ANALYZING ENERGY

Lesson Concepts: Students will analyze the advantages and disadvantages of nine different energy sources. They will use their knowledge to predict what would happen if the world did not use fossil fuels. They will also propose a plausible solution to the issues surrounding our current energy choices.

Learning Objectives — Students will be able to:

- **Analyze the advantages and disadvantages associated with the following energy sources: coal, natural gas, hydrogen, geothermal, hydropower, oil, solar, wind, and nuclear energy.**
- **Predict the economical and environmental consequences of choosing to use alternative fuels.**
- **Synthesize a plausible solution to the limited amounts of fossil fuels and the pollution caused by their burning, while still providing adequate amounts of energy.**

Link to *Air –The Search for One Clean Breath* from Executive Producer Barbara L. Page

In the film we view footage of how the Industrial Revolution changed air quality forever by dramatically increasing air pollution. Burning fossil fuels for energy use has caused this rise in air pollutants (e.g. ozone & particulate matter) and greenhouse gases (e.g. carbon dioxide and methane). We also visit Iceland, London's BedZED green community, and the EVS-23 Show to see how technology and good sense are cleaning the air.

Materials

- Copies of Energy Sources Table and Energy Sources Analysis Worksheet
- Large butcher paper for student presentations of Consequence Wheels
- Markers (one pack per group)

Advanced Preparation

Make copies of student handouts (one per student).

Time and Student Grouping

Energy Source Analysis and Consequence Wheel: One class period

Teacher Tips

It would be helpful to use cooperative learning techniques in completing the group work. Some suggested roles to assign students are: leader, time keeper, recorder, presenter, errand runner, encourager, and summarizer. It is beneficial to stop and discuss each section of the Energy Source Analysis worksheet to keep students on task and monitor their understanding. The Consequence Wheel should include both positive and negative consequences.

Grade Levels: 6-12

California Science Standards

Grade 6, 6.a. Students know the utility of energy sources is determined by factors that are involved in converting these sources to useful forms and the consequences of the conversion process.
Grade 6, 6.b. Students know different natural energy and material resources, including air, soil, rocks, minerals, petroleum, fresh water, wildlife, and forests, and know how to classify them as renewable or nonrenewable.
HS Chemistry, 7.b. Students know chemical processes can either release (exothermic) or absorb (endothermic) thermal energy.
HS Chemistry, 7.c. Students know energy is released when a material condenses or freezes and is absorbed when a material evaporates or melts.

National Science Standards

Grade 9-12 Science & Technology Content Standard F: Science in Personal and Social Perspective.

Education and the Environment Initiative Educational Principles and Concepts

Principle IV: The exchange of matter between natural systems and human societies affects the long-term functioning of both. As a basis for understanding this principle:
Concept a. Students need to know that the effects of human activities on natural systems are directly related to the quantities of resources consumed and to the quantity and characteristics of the resulting byproducts.
Concept b. Students need to know that the byproducts of human activity are not readily prevented from entering natural systems and may be beneficial, neutral,

Vocabulary

Coal: a combustible black or dark brown rock consisting of carbonized plant matter, found mainly in underground deposits and widely used as fuel.

Natural Gas: flammable gas consisting largely of methane and other hydrocarbons, occurring naturally underground and used as fuel.

Hydrogen: a colorless, odorless, highly flammable gas that can be combined with oxygen to release energy.

Geothermal: energy produced by the internal heat of the Earth.

Hydropower: the generation of electricity using flowing water to drive a turbine that powers a generator.

Oil: a viscous liquid derived from petroleum, especially for use as a fuel.

Solar: energy produced by the sun.

Wind: energy produced by the movement of air.

Nuclear: energy released in fission or fusion.

Teacher Background

Energy is defined as the capacity to do work. We use energy in almost every aspect of our lives. For many people, it is difficult to think of a part of our day that we do not use mass-produced energy. While the use of energy makes our lives easier, there are negative consequences to the environment associated with it. For fossil fuels, there is the release of carbon dioxide, a greenhouse gas, as well as other pollutants. Others, such as wind and hydropower can disrupt the environment and negatively impact wildlife populations. In general, one downside of more environmentally-friendly sources of energy is a higher production cost. Therefore, there are economic and environmental costs to consider when determining the best sources.

The United States contains 5% of the world's population; however, it consumes 26% of the world's energy each year. With increases in population, technological advances, and the desire to provide a reasonable standard of living for the average American, our energy consumption will continue to increase. In fact, it is predicted that our energy consumption will increase by 11% before 2030.

