PowerUp Lesson Plan Overview

This lesson is one of six lessons developed as a classroom companion to PowerUp, a free, online, educational video game that allows students to experience the excitement and the diversity of modern engineering.

The lessons are designed to be flexible and scalable to meet your students' needs. Facilitation tips, extension activities and resources for learning more can be found in the Teachers' Guide, which is available for download along with each of the lessons. For these resources, as well as to download and play PowerUp for free, go to http://powerupthegame.org.

PowerUp was created by IBM and TryScience/The New York Hall of Science with scientific content and expertise provided by the Tech Museum of Innovation, the Bakken Museum, Idaho National Laboratory and the National Renewable Energy Laboratory.

Student Objectives

Students read and discuss articles about hydroelectric power generation covering the basics – how the energy of moving water is transformed into electricity – and describing current projects. Using development in China as a context, articles compare and contrast the pros and cons of different scales of hydropower projects. Students consider whether or not they would support building a large-scale hydroelectric dam in their own local community, suggest alternative methods of harnessing hydropower and consider the types of environments and specific natural features that are best suited for hydropower.

Using the Tech Museum of Innovation Design Challenge Learning pedagogy as a framework, students are introduced to the interconnected phases of the design cycle: Investigate, Create, Reflect.

Students are given a design challenge: Work in groups to design, prototype and market a better hydropower system. Students design on paper a schematic of the proposed system that indicates the scale of the system, the necessary specifications of the hydro energy source and the energy transformations that will take place. Students experiment with coils of wire, magnets and a galvanometer to experience, hands-on, what factors effect electromagnetic induction. Each group generates hypotheses, tests these hypotheses and records their data. The information gleaned from these experiments will be incorporated into the design of the hydropower system.

Students are provided with printed background information including pictures of a number of hydroelectric generators of various designs and scales, a few schematics illustrating how the parts of a generator work together, and worksheets with hints to help the team work together throughout the design process.

Students document their process by taking notes and drawing sketches and collecting their work in a design portfolio.

Teams present their final designs to the other groups and reflect on their design process.

Class Time

Period 1

- Introduction to the Design Cycle (10 minutes)
- Case Study: Three Gorges Dam Controversy (20 minutes)
- Begin Design & Build Challenge (10 minutes)
- Working in teams: Brainstorm, research, plan and sketch hydropower designs

Period 2

- Working in teams: Continue Design & Build Challenge (40 minutes)
- Collect Materials

- Experiment with coils of wire, magnets and galvanometer
- Incorporate conclusions into design of hydropower design
- Document process with notes and sketches
- Clean up

Period 3

- Finish Design & Build Challenge (15 minutes)
- Complete design portfolio and plan presentation (10 minutes)
- Clean up
- Present 2D and 3D designs. (15 minutes)

Optional Extension 1: Students write up a summary of their experiments with wire and magnets. Students explain their hypotheses, describe and sketch the variables they tested – speed of motion, angle of motion, moving coils vs. moving magnet, switching north and south poles, etc – and explain their results by using Faraday's law and/or Lenz's law.

Optional Extension 2: Team develops a logo for their engineering company and a marketing plan to attract customers to their product. Students may storyboard a television ad, design a print ad or a billboard, develop a scheme to place their product and messaging in TV shows and movies, etc. Marketing materials should explain the benefits of small scale hydropower, in general, and describe the elements of this new product that make it efficient, economical and attractive.

Materials

Research materials for learning more about large-scale hydroelectric dams and smaller-scale hydropower systems. (Some material for research is included in this teacher guide; you may want to supplement it with a collection of your own books, magazines, maps, computers with CD ROMS or internet connection.)

Per student:
- Student brainstorming guides (included in this teacher guide)
- electromagnetic induction experiment worksheet (included in this teacher guide)

Per group of students:
For electromagnetic induction exploration:
- exploration worksheet
- bar magnet (2 or more, different sizes if possible)
- coil of magnet wire (enamel-covered copper wire)
- galvanometer

  optional – cardboard cylinders (students can collect from home)

For documenting and designing plan for hydropower system:
- ruler
- scrap paper
- colored pencils/markers

- pencils
- binder clips or pocket folder to keep group's design portfolio together

