Hidden Relationships: Energy Sources and Water Usage

INTRODUCTION

Every source of human-based energy requires water during the extraction, production, processing, transportation, and consumption of energy. In this lesson, students will examine the major ways that water is utilized for a variety of energy sources. They will also participate in a photographic matching activity that compares energy usages to further understand the role water plays in energy consumption. Lastly, students will analyze the amounts of water used by various energy sources through a graphing activity.

LESSON OVERVIEW

Grade Level & Subject: Grades 9-12; Science, Social Studies and Math

Length: 1-2 classes (depending on whether activities are done as homework or in class)

Objectives:
After completing this lesson, students will be able to:

- Identify specific ways water is used in the process of providing energy for fuel and electricity.
- Match photographs of water usage to descriptions of various energy production methods.
- Graph the quantities of water used by various energy sources and compare them.

National Standards Addressed:
This lesson addresses the following National Science Education Standards from the National Academies of Science:

- **Content Standard: NS.9-12.5 SCIENCE AND TECHNOLOGY**
  As a result of their activities, students should develop an understanding of:
  - Abilities of technological design
  - Understandings about science and technology
- **Content Standard: NS.9-12.6 PERSONAL AND SOCIAL PERSPECTIVES**
  As a result of activities in grades 9-12, all students should develop understanding of
  - Personal and community health
  - Population growth
  - National Resources
  - Environmental quality
  - Natural and human-induced hazards
  - Science and technology in local, national, and global challenges

This lesson addresses the following Standards & Position Statement from the National Council for the Social Studies:

- **Content Standard: NSS-G.K-12.5 ENVIRONMENT AND SOCIETY**
  As a result of activities in grades K-12, all students should
  - Understand how human actions modify the physical environment.
  - Understand how physical systems affect human systems.
  - Understand the changes that occur in the meaning, use, distribution, and importance of resources.

This lesson addresses the following Standards for School Mathematics from the National Council of Teachers of Mathematics:

- **Content Standard: NM REPRESENTATION STANDARD FOR GRADES 9–12**
  Instructional programs from prekindergarten through grade 12 should enable all students to—
  - Create and use representations to organize, record, and communicate mathematical ideas.
  - Select, apply, and translate among mathematical representations to solve problems.
  - Use representations to model and interpret physical, social, and mathematical phenomena.
- **Content Standard: NM NUMBER AND OPERATIONS STANDARD FOR GRADES 9–12**
  Instructional programs from prekindergarten through grade 12 should enable all students to—
  - Compute fluently and make reasonable estimates.
    In grades 9–12 all students should—
    - Develop fluency in operations with real numbers, vectors, and matrices, using mental computation or paper-and-pencil calculations for simple cases and technology for more-complicated cases.

Materials Needed:

- Reproducible #1 – Energy Sources and How They Use Water
- Reproducible #2 – Energy Sources and How They Use Water Follow-up Questions
- Reproducible #3 – Energy Sources and How They Use Water Follow-up Questions ANSWER KEY and Energy Source and Water Intensity Graphic Example
- Reproducible #4 – Matching Energy Sources to Photos Challenge
- Reproducible #5 – Matching Energy Sources to Photos Challenge Answer Sheet for Students
- Reproducible #6 – Matching Energy Sources to Photos Challenge ANSWER KEY
- Reproducible #7 – Graphing Water Intensity of Energy
- Reproducible #8 – Graphing Water Intensity of Energy ANSWER KEY
- Reproducible #9 – Energy versus Water: Solving Both Crises Together
- Reproducible #10 – Energy versus Water: Solving Both Crises Together Questions
- Reproducible #11 – Energy versus Water: Solving Both Crises Together ANSWER KEY

Assessment: Students will be assessed through the following activities:

- Completion of Reproducible #1 – Energy Sources and How They Use Water.
- Completion of Reproducible #4 – Matching Energy Sources to Photos Challenge.
- Completion of Reproducible #7 – Graphing Water Intensity of Energy.
- Participation in Wrap-up discussion.

LESSON BACKGROUND

Relevant Vocabulary:

- **Carboniferous Period:** a geologic period of time that occurred about 300-345 million years ago when vast lowland swamp forests transformed over time and eventually provided the material of coal deposits that we use today.[1]
- **Coal-water Slurry:** consists of coal particles suspended in water. This can be the result of the process of washing coal into waterways;[2] sometimes coal is transported through pipelines as slurry.[3]
- **Club Moss:** a primitive vascular plant that was common during the Carboniferous Period and contributed to the coal deposits that formed at that time.[4]
- **Fossil fuel:** hydrocarbons such as coal, oil, and natural gas that formed from the remains of dead plants and animals.[5]
- **Horsetail:** primitive vascular plants that thrived during the Carboniferous Period and contributed to the coal deposits that formed at that time. There is only one remaining genus of the plant group.[6]
- **Hydropower:** works by harnessing the gravitational descent of a river that is compressed from a long run to a single location with a dam or a flume. This creates a location where concentrated pressure and flow of water can be used to turn turbines or water wheels. These can then drive an electric generator.[7]

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[1] *Carboniferous Period.* National Geographic. Retrieved 9 March 2010 from http://science.nationalgeographic.com/science/prehistoric-world/carboniferous.html.

[2] *What is Underground Coal Slurry Injection?.* Sludge Safety Project. Coal River Mountain Watch/Ohio Valley Environmental Coalition. Retrieved 12 March 2010 from http://www.sludgesafety.org/coal_slurry_inj.html.

[3] Energy Demands on Water Resources: Report to Congress on the Interdisciplinary of Energy and Water. River Network/U.S. Department of Energy. December 2006, page 55. Retrieved 10 March 2010 from http://www.rivernetwork.org/resource-library/energy-demands-water-resources.

[4] *Club Moss.* The Columbia Encyclopedia 6th edition, 2008. Retrieved 12 March 2010 from http://www.encyclopedia.com/topic/club_moss.aspx.

[5] *Fossil Fuel.* Science Daily. Retrieved 9 March 2010 from http://www.sciencedaily.com/articles/f/fossil_fuel.htm.

[6] *Horsetail.* The Columbia Encyclopedia 6th edition, 2008/ Retrieved 12 March 2010 from http://www.encyclopedia.com/topic/horsetail.aspx.

[7] *Hydro power Entry.* About.com Physics. Retrieved 12 March 2010 from http://saveenergy.about.com/od/alternativeenergysources/a/altenergysource_2.htm.

