Engineering and Public Policy
MEPP Final Inquiry
The Impact of Energy Generation on Water Resources in the Great Lakes Basin

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Abstract

The generation and consumption of energy have major negative impacts upon water quality in the Great Lakes Region. Yet, despite the strain that energy puts on the Great Lakes, much of the debate in recent years around energy has been on air quality and greenhouse gas emissions. This is an analysis of impacts to water quality and quantity in the Great Lakes from several different forms of energy used for generating electricity, space heating, water heating and transportation. Using this information, policy recommendations are made with the purpose of improving the relationship between energy and water quality and quantity in the Province of Ontario.

The most effective way to reduce impacts to water from is to reduce the amount of energy that is required. Conservation and energy efficiency are key tools to preserve aquatic ecosystems. Fuel switching can also reduce the amount of overall primary energy that is consumed. Renewables such as solar and wind power have minimal direct impacts on water. Biofuels derived from corn and soy, on the other hand, require almost as much energy during processing as they provide and consume vast amounts of water. Nuclear power does cause some harm to water resources, both during mining the uranium fuel and during power plant operation through thermal impacts. However, currently there are no other reliable base power sources that are able to displace the power that is currently provided by nuclear. Longer term goals for the Province should include developing a plan to replace existing nuclear power supply with other forms of energy that are more protective of water quality and quantity.

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1.0 Introduction

Over the past few years, much of the environmental focus on the generation of energy, including electricity, has been upon air quality impacts and the greenhouse gas emissions. In many regions of the world, the generation of energy also has adverse impacts upon water quality and quantity. This is true for the Great Lakes Region, the largest fresh water surface system on Earth. The region is home to 40 million people who use this system as drinking water and to drive the local economies. As a result, the health of this system is vital to all of the surrounding residents and to both Canada and the United States.

The health of the Great Lakes is under threat from a variety of different human activities, one of the biggest being the generation of energy to keep the local economy thriving. Many of the different forms of energy in use today use water and have negative impacts on water quality and the health of the Great Lakes. Coal-fired power plants emit sulphur and nitrogen oxides that lead to acid rain, along with heavy metals that endanger the health of organisms using the lakes, including humans. Nuclear power plants have thermal impacts, due to the vast amount of water that is used for cooling. Oil refineries along the Great Lakes emit air pollutants that eventually make their way to the Lakes as well.

1.1 Background and Motivation

Water is used and consumed in many different facets of energy production. For hydroelectric power, falling water is used directly to produce electricity. Water is used for cooling in thermoelectric applications such as nuclear power, natural gas-fired power plants and coal-fired power plants. Water is used extensively in fuel extraction, mining and refining. For bio-fuels, water is required for plant irrigation and fuel processing. There is additional water required, for instance, to produce the diesel fuel that is used to transport uranium from the mine, to the processing facilities and then to the nuclear power plant.

Before discussing water consumption any further, it is important to differentiate between water withdrawals and water consumption. Maas (2008, p.7) defines the two as the following:

> "Withdrawal - Water removed from a source and used for human needs
>
> Consumption – Part of withdrawals made unavailable for reuse in the same basin"

In the US, thermoelectric electricity generation is responsible for almost 40% of water withdrawals, however, the majority of this water is returned to the source at an elevated temperature (U.S. Department of Energy, 2006). Thermoelectricity accounts for 3.3% of total freshwater consumption.

There is also a connection between air quality and water quality. Many of the pollutants emitted through the combustion of coal and other fossil fuels, damage lakes and rivers located downwind of the emission point. Sulfur dioxide and nitrogen oxides, major pollutants from coal-fired power plants, are examples of this damage due to the fact they cause acid rain. Mercury emissions released into the air from coal-fired power plants can also damage lakes and rivers (Rogers, 2004).

Since the Great Lakes are bordered by two countries, electricity and other energy decisions on both sides of the border will impact the health of the water in the Great Lakes basin. Eliminating all of Ontario’s fossil fuel power plants, or even all of the fossil fuel plants surrounding the Great Lakes, will not eliminate all of the pollutants impacting the basin. About half of the pollutants in Ontario’s air originate from the US; this pollution comes mostly from coal-fired power plants in the US Midwest (Rogers, 2004).

Many of the jurisdictions in the Great Lakes basin are at a pivotal point in determining the future of energy generation in the Great Lakes. Ontario, for instance, must make key decisions on its electricity generation future: the Province is faced with the need to replace more than half of its electricity generating infrastructure over the next 15 years. Most of the analysis in the media around the pros and cons of different types of energy has been around air quality and greenhouse gas impacts. Since energy generation and processing has such significant impacts upon water quality and quantity, any comparison of different types of energy needs to include water impacts as well.

1.2 Central Question

This inquiry will review the different options for generating energy and electricity in the Great Lakes and their impacts upon Great Lakes water quality. The Central Question for this inquiry is:

“Where should Ontario steer energy policy to ensure minimal impacts to water quality in the Great Lakes, while ensuring healthy economies?”

2.0 Anticipated Findings

It is expected that this inquiry will recommend a variety of different technologies/methods for generating energy for the Great Lakes. There does not appear to be any single solution that will meet the needs of energy supply in the region: sustainability, reliability and affordability. As a result, this inquiry will focus on different methods for generating energy and their impacts on water quality, including coal-fired electricity, nuclear power, hydroelectricity, solar power, wind power, oil, biofuels and natural gas.

In order to focus this extremely wide topic, this inquiry will focus on the energy supply question in the Province of Ontario. Ontario currently uses a wide variety of different methods for supplying energy, has an industrial-based, energy-intensive economy. The Province is also in the midst of framing energy policy for the next few decades. Its boundaries span the entire Northern section of the Great Lakes, and a section of the St Lawrence River, therefore the health of the Great Lakes is pivotal to the Province’s future. Where data for the US is available and relevant, it will be included as well.

3.0 Evidence and Arguments: Impacts to Water from Different Types of Energy

When discussing impacts of energy on water, it is important to consider both water consumption and water quality. The health of a body of water can be harmed by different toxins that are introduced through the development or use of energy. Examples of this include mercury emissions from coal power plants or sulfur emissions from vehicles that are introduced to lakes and rivers through rainwater.

