NYSERDA
New York State Energy Research and Development Authority

New York Energy Smart℠
EMEP
Environmental Monitoring, Evaluation, & Protection

Comparison of Reported Effects and Risks to Vertebrate Wildlife from Six Electricity Generation Types in the New York / New England Region

Prepared for

The New York State Energy Research and Development Authority
Albany, NY

Prepared by

Environmental Bioindicators Foundation, Inc.
207 Orange Avenue, Unit G
Fort Pierce, FL 34950
and
Pandion Systems, Inc.
102 NE 10th Ave, 1st Floor
Gainesville, FL 32601

NYSERDA Report 09-02 | NYSERDA 9675 | March 2009

Executive Summary

Background

Electricity generation causes adverse effects on both people and the environment, including wildlife and wildlife habitat. In recent years,concerns about global climate change, caused in part by fossil fuel combustion, have focused enhanced attention on these effects and the need to move toward a mix of electricity generation sources that will reduce adverse effects of all types on the environment. The effects and relative levels of risk vary among the different electricity generation sources.

Electricity generation is the process of converting some form of energy into electricity. For all six forms of electricity generation considered here, a turbine must be turned to drive a shaft in a generator. The generator produces electricity by spinning copper coils, or armature, through a magnetic field. A source of energy is needed to turn the turbine. Four of the electricity generation sources considered here (coal, oil, natural gas, and nuclear) turn the turbine by creating heat that is used to boil water, which in turn makes steam that under pressure turns the turbine. The other two electricity generation sources (hydro and wind) turn turbines directly with pressure; water turns a wheel that is connected to a turbine (see graphic on page 2), and wind turns blades that are connected to a turbine.

Global warming can contribute to a multitude of ecological effects, including shifts in seasonal patterns of migration, food availability, and increased vulnerability of some species due to climate-related adaptive strategies.

Before the electricity generation source can turn the turbine, it must be extracted or harnessed. Coal, oil, natural gas, and nuclear materials are extracted from the ground and then transported to the power station, sometimes hundreds or thousands of miles away. Electricity generation by hydro requires a ready source of flowing water (river or reservoir), whereas electricity generation from wind energy requires a steady and reliable wind flow pattern.

Since most electricity is generated in one place and consumed somewhere else, wires are used to transport electricity from where it is made (power station) to where it is used (primarily in cities with homes and businesses). This requires a vast network of transmission and distribution lines known as the national grid system.

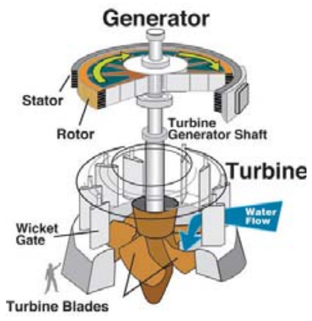
There are several important limitations that must be considered when interpreting the information contained in this report. The most important limitations are as follows:

- Life cycle risks can vary considerably, depending on the size of the facility. No attempt was made in this study to quantify and compare the relative wildlife risks by considering the size of electricity generation sources, such as risk per unit of energy produced. For some effects, such as collisions, quantitative information can be developed to characterize the relative contribution of different electricity generation sources to risks.

- Certain catastrophic events and effects to wildlife, such as a nuclear reactor incident releasing a significant amount of radiation into the environment or a catastrophic breaching of a hydro dam, were not evaluated because of the very low probability of the event occurring and the lack of sufficient information on the resulting wildlife effects.

- Wildlife covered in this study include only terrestrial and aquatic vertebrate wildlife and their habitats – not invertebrates.

- Analyses of impacts and risks in this report focus on the total wildlife impact or risk. The report does not evaluate the ability of a specific wildlife population or habitat to recover once the stressor is removed.



Simple view of a hydroelectric generator.
Source: U.S. Army Corps of Engineers.

- For some stressors, where the effects are obvious and not reported in the literature (e.g., loss of habitat from land clearing activities for a power plant), professional judgment was used to characterize the effects and risks.

Approach

This summary compares effects on vertebrate wildlife, as reported in the published scientific literature, from electricity generation by coal, oil, natural gas, nuclear, hydro, and onshore wind. The focus is on electricity generating sources that are important to New York and the New England states (collectively referred to as the NY/NE region) and their effects on birds, mammals, fish, reptiles, and amphibians.

A literature review was conducted to provide the basis for a Comparative Ecological Risk Assessment of the known and documented effects of electricity generation on vertebrate wildlife. The focus was on peer-reviewed literature and scientifically accepted and published reports or documents regarding wildlife effects from electricity generation. No original analyses of source contributions or effects were conducted. The results of the literature review were used to construct a Comparative Ecological Risk Assessment in order to make objective comparisons among the six types of electricity generation important to the NY/NE region. The Assessment included conducting a Life Cycle Assessment within the Ecological Risk Assessment framework developed by the U.S. Environmental Protection Agency (US EPA).