- **Kilowatt Hour (kWh):** the amount of energy that would be transferred at a constant rate of one kilowatt for one hour.[8]
- **Megawatt (MW):** a unit for measuring power that is equivalent to one million watts.[9]
- **MWh:** one megawatt hour of electric energy.[10]
- **Noncombustible**: The property of a material to withstand high temperature without ignition.[11]
- **Nuclear Energy:** energy that is released through the process of fission, the splitting of atoms to release energy from the atomic nucleus;[12] power generated by a nuclear reactor or apparatus in which fissile material can be made to undergo a controlled, self-sustaining nuclear reaction releasing energy.[13]
- **Nuclear Fission:** a nuclear reaction in which a large nucleus such as uranium is split, forming two smaller nuclei. This process releases energy and sometimes radioactive particles.[14]
- **Oil Refinery:** An industrial plant for purifying crude oil.[15]
- **Reservoir:** a body of water collected and stored in a natural or artificial lake.[16]
- **Solar Power:** electricity generated from the natural energy (radiation) in sunlight.[17]
- **Thermoelectric Power:** electricity produced by a generator that converts heat into electricity.[18] Thermoelectric generators receive heat from a variety of sources including coal, natural gas, nuclear, oil, biomass, concentrated solar, and geothermal energy.[19]
- **Tree Fern:** any of various treelike tropical ferns, especially of the family Cyatheaceae, having a woody, trunk like stem and a terminal crown of large divided fronds.[20]

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8 *Killowat Definition,* About.com. Retrieved 10 March 2010 from http://saveenergy.about.com/od/energyefficientappliances/g/kilowatt_def.htm.

9 *Megawatt.* About.com. Retrieved 12 March 2010 from http://saveenergy.about.com/od/alternativeenergysources/g/Megawatt.htm.

10 Energy Demands on Water Resources: Report to Congress on the Interdisciplinary of Energy and Water. River Network/U.S. Department of Energy. December 2006, page 6. Retrieved 10 March 2010 from http://www.rivernetwork.org/resource-library/energy-demands-water-resources.

11 *Non combustible.* About.com Physics. Retrieved 12 March 2010 from http://composite.about.com/library/glossary/n/bldef-n3621.htm.

12 *Nuclear Energy,* Wordnet Princeton. Retrieved 10 March 2010 from http://wordnetweb.princeton.edu/perl/webwn.

13 *Nuclear Power.* Oxford English On line Dictionary. Retrieved 12 March 2010 from http://www.askoxford.com/concise_oed/orexxactor?view=uk.

14 *Nuclear Fission.* About.com Physics. Retrieved 12 March 2010 from http://physics.about.com/od/glossary/g/nuclearfission.htm.

15 *Oil Refinery*. The American Heritage Dictionary. 4th ed. 1981.

16 *Reservoir Entry*. The American Heritage Dictionary. 4th ed. 1981.

17 *Solar Power.* Clean Energy Ideas. Retrieved 12 March 2010 from http://www.clean-energy-ideas.com/articles/what_is_solar_power.html.

18 *Thermoelectric Power.* Britannica Online. Retrieved 14 March 2010 from http://www.britannica.com/EBchecked/topic/591615/thermoelectric-power-generator.

19 *Thermoelectric Power.* Energy Demands on Water Resources: Report to Congress on the Interdisciplinary of Energy and Water. River Network/U.S. Department of Energy. December 2006, page 18. Retrieved 10 March 2010 from http://www.rivernetwork.org/resource-library/energy-demands-water-resources.

20 *Tree Fern Entry*. The American Heritage Dictionary. 4th ed. 1981.

- **Water Intensity of Energy:** is the total amount of water, calculated on a whole-system basis, required for the generation of electricity; often expressed as the number of gallons of water required to produce one Megawatt of electricity and is expressed as gal/MWh.[21]

Information:

When people turn on a light switch or charge their cell phone, they may ponder how much energy they use, but they are probably not thinking about the water used to generate the electricity! Water usage in the production of energy is an often not clear to consumers, but massive quantities of water are used. Water is utilized in the process of extracting fuels such as coal, natural gas and uranium. It is also employed in some steps of processing, such as in an oil refinery. Power plants with turbines often need large quantities of water to produce steam and to condense steam back into liquid water.

How water is used and where it ends up varies considerably from one source of energy to another. Sometimes it is withdrawn from a source, such as a river, then used in a power plant and returned to the river at a higher temperature. This is true of open loop nuclear power plants. Closed loop systems withdraw far less water, but much of it is lost to the atmosphere through evaporation.

A growing population means a rising demand on energy. Increased demand for energy means greater quantities of water being used. Already, there are significant water shortages and challenges in several parts of the United States and world. Water shortages can cause a reduction in the amount of energy being produced and a higher cost for both water and energy. As a result, water and energy are inextricably linked.

Resources:

- "Energy Demands on Water Resources: Report to Congress on the Interdependency of Energy and Water." U.S. Department of Energy. December 2006. http://www.rivernetwork.org/resource-library/energy-demands-water-resources.
- "Alternative Energy Projects Stumble on a Need for Water." *The New York Times*. September 29, 2009.
- "Energy Demands on Water Resources: The Federal Perspective." Southwest Hydrology, University of Arizona. September/October 2007. http://www.swhydro.arizona.edu/archive/V6_N5/feature2.pdf.
- "Carboniferous Period." National Geographic. http://science.nationalgeographic.com/science/prehistoric-world/carboniferous.html.
- "Energy versus Water: Solving Both Crises Together." Excerpted from Scientific American Special Editions. October 22, 2008. http://www.scientificamerican.com/article.cfm?id=the-future-of-fuel.

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[21] "Integrated Water and Energy Policies," Agriculture and Natural Resources - University of California Water Resources Coordinating Conference, April 19, 2007. Retrieved 17 March 2010 from http://groups.ucanr.org/waterquality/documents/2007_Water_Resources_Coordinating_Conference11456.pdf.

LESSON STEPS

Warm Up: ***Introduction to Water in Energy Sources***

1. Start this lesson by reading the statements below. Students should decide if they think they are true or false. Ask students to raise their hands to indicate their answers.
    a. Nuclear power plants use a substantial amount of water in the process of making electricity. *True.*
    b. Coal power plants use a substantial amount of water in the process of making electricity. *True.*
    c. Solar power plants use a substantial amount of water in the process of making electricity. *True.*

2. Ask which of these three energy sources they think uses the most water. Then, explain that in this lesson they will examine the answers to this question and more concerning electricity generation and water usage.