Water consumption can have major impacts if more water is removed from the body of water than is naturally replaced. Water consumption is starting to be a problem in Northern Alberta where the tar sands industry is removing large amounts of water from the Athabasca River (Nikiforuk, 2008). Low water flows can kill aquatic life and have negative impacts upon other water users, including residents of the area and other industries that depend upon the water use. Table 3.1 outlines water consumed by different types of energy to produce electricity on a per MWh basis in the United States. The data includes the amount of water consumed for mining and extraction of all raw materials used, for refining the fuel, and for power plant operation. Obviously, there is some variation in the water consumption depending upon the source of the fuel. Values for water consumption for transportation fuels would be similar, except the power plant operation would not be included for oil/gasoline, biofuels and natural gas.

Table 3.1 Water Consumed by Different Types of Energy when Generating Electricity. Data includes water consumed during extraction, refining and power plant operation (DHI Group, 2008).

Energy Type	Approximate Total Water Consumed (m^3/MWh)
Solar	0.001
Wind	0.001
Gas	1
Coal	2
Nuclear	2.5
Oil/Petrol	4
Hydropower	68
Biofuel (1st Generation)	178

The following sections will further discuss the amount of water consumed, and impacts to water quality from the different types of energy listed, along with the role each type of power plays in the Ontario energy mix.

3.1 Solar and Wind Power

From the data in Table 4.1, both solar and wind power consume less water than any other energy technology listed. The majority of the water consumed by these technologies is for cleaning where required, and this tends to vary depending upon the conditions where the technology is installed (DHI Group, 2008). Water is consumed during the manufacture, transportation and installation of the units, mainly due to the consumption of electricity or fossil fuels, but these are generally one-time consumptions for the life of the units. There is no significant ongoing water consumption through the use of wind power or solar power (DHI Group, 2008).

3.1.1 Solar Power

Most solar power generating stations use photovoltaic cells; generally, the water consumption during operations is very low Griffiths-Sattenspiel (2009). There is some concern with water consumption of solar panels that require water for cooling in areas with water shortages (Streater, 2009).

3.1.2 Wind Turbines

As wind power is expanded to locations offshore in the Great Lakes, questions are being raised as to the impacts to the aquatic ecosystem. In January 2008, Ontario lifted the moratorium on offshore wind farms in the Great Lakes. This moratorium was in place for 14 months in order to study the environmental impacts of offshore wind projects in the Great Lakes (Hamilton, 2008).

According to the Minerals Management Service, the Renewable Energy and Alternate Use Program, and the U.S. Department of the Interior (2006), the construction and decommissioning phases for offshore wind turbines normally last 6 months each. During either period, there are concerns about sedimentation, noise, vibration and the potential for oil or other toxic chemical spills. The construction of a wind turbine will also alter a small section of the lakebed permanently. This could potentially have some negative impacts on migrating species (Minerals Management Service et al. 2006).

There are several potential impacts to water quality during the operating phase of a wind turbine, however, these pale in comparison to the impacts of other types of energy described later in this inquiry. Wind turbines have been known to kill migrating birds and bats, although several studies conducted by wildlife groups have indicated that predators and high-rise buildings with windows pose more of a risk for migrating birds that wind turbines (Jay, 2007). Underwater cables are required to transport electricity from the turbines back onshore to the final user. It is not known if there are impacts caused by electromagnetic fields emanating from these cables (Minerals Management Service et al, 2006). Impacts of low frequency noise from wind turbines also require further study.

3.2 Natural Gas

Natural gas represents 32% of Ontario's overall energy use, however, it represents only 16% of Ontario's installed electricity generating capacity (Purchase, 2008, the IESO, 2009). The majority of natural gas use in Ontario (54%) is for space and water heating (Purchase, 2008). Ontario's two major natural gas distribution companies service over 3.1 million customers (Chute, 2009). Natural gas is used by 71% of Ontario residents as the primary heating source (Norton, 2008).

Natural gas can have different composition depending upon the source. Natural gas used in Ontario comes mostly from Western Canada, with smaller amounts coming from different regions in the US. Methane makes up approximately 95% of the natural gas used in Ontario, with ethane, nitrogen and other gases making up the remainder (Union Gas, 2009). Natural gas used in Ontario contains a small amount of sulfur: 0.6 mg/m^3, although an additional 4.9 mg/m^3 is added as an odourant for safety reasons (Union Gas, 2009).

3.2.1 Natural Gas Wells

Since most of the natural gas used in the Great Lakes region comes from outside of the basin, impacts from drilling for natural gas do not have major impacts on the Great Lakes. However, there were 1200 commercial natural gas wells and an unknown number of private wells located in the Province at the beginning of the current decade (Manocha and Carter, 1999). Depending upon the source, natural gas production can yield water found underground with the gas (Veil, Puder, Elcock & Redweik, 2004). Produced water from natural gas, while much lower in volume compared to water produced from oil production, can contain levels of aromatic hydrocarbons and other pollutants (Veil, et al., 2004). Any water must therefore be treated before it is discharged back into the environment.

As easily accessible natural gas becomes harder to find, sources such as shale gas and coal bed methane, some found in the Great Lakes basin, will become more highly coveted by energy companies. Shale gas and coal bed methane are harder to access than traditional natural gas, require more drilling, and pose a significant threat to groundwater (Nikiforuk, 2008). The impacts of drilling for shale gas were recently illustrated in a Pennsylvania town where aluminum and iron from shale gas drilling fluids began to turn up in well water (Lustgarten, 2009).

3.2.2 Natural Gas Distribution

Natural gas is distributed to homeowners, commercial and industrial customers, using steel and plastic pipelines (NaturalGas.org, 2004). Natural gas is non-toxic and is lighter than air, so there are no concerns for water quality with spills or escapes (Lustgarten, 2009). Installing natural gas pipelines in the vicinity of water resources can have impacts if care is not taken (Fisheries and Oceans Canada, 2006). When crossing rivers or streams, directional drilling can be used instead of open cutting through the watercourse to minimize impacts. The largest risk with drilling a pipeline under a river or stream is a ‘frac-out’; this occurs when the directional drilling mud, used as a lubricant during the drilling process, escapes the drill channel and enters the watercourse (Fisheries and Oceans Canada, 2006). While the directional drilling mud is mainly composed of water and bentonite, a natural clay, procedures are required to minimize the chances of a frac-out (Fisheries and Oceans Canada, 2006).

