

How our energy future affects our water future

By Gail Krantzberg, PhD, and Roddi Bassermann, P.Eng.



Executive summary

Our water supplies, and the Great Lakes specifically, are under a largely ignored threat from both existing and potential forms of energy generation. While acknowledging the need for new energy sources to meet increasing demand and confront climate change, Gail Krantzberg and Roddi Bassermann call for the impact on water and the Great Lakes to be considered before any new projects are approved.

The authors point out that almost all current and proposed energy sources have an effect on water. For example, nuclear plants, especially, and other power plants use water to cool their operations. When the water is returned to the source in an altered, warm state, it has negative consequences for the water quality and the habitat. Even “clean” hydroelectric plants involve dams that impact upon the local fish.

To preserve the Great Lakes and the 40 million people who depend on them, Krantzberg and Bassermann call for heightened research into energy technologies that are sensitive to both water quality and quantity. These considerations, they say, must be part of the national energy policy debate.

Introduction

Despite all the public attention paid in recent years to the environmental impact of most forms of

energy generation, one significant consequence has been barely mentioned. Hardly discussed at all is how energy generation adversely impacts water quality and quantity. This is particularly threatening to the Great Lakes, the largest surface freshwater system on Earth.

The region is home to 40 million people who rely predominantly on the lakes for drinking water and a range of economic activities. Safeguarding the health of the basin’s water resources is vital to Canada and the US. However, the Great Lakes’ ecological and economic integrity is under siege from a variety of anthropogenic pressures, especially the potentially enormous impacts of climate change.

Many forms of energy generation use water indiscriminately in a manner that impacts negatively on both water quality and quantity. The use of falling water to produce hydroelectric power, for example, dams waterways, resulting in downstream depletion of base flow needed for successful spawning and can create a physical barrier to fish passage for upstream movement and successful “recruitment.”

Water is also used for cooling in thermo-electric applications such as nuclear power and in power plants, whether natural gas or coal-fired. Other extensive energy-producing uses of water include fuel extraction, mining and refining. For biofuel production, water is required for plant irrigation and fuel processing. Furthermore, water is required in the production of diesel fuel used to transport uranium from mines to processing facilities and then to nuclear power plants. In all cases, there can be significant environmental impacts.

At nuclear plants, large amounts of fresh water are required to cool fuel rods. As a result, nuclear power plants are usually located close to large bodies of water to which the warmer water is returned. Winfield et al. (2006) note that approximately 225 litres of water are required for every kilowatt hour of electricity produced by nuclear power plants. (The amount of cooling water used annually at Ontario’s Pickering and Darlington nuclear power plants is 19 times the water consumption of Toronto.) The return of the cooling water in a warm state to its source is known to have negative impacts upon fish populations

(Winfield et al., 2006). Many aquatic animals depend on a particular temperature to survive and reproduce, and they can die if temperatures change even slightly. Warmer water can also decrease dissolved oxygen levels, making it difficult for some species to survive.

Water is a dangerously effective carrier of pollutants emitted into the air from the combustion of coal and other fossil fuels. Rain transports the pollutants to lakes and rivers. Sulfur dioxide and nitrogen oxides, major pollutants from coal-fired power plants, are acid rain precursors. Of particular concern are mercury emissions from coal-fired power plants that can injure lakes and rivers (Rogers, 2004) and pose a serious health threat to humans, particularly developing embryos (Carpenter, 2001). The effects in the Great Lakes are well documented (Mohaptra et al., 2007).

Coal-fired power plants also draw from local water bodies to condense steam after it has been used by a turbine/generator. Most coal plants use once-through cooling, which means they pump water out of a river/lake/pond through a condenser and back into the main body of water. A 500-megawatt power plant uses about 8.3 million cubic metres of water a year. The use of water for this purpose kills fish eggs and larvae that are too small to be filtered during water intake. And, as is the case with nuclear plant cooling, the water used to cool coal-fired plants in the Great Lakes can have thermal impacts when the water is returned, including disruption of fish habitat and proliferation of nuisance algae.

Ontario Power Generation currently has four coal units that will be permanently shut down in late 2010. The closure of these four units is a step toward meeting Ontario's commitment to fight climate change through the elimination of all coal-fired generation by the end of 2014. In the meantime and beyond, continued reliance on coal plants in many of the Great Lakes states will continue to injure water quality in the region through its pollutants and warming effect.