Activity One: ***How Do Our Sources of Energy Use Water?***

1. Pass out copies of Reproducible #1 – Energy Sources and How They Use Water and Reproducible #2 – Energy Sources and How They Use Water Follow-up Questions. Explain to students that this assignment provides background information on various sources of energy including the fuels we use (coal, natural gas and oil) and the energy sources used to produce electricity (nuclear fission, coal and natural gas, hydropower and solar). Each of these sources of energy uses water at various steps, and the major uses of water are outlined.

2. Ask students to read the background and then answer the follow-up questions. They can do this in class or as a homework assignment.

Activity Two: ***Energy-Water Photo Matching Game***
By playing a photo matching game, the sources of energy and uses of water will become more concrete to students.

1. Pass out copies of Reproducible #4 – Matching Energy Sources to Photos Challenge and Reproducible #5 – Matching Energy Sources to Photos Challenge Answer Sheet. Explain to your students that they will be matching each photo to one of the explanations, which are lettered. These photos will help them to better visualize each source of energy and some of the ways water is used in the production process. This could be done as a homework assignment, but would probably work best in class with students working in small groups.

2. Review the answers as a class.

Activity Three: ***Comparing Water Use and Energy Sources: A Graphing Activity***

1. Pass out copies of Reproducible #7 – Graphing Water Intensity of Energy. Explain to students that they will be graphing the intensity of water usage of different sources of energy. Water Intensity Energy is the total amount of water, calculated on a whole-system basis, required for the generation of electricity; often expressed as the number of gallons of water required to produce one Megawatt of electricity and is expressed as gal/MWh.[22]

2. Let your students know whether you would like them to graph the data by hand or by using your preferred graphing software program. This can be done in class or as a homework assignment.

3. Go over the answers to the worksheet as a class. Then, use the following questions to close the activity:
    1. What results surprised you?
    2. What questions did this raise in your mind?
    3. What challenges do you think our society might face as we seek to produce more energy for a growing population?

Wrap Up: *Energy, Water and Your Future Productivity*

1. Ask students how the use of water during the production of energy is connected to future productivity (their own, in the region, in the U.S. and globally).
    a. How does the population of an area relate to water and energy? *A growing population will require larger amounts of energy to be produced, and this will require larger quantities of water to be used.*
    b. How does natural resource distribution relate to energy? *Water is already a limited resource in several parts of the United States and world. Limited water can result in limited energy.*
    c. How does resource limitation relate to productivity? W*ater shortages and/or the rising cost of water are inhibitive to productivity in the affected region or area. This could also result in a rising cost of energy sources that use large amounts of water.*

Extension:

1. Make copies of Reproducible #9 – Energy versus Water: Solving Both Crises Together and Reproducible #10 – Energy versus Water: Solving Both Crises Together Questions. Ask students to read the article and answer the questions as homework. Then facilitate a discussion using the questions on Reproducible #10.
    a) Why did the state of Florida plan to sue the U.S. Army Corps of Engineers for its plan to reduce water from Georgia reservoirs? *The reservoir water runs into the Apalachicola River, which flows through Florida. Florida was concerned that less water flow would threaten certain endangered species.*
    b) Why did the state of Alabama object to the Corps' plan? *The reduced flow of water might shut down a nuclear power plant in Alabama.* Why would the nuclear power

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[22] "Integrated Water and Energy Policies," Agriculture and Natural Resources - University of California Water Resources Coordinating Conference, April 19, 2007. Retrieved 17 March 2010 from http://groups.ucanr.org/waterquality/documents/2007_Water_Resources_Coordinating_Conference11456.pdf.

plant be threatened? *It uses vast amounts of water from the Apalachicola River for cooling to help condense steam back into liquid water.*

c) To what lengths might Georgia be willing to go to guarantee freshwater? *Georgia has considered moving its northern border one mile farther north to access freshwater resources now located in Tennessee.*

d) What is causing a shortage of water in the south? *A rapidly growing population, drought, overdevelopment, and a lack of planning for broader water conservation.*

e) What is the paradox the author describes on the first page? *When water is limited, less energy can be produced; rising energy costs are hurting efforts to supply even greater amounts of clean water.*

f) What is an example of this paradox if Lake Mead in Nevada continues to be lowered? *Las Vegas would have to ration water use and the Hoover Dam might not be able to produce much energy, limiting electricity to Las Vegas.*

g) Why are activists fighting a plan in San Diego to construct a desalination plant (a plant that removes salt from salt water to produce fresh water)? *Desalination plants use a lot of energy and the supply of energy is already stretched thin.*

h) What does the author think the solution to the water-energy paradox requires? *New national policies that integrate energy and water solutions; innovative technologies that help to boost one resource without draining the other.*

i) Why is trucking water to water-stressed areas and cleaning dirty water supplies not the best solutions for providing clean water to water-stressed areas? *Both use a large amount of energy. Energy can be in limited supply and is costly.*

j) What are the two greatest users of freshwater in the United States? *Agriculture and power plants.*

k) Which of the two resources—water or energy—does the author think is ultimately more important and why? *He feels water is more important because it is more immediately crucial for life and there is no substitute for it.*

CONCLUSION

Students examined specific ways water is used in the process of extracting, processing, generating, transporting and consuming various sources of energy. By playing a matching game using photos of energy sources and processes, they were able to more concretely visualize the steps in extraction, processing, and generation of energy. After graphing data on water intensity of different forms of energy, they compared which use the most water per megawatt of electricity generated. Finally, they considered how the use of water during energy production is connected to future productivity.

LESSON PLAN CREDITS

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Energy Sources and How They Use Water

Directions: Please read the following background information. It describes the major ways that water is used to extract, process, transport, and generate the energy that we use everyday – whether it be the energy in the fuel that runs our vehicles or in the electricity that lights our homes. There are many other ways that water is used than those described here, but this activity outlines the most significant uses of water. When you are done reading, please answer the follow-up questions.

FOSSIL FUELS:

Coal, natural gas and oil are examples of fossil fuels. They are called "fossil fuels" because they are made of carbon formed from the remains of dead plants and animals millions of years ago.[23] For example, much of the coal we burn today formed during the Carboniferous Period 300-350 million years ago. The carbon that formed during the Carboniferous Period came mostly from bark-bearing trees that grew in vast lowland swamp forests.[24] To give you a sense of how long ago this was, 350 million years ago the continents were in very different locations than they are now. What is now North America was back then attached to Northern Europe and Greenland. Other land masses formed a giant continent known as "Gondwana." [25] What plants were growing at this time on planet Earth? Giant club mosses, tree ferns, great horsetails and towering trees, now extinct. Just as you may burn logs to make a campfire, when we burn fossil fuels we are burning ancient organisms that died millions of years ago.

