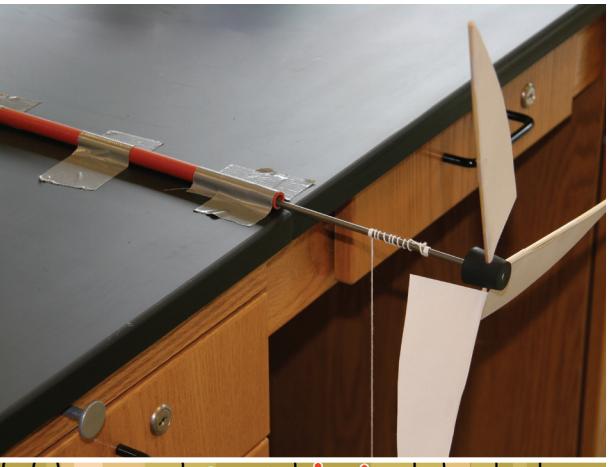
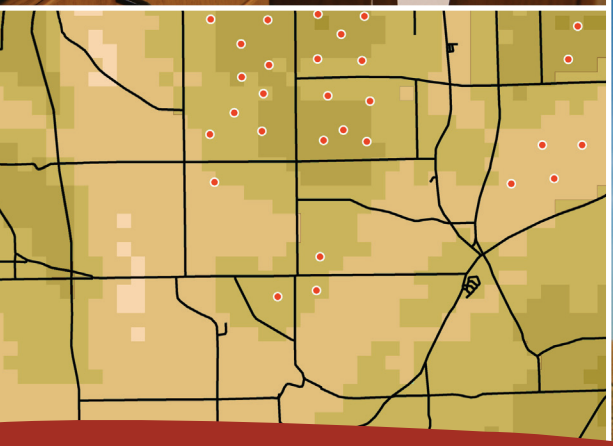
WindWise Education

Transforming the Energy of Wind into Powerful Minds





A Curriculum for Grades 6–12

2nd edition

windwise education

www.WindWiseEducation.org

WindWise Education was developed with funding from the New York State Energy Research & Development Authority

Updates to Lessons 3 & 5 and the addition of Lesson 16 were funded by the Department of Energy: subcontract No. AFT-1-40657-01

HOW DOES ENERGY AFFECT WILDLIFE?

LESSON 12

KEY CONCEPT

Students learn that different electricity generation sources have very different effects on wildlife.

TIME REQUIRED

1 class period

GRADES

9–12

SUBJECTS

Living Environment
Earth Science
Environmental Science

BACKGROUND

To accurately compare the effects of different electricity generation sources (or energy sources, such as coal, nuclear, hydroelectricity, and wind), the complete life cycle of each electricity generation source is examined along with an assessment of their direct and indirect effects on wildlife. This information is then used to predict the total wildlife impacts of each electricity generation type. The results of this assessment yield balanced information that can be used to make informed decisions about which type of energy to use in a community.

OBJECTIVES

At the end of this lesson, students will:

- understand the different wildlife effects and risks from electricity generated by coal, nuclear, hydro, and wind
- complete a thorough life cycle analysis of each of the fuels to understand how the different phases are related to the different wildlife effects

METHOD

Students will work in teams of two to four. Teams will use the fact sheets and worksheets to research and compare the effects of four electricity generation sources on wildlife. They will then compare and discuss their findings with the class and be prepared to write a summary report.

MATERIALS

❑ Student pages*
*included with this activity

windwise education
www.WindWiseEducation.org

GETTING READY

- Provide students with basic information about the energy sources used to generate electricity.
- Make copies of fact sheets, worksheets, and the reading passage for each team.

ACTIVITY

Step 1: Beginning questions for students

If students have not discussed energy generation and wildlife before, begin the class by asking students what they know about these topics.