To objectively compare adverse effects caused by different electricity generation source types, the total life cycle of electricity generation was examined. The Life Cycle Assessment identified the stages of electricity generation: resource extraction, fuel transportation, construction of facility, power generation, transmission and delivery, and decommissioning of facility (Table ES-1). Wildlife effects from exposure to stressors encountered at each life cycle stage were identified and compiled for each electricity generation source.

Information from the literature review and the Life Cycle Assessment was incorporated into an Ecological Risk Assessment framework in order to construct a Comparative Ecological Risk Assessment that identified the stressors and receptors (wildlife and/or wildlife habitat) for each life cycle stage of each electricity generation source type. Next, the level of exposure and types of wildlife effects were identified for each stressor. This information was used to characterize the relative level of risk, or likelihood of an adverse effect occurring. The resulting assessment provides a general evaluation of relative risk. Comparable data are not available for quantifying risks to wildlife groups among the six electricity generating source types or among life cycle stages.

The estimated level of relative wildlife risk potential was classified into five separate categories (Highest Potential, Higher Potential, Moderate Potential, Lower Potential, Lowest Potential) based on defined criteria. The criteria were based on the extent to which the exposure to a particular stressor may cause adverse effects on wildlife habitat, individuals, or populations. The adverse effects range from large-scale, population-level mortality at the highest potential risk level to limited or no mortality of wildlife individuals at the lowest potential risk level.

Highest and Higher Potential risk levels are associated with effects to both wildlife individuals and populations. Moderate, Lower, and Lowest Potential risk levels are associated only with

Table ES-1: Life cycle stages of electricity generation.

Life Cycle Stage	Definition
Resource Extraction	Getting the raw materials to make electricity and all the associated supporting activities (e.g., waste disposal, road construction). For example, for coal and uranium this includes surface and underground mining. For oil and natural gas this includes onshore and offshore drilling and extraction.
Fuel Transportation	Transporting the raw materials from the mine or well to the electricity generating facility by rail, truck, barge, ship, or pipeline. This includes construction of pipelines.
Construction of Facility	Building the electrical generation facility and associated supporting activities. For coal, oil, natural gas, and nuclear facilities, construction includes power blocks, stacks, cooling ponds or towers, lay-down areas and waste areas, and transmission and distribution lines. For hydro facilities, construction includes the dam, power house, impoundment area, and associated transmission lines and roads. For wind facilities, construction includes turbines, transmission and distribution lines, and roads.
Power Generation	All aspects of operating an electricity generating facility. For coal, oil, and natural gas this includes the combustion of fuels. For nuclear this includes heat energy production by fission. For wind this includes the action of the wind turbine blades. For hydro this includes reservoir management.
Transmission and Delivery	Getting electricity from the generation facility to where it will be used. This includes transmission lines, distribution lines, and substations.
Decommissioning of Facility	The demolition and removal of the electricity generating facility. All electricity generation facilities have a lifespan and must eventually be taken offline and removed. This report does not consider repowering.

wildlife individuals, without evidence of, or reason to expect, an adverse effect at the population level. This does not mean that wildlife effects to individuals are not important. Nevertheless, if an individual effect does not result in a measurable impact on the population, then it is not considered ecologically significant. It is important to note, however, that effects to individual animals can be ecologically significant in at least two situations. First, endangered and threatened species often cannot afford to lose even small numbers of individuals without further imperiling the population or even the species. Second, demonstrated effects on individuals can become ecologically significant when they are shown to indicate a population-level effect.

Worker at power station switchyard.

Results: Risks to Wildlife From Electricity Generation

Offshore oil rig drilling platform in the ocean.

All electricity generation sources affect wildlife to some degree, although the mechanism and severity of impacts differ. There are many ways to classify the impacts of electricity generation on wildlife. Effects can be direct and/or indirect; acute or chronic; individual or cumulative; and local, regional, or global. Each type of effect was explored in this study.

In general, three key factors control the status and health of wildlife populations: birth rate, death rate, and availability of habitat. A change in any one of these factors will cause wildlife populations to increase or decrease.

All life cycles of electricity generation affect wildlife and therefore pose risks to wildlife individuals and populations. The degree and extent of the risks depends on the energy generation source, although some effects are common across life cycle stages of many electricity generating sources.