How is water used when we extract and process coal? Coal is mined from under or on the Earth's surface. Coal that is removed from the underground is typically cut with large saw-like devices. This process requires water to cool the equipment. Many unpaved roads are created to extract coal from the surface. Water is often sprayed on these roads to suppress dust.[26] If you have ever driven on a dirt road, you may know how dust can be irritating to breathe and make it difficult to see! Some coal is washed to increase the heat content. Washing removes noncombustible sulfur from the coal.[27] When surface mines are closed, they must be re-planted with vegetation and this requires watering. Finally, coal may be transported by river barge, train or transported by pipeline in the form of coal-water slurry.[28]

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23 *Fossil Fuel.* Science Daily. Retrieved 9 March 2010 from http://www.sciencedaily.com/articles/f/fossil_fuel.htm.

24 *Carboniferous Period.* National Geographic. Retrieved 9 March 2010 from http://science.nationalgeographic.com/science/prehistoric-world/carboniferous.html.

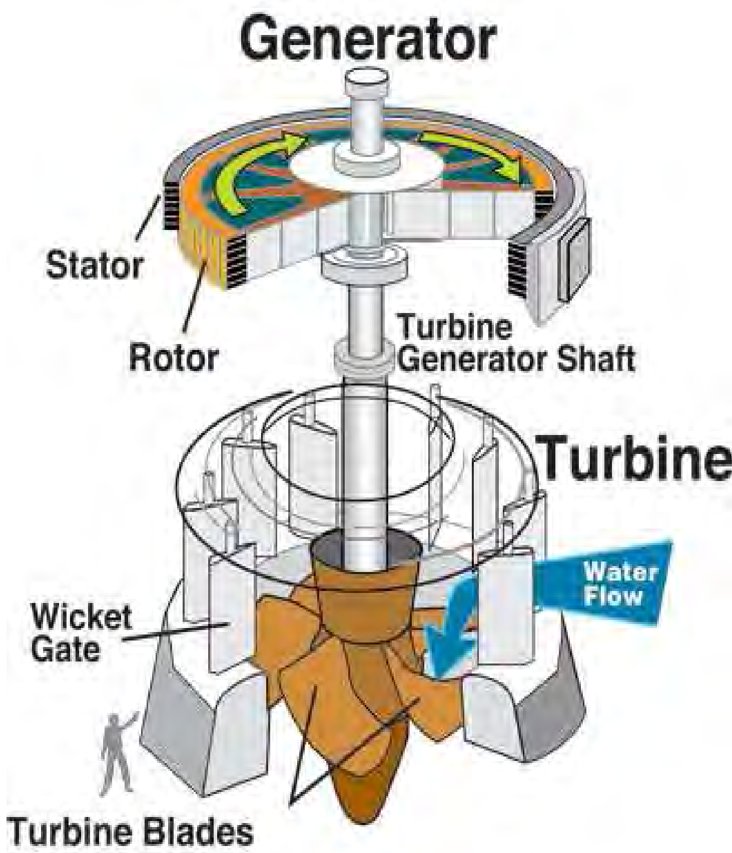
25 *Carboniferous Period.* National Geographic. Retrieved 9 March 2010 from http://science.nationalgeographic.com/science/prehistoric-world/carboniferous.html.

26 Energy Demands on Water Resources: Report to Congress on the Interdisciplinary of Energy and Water. River Network/U.S. Department of Energy. December 2006, page 53. Retrieved 10 March 2010 from http://www.rivernetwork.org/resource-library/energy-demands-water-resources.

27 Energy Demands on Water Resources: Report to Congress on the Interdisciplinary of Energy and Water. River Network/U.S. Department of Energy. December 2006, page 53. Retrieved 10 March 2010 from http://www.rivernetwork.org/resource-library/energy-demands-water-resources.

28 Energy Demands on Water Resources: Report to Congress on the Interdisciplinary of Energy and Water. River Network/U.S. Department of Energy. December 2006, page 55. Retrieved 10 March 2010 from http://www.rivernetwork.org/resource-library/energy-demands-water-resources.

How is water used when extracting oil and natural gas? When oil and gas are extracted onshore, water or steam is injected into the well to displace and move the oil or gas to nearby wells. Oil refineries are large industrial complexes, and they use water in the process of refining crude oil (the oil taken out of the ground) into useful products such as gasoline, diesel fuel, heating oil and kerosene.[29] A great deal of water is used in electric power plants that run on fossil fuels. This process is described below.



ELECTRIC POWER GENERATION:

About 80% of the electricity generated in the United States is produced in power plants that use fossil fuels or nuclear power to generate the power.[30] These power plants are also called "thermoelectric" generating plants.[31]

How is water used to generate electricity, whether through fossil fuels or nuclear power? Both of these methods of electricity generation require a turbine (see image of Hydro turbine).[32] The turbine is connected to a generator that produces electricity when the turbine spins. What spins the turbine? This is where water comes in! When water is turned to steam, the steam causes the turbine to spin. Of course, water must be heated to turn into steam. In nuclear power plants, the energy to heat the water comes from the process of nuclear fission. In fossil fuel plants, coal or natural gas are burned to heat the water. Later, the steam must be condensed back into water. This means the water must be cooled again, and this is often done with vast quantities of chilled water! This is why electric power plants are often located on bodies of water such as rivers. Some plants pull or withdraw the water and then return the warmer water to the river after usage. Other plants withdraw less water from the river, but return most of it to the atmosphere through evaporation.[33]

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[29] *Oil Refineries.* Energy Kids/U.S. Energy Information Administration. Retrieved 11 March 2010 from http://tonto.eia.doe.gov/kids/energy.cfm?page=oil_home-basics.

[30] Energy Demands on Water Resources: Report to Congress on the Interdisciplinary of Energy and Water. River Network/U.S. Department of Energy. December 2006, page 63. Retrieved 10 March 2010 from http://www.rivernetwork.org/resource-library/energy-demands-water-resources.

[31] Energy Demands on Water Resources: Report to Congress on the Interdisciplinary of Energy and Water. River Network/U.S. Department of Energy. December 2006, page 63. Retrieved 10 March 2010 from http://www.rivernetwork.org/resource-library/energy-demands-water-resources.