Preparation

- Review Tips for Project Based Learning Section
- Decide how you will adapt lessons to fit your students' learning needs.
- Plan your assessment strategy – adapt rubric as needed (See Rubric in Teacher's Guide pdf)
- Gather research materials on large-scale hydroelectric dams and small-scale hydropower in China
- Gather materials for hands-on experimentation (magnet wire, magnets, cardboard cylinders, galvanometers, etc)
- Plan and prepare procedure and materials for hands-on exploration as best fits your needs and the constraints on your class time and your materials budget. You may give each group a single spool of magnet wire and have them use the spool as a solenoid, as is - as long as it is wide enough to allow a magnet to pass through. You may provide students with cardboard cylinders and spools of wire with which to make their own solenoids so that they may test, as a variable, the effect of number of "turns" of wire in a solenoid (the more turns, the greater the current). To save class time, you may prepare different sized solenoids yourself (I.e. 200 turns, 400 turns) before class time, and have the groups take turns testing.
- Make copies of Student Pages (including articles about hydro power projects in China, background information about hydropower, brainstorming guide and electromagnetic induction exploration worksheet)

National Science Standards 9-12

NS.9-12.1 Science as Inquiry
As a result of activities in grades 9-12, all students should develop understanding of:

- Abilities necessary to do scientific inquiry
- Understandings about scientific Inquiry

NS.9-12.2 Physical Science
As a result of activities in grades 9-12, all students should develop understanding of:

- Motions and Forces
- Conservation of energy and increase in disorder
- Interactions of energy and matter

NS.9-12.4 Earth and Space Science
As a result of activities in grades 9-12, all students should develop understanding of:

- Energy in the earth system

NS.9-12.5 Science and Technology
As a result of activities in grades 9-12, all students should develop understanding of:

- Abilities of technological design
- Understandings about Science and technology

NS.9-12.6 Personal and Social Perspectives
As a result of activities in grades 9-12, all students should develop understanding of:

- Natural Resources
- Environmental quality
- Natural and human-induces hazards
- Science and technology in local, national and global challenges

NS.9-12.7 History and Nature of Science
As a result of activities in grades 9-12, all students should develop understanding of:

- Science as a human endeavor
- Nature of scientific knowledge
- Historical perspectives

Classroom—Game Connections

When your students log in to PowerUp and enter the Hydro Mission they will have many opportunities to apply and investigate concepts addressed in this lesson. You may chose to have your students play PowerUp before the lesson, as a primer on hydroelectric dam and generator components and a review of energy concepts or you may assign gameplay for homework after this lesson to reinforce lesson concepts in a highly motivating context.

- **Careful experimentation leads to optimal design.**
  As students repair damaged turbines and generators in the game environment they will receive tailored feedback about the efficiency of their design and how much electricity each turbine is generating. If a turbine is not performing well the students must troubleshoot. They will learn through experience that success can be found when one variable at a time is isolated and tested.

- **Electricity can be induced by moving a conductor in and out of a magnetic field. This is the process by which generators turn kinetic energy into electricity.**
  This concept is present in each of the three missions in the game – each involves a generator that uses electromagnetic induction to turn kinetic energy into electricity -- but the gameplay in the Hydro mission requires that players piece together the magnets and wire coils that make up the generators and, later, troubleshoot their designs making the process explicit.

- **Energy can not be created or destroyed; it can only be changed from one form to another.**
  Students will understand that the greater the height of the head or the point from which the water begins to flow down to the generator, the greater the water's potential energy. It is this energy which is transformed to kinetic energy as the water rushes through the turbine and, by spinning the generator shaft, is transformed through electromagnetic induction, into electricity.

- Large scale hydroelectric dams can have considerable social and cultural costs. As students explore the terrain within the hydro mission they will find artifacts that introduce a backstory about a town that was flooded in order to create the reservoir for the large hydroelectric dam.

Facilitation

Period 1

Introduction to the Design Cycle (10 minutes)

- Explain to your students that for the next few days they will be working in groups on a green energy design project. (You may wish to pre-assign groups or to let the students form their own groups, do what works best for your students.)
- Explain that in order to maximize the creativity and the knowledge of every group member the groups will work through a cycles of investigate, create, and reflect. Engineers use these same cycles when solving problems and designing products. Explain that each cycle must be documented with sketches, diagrams, lists of ideas, and notes. These will be collected in a design portfolio. Each group will hand in a portfolio; each student is responsible for contributing to it.