Classification of Wildlife Risks

Effects and risks can range from injury and mortality of individuals to habitat loss and decline in species occurrence. Risks can be classified according to immediacy of response, level of impact (individual to population), electricity generation life cycle stage, and spatial extent of response, as follows:

- Electricity generation can cause acute and immediate effects (such as toxicity of oil spills, exposure to acid mine drainage, collision and electrocution). It also can cause chronic, cumulative, and long-term effects (for example, biomagnification of mercury in the food chain, which can cause toxicity; acidification of soils from acidic deposition, which leads to decline in forests or water quality; and climate change, which results in altered timing of wildlife reproduction, disruption of migration patterns, and alteration of species ranges).

- Electricity generation can affect wildlife at the level of individuals (resulting in Lowest to Moderate Potential risks) or populations (resulting in Higher and Highest Potential risks).

- Population-level effects are more likely to be associated with energy resource extraction

Marine mammals, such as dolphins and whales, can be adversely affected by offshore oil drilling. Not only is there a risk for oil spills, but it has been suggested that sonar used for oil exploration may cause marine mammal beach strandings. Photo Source: NOAA.

and power generation than other life cycle stages of electricity generation.

- Effects on wildlife in the NY/NE region from an electricity generation source can occur locally at the site (such as at a coal mine), regionally (such as regional transport of acidic deposition to the Northeast), and globally (such as climate change).

- Wildlife species differ in the degree to which they are sensitive to adverse impacts from electricity generation. Some species are more sensitive to one electricity generation source than to others. A number of species are considered to be especially vulnerable and at risk in the NY/NE region.

Most Significant and Widespread Effects

Acidic deposition, climate change, and mercury bioaccumulation are identified as the three most significant and widespread stressors to wildlife from electricity generation from fossil fuels combustion and hydro; these pose Moderate to Highest Potential risks to wildlife. Major conclusions regarding these stressors are as follows:

- Acidic deposition results from electricity generation from coal, oil, and to a lesser extent natural gas. Acidification of forest soils, streams, and lakes causes widespread, and only partially reversible, effects on fish and wildlife and their aquatic and terrestrial habitats throughout major portions of the NY/NE region.

Birds such as this chickadee are sensitive to harm caused by climate change and other stressors associated with electricity generation.

- Mercury bioaccumulation results from electricity generation from coal, oil, and to a lesser extent hydro. Bioaccumulation of mercury has affected wildlife throughout the region, especially fish, birds, and mammals. Although it can be a major risk to wildlife, mercury bioaccumulation and its effects are generally reversible, as evidenced by reported reductions of both mercury emissions and biotic uptake since the late 1980s at locations in the United States where both sources and deposition have been measured.

- Climate change produces the most widespread effects, posing risks to fish and wildlife and their habitats globally. These effects are not likely to be reversible. Electricity generation from coal, oil, gas, and hydro contribute (albeit unequally) to the risks for climate change.

Graphic rendition of one risk of power transmission: wildlife contact with power lines. Power lines pose risk of collision and electrocution to birds and bats.

Effects Associated With Life Cycle Stages of ElectricityGeneration

In order to fully evaluate the potential impacts of a particular electricity generation source, effects at each stage must be considered. Effects are not equally distributed across life cycle stages. Important conclusions regarding life cycle effects include the following:

- During the transmission and delivery stage, bird and bat collisions pose Moderate Potential risks common to all forms of electricity generation; they affect birds and bats to some extent within and outside the NY/NE region. Collision objects vary with electricity generation source and include offshore drilling platforms (oil and natural gas), wind turbines, stacks, and cooling towers during power generation. Wildlife species exhibit varying risk, depending on location and dimensions of the collision objects relative to species ranges, flight patterns, and migratory behavior.

A gas power plant.

- The resource extraction stage of oil and natural gas poses Higher Potential risks to local and regional wildlife both within and outside the NY/NE region.

- The fuel transportation stage of oil poses Highest Potential risks to local and regional wildlife both within and outside the NY/NE region, largely because of risks of oil spills.

- Risks vary substantially by life cycle stage. Since there are more conditions, by-products, and actions in the resource extraction and power generation stages that act as stressors to wildlife, higher risks to wildlife are generally associated with these life cycle stages, as compared with other life cycle stages. The degree and extent of the risks depends on the electricity generation source, although some effects are common across life cycle stages and electricity generation sources. Table ES-2 summarizes the highest wildlife risk level for each electricity generation source during each life cycle stage. Construction, transmission and delivery, and decommissioning stages generally have fewer stressors affecting wildlife. However, the construction, operation, and decommissioning of dams pose relatively Higher Potential risks to ecosystems, fish, and stream habitat.