3.2.3 Natural Gas Power Generation

Most of the water used in a natural gas-fired power plant, not unlike other thermoelectric power plants, is for cooling. As shown in Table 4.1, consumption levels for natural gas-fired electricity are low compared to other fuels. Since natural has does not have large amounts of sulfur, sulfur dioxides levels from natural gas-fired power plants are low compared to other fossil fuel power plants.

3.3 Coal

The Province of Ontario currently has four coal power plants that are run by Ontario Power Generation: Nanticoke, Lambton, Atikokan and Thunder Bay. Together the four power plants have a capacity of 6250 MW and represent 19.4% of Ontario's installed electricity generation capacity (Ontario Power Generation, 2009, and the IESO, 2009). The Nanticoke facility is Canada's largest single emitter of greenhouse gases, nitrogen oxides and airborne mercury emissions, and Southern Ontario's largest emitter of sulfur dioxide (Clean Air Alliance, 2009).

In order to reduce greenhouse gas emissions as well as other pollutants, the Province of Ontario has committed to closing all coal-fired power plants by 2014. These plants will be gradually phased out as other generation capacity is constructed. The original date proposed by the McGuinty Provincial Government for closing all coal plants was 2007, however this was abandoned due to a lack of replacement generating capacity.

Coal is the major source of electricity in the United States. At over 2 Billion MWh of electricity generated from coal in 2004, the US generates more coal electricity than any other country (NationMaster, 2009). Coal-fired power plants account for 54% of the electricity generated in the US and 60% of the electricity generated by the six states that surround the Great Lakes (Union of Concerned Scientists, 2009 and Kling, Hayhoe, Johnson, Magnuson, Polasky, Robinson, et al, 2003). Due to the age of many US Coal-fired power plants, many new plants are being proposed; there are currently plans to build

159 new coal power plants in the US, many of which will be located in the Great Lakes area (Purchase, 2008).

3.3.1 Coal Mining

Over 90% of the coal used in the Great Lakes area for power generation and steel manufacturing originates from outside the basin (Business North, 2009). Nonetheless, almost 3.7 million tons of coal used in the Great Lakes in 2008 was mined in Pennsylvania, Ohio and Illinois (Business North, 2009). The coal that is mined in the Eastern US, has a much higher sulfur content than that in Western US coal (US Department of Energy, 2006, p.53). Projections are that coal will continue to be a major component of the US electricity mix; according to the National Energy Board of Canada (2008), the US is predicting an increase of 125,000 MW of coal-fired electricity generating capacity before 2030.

Like other mining operations, coal mining can impact groundwater flows. Mining of coal uses significant amounts of water. The US Department of Energy (2006) states that coal mining uses between 3.5 – 22 Liters of water for every 1000 MJ of coal electricity produced by coal power plants (40-400 liters of water per ton of coal). This is dependent upon the source of the coal. Coal is washed to remove some of the sulfur and increase the heat content (US Department of Energy, 2006, p.53).

3.3.2 Coal-fired Power Plant Operation

Coal-fired power plants use water from local water bodies for cooling. According to the Union of Concerned Scientists (2009), a 500 MW power plant uses about 8.3 million cubic meters of water per year for this purpose. The use of water for this purpose kills fish eggs and fish larvae that are too small to be filtered during water intake and can have thermal impacts upon the body of water when the water is returned.

Coal-fired power plants also emit a large amount of different toxins into the air. Many of these chemicals make their way into lakes and rivers, causing negative impacts. Table 3.3.2 lists the amounts of pollutants emitted from a typical 500 MW coal-fired power plant in a year, along with some of the environmental impacts.

Table 3.3.2 Pollutants emitted from a typical 500 MW coal-fired power plant in the United States in a year (Union of Concerned Scientists, 2009).

Pollutant	Amount Emitted per Year	Environmental Impact
Carbon Dioxide	3,700,000 tons	Climate Change
Sulfur Dioxide	10,000 tons	Acid rain that damages lakes, rivers and forests
Small Particulates	500 tons	Smog/haze and respiratory problems
Nitrogen Oxides	10,200 tons	Leads to the formation of ozone, causing smog and respiratory problems
Hydrocarbons and Volatile Organic Compounds (VOCs)	220 tons	Ozone and smog, cuasing respiratory problems
Mercury	80 kg	Extremely toxic, carcinogen, accumulates in the food chain
Arsenic	100 kg	Carcinogen
Lead	50 kg	Carcinogen

3.3.3 Clean Coal

New technologies are available that can greatly reduce emissions from coal power plants, many of which can be installed on existing coal-fired power plants (Purchase, 2008). Table 3.3.3 lists emissions reductions that are possible when using super-critical pulverized coal technology.

Table 3.3.3: Emissions reductions in coal-fired power plants using super-critical pulverized coal technology compared to conventional pulverized coal power plants (Purchase, 2008).

Pollutant	% Reduction
Particulates	99.9%
Sulfur Dioxide	77%
Nitrous Oxide	70%
Carbon Dioxide	18%

While new technologies may reduce toxic emissions from coal-fired power plants, the impacts of coal mining remain unchanged. This form of energy is also still carbon intensive compared to other forms of electricity. Greenhouse gas emissions and climate change will continue to have negative impacts on water resources despite a shift to cleaner coal technologies.

3.4 Nuclear Power

Nuclear power plants make up over 1/3 of Ontario’s installed electricity generating capacity (IESO, 2009). With the three main nuclear power plants in the Province (Darlington, Pickering and Bruce) nearing the end of their expected lives, the current plan is to build an additional 14,000 MW of nuclear generating capacity in Ontario (Ontario Power Authority, 2007). As a start to this process, Ontario Power Generation (2007) is looking at building new nuclear generators at the Darlington site.

Uranium used at Ontario’s nuclear power facilities is mined in Northern Saskatchewan (Winfield, Jamison, Wong, & Czajkowski, 2006). The majority of US Uranium is mined in Wyoming, Texas and Nebraska (US Department of Energy, 2006). Impacts to water from mining and milling do not have direct impacts upon the Great Lakes and can be found in Appendix C. The section below will focus on uranium processing and on nuclear power plant operation since these activities occur in Ontario.

