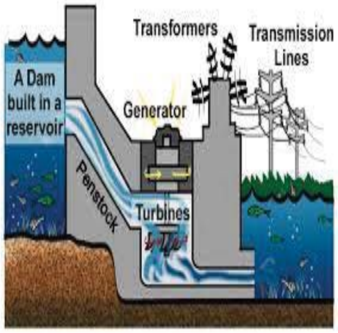


Summer Camp 2014
Hydro-Electric Energy

Introduction:

Hydroelectricity is the term referring to electricity generated by hydropower; the production of electrical power through the use of the gravitational force of falling or flowing water. It is the most widely used form of renewable energy, accounting for 16 percent of global electricity generation.

Hydropower is produced in 150 countries, with the Asia-Pacific region generating 32 percent of global hydropower in 2010. China is the largest hydroelectricity producer, with 721 terawatt-hours of production in 2010, representing around 17 percent of domestic electricity use. There are now three hydroelectricity plants larger than 10 GW: the Three Gorges Dam in China, Itaipu Dam across the Brazil/Paraguay border, and Guri Dam in Venezuela.

The cost of hydroelectricity is relatively low, making it a competitive source of renewable electricity. The average cost of electricity from a hydro plant larger than 10 megawatts is 3 to 5 U.S. cents per kilowatt-hour. Hydro is also a flexible source of electricity since plants can be ramped up and down very quickly to adapt to changing energy demands. However, damming interrupts the flow of rivers and can harm local ecosystems, and building large dams and reservoirs often involves displacing people and wildlife. Once a hydroelectric complex is constructed, the project produces no direct waste, and has a considerably lower output level of the greenhouse gas carbon dioxide (CO_2) than fossil fuel powered energy plants.

Objectives:

- Students will be able to differentiate between Kinetic and Potential Energy
- Students will be able to demonstrate how a water wheel works
- Students will be able to identify and describe the different parts of a hydro-electric damn
- Students will be able to understand the ways that a hydro-electric damn can impact the environment around it
- Students will be able to design and revise their own hydro-electric turbine

Standards Covered:

9-10.1.1	Explain how models can be used to illustrate scientific principles
11-12.2.2	Select and use appropriate instruments, measuring tools, and units of measure to improve scientific investigations
11-12.2.4	Formulate and revise explanations based upon scientific knowledge and experimental data

Session Organization:

9:00 – 9:30	Cultural Connection and General Organization
9:30 – 10:00	Power Point part 1 (background information and Activity 1)
10:00 – 10:20	Activity 1: Kinetic energy vs. Potential energy and discussion
10:20 – 10:30	Power Point part 2 (water wheels info and characteristics)
10:30 – 12:00	Activity 2: Building a water wheel
12:00 – 12:30	Lunch
12:30 – 12:45	Power Point part 3 (Hydro-electric dam information)
12:45 -1:00	Activity 3: Identify parts of a hydro-electric dam
1:00 – 1:10	Power Point part 4 (environmental impact of dams)
1:10 – 1:30	Activity 4: Best Dam Simulation EVER
1:30 – 1:40	Power Point part 5 (Turbine information)
1:30 – 2:45	Activity 5: Design turbine and test electrical output
2:45 – 3:00	Wrap up and closing discussion

Activity 1: Kinetic energy vs. Potential energy worksheet

- Determine whether the objects in the following problems have kinetic or potential energy. Then choose the correct formula to use:

KE= 1/2 m v^2

PE = mass x gravitational acceleration (9.8m/s^2) x height **OR** Weight X Height

Energy= joules
Weight= Newton
Mass= kilograms
Velocity= m/s
Gravitational acceleration= (9.8 m/s^2)

1. You serve a volleyball with a mass of 2.1 kg. The ball leaves your hand with a speed of 30 m/s. The ball has ________________________ energy. Calculate it.

2. A baby carriage is sitting at the top of a hill that is 21 m high. The carriage with the baby weighs 12 N. The carriage has _____________ energy. Calculate it.