[32] *Hydro turbine.* U.S. Department of the Interior/U.S. Geological Survey. Retrieved 8 March 2010 from http://ga.water.usgs.gov/edu/graphics/hydroturbine.jpg.

[33] Energy Demands on Water Resources: Report to Congress on the Interdisciplinary of Energy and Water. River Network/U.S. Department of Energy. December 2006, page 63 and 66. Retrieved 10 March 2010 from http://www.rivernetwork.org/resource-library/energy-demands-water-resources.

How is water used to produce solar electricity? When you see solar panels on the roof of a building or nearby, water is not being used in the process of generating electricity. A surprising amount of water can be used, however, in a power plant that generates most of its electricity through solar panels. Just like a nuclear power or fossil-fuel power plant, solar power plants require a turbine to spin. A fluid is heated and used to create steam to drive the turbine, but as you learned above, the steam must be condensed back into water and cooled for reuse. With concentrated solar power, a form of solar power that requires oftentimes thousands of mirrors concentrating the sun's heat onto a small coil of fluid (usually a fossil fuel based entity), water is required again in vast amounts to cool the overall process.

How is water used to produce hydropower? Hydropower uses the force of falling water to make electricity. Dams are built on streams or rivers to make a lake or reservoir, or they can be dug with equipment and filled over time by rainwater. When water is released at the dam, the water falls with great speed to turn the turbines, which are in turn connected to the generator. Hydropower supplies a significant fraction of the total energy used in the United States (ranging from 5.8% -10.2%).[34] Most water loss is through evaporation, and this is most significant on large storage reservoirs.

[34] Energy Demands on Water Resources: Report to Congress on the Interdisciplinary of Energy and Water. River Network/U.S. Department of Energy. December 2006, page 67. Retrieved 10 March 2010 from http://www.rivernetwork.org/resource-library/energy-demands-water-resources.

Energy Sources and How They Use Water
Follow-up Questions

Name: ___________________________
Date: ____________________________

1. Why are fossil fuels called 'fossil' fuels?

2. Give three examples of fossil fuels.

3. List three ways water is used in the extraction and processing of fossil fuels.

4. What are the two major uses of water when generating electricity in a power plant, whether in a nuclear, fossil fuel, or solar power plant?

5. What is the most significant loss of water in hydropower?

6. Which energy sources do you think use the most water? (You'll find out later in this lesson!) Rate them below with #1 using the most water.

   _____ Coal (all steps of the process)

   _____ Natural gas and oil (all steps of the process)

   _____ Hydropower

   _____ Nuclear power

   _____ Photovoltaic Solar power

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Energy Sources and How They Use Water
Follow-up Questions – Answer Key

Name: ____________________________
Date: _____________________________

7. Why are fossil fuels called 'fossil' fuels? *They are made of ancient or fossilized plants and animals – mostly from the carbon in ancient trees and plants.*

8. Give three examples of fossil fuels. *Coal, natural gas and oil*

9. List three ways water is used in the extraction and processing of fossil fuels. *Extracting coal, suppressing dust on mining roads and watering vegetation when closed surface mines are re-planted.*

10. What are the two major uses of water when generating electricity in a power plant, whether in a nuclear, fossil fuel, or solar power plant? *1. Creating steam to turn the turbine; 2. Most water is used to condense the steam back into liquid water.*

11. What is the most significant loss of water in hydropower? *Evaporation of water in large reservoirs.*

12. Which energy sources do you think use the most water? (You'll find out later in this lesson!) Rate them below with #1 using the most water. *From least to greatest, solar, natural gas and oil, coal, nuclear power, hydropower.*

__3__ Coal (all steps of the process)
__4__ Natural gas and oil (all steps of the process)
__1__ Hydropower
__2__ Nuclear power
__5__ Photovoltaic Solar power

Matching Photos to Energy Sources Challenge

Photo A.[35]

Photo B.[36]

[35] "Old Nodding donkey, close to Hemmingstedt, Dithmarschen." Franke, Dirk Ingo. May 2005.
[36] Codrington, Stephen. *Surface Coal Mine.* Planet Geography 3rd Edition, 2005.

Photo C.[37]

Photo D.[38]

[37] *Spraying Water in Underground Coal Mine.* National Institute for Occupational Safety and Health. Retrieved 7 March 2010 from http://www.cdc.gov/niosh/nas/mining/whatis-history.htm.
[38] *Kashiwazaki-Kariwa nuclear power plant in Japan.* International Atomic Energy Agency. Retrieved 8 March 2010 from http://www.iaea.org/NewsCenter/News/2010/protectnpp.html.

Photo E.[39]

Photo F.[40]

[39] *Crude Oil.* The Association for Science Education. Retrieved 09 March 2010 from http://resources.schoolscience.co.uk/SPE/knowl/4/2index.htm?crude.html.
[40]Delano, Jack. *U.S. Library of Congress Prints and Photographs Division*. January 1940.

Photo G.[41]

Photo H.[42]

[41] Small Hydropower Plant. September 29, 2006.
[42] *Coal Cutting*. AMC Consultants. Retrieved 11 March 2010 from http://www.amcconsultants.ca/images/services/Coal.jpg.

Photo I. [43]

Photo J. [44]

[43] *Mining Uranium*. International Atomic Energy Agency. Retrieved 8 March 2010 from http://www.iaea.org/NewsCenter/News/2008/uraniumreport.html.
[44] National Renewable Energy Laboratory. United States Department of Energy.

Photo K.[45]

Photo L. [46]

[45] *Underground Coal Mine*. Michigan Technological University. Retrieved 11 March 2010 from http://techalive.mtu.edu/meec/module19/images/UndergroundCoalMining.jpg.
[46] Aerial photo of the Gösgen Nuclear Power Plant from the south-west. Aare-Tessin Ltd. for Electricity.

Photo M.[47]

Photo N.[48]

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[47] *Offshore Oil Rig.* Vũng Tàu, Vietnam.
[48] H.C. White Co. PD- US GOV. c. 1907. Retrieved 11 March 2010 from http://hdl.loc.gov/loc.pnp/cph.3b42962.

Photo O.[49]

Photo P.[50]

[49] Siegmund, Walter. Anacortes Refinery (Tesoro Corporation).
[50] *Coal Washing Plant. Ames Laboratory/U.S. Department of Energy/Iowa State University.* Retrieved 11 March 2010 from http://www.ameslab.gov/60thanniversary/1970.html.