3.4.1 Uranium Processing

For Canada’s nuclear power plants, all refining and fuel processing takes place in the Great Lakes region; these stages are required to convert milled uranium into the fuel bundles that are used in Ontario’s nuclear power plants. According to Winfield et al. (2006), the only uranium refining facility in Canada is located in Blind River, a community located on the Northern shore of Lake Huron, between Sudbury and Sault Ste Marie. During refining, contaminants are removed and uranium trioxide is produced. The uranium trioxide powder is then sent to the conversion facility in Port Hope, Ontario, located an hour east of Toronto, on Lake Ontario, where it is converted to uranium dioxide. The final fuel bundles, used at the Darlington, Pickering and Bruce power plants, are manufactured using uranium dioxide at sites in Port Hope, Toronto and Peterborough (Winfield et al, 2006).

Low level radioactive wastes have historically been created by these sites. Winfield et al (2006) estimate that almost 4.5 million cubic meters of waste from the Port Hope conversion site, containing uranium and heavy metals, are being stored in the Port Hope area awaiting a permanent disposal site. The Port Hope area has also be flagged as an area of concern under the Great Lakes Water Quality Agreement due to low level radioactive waste in sediment, a result of emissions from the uranium facility in the 1930s and 1940s (Winfield et al, 2006).

3.4.2 Nuclear Power Plant Operation

The following sections outline the impacts to water in the Great Lakes through nuclear power plant operation. Dealing with the spent fuel bundles often gains the attention of opponents of nuclear power. There are also thermal impacts to water from nuclear power plant operation.

3.4.2.1 Spent Uranium Fuel

Once used, the uranium fuel bundles are extremely radioactive. According to Winfield et al (2006), it will take 1 million years for the radioactivity of the spent fuel used in Ontario’s nuclear power plants to return to the same radioactivity as natural uranium. Currently, there is no longterm disposal strategy for nuclear waste from Canada’s nuclear power plants. The Canadian Government is currently looking into longterm disposal options, including deep underground in abandoned mines, in the Canadian Shield in Northern Ontario, Northern Quebec or Northern Saskatchewan (Kemp, 2009). The Canadian Shield is an extremely stable geological area, therefore the risks of accidental radioactivity escape due to earthquakes are low. The spent fuel is currently stored at the nuclear power plant sites in large pools of water for cooling (Ontario Power Generation, 2007). Once cool, the used fuel is stored in a dry storage facility on the power plant site. Since the Darlington, Pickering and Bruce power plants are all situated on the banks of Lake Ontario and Lake Huron, any accidental release of radioactivity from these used fuel bundles could have major impacts on water in the Great Lakes.

3.4.2.2 Emissions from Nuclear Power Plant Operation

Compared to other methods of generating electricity, the operation of nuclear power plants creates almost no air or water emissions. However, nuclear power plants in Ontario are the largest sources of hydrazine emissions in Canada. In 2004, approximately 3.5 tons of hydrazine, a known carcinogen, were released into the Great Lakes (Winfield et al, 2006). There are also regular emissions of tritium oxide, a low level radioactive substance, into the water and air from nuclear power plants. Dr. Monica Campbell, the Toronto Medical Officer of Health, argues that the precautionary principle should be taken with respect to exposure to tritium oxide. Campbell (2008) has concerns that the Ontario drinking water standards for tritium are not stringent enough and are potentially putting Toronto area residents at risk to different forms of cancer due to releases of tritium oxide from the Province’s nuclear power plants.

3.4.2.3 Thermal Impacts to the Great Lakes

Large amounts of fresh water are used at nuclear power plants for cooling, and then returned to the source at a higher temperature. As a result, nuclear power plants are usually located close to a large body of water. Winfield et al (2006) note that approximately 225 L of water are required for every kWh of electricity produced by nuclear power plants. In a given year for the Pickering and Darlington power plants, the amount of cooling water used is 19 times the water consumption of the city of Toronto. The return of cooling water to the source is known to have negative impacts upon fish populations in the areas surrounding the nuclear power plants (Winfield et al, 2006).

3.5 Oil

The refined products from oil are by far the primary transportation fuels used in the World today. Gasoline, diesel, jet fuel and heavy fuel oil account for 94% of all transportation energy use (Harvey, 2008). The extraction of oil from the ground can consume varying amounts of water and can have differing impacts upon water quality, depending upon the source. Oil extraction in some locations can actually produce water if water is trapped below the ground with the oil (Veil et al., 2004). This water must be treated before it can be released into the environment as it will often contain oil and other contaminants (Veil et al., 2004). Other oil extraction procedures, such as the tar sands operations in Western Canada, consume large amounts of water.

An entire paper could easily be dedicated to the relationship between oil and water quality. This section will briefly focus only on the impacts to water from refining oil since there are currently many refineries located in the Great Lakes Area. Appendix B contains additional information on the Tar Sands and their relationship to water in the Athabasca Region in Alberta.

Refining is the process where crude oil is converted to different final petroleum products, such as gasoline and diesel fuel. During this process, many different chemicals can be released into the air, such as carbon monoxide, volatile organic compounds, nitrogen oxides, sulphur dioxide, particulates, ammonia and benzene (Marbek Resource Consultants and AMEC E&C Services Ltd., 2003). Table 3.5 contains data on pollutants that are released into the air from oil refineries in Canada and the US. Many of these pollutants have impacts on water quality. For instance, sulphur dioxide and nitrogen oxides released into the air form acid rain, which is know to degrade lakes and rivers (U.S. Environmental Protection Agency, 2008).

Table 3.5: Measured air emissions from North American Oil Refineries in 1999 (Levelton Engineering Ltd. and Purvin and Gertz Inc., 2003. Capacity data from Nation Master, 2009).

			Emissions (tons per year)						
	Number of Refineries	Total Capacity Barrels per day)	CO	VOC	NOx	SO2	Particulates	NH3	Benzene
Canada	20	1,954,000	13,529	21,736	29,535	118,593	15,395	26	213
US	138	17,042,000	164,192	127,157	215,031	355,293	72,404	13,104	654
Total	158	18,996,000	177,721	148,893	244,566	473,886	87,799	13,130	867
Average per refinery		120,228	1,125	942	1,548	2,999	556	83	5

Most of the water used during the refining of oil is used for cooling and is discharged back into the environment (World Petroleum Council, 2009). Despite this, refining consumes an average of 2 barrels of water for every barrel of oil that is refined (US Department of Energy, 2006, p.20). Since water used for cooling theoretically does not mix with the petroleum at any stage of the cooling process, cooling water is not a significant source of water pollution, unless there is a leak or an accident. Refineries must treat both rainwater and process water that mixes with petroleum before it is released back into the environment (World Petroleum Council, 2009).