Most of our current energy usage comes from non-renewable sources. This means we are quickly depleting our energy sources, and increasing pollution in the process. While there are ways to make the use of fossil fuels cleaner, this does not solve the issue surrounding their limited supply.

Procedure

Day 1:

1. Discuss what energy is and how students use energy on a daily basis. Make a list on the board of student responses. Energy uses: water heater, energy used by appliances when they are plugged in and not in use (vampire power), dishwasher, washing machine, refrigerator, wells (in rural areas), and stoves. Ask students to put the list in order of what they think consumes the most energy to the least energy. Energy usage can be broken down into different categories, see the table below. Source: Department of Energy, http://tonto.eia.doe.gov/kids/energy.cfm?page=us_energy_use-basics.

Industry and Manufacturing = 31%			
Transportation = 28%			
Automobiles	32%	Light Trucks	28%
Other Trucks	16%	Aircraft	9%
Ships	5%	Construction & Agriculture	4%
Pipelines	3%	Trains and Buses	3%
Residential = 22%			
Space Heating	41%	Lighting & Appliances	26%
Water Heating	20%	Air Conditioning	8%
Refrigeration	5%		
Commercial = 19%			
Space Heating	36%	Lighting	21%
Water Heating	8%	Cooling	8%
Ventilation	7%	Cooking	3%
Office Equipment	3%	Other	9%
Refrigeration	6%		

Day 1 continued:

2. Explain to students that the energy they use has to come from somewhere, because energy cannot be created nor destroyed (1st law of thermodynamics). Energy is stored (in chemical bonds, nuclear bonds, and gravitational energy) and then released in a different form (electricity, heat, motion, and sound).
3. Explain that with each source of energy there are advantages and disadvantages in terms of the amounts of energy they can produce and the by-products of their production and usage. Students will be looking at these using the worksheet and comparison table.
4. Have students work in groups to complete the Energy Sources Analysis worksheet.

Day 2:

1. Have students complete the Consequence Wheel answering the question: What would happen if there was a worldwide ban on the burning of fossil fuels? The students should first fill out their individual copies, then transfer their answers to a piece of butcher paper to be presented to the class. The first layer of circles is five primary consequences. The second layer of circles is three secondary consequences (resulting from the primary consequences). The third layer of circles is two tertiary consequences for each secondary consequence.
2. Have students present their Consequence Wheel to the class and build a class Consequence Wheel. Students should add new consequences to their personal copy.
3. Students will use their Consequence Wheel and Energy Source Comparison Table to write three paragraphs explaining what they think the United States should do to solve their energy issues.

Closure: Have the students write three paragraphs explaining what they think they U.S. should do to solve the issues associated with the current sources of energy. Students should use evidence from the Energy Sources Comparison Table and their Consequence Wheel to support their solution.

Assessment: Energy Analysis Worksheet, Consequence Wheel, and solution paragraphs.

Extension: The three paragraphs on the solutions to energy issues could be turned into a full research paper.

Resources:

http://www.solarenergy.org/resources/energyfacts.html
http://www.world-nuclear.org/info/inf02.html
http://www.eia.doe.gov/neic/brochure/oil_gas/rngp/index.html
http://www.popularmechanics.com/technology/industry/4199381.html?page=3
http://hydrogendiscoveries.wordpress.com/2008/04/11/hydrogen-fact-7-the-cost-of-hydrogen-produced-today-from-wind-power-without-any-subsidies-would-be-less-than-the-equivalent-of-gasoline-at-3-per-gallon/
http://www1.eere.energy.gov/geothermal/faqs.html
http://www.greenenergyohio.org/page.cfm?pageId=54
http://zebu.uoregon.edu/1998/ph162/l14.html
http://www.jc-solarhomes.com/solar_energy_facts.htm
http://www.solarbuzz.com/StatsCosts.htm
http://www.eia.doe.gov/emeu/aer/pecss_diagram.html
http://www.eia.doe.gov/kids/energyfacts/index.html
http://zebu.uoregon.edu/1998/ph162/l14.html
http://www.nei.org/resourcesandstats/documentlibrary/reliableandaffordableenergy/graphicsandcharts/uselectricityproductioncosts/

Energy Sources Analysis

Use the Energy Sources Comparison Table to answer the following questions.