Investigate

- The design process will begin with investigation, students will:
- identify the problem by reading a newspaper article,
- brainstorm ideas and solutions (students will record ideas on handouts, provided)
- research the issues and possible solutions using materials provided and other books and online resources
- The process starts with INVESTIGATE, and ends with REFLECT, but in the middle the process may go back and forth between the three cycles a bunch of times. Students may CREATE a prototype and ask for feedback from another student. As a group they may REFLECT and realize that they didn't take into account a certain constraint, and so the group may want to go back to INVESTIGATE and brainstorm some more ideas, and so on

Create, Re-create

- Select a solution from their brainstorming lists
- Design and construct a prototype
- Test
- Redesign or modify
- Retest

Reflect

- Share solutions
- Reflection and discussion

Case Study: Hydropower in China (20 minutes)
Distribute articles on the Hydropower and have students read to themselves. When students are finished, discuss the main ideas as a class:

- What are the benefits of the Three Gorges Dam project? To the local community? The province? The country?
- What are the drawbacks? To the local community? The province? The country?
- Are there alternative ideas that have some of the same benefits without the drawbacks? What are they?
- Review the following science concepts that underpin hydro electric power generation, (see Background Information section for some resources)
  - water cycle
  - potential and kinetic energy
  - electromagnetic induction
- Begin Design & Build Challenge (10 minutes)
- Distribute Brainstorming guides
- (optional - distribute a large binder clip or pocket folder for groups to clip all documentation together)
- Working in teams, students: Brainstorm, research, plan and sketch hydro designs.
- Document design process with notes and sketches

Period 2

- Discuss Design Journal (5 minutes)
  - Remind the students that each group's design journal should include notes from brainstorming sessions, sketches including a final sketch of the solution to be prototyped - with scale indicated, notes on the building process, details of testing, analysis of the trial, problem solving ideas/steps, etc.
  - Remind students that EACH student is responsible for contributing to the group's journal - there is no assigned "recorder." Discuss the value of recording all of your ideas – even the ones that don't pan out and the ones the group does not pursue.
- Continue Design & Build Challenge (35 minutes)
- Working in teams, students:
  - Collect Materials
  - Experiment with coils of wire, magnets and galvanometer
  - Incorporate conclusions into hydropower design
  - Document design process with notes and sketches
  - Clean up

Tips from the Tech Museum of Innovation for facilitating groups working on open-ended design projects are included in this Teacher's Guide.

Period 3

- Finish Design & Build Challenge (10 minutes)
  - Complete design portfolio and plan presentation (10 minutes)
  - Groups should be prepared to:
  - Present and explain a diagram of their design for a better hydropower system
  - Explain how the design will benefit the community and ecology of Hubei Province

- Explain how the group used research to inform the design.
- Explain what the group learned through hands-on experimentation with electromagnetic induction
- Describe the biggest challenge the group faced during their design process.

▪ Groups present their 2D and 3D designs to class. (20 minutes)
    - Groups demonstrate their invention and field questions.