Due to the expansion of the tar sands, oil pipelines are being constructed to many different areas of North America, including the Great Lakes, to carry synthetic crude oil and bitumen (Israelson, 2008). In order to handle this influx of petroleum product from Alberta, there are 17 different refinery expansions either in the planning or the construction phases in the Great Lakes Region (Israelson, 2008). The additional upgrading and refining occurring in the Great Lakes Region will consume additional water resources and impact water quality. Since bitumen also contains higher levels of sulphur, nitrogen and heavy metals than conventional crude oil, any upgrading that occurs will release many of these contaminants into the water or air in the Great Lakes (Price, 2008).

3.6 Hydroelectric Power

Hydroelectric power has been in use for 100 years, and plant sizes can range between a few hundred watts and thousands of megawatts (Boyle, 2004). It makes up one quarter of Ontario's installed electricity generating capacity, and supplies 19% of global energy (IESO, 2009, and Collier, 2004). Compared to non-renewable sources of energy, it is seen as a reliable and environmentally friendly way of generating electricity. Despite the good reputation, hydroelectric power can have serious environmental impacts, including impacts to water resources, which should be taken into account when comparing different types of energy. For one, the Canadian Energy Research Institute (2004) claims that hydroelectric power can be a source of greenhouse gases due to methane that is formed in flood areas from decomposing plant matter at the bottom of the reservoir.

According to Collier (2004), both small 'run of river' and large hydroelectric power plants can have negative impacts upon water resources, especially if site selection, planning and design are not completed with the health of water resource in mind. Often, achieving the highest output from a hydroelectric power plant can have significantly higher consequences to ecosystems and other users of the water resource (Collier, 2004).

The following sections outline some of the impacts to water from hydroelectric plants. Since the environment around every hydroelectric plant is different, different sites will have different negative impacts.

3.6.1 Evaporation due to Hydroelectric Water Reservoirs

Table 3.1 lists hydropower as the second largest water consumer amongst the different types of energy listed, with only biofuels consuming more water. This is a result of evaporation from large water reservoirs that are built to enable the conversion of hydropower to electricity. It is estimated that 4500 gallons of water are lost for every MWh of electricity produced from hydroelectric power that uses reservoirs to store water (US Department of Energy, 2006). If the water resource in a particular area is limited, or flow rates in downstream rivers are a problem at certain times of the year, this could cause damage to the waterway ecosystem.

3.6.2 Water Quality Impacts due to Hydroelectric Power

The construction of a hydroelectric plant often requires the diversion of the water resource and can have major impacts to the surrounding environment. The construction of some plants has flooded large areas of land and altered the surrounding ecosystem for eternity. Such an event can have major localized environmental and social impacts (Collier, 2004).

Dams, used for hydroelectric power, disrupt natural water flows, disrupt fish migration, and often injure or kill fish (Canadian Energy Research Institute, 2004). One example of this is the endangered American Eel in the St. Lawrence River, which has seen drastic declines in numbers of migrating species, due to hydroelectric power and other causes (Environment Canada, 2007). According to the Canadian Energy Research Institute (2004), decaying vegetation found under hydroelectric reservoirs can create bacteria able to convert mercury into a water soluble form. This mercury is then able to accumulate in the food chain. However, in general, emissions to water from hydroelectric plants are low compared to other forms of power generation because no fuel is consumed.

3.7 Biomass and Biofuels

Biomass and Biofuels are seen by many as an attractive energy source for North America due to their minimal impacts on global warming (Dominguez-Faus, Powers, Burken, & Alvarez, 2009). Greenhouse gases that are emitted by burning biomass and biofuels are reabsorbed by the next generation of crops grown to create more biofuels. Biofuels are also praised as an alternative to importing foreign oil from politically unstable countries and as a way to increase energy independence.

3.7.1 Solid Biomass

Solid biomass, including wood or other plant residues, can be used for generating electricity and heat. In the European Union, biomass accounts for generating nearly as much electricity as wind power (Ballista, Busnelli, & Granskog, 2008).

According to Ballista, Busnelli & Granskog (2008), biomass has several advantages compared to other renewable fuels. It is the only renewable fuel that can be used on a large scale to generate heat. Biomass can generate reliable baseload electricity, or peak electricity, on a larger scale than other renewables; a 300 MW facility is now under construction in the UK (Ballista, Busnelli & Granskog, 2008). The pulp and paper industry uses biomass on a large scale; waste wood products can be used to supply all of the heat and electricity used in the production of paper (Harvey, 2008).

A significant amount of water is consumed to create biomass, but this is generally rainwater. The main disadvantage with biomass is that large areas of forest are required as fuel. Cutting down these forests can have significant environmental impacts. Using biomass on a large scale for electricity destroys vast areas of forest land that can take a generation to replace.

3.7.2 Biofuels

Biofuel production has many disadvantages that must be considered before North America embarks upon a massive push for more biofuels, including impacts upon food prices, land use issues and the overall energy balance for biofuels. The Associated Press (2008) reports that due to the fact that many current biofuels are derived from food crops, such as corn and soybeans, World food prices have been climbing as large amounts of these crops are redirected for fuel production. In some countries, rainforests are being cut down to make way for farms used to grow biofuel crops (McDonald, 2007). These impacts will not be discussed any further in this paper, but must be considered when discussing the sustainability of biofuels. The following sections will focus on the impacts to water of producing biofuels.

The amount of energy used to produce biofuels is also an issue; in many cases, biofuels yield less energy than the fossil fuel energy input for their production, as described in a study by Ecologist David Pimentel from Cornell University (Lang, 2005). Even studies that have shown biofuels to have a positive energy balance, such as a 2006 study by the University of Minnesota, note that biodiesel and corn-based ethanol produce 93% and 25% more energy than they respectively consume for production (Science Daily, 2006). This is a minimal energy return compared even to the Alberta oil sands; this method of oil production produces four times the energy that is consumed (Kunzig, 2009).