Photo Q.[51]

[51] Paul, Arnold. Coal power plant in Datteln (Germany) at the Dortmund-Ems-Kanal. April 5, 2006.

Matching Photos to Energy Sources Challenge
Answer Sheet

Name: ____________________________________

Date: _____________________________________

Directions: For each of the descriptions listed below, give the letter of the photograph that matches it.

_____ Cutting coal

_____ Coal fired power plant

_____ Nuclear power plant showing source of cooling water and evaporated water

_____ Concentrated solar power plant with power generating station

_____ Oil refinery

_____ Surface coal mine

_____ Transporting coal

_____ Uranium being mined for nuclear power

_____ Underground coal mine

_____ Hydropower plant

_____ Crude oil

_____ Offshore oil rig

_____ Suppressing coal dust in underground mine

_____ Natural gas plant

_____ Onshore oil rig

_____ Coal barge transporting coal

_____ Coal washing plant

Matching Photos to Energy Sources Challenge

Answer Key

Name: ___________________________________

Date: ____________________________________

Directions: For each of the descriptions listed below, give the letter of the photograph that matches it.

__H.__ Cutting coal

__Q.__ Coal fired power plant

__L.__ Nuclear power plant showing source of cooling water and evaporated water

__J.__ Concentrated solar power plant with power generating station

__O.__ Oil refinery

__B.__ Surface coal mine

__N.__ Transporting coal

__I.__ Uranium being mined for nuclear power

__K.__ Underground coal mine

__G.__ Hydropower plant

__E.__ Crude oil

__M.__ Offshore oil rig

__C.__ Suppressing coal dust in underground mine

__D.__ Natural gas plant

__A.__ Onshore oil rig

__F.__ Coal barge transporting coal

__P.__ Coal washing plant

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Graphing Water Intensity in Energy

Name: ___________________________________

Date: ____________________________________

1. The table below shows how many gallons of water are needed to produce one Megawatt hour of electricity for each source of energy.[52] This is known as "water intensity" and is expressed as gal/MWh. Graph the data and attach your graph to this sheet. Then use your graph to answer the questions.

Energy Source	**Water Intensity (gal/MWh)**
Hydro	4500* gallons
Coal	657 gallons
Coal with slurry	877** gallons
Nuclear Power (open loop***)	43,027 gallons
Nuclear Power (closed loop****)	1797 gallons
Solar*****	1508 gallons
Natural Gas (open loop***)	13,858 gallons
Natural Gas (closed loop****)	418 gallons

*average; most of this water is evaporated
**coal-water slurry is sometimes used for transporting coal through pipelines
***open loop systems use large amounts of water for cooling, but much of the water is returned to its source but at a warmer temperature
****closed loop systems don't require a large inflow of water for cooling, but much of the water that is used evaporates and is returned to the atmosphere rather than the original source
*****solar tower rather than solar trough

2. Which three sources of energy account for the greatest loss of water by evaporation?

3. In energy sources not dominated by water evaporation, what are the top three consumers of water, in order?

4. How many times greater is the water intensity of coal when it is transported as slurry through pipelines than when it is not?

5. How many times greater is the water intensity of solar power plants than coal (without a coal-water slurry)?

[52] http://www.rivernetwork.org/resource-library/energy-demands-water-resources, p. 38. When a range of gallons was given, the median number of gallons of water was calculated at each step of the process.

6. How many times greater is the water intensity of nuclear power (open loop) than solar power?

7. As you have learned, nuclear power plants are often located on rivers so they can easily obtain large quantities of water. Can you think of a natural scenario that would challenge a nuclear power plant's ability to function with its great need for water?

8. Can you think of a natural scenario that might challenge the ability of concentrated solar power plants to function? (Hint: Think about the likely location of most concentrated solar power plants in the United States.)

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Graphing Water Intensity in Energy – Answer Key

Name: ___________________________________

Date: ____________________________________

1. The table below shows how many gallons of water are needed to produce one Megawatt hour of electricity for each source of energy.[53] This is known as "water intensity" and is expressed as gal/MWh. The table below shows how many gallons of water are needed to produce one Megawatt hour of electricity for each source of energy.[54] This is known as "water intensity" and is expressed as gal/MWh. Graph the data and attach your graph to this sheet (an example is provided on the next page). Then use your graph to answer the questions.

Energy Source	Water Intensity (gal/MWh)
Hydro	4500* gallons
Coal	657 gallons
Coal with slurry	877** gallons
Nuclear Power (open loop***)	43,027 gallons
Nuclear Power (closed loop****)	1797 gallons
Solar*****	1508 gallons
Natural Gas (open loop***)	13,858 gallons
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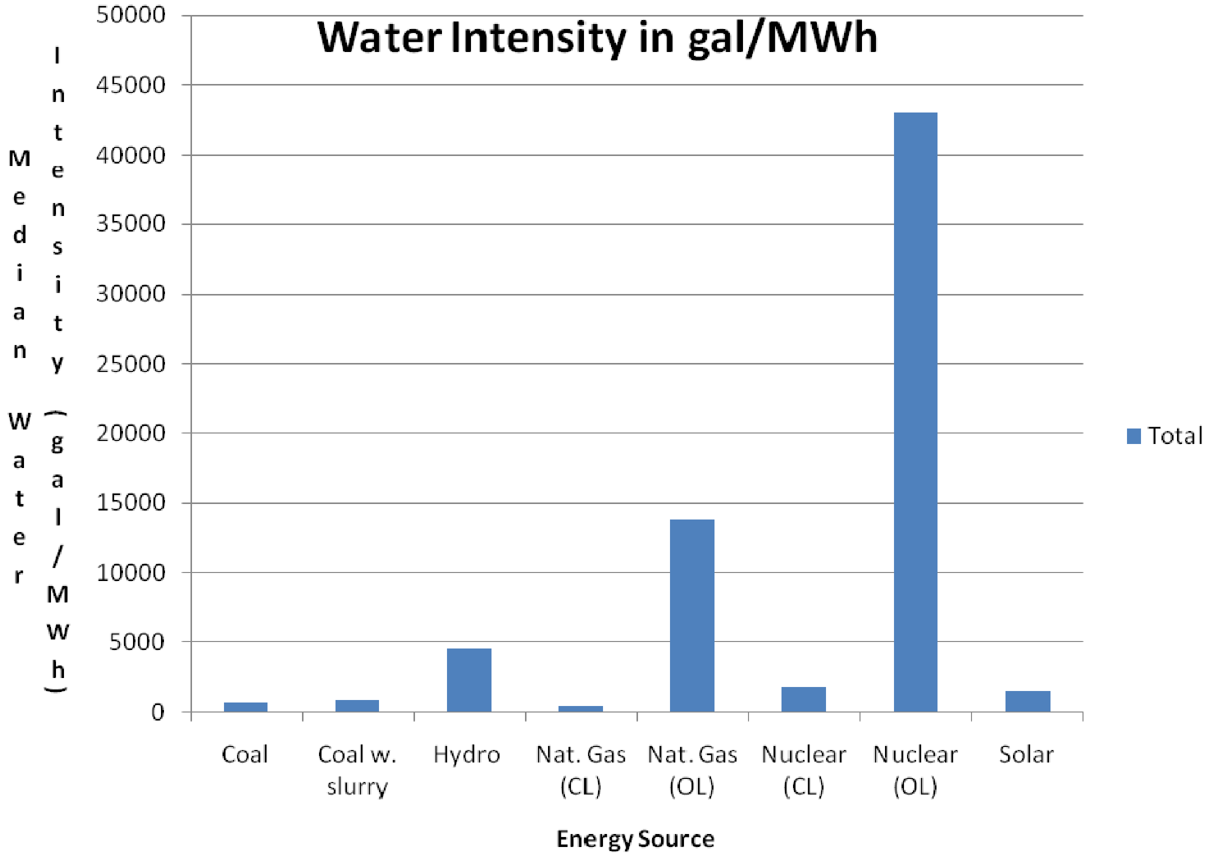
*average; most of this water is evaporated
**a coal-water slurry is sometimes used for transporting coal through pipelines
***open loop systems use large amounts of water for cooling, but much of the water is returned to its source but at a warmer temperature
****closed loop systems don't require a large inflow of water for cooling, but much of the water that is used evaporates and is returned to the atmosphere rather than the original source
*****solar tower rather than solar trough