Energy Usage

1. What are the different types of fossil fuels?

2. What percent of U.S. energy consumption is due to using fossil fuels?

3. What are the different types of renewable energy sources?

4. What percent of the U.S. energy consumption is due to renewable energy sources?

5. Heating is responsible for 47% of residential energy consumption. Which energy sources are used for heating homes?

6. Electricity is responsible for 35% of residential energy consumption. Which energy sources are used for generating electricity?

7. Water heating is responsible for 17% of residential energy consumption. Which energy sources are used for heating water?

Pollution

8. What are the by-products of the following sources of energy production:

a. Coal	f. Oil
b. Natural Gas	g. Solar
c. Hydrogen	h. Wind
d. Geothermal	i. Biomass
e. Hydropower	j. Nuclear

9. List the energy sources in order of least harmful to the environment to most harmful.

Costs

10. The average U.S. citizen consumes 12,133 kilowatt hours of electricity per year. How much would it cost to meet the average person's energy usage using each of the following energy sources?

    a. Coal
    b. Natural Gas
    c. Hydrogen
    d. Geothermal
    e. Hydropower
    f. Oil
    g. Solar
    h. Wind
    i. Biomass
    j. Nuclear

11. What is the least expensive on an annual basis?

    a. What is the cost difference on an annual basis between this energy source and the next most expensive?

    b. What percent of the U.S. energy consumption does this account for?

    c. Why do you think the least expensive is not the most frequently used?

12. What is the most expensive on an annual basis?

    a. What type of energy is this source?

    b. Why do you think this energy source is more expensive than other energy sources?

Comparison

13. Fill in the Pro/Con Table for each energy source.

14. List the energy sources in order of most frequently used to least frequently used.

15. Why do you think the list is in the order that it is? Include cost; what it is used for; and pros/cons of the different energy sources.