STUDENT PAGES

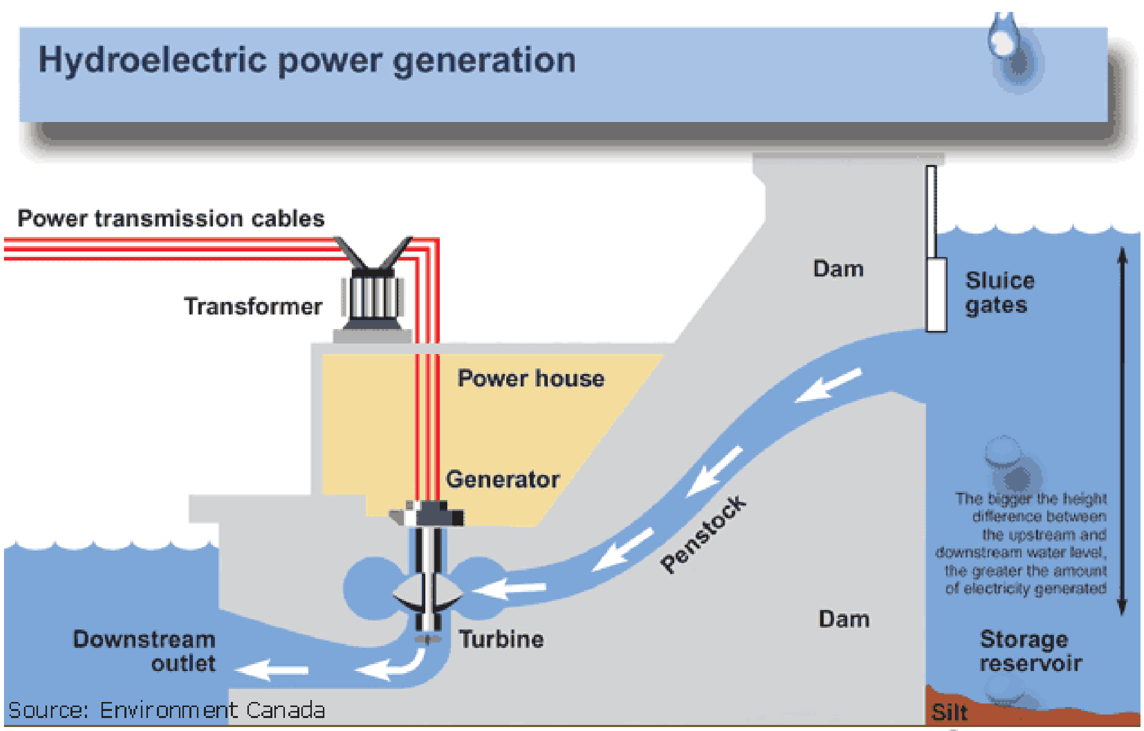
BACKGROUND INFORMATION

Hydroelectric power: How it works

So just how do we get electricity from water? Actually, hydroelectric and coal-fired power plants produce electricity in a similar way. In both cases a power source is used to turn a propeller-like piece called a turbine, which then turns a metal shaft in an electric generator which is the motor that produces electricity. A coal-fired power plant uses steam to turn the turbine blades; whereas a hydroelectric plant uses falling water to turn the turbine. The results are the same. Take a look at this diagram of a hydroelectric power plant to see the details.

The theory is to build a dam on a large river that has a large drop in elevation (there are not many hydroelectric plants in Kansas or Florida). The dam stores lots of water behind it in the reservoir. Near the bottom of the dam wall there is the water intake. Gravity causes it to fall through the penstock inside the dam. At the end of the penstock there is a turbine propeller, which is turned by the moving water. The shaft from the turbine goes up into the generator, which produces the power. Power lines are connected to the generator that carries electricity to your home and mine. The water continues past the propeller through the downstream outlet into the river past the dam. By the way, it is not a good idea to be playing in the water right below a dam when water is released!

Source: Hydroelectric power generation, http://www.ec.gc.ca/Water/en/manage/use/e_hydro.htm
Environment Canada, 2007. Reproduced with the permission of the Department, 2008.
Source: http://ga.water.usgs.gov/edu/hyhoworks.html



Advantages and Disadvantages of Hydroelectric Power Plants

Hydropower offers advantages over other energy sources but faces unique environmental challenges.

Advantages

- Hydropower is a fueled by water, so it's a clean fuel source. Hydropower doesn't pollute the air like power plants that burn fossil fuels, such as coal or natural gas.
- Hydropower is a domestic source of energy, produced in the United States.
- Hydropower relies on the water cycle, which is driven by the sun, thus it's a renewable power source.
- Hydropower is generally available as needed; engineers can control the flow of water through the turbines to produce electricity on demand.
- Hydropower plants provide benefits in addition to clean electricity. Impoundment hydropower creates reservoirs that offer a variety of recreational opportunities, notably fishing, swimming, and boating. Most hydropower installations are required to provide some public access to the reservoir to allow the public to take advantage of these opportunities. Other benefits may include water supply and flood control.

Disadvantages

- Fish populations can be impacted if fish cannot migrate upstream past impoundment dams to spawning grounds or if they cannot migrate downstream to the ocean. Upstream fish passage can be aided using fish ladders or elevators, or by trapping and hauling the fish upstream by truck. Downstream fish passage is aided by diverting fish from turbine intakes using screens or racks or even underwater lights and sounds, and by maintaining a minimum spill flow past the turbine.
- Hydropower can impact water quality and flow.
- Hydropower plants can cause low dissolved oxygen levels in the water, a problem that is harmful to riparian (riverbank) habitats and is addressed using various aeration techniques, which oxygenate the water. Maintaining minimum flows of water downstream of a hydropower installation is also critical for the survival of riparian habitats.
- Hydropower plants can be impacted by drought. When water is not available, the hydropower plants can't produce electricity.
- New hydropower facilities impact the local environment and may compete with other uses for the land. Those alternative uses may be more highly valued than electricity generation. Humans, flora, and fauna may lose their natural habitat. Local cultures and historical sites may be impinged upon. Some older hydropower facilities may have historic value, so renovations of these facilities must also be sensitive to such preservation concerns and to impacts on plant and animal life.