Meanwhile, Ontario faces the need to replace more than half of its electricity generating infrastructure over the next 15 years. Since energy generation and processing has such significant impacts upon water quality and quantity, comparisons among energy futures and alternatives must include water resource

considerations. To illustrate how diverse the energy alternatives are with regard to energy consumption, Table 1 outlines US water consumption on a per-megawatt-hour basis.

Table 1: Water consumed when generating electricity by different types of energy (includes water consumed during extraction, refining and power plant operation)

Energy type	Approximate total water consumed (cubic metres/megawatt hours)
Solar	0.001
Wind	0.001
Gas	1
Coal	2
Nuclear	2.5
Oil/petrol	4
Hydro power	68
Biofuel (1st generation)	178

Source: DHI Group, 2008

Policy responses to preserve the Great Lakes

Conservation and efficiency

Aggressive conservation programs and advances in energy efficiency are highly promising means to substantially reduce the impacts of energy generation on water quality and quantity. Both Canada and the US are among the world's top per capita electricity and energy consumers. Granade et al. (2009) identify significant potential to reduce energy consumption, including energy efficiency measures that would result in 16 per cent lower US per capita consumption by 2020. While the total required investment to attain these consumption savings would be US\$520 billion, the overall estimated energy cost saving through the year 2020 would be US\$1.2 trillion (Granade et al., 2009).

Conserving electricity has the added benefit of delaying or eliminating the need to construct additional power plants, further saving energy for construction as well as preserving water quantity and quality. This avoided cost could be used to promote further energy efficiency and conservation.

Wind and solar power

Financial incentives, especially the newly announced feed-in tariffs in Ontario's *Green Energy and Green Economy Act, 2009*, are expected to accelerate the expansion of both wind and solar generation. As of July 31, 2009, the Ontario Power Authority was managing 1575 megawatts of wind power contracts, with roughly a further 500 megawatts under development across the province (OPA, 2009).

Among the proposals is one by Canadian Hydro Developers Inc. of Calgary to erect enough wind turbines in Lake Erie to power two million homes. Yet this and other Great Lakes wind power proposals are engendering vocal opposition. Lakeshore residents oppose the turbines' proximity to the shoreline, their effects on birds and bats and potential impacts on fish habitat. Engineering solutions are required to advance the development of such wind farms through public policy that protects the environment while generating energy that is benign to water quality.

For its part, solar energy requires significant innovation to become more efficient and cost effective. At present, the production of solar panels leaves a significant carbon footprint. Once again, the *Green Energy and Green Economy Act, 2009* incentives are seen as providing the stimulus necessary to make solar energy a reliable component of a sustainable energy future that remains protective of water quality and quantity.

Hydro power

While hydroelectric power can have significant negative impacts on water resources, these impacts can be mitigated if carefully sited and planned, as described by Collier (2004). Fossil fuel production, in contrast, causes much further reaching environmental damage due to continuous air and water emissions for the entire life of plant operations.

Unfortunately, the majority of potential hydroelectric sites in Ontario have already been developed. Sites farther north could yield significant sources of hydroelectricity, but the infrastructure to transport the electricity from northern Ontario to the south where the electricity is needed does not exist. Since high-voltage transmission lines cost \$3 million a kilometre to build (Hamilton, 2009), this enormous price tag combined with the loss of

energy during transmission may make this an unviable complement to conservation or other types of renewable energy.

Natural gas

Although natural gas is a fossil fuel, it is relatively clean burning compared to gasoline, diesel fuel, oil and coal. Natural gas also has the advantage of having minimal impacts on water resources compared to other fuels, with only solar and wind power consuming less water (DHI Group, 2008). In recent years, the Ontario government has been switching to natural gas electricity generation as it closes coal-fired power plants.

However, an important fact has so far been ignored—generating electricity with natural gas is far less efficient than using most other sources. Single-cycle gas turbines typically can convert only 30 to 40 per cent of the energy in natural gas to electricity, while combined-cycle gas turbines are only somewhat better with efficiencies of 50 per cent (Harvey, 2008). In addition, large centralized power plants lose approximately 8 per cent of the electricity generated through transportation, further decreasing the efficiency of the natural gas output (WWF Canada et al., 2007).