3. A car is traveling with a velocity of 40 m/s and has a mass of 1120 kg. The car has ____________energy. Calculate it.

4. A cinder block is sitting on a platform 20 m high. It weighs 79 N. The block has ______________ energy. Calculate it.

5. There is a bell at the top of a tower that is 45 m high. The bell weighs 190 N. The bell has _____________ energy. Calculate it.

6. A roller coaster is at the top of a 72 m hill and weighs 966 N. The coaster (at this moment) has _____________ energy. Calculate it.

7. What is the kinetic energy of a 3-kilogram ball that is rolling at 2 meters per second?

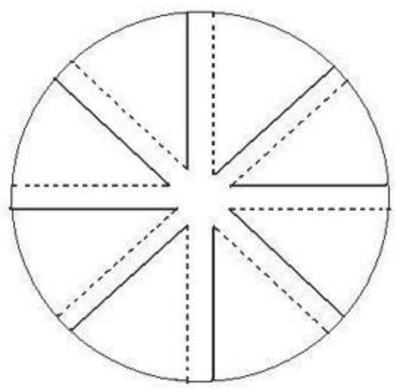
8. Two objects were lifted by a machine. One object had a mass of 2 kilograms, and was lifted at a speed of 2 m/sec. The other had a mass of 4 kilograms and was lifted at a rate of 3 m/sec.

a. Which object had more kinetic energy while it was being lifted?

b. Which object had more potential energy when it was lifted to a distance of 10 meters? Show your calculation.

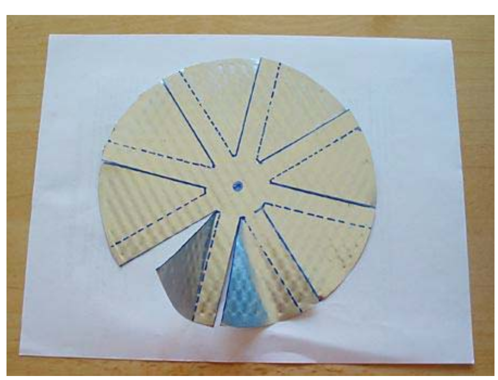
Activity 2: Building a water wheel

1. Take your scissors and cut out the flat bottom part of the aluminum pie plate.
2. With the permanent marker, copy the design from the waterwheel template (Figure 5) onto the circle of aluminum. Draw the lines from the edge of the circle to about 2 centimeters (cm) from the middle of the circle.



Waterwheel Template

3. Cut the aluminum circle along the eight solid lines. End each cut at 2 cm from the center. These are the paddles of the waterwheel.
4. Carefully bend each paddle at its dotted line. Put the ruler at each dotted line so that you can make a straight bend.



This waterwheel has eight paddles. Bend each paddle at its dotted line

5. Drill a 5/16-inch hole through the middle of the waterwheel. Ask an adult to help you and always wear safety goggles when using power tools. You could also use a hammer and nail to make the $\frac{1}{4}$-inch hole in the middle. If you use a hammer and nail, clip off any sharp metal edges around the hole with the scissors.
6. Glue the nylon spacer to the middle of the waterwheel. Be careful to follow the instructions on the epoxy glue package. Ask an adult for help. The nylon spacer stiffens the waterwheel.

Here is a completed waterwheel

7. Wait until the glue is fully dry before continuing. Consult the packaging of the epoxy for drying times.
8. After the glue dries, use thin strips of Scotch tape to secure the nylon spacer to the waterwheel. Make sure that the hole in the center is not covered with tape. Set the waterwheel aside.
9. Remove the handle from the bucket. Now ask an adult to drill two 3/8-inch holes where the ends of the handle use to be. Always wear safety goggles when using power tools. Make sure that the wood dowel can fit comfortably through the holes and spin freely. It should *not* be a tight fit.

The wood dowel fits comfortably through the two drilled holes.