Source: U.S. Department of Energy, Energy Efficiency and Renewable Energy Website
www.eere.energy.gov

Hydroelectric Power
Water has long been used as a source of energy. It began with the Greeks using water wheels to grind wheat into flour over 2,000 years ago. From there, the use of water wheels expanded to wood and power textile mills and other manufacturing plants. Even today, you can still see this ancient technology in action.

For over a century, hydroelectric power has been used to generate electricity from falling water. Bernard Forest de Belidor, a French hydraulic and military engineer, is credited with developing the first modern hydroelectric turbine in 1833.

Hydroelectric power, also known as hydropower, refers to the process of using water's energy to create electricity. Simply put, hydroelectricity involves power being generated by hydraulic turbines that rotate due to moving water as it flows from a higher to lower elevation.

Twenty percent of the world's electricity is produced by hydropower plants and there are over 2,000 hydropower plants in the United States, providing approximately 10 percent of our total electricity. Canada, Norway, and New Zealand are three countries that use hydroelectric power as their primary source of electricity generation.

Hydroelectric power is considered to be a clean, renewable source of energy, emitting a very low level of greenhouse gases when compared to fossil fuel plants. Hydropower has a low operating cost, once installed, and can be highly automated. An additional benefit is that the power is generally available on demand since the flow of water can be controlled. Reservoirs can also offer a variety of recreational opportunities, including fishing, boating, and swimming.

Using hydroelectric power also has its disadvantages. Dams can block fish passage to spawning grounds or to the ocean, although many plants now have measures in place to help reduce this impact. The diversion of water can impact stream flow, or even cause a river channel to dry out, degrading both aquatic and streamside habitats. Hydroelectric plants can also have an impact on water quality by lowering the amount of dissolved oxygen in the water. In the reservoir, sediments and nutrients can be trapped and the lack of water flow can create a situation for undesirable growth and the spread of algae and aquatic weeds.

The construction of the Three Gorges Dam project on the Yangtze River in China, the largest hydroelectric dam in the world, raised another factor that can result from dam construction – the displacement of people. Structural work on the dam was completed in May 2006, and although several generators have yet to be installed, it is expected to be fully operational by 2009. The reservoir started being filled in 2003, and when filled will span 360 miles. It is anticipated that the rising waters of the expansive reservoir could submerge over 140 towns and 326 villages, causing over one million people to be moved from the general area. The Chinese government, however, defends the construction because the dam will boost industrial output and create millions of new jobs. The dam is expected to generate electricity equal to 40 million tons of coal, significantly reducing both sulfur dioxide and carbon dioxide emissions. The dam will also help to control natural flooding, protecting millions of people who were previously left homeless when the waters surged beyond their banks.

While the use of water to produce electricity is an attractive alternative to fossil fuels due to the plentiful availability of water and the significant reduction in emissions, the technology must still overcome obstacles related to building costs, space requirements, environmental impacts, and the displacement of people.

Courtesy of the Environmental Literacy Council, www.enviroliteracy.org

Clean electricity, on a small scale, in China by Odilon Couzin
October 12, 2000

America's thirst for oil came up again in last night's presidential debate. George W. Bush applauded the Administration's efforts in the Middle East, saying they were necessary because of US reliance on oil from the region. And Al Gore said the country should pursue energy sources and technology that are kinder to the environment. Other nations are responding in their own ways to their dependence on fossil fuels. In the second story of our four-part series, The Worlds Odilon Couzin tells us about China's efforts to expand its use of water power.

The Eastern Chinese city of Hangzhou has long been famed for its beauty and lakes -- more than 700 years ago, Marco Polo called it one of the most splendid cities in the world. Now, like most Chinese cities, Hangzhou suffers from the ill effects of rapid industrial growth.

An old coal-fired power plant looms over one city neighborhood, keeping the sky a uniform grey. Factories and a quickly growing fleet of cars and trucks -- many with little or no pollution controls -- make the roadside air almost unbreathable.

The Chinese government is trying to combat the pollution problem: It’s passed regulations on everything from catalytic converters to Styrofoam lunch containers, and across the country aggressive reforestation projects are underway, but in most cities, including Hangzhou, change has been slow.

