green house.

create as it moves through turbines four times a day is enormous.

In Alaska, Ocean Renewable Power Co. has plans to place a test a tidal turbine in Cook Inlet, which has some of the greatest tide fluctuations and swiftest currents in the world, in 2011. If that initial project succeeds, the next step would be to install additional turbines that would create five megawatts of power, enough to power 6,250 households.

"With this pilot project, Alaska is on the leading edge and vanguard of tidal energy in the United States," said Doug Johnson, ORPC's director of projects in Alaska. "We still have a lot to learn in terms of deployment and environmental impact." For example, how will the generators affect migrating salmon and beluga whales? According to Johnson, although the turbines create a slight pressure barrier, indications so far are that fish swim around it.

The Yukon River Inter-Tribal Watershed Council has installed the first in-stream hydrokinetic power generator in the United States. It can provide enough energy to power two households.

Water technology is gaining interest in the Interior, as well. In 2008, the Yukon River Inter-Tribal Watershed Council installed the first in-stream hydrokinetic power generator in the United States. The 5-kilowatt demonstration project, mounted on a pontoon boat and floated in the moving current of the Yukon River near Ruby, has the capacity to provide enough energy to power two households. In 2009, the Watershed Council installed a data-gathering device that monitors performance and will provide the information that will be used to refine in-stream hydrokinetic systems worldwide, said Martin Leonard the Watershed Council's energy program manager.

"POWER LAB" REPRINT FROM *ALASKA MAGAZINE*, JUNE 2010

Golden Valley Electric Association in Fairbanks is investigating ways to make its Battery Energy Storage System compatible with large scale renewable energy projects.

The technology is simple and reliable.

"All of this is done by hand with a skiff," Martin said. "The beauty of the system is that it can be implemented at the local level."

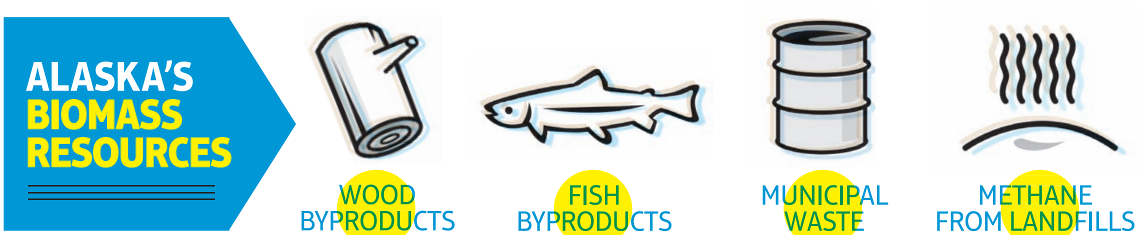
Brian Hirsch, Alaska senior project leader for the National Renewable Energy Laboratory, said that the development of small-scale projects such as the one at Ruby puts Alaska in the position to export renewable energy technologies.

"Alaska is unique in that it can provide a bridge between the industrial and developing world," Hirsch said. "Technologies can be developed here and applied elsewhere."

BIOFUEL BENEFITS

WITH ITS WELL-ESTABLISHED lumber and fishing industries, Alaska is a great source of biomass resources, including wood, sawmill waste, fish byproducts and municipal trash, which can create energy to replace fossil fuels. That's good news for Alaskans struggling with high fuel prices.

The city of Craig recently built a wood-fired boiler system that will use local sawmill waste to heat a municipal pool and the town's elementary and middle school buildings. The project will save up to 36,000 gallons of fuel oil and as much as $60,000 a year.



"POWER LAB" REPRINT FROM *ALASKA MAGAZINE*, JUNE 2010

Meanwhile, Superior Pellet Fuels is building the state's first large-scale wood pellet manufacturing plant in Fairbanks. The plant, scheduled to be fully operational this year, will use sawdust, chips and shavings from local sawmills, as well as wood salvaged from land-clearing and fire-mitigation projects. The company plans to produce 30,000 tons of pellets a year, enough to fuel 7,000 homes.