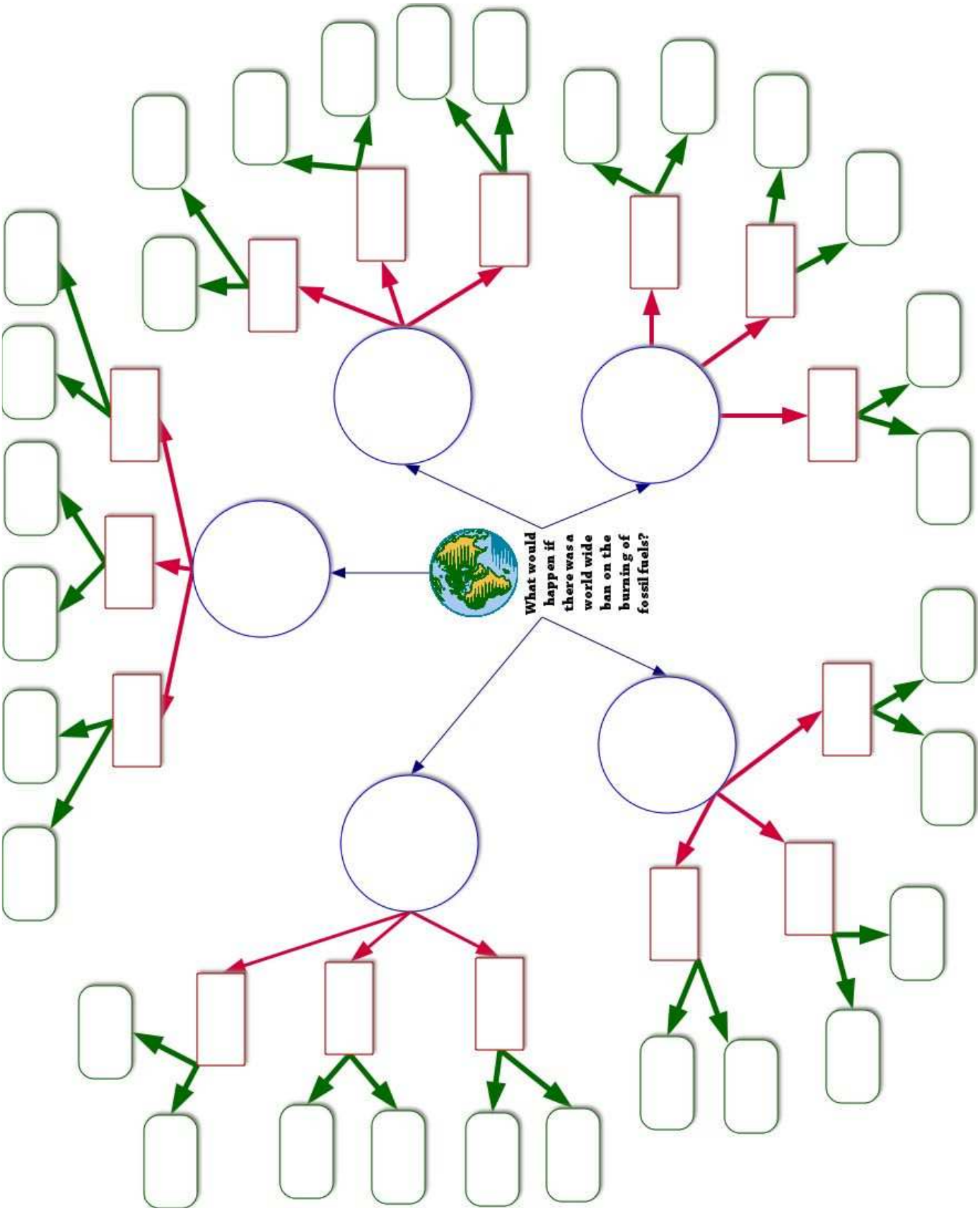
Pros and Cons of Energy Use

Coal	
Pros	Cons
Natural Gas	
Pros	Cons
Hydrogen	
Pros	Cons
Geothermal	
Pros	Cons
Hydropower	
Pros	Cons

Pros and Cons of Energy Use

Oil	
Pros	Cons
Solar	
Pros	Cons
Wind	
Pros	Cons
Biomass	
Pros	Cons
Nuclear	
Pros	Cons

Consequence Wheel



Energy Sources Analysis Key

Use the Energy Sources Comparison Table to answer the following questions.

Energy Usage

1. What are the different types of fossil fuels?
   Coal, Natural Gas, Oil
2. What percent of U.S. energy consumption is due to using fossil fuels?
   83.7%
3. What are the different types of renewable energy sources?
   Hydropower, solar, wind, geothermal, biomass
4. What percent of the U.S. energy consumption is due to renewable energy sources?
   7.3%
5. Heating is responsible for 47% of residential energy consumption. Which energy sources are used for heating homes?
   Natural gas, geothermal, oil, solar, coal
6. Electricity is responsible for 35% of residential energy consumption. Which energy sources are used for generating electricity?
   Coal, hydrogen, geothermal, hydropower, solar, wind, nuclear, natural gas, oil
7. Water heating is responsible for 17% of residential energy consumption. Which energy sources are commonly used for heating water?
   Natural gas, geothermal, solar

Pollution

8. What are the by-products of the following sources of energy production:
   a. Coal—methanol, ethylene, land destruction, water pollution, sulfur, nitrogen oxides, mercury, carbon dioxide, smog, acid rain
   b. Natural Gas—carbon dioxide, nitrogen oxide
   c. Hydrogen—steam, carbon dioxide
   d. Geothermal—zinc, silica, sulfur, carbon dioxide
   e. Hydropower—land destruction (man-made reservoirs)
   f. Oil—gasoline, diesel, propane, asphalt, heating oil, artificial reefs, oil spills, carbon dioxide, nitrogen oxides, unburned hydrocarbons
   g. Solar—none
   h. Wind—none
   i. Biomass- ethanol, biodiesel, biogas, carbon dioxide, ash
   j. Nuclear—steam, heat, radioactive waste

9. List the energy sources in order of least harmful to the environment to most harmful.
   Solar, wind, hydropower, geothermal, biomass, nuclear, hydrogen, natural gas, coal, oil (Rankings are subject to change. It is important for students to analyze the information and use it to form opinions.)

Costs

10. The average U.S. citizen consumes 12,133 kilowatt hours of electricity per year. How much would it cost to meet the average person's energy usage using each of the following energy sources?

a. Coal	$287.55	f. Oil	$1168.41
b. Natural Gas	$496.24	g. Solar	$3639.90
c. Hydrogen	$2546.72	h. Wind	$849.31
d. Geothermal	$424.66	i. Biomass	$812.91
e. Hydropower	$485.32	j. Nuclear	$203.83

11. What is the least expensive on an annual basis? Nuclear
    a. What is the cost difference on an annual basis between this energy source and the next most expensive? $83.72
    b. What percent of the U.S. energy consumption does this account for? 8.3%
    c. Why do you think the least expensive is not the most frequently used? The cost difference is not very significant over the year, especially when weighed with the safety concerns associated with nuclear energy and the disposal of nuclear waste.
12. What is the most expensive on an annual basis? Solar
    a. What type of energy is this source? Renewable
    b. Why do you think this energy source is more expensive than other energy sources? It does not generate as much electricity and it is not always dependable. It is only effective in certain areas of the country (deserts, etc.).