[53] http://www.rivernetwork.org/resource-library/energy-demands-water-resources, p. 38. When a range of gallons was given, the median number of gallons of water was calculated at each step of the process.

[54] http://www.rivernetwork.org/resource-library/energy-demands-water-resources, p. 38. When a range of gallons was given, the median number of gallons of water was calculated at each step of the process.

Energy Source and Water Intensity Graphic Example[55]



2. Which three sources of energy account for the greatest loss of water by evaporation? *Nuclear power open loop systems, natural gas open loop systems and hydropower.*

3. In energy sources not dominated by water evaporation, what are the top three consumers of water, in order? *Nuclear power closed loop systems, concentrated solar power plants and coal.*

4. How many times greater is the water intensity of coal when it is transported as slurry through pipelines than when it is not? *877/657 = 1.33 times greater.*

5. How many times greater is the water intensity of solar power plants than coal (without a coal-water slurry)? *1508/657 = 2.3 times greater.*

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[55] http://www.rivernetwork.org/resource-library/energy-demands-water-resources, p. 38.

6. How many times greater is the water intensity of nuclear power (open loop) than solar power? *43,027/1508 = 28.5 times greater.*

7. As you have learned, nuclear power plants are often located on rivers so they can easily obtain large quantities of water. Can you think of a natural scenario that would challenge a nuclear power plant's ability to function with its great need for water? *A drought might draw the river level down so much that there isn't enough water for the power plant to function.*

8. Can you think of a natural scenario that might challenge the ability of concentrated solar power plants to function? (Hint: Think about the likely location of most concentrated solar power plants in the United States.) *Many solar power plants would be best placed in the desert southwest, where there is little rain and where ground water is already in high demand by large population centers and agriculture.*

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Energy versus Water: Solving Both Crises Together

Excerpted from *Scientific American Special Editions*
(http://www.scientificamerican.com/article.cfm?id=the-future-of-fuel) - October 22, 2008

Water is needed to generate energy. Energy is needed to deliver water. Both resources are limiting the other—and both may be running short. Is there a way out?

By Michael E. Webber

In June the state of Florida made an unusual announcement: it would sue the U.S. Army Corps of Engineers over the corps's plan to reduce water flow from reservoirs in Georgia into the Apalachicola River, which runs through Florida from the Georgia-Alabama border. Florida was concerned that the restricted flow would threaten certain endangered species. Alabama also objected, worried about another species: nuclear power plants, which use enormous quantities of water, usually drawn from rivers and lakes, to cool their big reactors. The reduced flow raised the specter that the Farley Nuclear Plant near Dothan, Ala., would need to shut down.

Georgia wanted to keep its water for good reason: a year earlier various rivers dropped so low that the drought-stricken state was within a few weeks of shutting down its own nuclear plants. Conditions had become so dire that by this past January one of the state's legislators suggested that Georgia move its upper border a mile farther north to annex freshwater resources in Tennessee, pointing to an allegedly faulty border survey from 1818. Throughout 2008 Georgia, Alabama and Florida have continued to battle; the corps, which is tasked by Congress to manage water resources, has been caught in the middle. Drought is only one cause. A rapidly growing population, especially in Atlanta, as well as overdevelopment and a notorious lack of water planning, is running the region's rivers dry.
Water and energy are the two most fundamental ingredients of modern civilization. Without water, people die. Without energy, we cannot grow food, run computers, or power homes, schools or offices. As the world's population grows in number and affluence, the demands for both resources are increasing faster than ever.

Woefully underappreciated, however, is the reality that each of these precious commodities might soon cripple our use of the other. We consume massive quantities of water to generate energy, and we consume massive quantities of energy to deliver clean water. Many people are concerned about the perils of peak oil—running out of cheap oil. A few are voicing concerns about peak water. But almost no one is addressing the tension between the two: water restrictions are hampering solutions for generating more energy, and energy problems, particularly rising prices, are curtailing efforts to supply more clean water.
The paradox is raising its ugly head in many of our own backyards. In January, Lake Norman near Charlotte, N.C., dropped to 93.7 feet, less than a foot above the minimum allowed level for Duke Energy's McGuire Nuclear Station. Outside Las Vegas, Lake Mead, fed by the Colorado River, is now routinely 100 feet lower than historic levels. If it dropped another 50 feet, the city would have to ration water use, and the huge hydroelectric turbines inside Hoover Dam on the lake would provide little or no power, potentially putting the booming desert metropolis in the dark.