- What types of energy sources are used to generate electricity?
- What is the difference between renewable and nonrenewable energy sources?
- Which sources are renewable and which are nonrenewable?
- Which energy sources do you think have the greatest impacts on wildlife populations? Why?
- Which energy sources are extracted and purified?
- Which energy sources produce pollution? What kinds of pollution?

Step 2: Form teams

Form teams of two to four students for this activity.

Step 3: Reading passage

Tell the students to read the reading passage. (Reading may be assigned as homework before the lesson.)

Step 4: Life cycle assessment

Provide each student with Table 1 and the fact sheets. Each student in the team should select one or two electricity generation sources to research (using the fact sheets) and complete the corresponding column(s) in Table 1. The fact sheets are based on a NYSERDA research document, "Comparison of Reported Effects and Risks to Vertebrate Wildlife from Six Electricity Generation Types in The New York/New England Region." Students can also use the internet or other sources available to them.

Step 5: Rank energy sources based on effects

Provide each team with Table 2. Based on the information they completed in Table 1, each team will rank the electricity generation sources on Table 2 from lowest to highest for effects on wildlife. Use 1 for the lowest effect and 4 for the highest. Students should provide a reason for their decisions.

Step 6: Class discussion

After each team has completed Table 2, hold a brief class discussion about team members' initial thoughts and feelings and the ranks they have assigned to each source. Some sample questions:

- Did team members' original thoughts and feelings about the different electricity generation sources hold true after the life cycle assessment? Why or why not?
- Is there general agreement among the teams about the ranking for each source? Why or why not?

VOCABULARY

Energy life cycle – The phases needed to produce energy, including extraction, transportation, construction, operation, transmission, and decommissioning.

extraction – Removal, most often from the ground.

decommissioning – Closing down a facility and removing it from service.

habitat – The environment in which an organism or group normally lives.

habitat fragmentation – Isolation of patches of habitat through land clearing and deforestation.

mortality – The number of animals killed.

risk (to wildlife) – The probability that loss or other adverse effects will occur to wildlife.

transmission – To move from one place to another. In energy, this is moving energy from its source to the location where it will be processed.

wildlife effect – The result of something causing harm to an animal or population of animals. Death, injury, and loss of habitat are examples of effects.

READING PASSAGE

The New York State Energy Research and Development Authority (NYSERDA) recently produced a report titled "Comparison of Reported Effects and Risks to Vertebrate Wildlife from Six Electricity Generation Types in The New York/New England Region." This report compared the effects and risks to wildlife from six different electricity generation sources: coal, oil, natural gas, hydro, nuclear, and wind.

The study identified the stages involved in most types of electricity generation and called these the "life cycle" for energy generation: extracting the fuel, transporting the fuel to the power generation site, construction of the power generation facility, operation of the facility, transmission and delivery (via power lines) of the electricity generated, and decommissioning of the facility at the end of its lifespan. Fuel extraction and transportation are not required for renewable energy sources, such as hydro and wind, because they are harnessed at the location where the electricity is generated.

To make an accurate comparison, the effects to wildlife were assessed for each life cycle stage of each electricity generation source. An effect is something that has a negative impact on wildlife. There are four types of direct effects on wildlife: injury, mortality (death), disruption of normal behavior, or destruction and damage of habitat.

To accurately assess and compare the wildlife effects from different electricity generation sources, the study authors considered all four types of effects to wildlife. Researchers also considered the risks to wildlife. Risk is the probability of an effect (injury, death, disruption of normal behavior, or destruction and damage to habitat) actually occurring.

Wildlife can be injured or killed when they come in contact with equipment and facilities used in all stages of the electricity generation cycle. Exposure to harmful chemicals can have toxic effects on wildlife that also result in injury or mortality. Noise and other disturbances associated with the life cycles stages of electricity generation can affect (or disrupt) normal movements, home range, or breeding behaviors of wildlife. Destruction and damage to wildlife habitat occurs when vegetation is removed or cleared from an area. It also occurs when habitat is divided up and goes from being one large area to several small areas that are isolated from one another (called habitat fragmentation). Habitat destruction includes damage to the ecosystem, trees, plants, soil, and food sources.