10. Wind a piece of Scotch tape around the middle of the wood dowel. This is to add some thickness in order to keep the waterwheel in place. Now insert the dowel through the holes of the bucket. Move the dowel out of one of the holes and carefully slip the waterwheel onto the dowel over the piece of tape. Reinsert the dowel through the hole in the bucket. Turn the waterwheel and make sure that the wood dowel turns as well. If the dowel doesn't move, you should gently move the waterwheel off of the tape and wind another piece of tape over the original piece of tape to add thickness so the two objects move at the same time. The waterwheel must sit tightly on the dowel so that when the waterwheel turns, the dowel turns.

Waterwheel apparatus

11. Take the cotton string and tie one end to the metal nut. Tie the other end of the string to one end of the wood dowel, outside of the bucket. Tie the end such that when the dowel starts to turn, it immediately starts to wind up the string. You need to pay attention to how the waterwheel turns to do this; either clockwise or counterclockwise.

12. Wind some tape and make a little tab (by folding the end of the piece onto itself) on the dowel *outside* of the bucket on both ends so that the waterwheel and dowel don't move horizontally too much—you don't want the dowel slipping out of the holes. The waterwheel should be sitting in the middle of the bucket and should be able to turn freely, without hitting the bucket. Now you are ready to start converting the kinetic energy in falling water to mechanical energy.

13. To do these experiments you can use any source of moving water, like a sink or bathtub faucet, or an outdoor hose.

    a. Pick a water source where the water comes out in a steady stream. *Do not* use a water source where the water is a wide, cone shaped spray it will lead to poor results. For example, a shower head would not be a good water source. If you are using a hose with several different nozzle settings choose the setting that is least like a shower and most like a steady stream.

14. Using the measuring cup and the stopwatch, first calculate the flow rate of the water source you are using. You will do this by seeing how long it takes to fill 2 cups of water. Note this time down in your lab notebook in a data table like the one below.

    a. Divide 2 cups by the number of seconds it took to fill 2 cups. This is the flow rate and its unit of measure is cups per second. Note down the flow rate in your lab notebook.

    b. Do not turn off the water between measuring the flow rate and testing the waterwheel or else you will have to redo the flow rate calculation (you might turn the faucet on harder or softer the next time, which would negatively affect your results).

15. Make sure that the string and weight are unwound before you begin. Place the waterwheel under the flowing water. Measure the height of the flowing water with the ruler. Record this information in your lab notebook. Using the stopwatch, time how long it takes to wind the weight up. Note this time in your lab notebook.

    a. Repeat this measurement two additional times at the same water height and record the information in your lab notebook.

    b. One thing to keep in mind is to not let the bucket get too full of water or else the bucket water will get in the way of the waterwheel.

    c. Once you've filled the bucket to the point where the waterwheel won't turn anymore, don't just waste it—you can use this water to water your garden or put it in your dog's water bowl.

    d. *Note:* Make sure that the water hits the waterwheel in the same spot for every trial. The waterwheel should go either clockwise or counterclockwise each time. Record all information in your lab notebook.