Research scientist Gregory J. McCabe of the U.S. Geological Survey reiterated the message to Congress in June. He noted that an increase in average temperature of even 1.5 degrees Fahrenheit across the Southwest as the result of climate change could compromise the Colorado River's ability to meet the water demands of Nevada and six other states, as well as that of the Hoover Dam. Earlier this year scientists at the Scripps Institution of Oceanography in La Jolla, Calif., declared that Lake Mead could become dry by 2021 if the climate changes as expected and future water use is not curtailed. Conversely, San Diego, which desperately needs more drinking water, now wants to build a desalination plant up the coast, but local activists are fighting the facility because it would consume so much energy and the power supply is thin. The mayor of London denied a proposed desalination plant in 2006 for the same reason, only to have his successor later rescind that denial. Cities in Uruguay must choose whether they want the water in their reservoirs to be used for drinking or for electricity. Saudi Arabia is wrestling with whether to sell all its oil and gas at record prices or to hold more of those resources to generate what it doesn't have: freshwater for its people and its cities.

We cannot build more power plants without realizing that they impinge on our freshwater supplies. And we cannot build more water delivery and cleaning facilities without driving up energy demand. Solving the dilemma requires new national policies that integrate energy and water solutions and innovative technologies that help to boost one resource without draining the other.

Vicious Cycle The earth holds about eight million cubic miles of freshwater—tens of thousands of times more than humans' annual consumption. Unfortunately, most of it is imprisoned in underground reservoirs and in permanent ice and snow cover; relatively little is stored in easily accessible and replenishable lakes and rivers.

Furthermore, the available water is often not clean or not located close to population centers. Phoenix gets a large share of its freshwater via a 336-mile aqueduct from, of course, the Colorado River. Municipal supplies are also often contaminated by industry, agriculture and wastewater effluents. According to the World Health Organization, approximately 2.4 billion people live in highly water-stressed areas. Two primary solutions—shipping in water over long distances or cleaning nearby but dirty supplies—both require large amounts of energy, which is soaring in price.
Nationwide, the two greatest users of freshwater are agriculture and power plants…. At the same time, we use a lot of energy to move and treat water, sometimes across vast distances. The California Aqueduct, which transports snowmelt across two mountain ranges to the thirsty coastal cities, is the biggest electricity consumer in the state. As convenient resources become tapped out, providers must dig deeper and reach farther…. In addition, local municipalities have to clean incoming water and treat outgoing water, which together consume about 3 percent of the nation's electricity. Health standards typically get stricter with time, too, so the degree of energy that needs to be spent per gallon will only increase….

New Mind-set Needed, Too Regardless of which energy source the U.S., or the world, might favor, water is ultimately more important than oil because it is more immediately crucial for life, and there is no substitute. And it seems we are approaching an era of peak water—the lack of cheap water. The situation should already be considered a crisis, but the public has not grasped the urgency…. Peak oil might cause some human suffering, but peak water would have more extreme consequences: millions already die every year from limited access to freshwater, and the number could grow by an order of magnitude. Perhaps signposts will wake our collective minds. Kansas lost a lawsuit to Missouri recently over interstate water use, causing Kansan farmers to reconfigure how they will grow their crops. Rationing should certainly put society on notice, and it is beginning. My hometown of Austin, Tex., now imposes strict lawn-watering restrictions. California, suffering record low snowfalls, has issued statewide requirements for municipal water conservation and rationing of water that are reminiscent of gasoline controls in the 1970s.

Someday we might look back with a curious nostalgia at the days when profligate homeowners wastefully sprayed their lawns with liquid gold to make the grass grow, just so they could then burn black gold to cut it down on the weekends. Our children and grandchildren will wonder why we were so dumb.

Energy versus Water: Solving Both Crises Together Questions

1. Why did the state of Florida plan to sue the U.S. Army Corps of Engineers for its plan to reduce water from Georgia reservoirs?

2. Why did the state of Alabama object to the Corps' plan? Why would the nuclear power plant be threatened?

3. To what lengths might Georgia be willing to go to guarantee freshwater?

4. What is causing a shortage of water in the south?

5. What is the paradox the author describes on the first page?

6. What is an example of this paradox if Lake Mead in Nevada continues to be lowered?

7. Why are activists fighting a plan in San Diego to construct a desalination plant?

8. What does the author think the solution to the water-energy paradox requires?

9. Why is trucking water to water-stressed areas and cleaning dirty water supplies not the best solutions for providing clean water to water-stressed areas?

10. What are the two greatest users of freshwater in the United States?

11. Which of the two resources—water or energy—does the author think is ultimately more important and why?

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Energy versus Water: Solving Both Crises Together Questions – Answer Key

1. Why did the state of Florida plan to sue the U.S. Army Corps of Engineers for its plan to reduce water from Georgia reservoirs? *The reservoir water runs into the Apalachicola River, which flows through Florida. Florida was concerned that less water flow would threaten certain endangered species.*

2. Why did the state of Alabama object to the Corps' plan? *The reduced flow of water might shut down a nuclear power plant in Alabama.* Why would the nuclear power plant be threatened? *It uses vast amounts of water from the Apalachicola River for cooling to help condense steam back into liquid water.*

3. To what lengths might Georgia be willing to go to guarantee freshwater? *Georgia has considered moving its northern border one mile farther north to access freshwater resources now located in Tennessee.*

4. What is causing a shortage of water in the south? *A rapidly growing population, drought, overdevelopment, and a lack of planning for broader water conservation.*

5. What is the paradox the author describes on the first page? *When water is limited, less energy can be produced; rising energy costs are hurting efforts to supply even greater amounts of clean water.*

6. What is an example of this paradox if Lake Mead in Nevada continues to be lowered? *Las Vegas would have to ration water use and the Hoover Dam might not be able to produce much energy, limiting electricity to Las Vegas.*

7. Why are activists fighting a plan in San Diego to construct a desalination plant (a plant that removes salt from salt water to produce fresh water)? *Desalination plants use a lot of energy and the supply of energy is already stretched thin.*

8. What does the author think the solution to the water-energy paradox requires? *New national policies that integrate energy and water solutions; innovative technologies that help to boost one resource without draining the other.*

9. Why is trucking water to water-stressed areas and cleaning dirty water supplies not the best solutions for providing clean water to water-stressed areas? *Both use a large amount of energy. Energy can be in limited supply and is costly.*

10. What are the two greatest users of freshwater in the United States? *Agriculture and power plants.*

11. Which of the two resources—water or energy—does the author think is ultimately more important and why? *He feels water is more important because it is more immediately crucial for life and there is no substitute for it.*