Examples of effects on wildlife from electricity generation include:

- Bird or bat injury or mortality from collisions with structures such as smoke stacks, power lines, or wind turbine blades
- Bird mortality from contact with an oil spill
- Fish and other aquatic animals becoming trapped in cooling water intake systems at power plants
- Mercury pollution from burning fossil fuels, particularly coal. Mercury escapes into the atmosphere, travels many miles on air currents, dissolves in rain, and returns to the Earth where it becomes toxic and enters the food chain.
- Fish being prevented from migrating up a river to spawn due to construction of a dam
- Power line corridors, service roads, and elevated pipelines all change and fragment habitat, which can impact the ability of wildlife to survive by making it more difficult to find food, shelter, and breeding partners.
- Carbon dioxide and methane released from burning fossil fuels. These greenhouse gases contribute to global climate change, which threatens many of the world's wildlife and ecological systems.

There are also indirect effects from electricity generation that can impact wildlife. Climate change is one of the biggest environmental, economic, and social challenges in the world today. Carbon dioxide (CO_2) and other gasses found in the atmosphere act as "greenhouse gases," which means that they trap heat energy and hold it in the atmosphere. The more greenhouse gases present, the more heat is trapped. It is similar to adding a blanket to your bed on a cold night; the blanket will trap more of your body heat and prevent it from escaping so that you stay warmer.

Many natural sources of CO_2 supply the atmosphere, such as volcanic eruptions, natural biological decay, and forest fires, which combine to account for about 95 percent of annual emissions. These have been present on Earth for many millennia. While there is natural variation from year to year and millennium to millennium, the amount of CO_2 emitted by natural sources is roughly equal to the amount absorbed by plants during photosynthesis and by the ocean.

However, human sources have accounted for the dramatic rise in CO_2 through the last two centuries, principally from CO_2 released when fossil fuels are burned. The industrial revolution in Europe and North America in the latter half of the 19th century marked the beginning of civilization's reliance on fossil fuels for energy. Today about 70 percent of US electrical energy is made by burning fossil fuels in power stations, and about 82 percent of the associated emissions of greenhouse gases are attributed to coal by the US Department of Energy.

Already there have been documented wildlife effects globally and regionally from climate change and there is great concern that those effects will continue and expand. Here are a few examples.

- Climate change has been found responsible for massive coral bleaching that has decimated numerous coral reef habitats around the world.
- Polar habitats have become threatened due to increased and more rapid melting of sea ice, which diminishes foraging opportunities for polar bears.
- Climate change has also resulted in range expansion of pest species such as the mountain pine beetle and may contribute to the spread of Lyme disease with more temperate conditions increasing tick populations.

The continued warming of the Earth's atmosphere from greenhouse gasses will have dramatic effects on wildlife in the coming decades.

FACT SHEET: COAL POWER

Electricity generation from coal power produces wildlife effects at every stage of its life cycle.

Extraction

In the resource extraction stage, the wildlife effects and risks from coal are high because 62 percent of US coal is extracted through above ground mining. Aboveground mining poses high risks to wildlife populations because of resulting large-scale habitat destruction. For example, mountaintop mining removes the top of a mountain to uncover coal seams (a layer of coal between rock) near the surface. The spoils from the removal are dumped in nearby valleys. The wildlife effects are substantial and impact all types of wildlife and habitats including those in the area of the mining and in valleys where the spoils are dumped. Coal mining is extensive in the Appalachians in both West Virginia and Pennsylvania where much of the coal for the New York/New England region originates. In 2002 alone, 65,000 acres in West Virginia were permitted for mountaintop removal coal mining. Aboveground mining includes strip mining, open pit mining, and mountaintop mining, and valley fill. Underground coal is extracted using mining machines or explosives to expose the coal, which is then dug up and removed from the mine. Underground deep shaft mining causes minimal harm to forest habitats in comparison to strip mining.