On the other hand, it makes sense to use natural gas for space and water heating in the home. Space and water heating are a home's two largest energy users (Natural Resources Canada, 2009), and new, high-efficiency natural gas heating furnaces have efficiencies of 96 per cent (Enbridge, 2008). While conventional gas water heaters have efficiencies of 50 to 55 per cent, high-efficiency condensing gas water heaters can have efficiencies of over 90 per cent (Natural Resources Canada, 2009).

Since natural gas distribution pipelines are already present in most Ontario communities, the province should promote natural gas as an end-source fuel instead of as a fuel for electricity generation. By encouraging more homeowners to switch to natural gas, Ontario could offset some of the electricity demand that is currently met by coal and natural gas power plants, further advancing the protection of water resources.

Biofuels

From an energy balance perspective, many biofuels make little sense; some consume about as much energy as they yield (Lang, 2005). Practically speaking, biofuels are currently not

a reasonable replacement for petroleum. For example, if all corn and soybeans grown in the US were used for biofuel production, only 11 per cent of gasoline and 8.7 per cent of diesel fuel would be replaced (Tay, 2006).

The production of biofuels requires a great deal of water, which can have localized impacts on receiving waters, particularly when the source is tributaries with threats to base flow conditions. Further advancements in technology need to be directed at reducing biofuels' impact on water quantity and quality and the collateral inputs of fertilizers and pesticides, particularly given the large amounts required for irrigation.

Algae may prove to be the solution to making biofuels more palatable. For example, American "algae-to-ethanol" company Algenol Biofuels has developed a process for producing biofuels without occupying land or consuming feedstocks needed for food or feed production. It produces ethanol by growing metabolically enhanced algae in proprietary bioreactors, which are sealed units that prevent contamination, maximize ethanol recovery, and allow for fresh water recovery.

This process converts as much carbon dioxide as possible into ethanol using a method that doesn't require algal harvesting. Applications to the Great Lakes region would represent innovation in engineering excellence and avert the consumptive use of water and loadings of pesticide and fertilizer loads where current crops for biofuels are being cultivated in the Great Lakes region.

Nuclear power

Nuclear power currently provides 50 per cent of Ontario's base load electricity. Since it takes between eight and 10 years to build a nuclear power plant, decisions must be made now on how to replace the province's aging plants. If the province is to replace nuclear power, it must do so with a fuel that is as reliable, taking into account operational capacity in Ontario's climate.

Mining, purifying and transporting the required uranium fuel, along with constructing and maintaining a nuclear power plant, are very energy-intensive activities. According to Hartmann (2004), the energy consumed for these activities during the lifetime of a nuclear plant is equivalent to that produced

by the same nuclear power plant over an 18-year period. Winfield et al. (2006) calculate that Canada has only 40 years of proven uranium reserves left at current extraction levels, although other solutions could be pursued, such as reprocessing spent fuel rods or developing thorium-based technologies. Looking to the longer term, investment is required to develop alternative ways of generating base load once the next generation of nuclear power plants is up for replacement.

Conclusion

While there is broad consensus that a comprehensive national energy policy is needed to confront climate change and fossil fuel dependence, the Great Lakes region must ensure that any such policy preserves its vital waters. The region must take the lead in advancing new energy technologies that are sensitive to water quality and quantity, engage the region's universities in leading-edge energy research and innovation, and improve cross-jurisdictional decision-making for a shared and consistent energy future that ensures the lakes remain great.

Such an approach is the path forward for secure jobs and a sustainable green economy. Energy efficiency, emissions offsets and low-carbon supply technologies comprise a sound energy mix for the 21st century. To advance such a Great Lakes vision, experts will gather at a one-day conference on April 29, 2010, to explore the topic, *Engineering in a Climate of Change: Making the Lakes Great*.

The conference, sponsored by the Dofasco Centre for Engineering and Public Policy at McMaster University, will consider what a changing climate will mean for the Great Lakes and ways we can both mitigate and adapt to such change in the near future. (For more information, visit www.ospeclimatechange.ca.) Specifically, it will attempt to produce a clear understanding of the impacts to water quality and quantity from energy generation based on fossil fuels. As a result, we hope for a more informed public policy debate on a secure and sustainable future energy mix for Ontario.

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