Alaskans generate about 650,000 tons of garbage each year, which can be used to generate energy. Small biofuel projects have had some success in Sitka, Fairbanks and Juneau, but energy recovery from the Anchorage landfill may prove to be the best prospect. According to a report prepared for the Municipality of Anchorage Solid Waste Services, the landfill could produce the energy equivalent of 1.9 million gallons of diesel per year over the next 10 years by capturing and using the methane escaping from the landfill. Although this project is still on the drawing board, it could produce enough energy to power 2,500 homes.

Fish oil is another abundant resource in Alaska. Ground-fish processors produce about 8 million gallons of fish oil annually as a byproduct of fishmeal plants. The oil is used as boiler fuel for drying fishmeal, and some processors blend fish oil with diesel to run their electric generators. James Jensen, Alaska Energy Authority's biofuels program manager, said Alaska has the potential to render roughly 21 million gallons of fish oil a year, although advances in technology are needed to make fish oil a practical substitute for diesel fuel.

"Fish oil doesn't have a stable shelf life," Jensen said. "It's perishable and it's also more difficult to use in colder temperatures."

THE POLITICS OF ENERGY

THE ALASKA ENERGY AUTHORITY has funded 26 bio-energy projects around the state this year through the Alaska Renewable Energy Fund.

The big question facing Alaska's communities is: Which renewable power sources are the best investments. Politics often plays a role in which projects receive funding.

Legislators decide how to fund the projects. The possibilities include fully funding specific projects or offering loan guarantees and letting private investors take the lead. The Alaska Renewable Energy Grant fund has given seed money to a number of smaller renewable energy projects.

Some energy experts and legislators have proposed combining the six existing electric utility companies into a single corporation. That corporation could then pursue large projects such as the Susitna hydroelectric dams that have been considered for more than 30 years. But others worry about the multibillion dollar price of the dams.

"The Susitna hydro project is so big it could eliminate the market for every other competing project," said Jim Jager, the spokesman for CIRI, which is building the Fire Island wind farm.

Large energy projects hinge on power-purchase agreements from utility companies. To pay for the two proposed dams on the Susitna, utility companies would have to commit to 25- or 30-year purchase agreements. Jager said the same is true of building a pipeline to bring natural gas from the North Slope.

Wind farms and other sources of renewable energy could sit idle because there is no market for their energy if utilities are under long-term agreements with other providers. And what if one of those sources of power is interrupted?

"Diversity of power sources is part of how you get reliability," Jager said. "You don't look for one silver bullet. Instead, you have a variety of energy sources like geothermal, hydro and wind."

Many energy experts agree with the need for diversity.

"If you want energy security, the closer you can produce it to home, the more secure you are," said Mark Masteller, executive director of Alaska Center for Appropriate Technology.

"The industry term is 'distributed generation,' the more sources of power generation you have, the less you are impacted when one of those sources experiences a disruption."

Smaller projects could remain viable if utility companies were required by state or federal law to generate a certain percentage of their energy through renewable sources.

"Alaska can become a leader in renewable energy and technology if we have the political will to do so—if we can see ourselves in the energy business rather than the oil business," said George Menard, the energy systems producer who installed the system at Denali West Lodge. "We have to put the oil era in our rear-view mirror and move on."

Chris Rose, of the Renewable Energy of Alaska Project, is optimistic that Alaska can make that shift and feed a global market for energy. And while he doesn't see fossil fuels going away completely, he believes oil will become scarcer and more expensive. With a world hungry for energy, a diminished supply of fossil fuels and the threats associated with climate change, investing now in clean, renewable energy will garner big dividends, he said.

"We're looking at two different futures depending on the decisions we make today," Rose said.

But the Waldrips of Juneau, whose power outage threatened their chicken operation last winter, are not waiting. A home-built hydrogen energy system will be up and running in their home before the next avalanche season. ■

"WE HAVE THE BEST RENEWABLE RESOURCES IN THE COUNTRY. WHAT WE NEED IS A VISION FOR THE NEXT 50 YEARS, A ROADMAP OF WHERE WE'RE GOING."

—*Chris Rose, Renewable Energy of Alaska Project*

Kaylene Johnson is author of several books about Alaska including *A Tender Distance: Adventures Raising My Sons in Alaska* (2009), and *Sarah: How a Hockey Mom Turned Alaska's Political Establishment Upside Down* (2008).

PATRICK J. ENDRES/ALASKAPHOTOGRAPHICS.COM