Both aboveground and underground mining cause habitat degradation, direct injury and death to wildlife from toxic runoff into bodies of water. Mine wastes and coal processing wastes are highly acidic and often contain trace elements at toxic concentrations. Seventy-five percent of acid runoff is associated with underground mining. This acid runoff from mine tailings (acid mine drainage) can reach streams and injure and kill fish and other aquatic wildlife. It is estimated that about 6,400 streams in the mid-Atlantic and southeastern US have been affected by toxic mine drainage and runoff, primarily from coal mining.

Transportation

The coal is transported via truck and train to the power plants where it is burned. There is a low risk of injury or death to wildlife from vehicle collisions and from any fuel spills.

Construction

Construction of coal facilities has a low risk of destruction of habitat from land clearing for facilities, of fragmentation of habitat, and of disturbance of wildlife from construction noise and activity.

Operation

Burning the coal produces energy, which heats water that turns to steam. This steam turns turbines that produce electricity used to power homes, buildings, and electrical devices.

Because coal is a fossil fuel, when it burns during the power generation stage it releases multiple emissions that cause regional and global wildlife effects. As a result, electricity generation from coal is a significant contributor to acidic deposition (acid rain and acid deposits), climate change, and mercury bioaccumulation (release of mercury into the environment), which create very high risks to wildlife. Other wildlife effects associated with power generation from coal include bird collisions with power plant facilities and effects to aquatic wildlife from power plant cooling (once-through cooling) and chemical discharges to surface waters. These pose medium risks to wildlife. Coal-fired plants produce large amounts of waste heat that is disposed of in cooling lakes or towers. In lakes, this represents thermal pollution that causes medium risk wildlife effects.

Transmission
Effects associated with transmission and delivery include injury and mortality to wildlife from collisions and electrocutions associated with power lines, which pose medium potential risks.

Decommissioning
The operation of coal-fired power stations has a low potential to contaminate local aquatic systems from waste churned up when sites are decommissioned.

FACT SHEET: NUCLEAR POWER

Electricity generation from nuclear power effects wildlife at every stage of its life cycle.

Extraction
Similar to coal, the effects from resource extraction from aboveground surface mining have a very high potential risk to wildlife because of the amount of surface habitat that is destroyed. Underground mining is considered to have a low risk because of the limited habitat disturbance compared to surface mining. Toxic runoff from mine tailings (acid mine drainage) has medium risk for injury and death to wildlife locally.

Transportation
The quantities of uranium needed for operation of a nuclear power station are small and so transportation has low risk of wildlife effects. Trucks and trains are used for transportation. There is a low risk of injury or death to wildlife from vehicle collisions and from any fuel spills.

Construction
Construction of nuclear facilities has a low risk of destruction of habitat from land clearing for facilities, fragmentation of habitat, and disturbance of wildlife from construction noise and activity.

Operation
Nuclear plants create energy when nuclear fission splits uranium atoms, releasing heat that boils water to produce steam. This steam is used to turn turbines producing power for homes and businesses.

Nuclear plants, like coal-fired plants, create large amounts of heat and require water to cool the generator. If the cooling process involves drawing water from a lake, river, or ocean (such as in once-through cooling), it poses medium potential risks to wildlife. The warm water discharge from cooling systems and the potential for chemical discharge in the water pose medium risk to wildlife.

Nuclear energy has a low risk for accidental or catastrophic release of radioactive materials. In the event of radioactive release, the wildlife effects would be large. However, there have been no such occurrences in the US. The worst example outside the US was the Chernobyl accident in the former Soviet Union where there were major impacts on the ecosystem. The likelihood of a similar instance in the US is very low because the faulty Chernobyl-style reactor design and its lack of containment for radioactive materials would not be licensed in the US. The most serious accident in the history of US nuclear facilities was a partial meltdown of the Three Mile Island 2 reactor core in 1979. This resulted in only very small offsite releases of radioactivity with an end result of substantially enhanced safety regulations. There is also a very low risk of radioactive release during normal operation that may cause injury and mortality. There may be some bioaccumulation of strontium-90, but this would likely be limited to individuals and not populations.