Drive 50 miles outside of Hangzhou and the air quality improves dramatically and that's not just because you're in the countryside.

Shen Shunchu (in Chinese with translation): Nearby villages used to depend on wood for power, which created both deforestation and heavy pollution. Hydropower is a clean solution, and fits into the government's new push for environmental protection.

Shen Shunchu is the assistant director of the sprawling Moganshan reservoir and hydro-electric power plant. It not only generates electricity but provides drinking water for surrounding villages and towns.

Inside, the plant is surprisingly small. A single room houses the facility's lone turbine, and the operations -- largely automated -- are monitored from a small adjoining control room. Shen Chuqing is in charge of engineering at the power plant and says the simple-looking operation is actually a state of the art small hydro facility. It was completely overhauled last year.

Shen says with the new equipment they've almost doubled electricity production, and now only need half the staff. They expect to pay back the cost of the new equipment within a few years, and whatever's left will go into maintaining the small nature reserve surrounding the reservoir. The new equipment was provided by the East Asian Regional Center for Small hydropower, a government-run agency back in Hangzhou that promotes small hydro projects in China.

The center is part of a new trend here: investing in clean power. The government recently poured an estimated $7 billion into the research and construction of small hydro projects. Those projects now provide nearly a hundred million Chinese villagers with electricity.

Developing clean power sources is an urgent priority for China. Its impressive economic growth has relied almost entirely on dirty power like coal and wood, and the cost has been quality of life. The director of the Hangzhou Center Liu Yong, says everything from lung disease to increased flooding can be blamed on deforestation and air pollution, and that small hydro is a cheap, clean alternative.

Liu: We need power to keep growing the economy. In the countryside, if they don't have hydropower they have to rely on burning coal or trees, because they need power. But with electricity they can both protect the environment and have cheap dependable power.

But clean power for China is not only a Chinese concern. The US department of Energy has been trying to help the Chinese government move over to sustainable energy, including small hydro. US department of Energy researcher Debra Lew helped host a recent conference on renewable energy in Shanghai. Lew says China is especially well-suited to small hydro. It's home to three of the world's longest rivers, and much of China's history has been spent trying to contain those rivers. With its low start-up costs, many here say small hydro not only provides much-needed energy, but also holds out hope of finally harnessing the rivers' power.

Lew: Small hydro is actually one of the huge success stories of China. China's been, they're very successful in lots of renewable energy programs...but especially in small hydro, probably more so than in any other country...they've got quite a bit of capacity to design, build, install, operate and maintain small hydro, and they export it to other countries.

But Lew admits that China has a long way to go before it outgrows its reliance on coal, which still accounts for two-thirds of China's power. And until recently, China concentrated on nuclear or large hydropower as substitutes.

Critics say China's success with small hydro is deceptive and future plans unrealistic. They claim the Chinese government isn't pursuing hydropower in a renewable fashion; instead it's concentrating on huge money-draining projects like the Three Gorges Dam. That dam will be the world's largest when it's completed in 2009 -- but over a million people will be displaced in the process and hundreds of villages flooded by the dam's reservoir.

Doris Shen is the China coordinator for the California-based International Rivers Network. she says Three Gorges is eating up funds that would be better used on small hydro projects like the one near Hangzhou.

Shen: When you look at the numbers, you see that microhydro is definitely the way to go, but what you see is a trend of more money going to large hydro and the question is "Why is this happening? Why are uneconomic programs being pushed forward?"

At the Center for Small Hydro in Hangzhou, director Liu Yong agrees with at least some of the criticism. Though his center is state-run, Liu is surprisingly frank when it comes to assessing the "large hydro" projects so popular with state planners.

Liu (in Chinese with translation): Large dams may be more efficient in terms of cost per watt, but it has other costs like pollution, the dislocation of people that have to be considered. Small hydropower has much less serious impacts on local populations and ecosystems.

And the real beneficiaries of expanded hydro projects -- critics say -- are neither Chinese bureaucrats nor Chinese consumers. Again, Doris Shen of the International Rivers Network.

Shen: The era of large dam building in the US is now over, it's dead. But the industries are still around, pushing these projects and seeking market in countries like China.