3.7.2.1 The Production of Biofuels

The two main types of biofuel currently manufactured are ethanol and biodiesel. Corn is the main source of ethanol in North America, although other crops can also be used for ethanol production, including sugarcane (used in countries such as Brazil), sorghum, potatoes and switchgrass (Dominguez-Faus et al, 2009). Soybeans, rapeseed and jatropha are the main sources for biodiesel production (Science Daily, 2006).

Due to the perceived benefits of ethanol and other biofuels, many jurisdictions in Canada and the United States have been ramping-up biofuel production in recent years. Between 2004 and 2006, biofuel production increased by 25% worldwide, to a total of over 58 mllion cubic meters per year (Varghese, 2007). This total however only offsets 1.15% of worldwide petroleum consumption.

The Province of Ontario is home to 9 of Canada's 20 ethanol plants (Benzie, 2009). Most of the plants in Canada produce ethanol from corn. The Ontario Government recently scaled back its ambitions for ethanol consumption in the Province due to environmental concerns and impacts of biofuels on world food prices. Dalton McGuinty, current Premier of Ontario, had originally pledged to have 10% ethanol in Ontario gasoline by 2010, however, this was scaled back in 2008 (Benzie, 2008).

3.7.2.2 Water Consumption to Produce Biofuels

The production of biofuels consumes more water than any other type of energy examined in this inquiry. The most significant consumption of water during the production of biofuels is for growing the feedstock (US Department of Energy, 2006, p.20). Processing and refining biofuels uses approximately the same amount of water as refining regular oil (about 2 barrels of water consumed per barrel of biofuel produced), however, this amount is negligible compared to the amount of water required to produce the feedstock for the biofuel (US Department of Energy, 2006).

The amount of water consumed from biofuels depends upon many different factors, including the plant used as feedstock for the biofuel, climate and geography. Depending upon the climate and the type of crop, the plants may be able to grow using rainwater as a water source. According to Gillam (2009), supporters for corn-based ethanol argue that for the majority of corn in the US, this is the case. However, in many areas of North America, and depending upon the amount of rainwater year to year, irrigation is often required to ensure the survival of the crop. With the push on for more biofuels, crops such as corn are now being grown in areas that do not get as much rain; as a result, more irrigation is required (Gillam, 2009). Irrigation removes water from water sources, such as lakes, rivers and underground aquifers.

The amount of water consumed to produce 1L of biofuel in the US varies between 800 L for ethanol produced by potatoes, to 4200 L for biodiesel from soybeans (Dominguez-Faus et al, 2009). To put this in perspective, and to show the variability in the amount of water consumed by different biofuel crops, Table 4.6 displays the water requirements for driving a vehicle using ethanol from different sources. The analysis is presented as the amount of water consumed per kilometer driven.

Table 4.7 Comparison of different biofuels grown in different regions of the US: amount of water consumed to produce enough biofuel to drive a vehicle with gasoline fuel efficiency of 10.2km/L (24 miles/gallon). (Source: Dominguez-Faus et al, 2009)

Biofuel	Origin of Crop	Water Consumption (L/km Driven)
Corn-based Ethanol	Nebraska	118
Corn-based Ethanol	Iowa	54
Sorghum-based ethanol	Nebraska	212
Sorghum-based ethanol	Texas	270

3.7.2.3 Biofuel Impacts on Water Quality

Biofuels also have major impacts upon water supplies. Fertilizers and pesticides used in growing biofuel crops run off into water ways and have negative impacts upon water quality and aquatic life (Dominguez-Faus et al, 2009).

Corn, the main crop used to produce ethanol in the US, is the most nitrogen fertilizer intensive crop amongst the major crops grown in the North America (Varghese, 2007). There have been problems in the Mississippi River and the Gulf of Mexico due to excess nitrogen leaching into waterways mainly from corn farmland; this has lead to an increase in algae growth and oxygen depletion, or dead zones, in some areas of the Gulf of Mexico (Varghese, 2007 and Science Daily, 2006).

Pesticide use also varies depending upon the feedstock used for biofuel production. According to Dominguez-Faus et al (2009), corn-based ethanol uses approximately 1g of pesticides for every litre of ethanol produced and soybeans use about 3g of pesticides for every litre of biodiesel produced. Potatoes use almost 16g of pesticides for 1 litre of ethanol (Dominguez-Faus et al, 2009).

3.7.2.4 The Future of Biofuels

The impacts to water from biofuel production can be reduced by using different crops as feedstock for the biofuels. Several different biofuels are under development that are far more water efficient than existing biofuels, such as non-food energy grasses and different shrubs that require less water to grow. (World Business Council for Sustainable Development, 2009). Algae may also prove to be a source for biofuels in the future. According to Colihan, (2008), researchers at the University of Minnesota have estimated that algae may be able to produce almost 57,000 litres of biofuel per hectare of surface water. Compared to corn that is able to produce 205 litres of biofuel per hectare of land, this is quite promising (Colihan, 2008). However, growing algae to produce biofuels creates significant amounts of waste. Some algae can be toxic to humans and aquatic ecosystems, depending upon the local environment. (Colihan, 2008). A cautious approach, and a great deal more scientific study, is required before biofuels from algae will become mainstream, if they ever do.

4.0 Policy Recommendations

This section is dedicated towards making several policy recommendations to reduce the negative impacts that energy has on water resources. Several of the opportunities listed below are easy to implement or are already underway on a smaller scale. While this is definitely not a complete list, this section serves as a starting point for policy discussions and will hopefully spawn other ideas.

4.1 Conservation and Energy Efficiency

Conservation, energy efficiency and reducing energy consumption are the easiest ways to reduce the impacts of energy on water quality and quantity. Both Canada and the United States are among the top per capita electricity consumers in the World; Canada ranking #3 and the US ranking #5 (Nationmaster, 2007). The average Canadian consumes more than twice the electricity of the average resident in countries such as Germany and Japan (Nationmaster, 2007). The United States and Canada are also the tope two per capita energy consumers in the world (Nationmaster, 2000). Based upon the electricity consumption rates of many of the other countries, Canada and the US should be able to cut electricity consumption significantly without having major impacts upon quality of life.