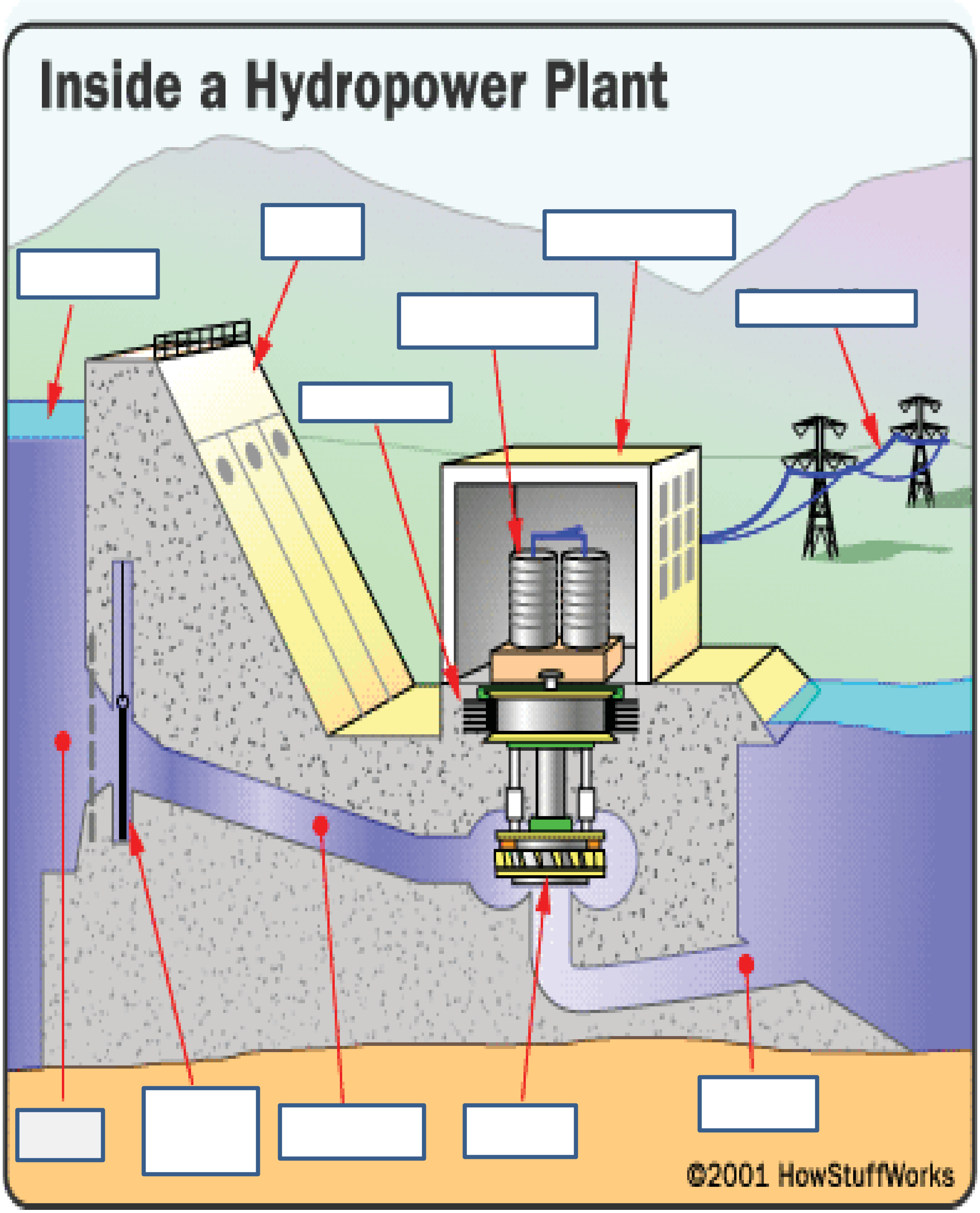
16. Now you *do* want to change the flow rate of your water source, so adjust it and repeat steps 13 and 14. Make sure that the trials are all done at the same water height. Change the flow rate one more time and repeat steps 13 and 14 again. So you should have three trials each for three different flow rates.

17. Does the time it takes to wind the weight change? Is there a limit to this time?

18. Plot your data on a scatter plot. Plot the flow rate on the x-axis and the wind-up times and the average wind-up time on the y-axis.