Transmission
Effects associated with transmission and delivery include injury and mortality to wildlife from collisions and electrocutions associated with power lines, which pose medium potential risks.

Decommissioning
There is a low risk of contamination of aquatic systems from radioactive leaks. There is also a low risk of habitat disturbance and displacement from the demolition process due to noise and activity.

FACT SHEET: HYDROELECTRIC POWER

Hydroelectric (hydro) power is the renewable energy source that produces the most electricity in the US. In 2008, it accounted for 6 percent of the total US electricity generation and 67 percent of generation from renewables. Electricity generation from hydroelectric has only four stages in its life cycle and each has wildlife effects.

Extraction and transportation
Water does not need to be extracted and transported the way coal or nuclear does. Hydroelectric power is a renewable energy source, and the water needed to generate electricity is harnessed at the source.

Construction
The risk to wildlife from construction of a hydropower plant is very high because of the terrestrial and aquatic habitat clearing and the inundation (flooding) of these habitats when the area behind the dam is filled with water. The loss of habitat includes not only the inundated land, but also the stream or river habitats, which poses risks to spawning, foraging, and nesting habitats for fish. This stressor can affect hundreds of acres of terrestrial habitats and tens of miles of stream habitat within the watershed when the reservoir is filled with water. There is also risk of reduction or change in wildlife and fisheries biodiversity. Changes in the numbers and types of fish caused by dams blocking upstream movement of these fish can have large-scale reproduction implications for fish (e.g., blocking normal fish movement and migration to spawning habitat). Depending upon the location of the dam, there could be a threat to species survival regionally and biologically significant habitat loss for endangered or threatened species. The consequences of the risk are continuous as long as the dam is in place.

Operation
The amount of available energy in moving water is determined by its flow or fall. Swiftly flowing water in a big river, like the Columbia River that forms the border between Oregon and Washington, carries a great deal of energy in its flow. Water descending rapidly from a very high point, like Niagara Falls in New York, has a lot of kinetic energy. In either instance, when energy is harnessed from moving water, the water flows through a pipe, then pushes against and turns blades in a turbine to spin a generator to produce electricity. In a river system, the force of the current applies the needed pressure, while in a storage system, water is accumulated in reservoirs created by dams, then released as needed to generate electricity.

Many reservoirs are very deep and the water released is cold water from the depths of the lake. These releases of very cold water can dramatically change downstream habitats in warmer regions and be very damaging to native fish and invertebrate populations. Greenhouse gases and methylmercury are emitted from the impounded water of a hydroelectric dam and pose medium potential risks to wildlife from the effects of climate change. During dam operation, upstream fish have a medium risk of being injured and killed during releases of water when they become trapped (entrainment and impingement) in the discharge of water.

Transmission
Effects associated with transmission and delivery of hydro power include injury and mortality from collisions and electrocutions associated with power lines. These pose medium potential risks.

Decommissioning
Hydropower generation poses high potential risks during the decommissioning. It causes mortality to aquatic wildlife and degradation of downstream aquatic habitat from release of sediments during the draining of the reservoir. Sediments often build up in large quantities in dammed lakes. The dismantling also results in the loss of the artificially created upstream lake habitat. Mortality or higher predation rates for fish can occur as water drawdown proceeds, leaving fish stranded in shallow pools. The risk is considered a medium risk for the fish and other aquatic life that have been using these created habitats.

FACT SHEET: WIND ENERGY

In 2008, wind power produced about 1.5 percent of worldwide electricity usage and it is growing rapidly, having doubled in the three years between 2005 and 2008.