According to Granade, Creyts, Derkach, Farese, Nyquist, & Ostrowski (2009), there is significant potential to reduce energy consumption through exploiting energy efficiency. The 2009 study indicates that through heavy investment in energy efficiency, end-use consumption in 2020 in the US would be 16.5% lower than today. This corresponds to a 19% decrease in primary energy consumption. The study also indicates that the total investment required to attain these savings in the US would be $520 Billion, but that the overall savings in energy costs for this investment would be $1.2 Trillion. Environmental costs under the business as usual scenario were not included in the study (Granade et al, 2009).

Conserving electricity will also delay or eliminate the need to construct additional power plants. This avoided cost could be used to promote further energy efficiency and conservation. According to Hamilton (2009), Atomic Energy of Canada recently bid $26 Billion to build two 12,000 MW nuclear reactors to replace some of Ontario's existing nuclear power supply. A study should be performed examining how much electricity could be saved using this same $26 Billion price tag.

4.2 Continue to Expand Wind, Solar and Hydro Power

Solar and wind power have negligible impacts to water resources compared to the other types of energy examined. The two technologies are very dependent upon the climate and weather where they are installed, and are not as reliable as other forms of energy, so it is unlikely that they will ever supply all of our energy needs. The cost of these sources of power, especially solar, must also be considered. Still, governments in the Great Lakes area should continue to expand these technologies as long as they are more feasible than massive conservation efforts and other forms of renewable energy.

While hydroelectric power can have significant impacts on water resources, they are usually localized to the area where the plant is constructed. Fossil fuels and nuclear power can cause much farther reaching environmental damage due to air and water emissions that are able to migrate.

As already discussed many of the impacts from hydroelectric power can also be minimized with careful design, site selection and planning (Collier, 2004). While the impacts that cannot be avoided may cause permanent damage ecosystems, they are one-time impacts, unlike fossil fuel power plants that continue to pollute for the entire lifetime of the plant.

For the Province of Ontario, the majority of potential hydroelectric sites have already been developed. There are some sites further north in the Province that could be significant sources of hydroelectricity, however, there are complications that must be overcome for these projects to become a reality. First of all, the infrastructure to transport the electricity from the Northern Ontario to the South, the area where the electricity is needed, does not currently exist. According to Hamilton (2008), high voltage transmission lines cost $3 million per kilometer to build. An analysis may show that the cost of building the transmission lines is just too high compared to conservation or other types of renewable electricity. The construction of high voltage power lines through remote areas of the province will likely have impacts on water resources as well. Secondly, agreements are required between the Ontario Government and the natives who live in the area. The Ontario Government should begin studying these two issues as soon as possible so that informed decisions can be made before the power is required, and so that environment impacts are minimized.

4.3 Efficient Use of Energy

According to Harvey (2008) coal mine productivity in the US has been decreasing steadily as easy to extract coal reserves are depleted and due to the fact that a large amount of US coal has high sulfur content. As Harvey (2008) argues, peak coal may actually be a lot closer than many actually believe. As the amount of accessible fossil fuels remaining on Earth becomes more and more of a concern, it is important to use what we have left as efficiently as possible. This also reduces impacts on water resources.

4.3.1 Efficient Use of Natural Gas

WWF Canada views natural gas as an “an important transition fuel” as our society moves away from heavy fossil fuel use (Hamilton, 2008). While natural gas is still a fossil fuel, it is relatively clean burning compared to gasoline, diesel fuel, oil and coal (Hamilton, 2008). 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 than natural gas for a given energy output (DHI Group, 2008). Natural gas production in Canada peaked in 2001 (Harvey, 2008). There are other options available for natural gas supply, including importing LNG from overseas, however, pressurizing and depressurizing the gas comes at an efficiency penalty (Harvey, 2008). In addition, importing natural gas will decrease Canada’s energy independence. As a result, natural gas must be used as efficiently as possible to minimize environmental impacts and conserve enough natural gas to use until the majority of our energy supply comes from renewable resources.

The Ontario Government has been pushing natural gas as a way to generate electricity for the Province and replace some of the capacity that will be removed when the coal-fired power plants are closed by 2014. Several new natural gas-fired power plants have been built in the Toronto area over the past few years, including the Portlands Power Plant in downtown Toronto, and the Goreway Power Plant in Brampton. However, generating electricity with natural gas is less efficient than other uses of the fuel; single cycle gas turbines typically convert 30-40% of the energy in the natural gas to electricity, whereas combined-cycle gas turbines can have efficiencies of 50% (Harvey, 2008). With large centralized power plants, approximately 8% of the electricity generated is lost through transportation, further decreasing the efficiency of the natural gas output (WWF Canada et al 2007).

Space and water heating are the two largest uses of energy in the home (Natural Resources Canada, 2009). New high-efficiency natural gas furnaces have efficiencies of 96% (Enbridge Gas Distribution, 2008). Conventional gas water heaters have efficiencies of 50-55%, but high efficiency condensing gas water heaters can have efficiencies of over 90% (Natural Resources Canada, 2009).

From an efficient use of energy standpoint, it makes little sense to use natural gas for electricity generation when customers are using electricity for space and water heating. Since natural gas distribution pipelines are already present in most communities in Ontario, the Government of Ontario should focus more on promoting natural gas as an end source fuel instead of a fuel for power generation. By promoting fuel switching to natural gas where it is appropriate, Ontario could offset some of the electricity demand that is currently provided by coal and natural gas power plants. Where natural gas is not available, other fuels such as propane or biomass could be used for space and water heating. This would come at a very low cost compared to building new power plants. By using natural gas efficiently, overall energy demands will decrease, as will the impacts to water resources in the Great Lakes Area.

4.3.2 Other Fuel Switching Opportunities

There are many other opportunities that exist for fuel switching that will reduce impacts to water resources. Solar water heaters are currently being installed in the Great Lakes area and have the potential to reduce natural gas consumption by 60% (Enbridge Gas Distribution, 2009). The sun can also be used to reduce electrical lighting and space heating requirements through better building designs. Fuel switching opportunities also exist for industrial customers; some steel plants get some of their electricity requirements through the use of biomass (Burford, 2007). For residents in the Province who do not have natural gas in their community, propane may be more efficient than electricity for space and water heating.