Flow Rate (cups/second)	Wind-up Time (seconds)
	Average:
	Average:
	Average:

Activity 3: Identify parts of a hydro-electric dam



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Activity 4: Best Dam Simulation EVER

Enter the link into your browser: **http://www.omsi.edu/exhibits/damsimulation/**

Based on the simulation answer the following questions:

1. How do dams affect recreation?

2. How do dams affect salmon?

3. How do dams affect agriculture?

4. How do dams affect power users?

5. How do dams affect resident fish?

6. How do dams affect flood control?

7. Describe the actions you took in the fall and what were the results?

8. Describe the actions you took in the winter and what were the results?

9. Describe the actions you took in the spring and what were the results?

10. Describe the actions you took in the summer and what were the results?

Collect and record the following data at three separate heights:

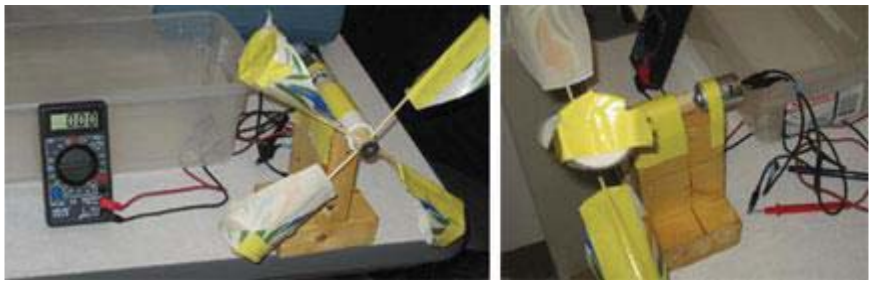
	Height 1	Height 2	Height 3
Height of water above turbine			
Mass of water to be poured			
Time water was flowing over blades			
Voltage produced			

1. Calculate the potential energy of the water using PE = mg
2. Calculate the water's final velocity just before hitting the turbine blades using

Activity 5: Design turbine and test electrical output

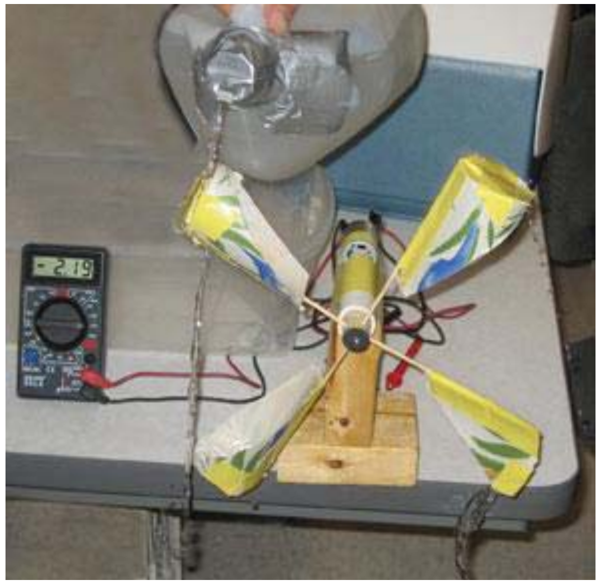
1. Divide the class into groups of three students each.
2. Distribute the worksheets and blocks of wood.
3. In a class discussion, generate the problem that the students are trying to solve by designing water turbines; this should include how to generate electricity for a house using a renewable energy source.
4. In groups, have students brainstorm how they might design their water turbines. Possible questions to address: How many blades? How to space them? From what material should we make the blades? What shape for the blades? Have students record all their brainstorm ideas on their worksheets.
5. From a review of their brainstorming exercise results, have each group agree upon one design to build for their turbine model. Direct them to draw their designs on their worksheets and explain why they chose that design.
6. Next, have each group use the available materials to build a prototype of their turbine based on the design. Note: Since the motor will be placed

directly into the cylindrical block of wood, make sure students attach their turbine blades to the end opposite of the hole drilled into the wood block; this prevents the motor from falling directly in the path of water during testing.



Front and side view of activity set up with a hobby motor and multi-meter connected to one team's block of wood and prototype water turbine.

7. Once a group has finished building its turbine, have them go outside or over a large sink to test how well they work.
8. For testing, have a group put the end of the model turbine through the PVC pipe on the testing device and onto the shaft of the motor. You may want to tape the front end of the testing device to the surface it is sitting on in order to prevent movement during testing. Once the turbine is connected, have one student pour water onto the turbine. Have the teacher or another student measure and record the length of time the water hits the blades.