Electricity generation from wind has only four stages in its life cycle and each has wildlife effects.

Extraction and transportation
This type of energy comes directly from wind, so no extraction or transportation is needed. Like hydro, wind is a renewable energy source, and the wind needed to generate electricity is harnessed at the source.

Construction
Wind farm construction requires the placement of multiple turbines on the landscape. This has a low potential for destruction or fragmentation of habitat, especially if the areas between the turbines are minimally disturbed, as is often the case.

Operation
Wind turbines harness the wind to generate electricity. Like old fashioned windmills, today's wind turbines use blades to collect the wind's kinetic energy. The wind flows over the blades, creating lift—like the effect on airplane wings—which causes the blades to turn. The blades are connected to a drive shaft that turns an electric generator to produce electricity. A local transformer is then used to step up the electrical voltage, so that the electricity can be sent through transmission and distribution lines to homes, businesses, and other users.

The most commonly cited effect from wind power generation is injury and mortality to birds and bats from collision with wind turbines. For birds, this is considered medium risk. Local mortality to individuals is likely to occur with no population-level effects and a high degree of species recovery. Biodiversity

declines are unlikely for birds. Endangered or threatened bird species may be exposed to potential injury or mortality. For bats, especially tree bats, the risk posed by wind turbines may be high, but this is uncertain because of the lack of accurate population information and mortality studies at wind farms. Ongoing research looks at the effects and risks to birds and bats from wind farms, but at this time there are no documented population-level effects. However, based on the few available studies, there is general consensus from the scientific community that bats are likely to be at the greatest risk.

The potential effects of wind turbines to birds and bats are to a large extent dependent upon decisions made during the siting process. If turbines are not sited in areas that are heavily used by birds and bats (such as migration corridors for birds and near heavily used roosts for bats) then potential mortality can be reduced.

Transmission

Effects associated with transmission and delivery of wind energy include injury and mortality from collision and electrocution associated with power lines. These pose medium potential risks.

Decommissioning

Decommissioning of a wind farm requires rehabilitation of the site. The footprint of each of the actual turbines is very small, even though the turbines are spread out over a large area. There will be some disturbance when turbines are removed. Much of the land upon which wind farms are built is agricultural or open land, so rehabilitation can be accomplished quickly.

Name_____ Date_____ Class_____

WORKSHEETS

Use the fact sheets provided and any additional information that you have available to fill in Table 1. For the Method boxes, list how this method (extraction, transportation, etc.) happens for each energy type. In the Effects box, record what effects these actions have on wildlife.

Table 1: Life cycle analysis of effects to wildlife from electricity generation sources

	COAL	NUCLEAR	HYDRO	WIND
Extraction Method				
Extraction Effects				
Transportation Method				
Transportation Effects				
Construction Method				
Construction Effects				
Operation Method				

	COAL	NUCLEAR	HYDRO	WIND
Operation Effects				
Transmission Method				
Transmission Effects				
Decommissioning Method				
Decommissioning Effects				

Table 2: Rank electricity generation sources based on their effects

Rank the electricity generation sources from lowest to highest based on their effects on wildlife. Assign 1 for the lowest and 4 for the highest. Provide a justification for each rank.

FUEL	RANK	STATEMENT OF JUSTIFICATION
Coal		
Nuclear		
Hydro		
Wind		

Name_____ Date_____ Class_____

Assignment

1. List four things that you learned about wildlife effects caused by the four electricity generation sources while you were doing this activity.

2. Describe anything that surprised you about electricity generation while you were doing this activity.

3. Assume that you are on a committee that is charged with recommending the type of power a community should use to increase its electrical capacity by 10 megawatts. The community's choices are building an extension of an existing coal-fired power station or building a brand-new wind energy facility with five 2-megawatt wind generators. You represent the state's natural resource management department on this committee, and the other committee members are looking to you for an assessment of which new power-generation facility will have the least impact on local wildlife populations.