Comparative Electricity Generation Source Risks

Overall, non-renewable electricity generation sources, such as coal and oil, pose higher risks to wildlife than renewable electricity generation sources, such as hydro and wind. Based on the comparative amounts of SO_2, NO_x, CO_2, and mercury emissions generated from coal, oil, natural gas, and hydro and the associated effects of acidic deposition, climate change, and mercury bioaccumulation, coal as an electricity generation source is by far the largest contributor to risks to wildlife found in the NY/NE region.

Major risks by source are as follows:

- Coal has risks that range from Lowest to Highest Potential, including unique risks during the resource extraction stage (e.g., Highest Potential risks associated with the effects of strip and mountain top mining). The combustion of coal during the power generation stage contributes disproportionately compared to other energy sources to acidification and mercury bioaccumulation, causing Highest Potential risks to wildlife.

A hydroelectric facility located on the Genesee River in New York.

- Oil risks range from Lowest to Highest Potential, with unique risks during the resource extraction and fuel transportation stages, owing to the potential for oil spills. Oil also contributes to acidification risks during the power generation stage.

- Natural gas has Lowest to Higher Potential risks, depending on life cycle stage. A number of the types of effects associated with the power generation life cycle stage of natural gas are similar to oil generation, but the magnitudes of these risks are lower, e.g. Moderate Potential risks of habitat change from greenhouse gas emissions associated with natural gas combustion compared to Higher Potential risks from oil combustion.

- Nuclear presents Lowest to Highest Potential risks. Some of these risks are not unique to nuclear but also are found with other non-renewable electricity generation sources, such as bird collisions with stacks and cooling towers associated with coal and oil generation sources.

- Hydro exhibits Lowest to Highest Potential risks, with some unique risks during the construction, power generation, and decommissioning stages, such as loss of large areas of terrestrial and aquatic upstream habitat, changes to downstream habitats, and blocking fish migration due to reservoir or impoundment construction.

- Wind has Lowest to Moderate Potential risks but has high risks of bird and bat collisions with wind turbines during operation. No population-level risks to birds have been noted. Population level risks to bats are uncertain at this time.

Table ES-2: Highest Levels of Relative Wildlife Risks for each Life Cycle Stage of Each Electricity Generation Source

Source	Relative Wildlife Risk Level for Potential Harm					
	Resource Extraction	Fuel Transportation	Construction of Facility	Power Generation	Transmission and Delivery	Decommissioning of Facility
Coal	**Highest Potential**	**Lower Potential**	**Lower Potential**	**Highest Potential**	**Moderate Potential**	**Lower Potential**
Oil	**Higher Potential**	**Highest Potential**	**Lower Potential**	**Higher Potential**	**Moderate Potential**	**Lower Potential**
Natural Gas	**Higher Potential**	**Moderate Potential**	**Lowest Potential**	**Moderate Potential**	**Moderate Potential**	**Lowest Potential**
Nuclear	**Highest Potential**	**Lowest Potential**	**Lowest Potential**	**Moderate Potential**	**Moderate Potential**	**Lowest Potential**
Hydro	**None**	**None**	**Highest Potential**	**Moderate Potential**	**Moderate Potential**	**Higher Potential**
Wind	**None**	**None**	**Lowest Potential**	**Moderate Potential**	**Moderate Potential**	**Lowest Potential**

Opportunities for Future Assessment of Wildlife Risk

Fish-eating mammals and birds, such as this river otter (left) and bald eagle (right) are sensitive to mercury bioaccumulation because of their positions at the top of the food chain.

There are a number of opportunities for future comparisons of wildlife risk that were identified during this study. In particular, it is important to attempt to rank recovery potential of affected populations and habitats. Wildlife species and groups of species have different abilities to handle risks. Some populations have the reproductive potential to offset losses more readily than others. Some habitats can quickly recover once a particular stressor is removed, whereas other habitats may have changed so much that recovery is not possible.

Changes in the recovery potential of wildlife in response to improvement in air quality (e.g., decrease in acidic and mercury deposition) during the past two decades in response to emissions controls have not yet been demonstrated. It also is important to evaluate changes in wildlife risks in response to future technologies. For example, improved coal combustion technologies should reduce some of the wildlife impacts from power generation.

Not all electricity generation sources in the NY/NE region are equally prevalent. A state-by-state analysis of wildlife risk could be conducted. This would be useful in looking at long-term trends to wildlife risks in the NY/NE region as shifts in electricity generation portfolios occur.

Citation for Full Report

Newman, J., E. Zillioux, C. Newman, C. Denny, P. Colverson, K. Hill, W. Warren-Hicks, and S. Marynowski. 2009. Comparison of Reported Effects and Risks to Vertebrate Wildlife from Six Electricity Generation Types in the New York / New England Region. New York State Energy Research and Development Authority (NYSERDA), 17 Columbia Circle, Albany, New York, 12203.