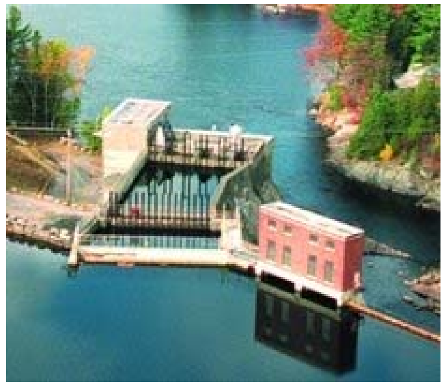
Shen says the Chinese government's mistaken policies are visible in a proposed dam project in Sichuan province, where a 2000 year old irrigation system that continues to provide water for one of the country's most fertile plains is slated to be replaced by a new and very large dam.

But there are encouraging signs for small hydro. At the Moganshan small hydro plant near Hangzhou, the staff hosts yet another visit by a group interested in reproducing such power stations across China. The central government is giving them a boost. The latest five year plan includes funding for 400 new small hydro projects.

And with only a fifth of the country's potential small hydro developed, there's still plenty of room for growth.

For The World, this is Odilon Couzin in Beijing.

Hydropower: Comparing Scale

Large Hydroelectric Plant	Small Hydroelectric generator	Micro Hydroelectric generator
		 Photo: Amber Harker
Max power output: up to 18,000 MW (predicted output of Three Gorges Dam)	Max power output: 100 kW –10 MW	Max power output: less than 100 kW
Enough to power a small American city or many small towns or contribute significantly to powering a large urban center.	Enough to power 100–10,000 typical American households. (On average, 1 MW can power 1000 American households.)	Enough to power up to 100 typical American households.
Large reservoir can be many miles in length.	Small reservoir or no reservoir necessary.	No reservoir necessary.
Many people displaced from homes.	Few or no people displaced.	No people displaced.
Major construction project	Moderate-sized construction project	Can be a home-made or a community building project.
Energy output reliable and predictable	Energy output reliable and predictable	Energy output may fluctuate with rainy/dry season changes.
Beneficial impacts beyond power generation often include flood control, irrigation and recreation opportunities.	Beneficial impacts beyond power generation sometimes include flood control, irrigation and recreation opportunities.	No further impacts besides power generation.

Your Design Challenge

Work with your group to design, prototype and market a hydropower system. Your work will demonstrate that your group has the scientific know-how to design a system that transforms the kinetic energy of flowing water into electricity. Your work should indicate the scale of the system, the necessary specifications of the hydro energy source and the energy transformations that will take place. Your design should also demonstrate that you understand the complex social, ecological and political issues that surround many large hydropower projects. Your design must take into account one or more of the concerns of the opponents of large hydropower projects.

Brainstorming Tips

- No criticism allowed! All ideas are welcome. Do not judge ideas at this stage.
- Work for quantity: aim to record 50 different ideas
- Hitch hiking is welcome: try riffing on, modifying and expanding other's ideas.
- Silly and outrageous ideas are encouraged: often the zaniest ideas contain some hint that will inspire or help solve a problem
- Use words, pictures, doodles, analogies and diagrams to describe your ideas
- If you get stuck, start another list to come up with the WORST design ideas possible

Electromagnetic Induction Exploration Worksheet

In this hands-on exploration of electromagnetic induction you will use a magnet to induce a current in a coil of copper wire, also called a solenoid, and you will use a galvanometer to measure the magnitude and the direction of the current.

Next you will make predictions about what variables will have an effect on the current; you will test these predictions and record your data.

Finally, you will describe how you will incorporate your knowledge of electromagnetic induction in the design of your hydropower system.

Follow your teacher's directions to build your circuit. The only components are wire and galvanometer.

Hold the bar magnet at the south pole. While observing the galvanometer, insert the north pole it into the solenoid and leave it there. Did the galvanometer's needle move? If so, how far did it swing? Did the needle remain at that point? Why or why not?

Now retract the magnet, removing it from the solenoid, while observing the galvanometer. Did the needle move? If so, what were the magnitude and the direction? Was it the same or different than when you inserted the magnet?

What is the galvanometer measuring? Brainstorm a list of variables that you think might have an effect on the magnitude and direction of the current through this circuit.

List variables you wish to test in the left column, record your hypotheses, or your predictions about what effect each variable will have on the current. Test your hypotheses, observe the galvanometer and record the data and any other observations that you make.

variable	hypotheses	current magnitude	current direction	observations
Speed of Magnet (Fast)				
Speed of Magnet (Slow)				

Conclusions:
Which variables have the greatest effect on induction of current?
How will you incorporate this knowledge into the design of your hydropower system?