Based on the work you have done in this lesson, write a one-page summary report to the rest of the committee that provides a recommendation for a course of action and with a clear justification for your recommendation..

Assignment

1. List four things that you learned about wildlife effects caused by the four electricity generation sources while you were doing this activity.
2. Describe anything that surprised you about electricity generation while you were doing this activity.
3. Assume that you are on a committee that is charged with recommending the type of power a community should use to increase its electrical capacity by 10 megawatts. The community's choices are building an extension of an existing coal-fired power station or building a brand-new wind energy facility with five 2-megawatt wind generators. You represent the state's natural resource management department on this committee, and the other committee members are looking to you for an assessment of which new power generation facility will have the least impact on local wildlife populations.

Based on the work you have done in this lesson, write a one-page summary report to the rest of the committee that provides a recommendation for a course of action, along with a clear justification for your recomendation.

For answer sheets: Answers will vary by student.

Table 1: Life cycle analysis of effects to wildlife from electricity generation sources (completed version for reference)

	COAL	NUCLEAR	HYDRO	WIND
Extraction Method	*Mining—aboveground and underground*	*Subsurface mining of uranium*	*N/A*	*N/A*
Extraction Effects	*Water pollution, habitat destruction, direct injury and death*	*Surface mining destroys habitat; runoff from mining could impact water*	*N/A*	*N/A*
Transportation Method	*Trains*	*Trains and trucks*	*N/A*	*N/A*
Transportation Effects	*Collisions with wildlife*	*Collisions with wildlife*	*N/A*	*N/A*
Construction Method	*Built—central power station*	*Built—central power station*	*Built—dam on river*	*Built—on open land often on hill tops*
Construction Effects	*Habitat destruction from land clearing*	*Habitat destruction from land clearing*	*Habitat changes and destruction due to flooding when blocking river*	*Habitat disturbance from building roads and foundations.*
Operation Method	*Coal burned to heat water to produce steam to turn turbines*	*Uranium used to split atoms to heat water to produce steam to turn turbines*	*Water pressure created behind dam is used to turn turbines*	*Wind turns turbines*

Operation Effects	*Acid rain and acid deposits, climate change, mercury bioaccumulation, bird collisions, chemical discharge into water*	*Drawing water from lake, river, or ocean, chemical discharge into water*	*Movement of fish up and down river is disrupted. Habitat change due to dam on river. Fish and wildlife killed when trapped in dam*	*Bird and bat death from collision with turbines*
Transmission Method	*Power Lines*	*Power Lines*	*Power Lines*	*Power Lines*
Transmission Effects	*Habitat destruction during installation, birds colliding with power lines and bird electrocutions*	*Habitat destruction during installation, birds colliding with power lines and bird electrocutions*	*Habitat destruction during installation, birds colliding with power lines and bird electrocutions*	*Habitat destruction during installation, birds colliding with power lines and bird electrocutions*
Decommissioning Method	*Removal of structure and rehabilitation of site*	*Removal of structure and rehabilitation of site*	*Removal of structure and major rehabilitation of site*	*Removal of structure and rehabilitation of site*
Decommissioning Effects	*Pollutants may remain; habitat may take a while to recover*	*Long-term contamination with radioactive material. Possibility of radioactive release*	*Original river habitats destroyed by released sediment and changed water levels*	*Limited intrusion of site requires limited restoration*

Table 2: Rank electricity generation sources based on their effects

Rank the electricity generation sources from lowest to highest based on their effects on wildlife. Assign 1 for the lowest and 4 for the highest. Provide a justification for each rank.

FUEL	RANK	STATEMENT OF JUSTIFICATION
Coal	*Rankings will depend on student answers*	*Students should consider the possible effects as well as the potential risk when creating their rankings. For example, nuclear could produce radioactive leaks, but this is a very low risk, so leaks should be considered a minor factor when deciding rankings.*
Nuclear		
Hydro		
Wind		