A student team's prototype water turbine design being tested by steadily pouring water from above at a point over the blade scoops.

9. Have each group take turns pouring water over the blades of their turbine from three different heights, recording the data on the worksheet.
10. Have students complete the calculations and analysis on their worksheets.
11. Conclude with a class discussion to review and compare the groups' findings. What improvements would they make? Where would they locate turbines near their energy efficient houses?

Testing and Analysis

Collect and record the following data at three separate heights:

	Height 1	Height 2	Height 3
Height of water above turbine			
Mass of water to be poured			
Time water was flowing over blades			
Voltage produced			

1. Calculate the potential energy of the water using $PE = mgh$

2. Calculate the water's final velocity just before hitting the turbine blades using

   $$PE = KE = \frac{1}{2}mv^2$$

3. Calculate the mass flow rate ($\dot{m} = \frac{m}{t}$).

4. Calculate the theoretical power your turbine should generate using the formula $P = \dot{m}gh$ at each height.

5. What can you conclude about the voltage produced as related to the height of the water?

b. The mass flow rate of a flowing fluid can be calculated using the equation $\dot{m} = Q\rho$ where Q is the volumetric flow rate (m^3/s) and ρ is the density of the fluid (the density of water is 1000 kg/m^3). Calculate the mass flow rate ($\dot{m}$) at each location.

$$\dot{m} = Q\rho$$

c. Calculate the power that the water could theoretically produce at each location.

$$P = \dot{m}gh, \text{ where } g=9.8 \text{ m/s}$$

d. If the turbines to be used at the power plant have an operating efficiency of 91.4% what is the actual power that will be generated at each location?

e. Calculate how much energy (in kW-hours) this turbine would produce in one year at each location.

$$E = P * t$$

f. If the hydroelectric power plant takes 150,000 kW-hours a year to operate and this energy is produced at the plant, how much energy would be left over for your neighbors and yourself to use at each location?

Evaluation/Questions

1. Most water turbines in use today are able to achieve efficiency ratings of at least 90%. Identify three causes of poor efficiency in your turbine design, that is: what are some reasons for why the efficiency of your (or any turbine) could never be 100%? Can you think of any ways to fix some of these causes for loss in power in your turbine? Why would it be important for engineers to identify where power is being lost and work on ways to reduce these effects?

2. Your engineering firm has been designing an energy-efficient house. The city that the house is located in has been chosen by the government as a site for a small hydroelectric power plant and dam. After analyzing the small river, three possible locations are found to be suitable for the dam and hydroelectric water plant. The city has enlisted your help to determine where to place the dam and hydroelectric power plant. The table below provides specific details of each location. Use this information to help the city determine the best location to place a hydroelectric power plant.

	Water head possible after dam placed (m)	Average Velocity of flowing water (m/s)	Cross-sectional area of water flow (m^2)	Cost of building dam ($)
Location 1	1.75	2.1	7.4	74,000
Location 2	1.9	1.8	8.4	84,000
Location 3	1.5	1.9	7.8	78,000

   a. Using information in the table, calculate the volumetric flow rate, Q, at each location.

$$Q = vA$$

g. The government would like to have the plant produce at least 6500kW-hours of energy each year for the town's 300 residents. Based on cost and performance, at which location would your group recommend the dam be built? Explain why.

h. Typical coal power plants can produce about 2 kW-hours of energy per kg of coal burned. How much coal must be burned to produce 6500kW-hours of energy for the town's 300 residents? If 1 kg is equal to 2.2 pounds, how many pounds of coal are burned in one year to produce 6500 kW-hours of energy for 300 people?

i. Why would you recommend the government to build a hydroelectric dam to power this city? How would the dam affect the individuals and the environment? Write a short persuasion piece to help the government understand the advantages of a hydroelectric dam in this area.