Comparison

13. Fill in the Pro/Con table for each energy source.

14. List the energy sources in order of most frequently used to least frequently used.

15. Why do you think the list is in the order that it is? Include cost, what it is used for, and pros/cons of the different energy sources.

Energy Sources Comparison Table

	Coal	Natural gas	Hydrogen	Geothermal	Hydro-power	Oil	Solar	Wind	Biomass	Nuclear
Classification	Fossil fuel	Fossil fuel	Renewable	Renewable	Renewable	Fossil fuel	Renewable	Renewable	Renewable	Non-renewable
% of U.S. energy consumption	22.50%	23.8%	NA	0.4%	2.40%	37.40%	0.10%	0.50%	3.9%	9.0%
How we get it	Surface mining and underground mining	Drilling wells, harvesting it from the decomposition of organic materials	By-product of other energy sources and processes (steam reform-ing and hydroly-sis are most common)	Volcanoes, hot-springs, and geysers	Dams capture the energy of moving water and use it to power electrical generators	Drilling wells	Collecting energy from sun using photo cells for electricity	Wind turns windmill which acts as a generator	Trees (wood), plants, organic waste	U-235 is mined
Beneficial By-products of production	Methanol, ethylene	Propane (used in gas grills) and butane (used in lighters)	None	Zinc, Silica, and Sulfur that can be sold for profit	None	Gasoline, diesel, propane, asphalt, heating oil, fertilizers, artificial reefs.	None	None	Ethanol, biodiesel	None
Harmful By-products of production	Water pollution and land destruction		CO_2 produced from stripping hydrogen from petroleum products (major source of hydrogen)	Sulfur but not much	None	Oil spills, emissions from refining	None	None	Biogas, CO_2 from burning, particulates such as ash	Small amounts of emissions from uranium processing
What is it used for	Generating electricity, industrial (plastics, steel)	Heating homes, generating electricity	Powering vehicles and generating electricity	Heating build-ings, generate electricity	Electricity production	Fuel for transporta-tion, plastics production, heating, fertilizers	Heating and electricity	Electricity	Heating, electricity	Generating electricity

Energy Sources Comparison Table

	Coal	Natural gas	Hydrogen	Geothermal	Hydro-power	Oil	Solar	Wind	Biomass	Nuclear
How is it used	Burning it to make steam to generate electricity	Burning it to make steam to generate electricity	Combines with O_2 to make steam. Captures energy released from chemical reaction	Direct and indirect heating from the Earth's core to generate electricity	Dams capture the energy of moving water and use it to power electrical generators	Burning it to make steam to generate electricity	Collected with solar panels, thermal and photo voltaic to generate electricity	Windmills turn when the wind blows and generate electricity.	Fermented to produce ethanol which is burned like gasoline	U-235 fission (nuclear reactions) to make steam to generate electricity
By-products of use	Sulfur, nitrogen oxide, mercury, CO_2	CO_2 (greenhouse gas), NO_x	Steam	<1% of the CO_2 of fossil fuels	None	CO_2, NO_2, unburned hydrocarbons	None	None	None	Steam, heat, radioactive waste, and spent fuel rods
How clean is it	Major contributor to smog and acid rain	Cleaner than other fossil fuels	Clean use but CO_2 is produced by steam reforming	Very clean. Steam is released	Very clean. No emissions	Major contributor to smog	100%	100%	Cleaner than burning fossil fuel	No air pollution, nuclear wastes
Expenses	Mining coal, power plants	Mining, transmission and distribution	Hydrogen production and storage	Building plants	Building and maintaining turbines, dams	Drilling, processing, transporting	Solar panels	Wind mills	Building plants	Mining uranium, running plant
Cost	2.37 ¢/kWh	4.09¢/kWh	20.99¢/kWh (assuming 100% efficiency)	3 – 3.5¢/kWh	4¢/kWh	9.63 ¢/kWh	30¢ / kWh	4 - 7¢/kWh	5.2-6.7¢/ kWh	1.68 ¢/kWh
Other Info			Electrolysis is expensive and hydrogen is difficult to store safely.		Dams can block migratory routes of native fish species, disrupt water temperatures and compositions, and cause flooding		Sun varies by location and time; requires large surface area to be effective	Wind is not always blowing and turbines can have a negative effect on wild bird populations		Potential for nuclear meltdown. Accidents can cause severe damage to the environment and people living in the surrounding community