4.3.3 Efficient Use of Transportation Energy

Reducing the energy consumed for transportation of people and goods is an obvious way to reduce impacts to water in the Great Lakes Region. Reducing the need to drive, choosing more fuel efficient vehicles, buying locally grown produce are just a few examples of easy ways to make a positive difference. The Government of Ontario should introduce more policy to reduce transportation energy consumption in the Province.

Urban sprawl has gobbled up vast quantities of farm land in Ontario and has led to an increase in the car culture that is prevalent in many areas of the Province. This type of development encourages more gasoline consumption through both longer trips to destinations and through increased traffic congestions. Due to the increased energy requirements from this type of living, and the fact that developing the land in this way also has negative impacts upon water resources, the Province must make every attempt to promote smarter and infill development in the Province.

Harvey (2008) outlines several other ideas for reducing transportation energy consumption. One technology discussed that is currently under development is the plug-in hybrid electric vehicles. Such a vehicle could draw electricity from the grid at off-peak times to provide much of its energy. Solar panels on the vehicle could also supplement energy requirements during the day.

4.4 Peak Shaving

Further efforts should be made to reduce the peak electricity consumption in the Province of Ontario through peak shaving. Currently in the Province, coal-fired power plants are used when electricity demand surpasses the amount that can be provided by other sources. Once the coal power plants are mothballed, peak generating capacity will be provided by other sources such as natural gas. By shifting some of the peak electricity consumption to off-peak times, more of the consumption can be supplied by base-load sources, such as nuclear and hydroelectric, which tend to be more water-friendly than coal. Peak shaving will also reduce the amount of capital expenditures required for building peak generating stations; these savings could in turn be spent on conservation.

Ontario currently has several programs in place to start shifting peak consumption. The Province is installing smart electricity meters for all electricity consumers so that higher rates can be charged during peak times. The theory is that consumers will start to shift non-time dependent consumption to save money. There are also programs in place for utilities to control residential air conditioners. During times of peak demand, the utilities have the ability to shut down central air units in an attempt to save electricity in exchange for a rebate on their electricity bill. Similar programs should be implemented Province-wide. Natural gas distribution companies have interruptible industrial customers who pay a special rate for their natural gas. When natural gas consumption peaks, the distribution companies can shut down supply to these customers to ensure that residential heating loads are met. Brining on more interruptible industrial electricity customers would also help reduce peak demand.

4.5 Charge More for Electricity

Politically, charging more for electricity would be an unpopular move for any government to make. However, if explained properly, there is better chance for public acceptance. The theory is that if electricity prices are increased, people will look for creative ways to reduce consumption. As described above, conservation is probably the most effective way at reducing impacts to water quality and quantity from energy. There are however social disadvantages to this approach that must seriously be examined. Charging more for electricity will impact those living in poverty most, since they do not have the disposable income to invest in conservation. Increasing electricity charges may also cause some businesses to move to other jurisdictions with lower electricity rates, costing the Province of Ontario jobs.

4.6 Education

A 2009 poll in the US indicated that only 9% of Americans are very knowledgeable about the source of their electricity (Gstalder, 2009). While the results in Ontario may be vary slightly due to increased media coverage on electricity over the past few years, the poll does indicate that Governments in North America could do a better job at educating citizens on the sources of electricity, and the pros and cons of the different ways to generate power. An education campaign in Ontario on the impacts of energy on water supplies will enhance the public debate and assist the Government with implementing a water-friendly energy strategy. Better knowledge on impacts will also make some Ontarians think twice about their use of energy in an effort to reduce their impacts upon water resources.

Education can also assist with conservation, energy efficiency, fuel switching and peak shaving. By knowing the benefits of these electricity reduction methods, especially the financial benefits, citizens will be more compelled to save energy.

4.7 Further Investigate Biomass

Biomass offers some benefits to water quality compared to other fuels, such as coal and oil. While using biomass on a large scale is unreasonable, due to the large areas of forest that would be destroyed to satisfy our hunger for energy, further studies should be completed to evaluate potential applications of this fuel.

4.8 Change the Production of Biofuels

From an energy balance ratio, many biofuels make little sense; some biofuels yield about as much energy as they consume (Lang, 2005). Considering that the energy output to input ratio for biofuels is not very favourable, the massive impact to water resources and water quality from biofuels is coming at very little benefit.

In addition, biofuels are just not a reasonable replacement for petroleum due to their land and water use. If all corn and soybeans grown in the US were used for biofuel production, only 11% of gasoline and 8.7% of diesel fuel would be replaced (Tay, 2006).

For the time being, biofuels do provide some benefit as additives to gasoline and diesel. Biodiesel protects engine parts when used as an additive, and both ethanol and biodiesel oxygenate the base fuel and allow it to burn cleaner (Science Daily, 2006).

Further advancements in technology will reduce the impacts on water from biofuels. Until these impacts can be greatly reduced, the Province of Ontario should hold off on increasing the amount of biofuels used. Longer term, biofuels will likely play a role in the energy mix, due to the fact that the feedstock is renewable. Algae may prove over time to be this solution.

4.9 Use Nuclear Power as a Transition Fuel

Nuclear power currently provides much of the base load electricity for the Province of Ontario. In order to keep the province running, a reliable, constant source of electricity is needed; this is currently what nuclear power delivers. For the time being, nuclear power is key to ensuring the economy in the Province continues to thrive.

Between eight and ten years are required to build a nuclear power plant (CBC News, 2007). As a result, decisions must be made now on how to replace the Province’s aging nuclear power plants. If the Province is to replace nuclear power, it must do so with a fuel that is as reliable and can produce constant amounts of electricity, irregardless of the weather. It will take time to develop such an alternate source. Wind and solar power are not able to provide the same reliability due to their dependence upon climate and weather conditions. Hydroelectric power is more reliable, but can have some variations depending upon the seasonal variations in water flows. In addition, most new opportunities for hydroelectric power in Ontario are limited to regions in the north of the province. Building the transmission lines from the north will have impacts to water resources along the way. Despite the fact that there are many opportunities for conservation and energy efficiency in the Province of Ontario, the Province will not be able to drastically reduce electricity consumption by the time decisions need to be made on replacing existing nuclear power. Using fossil fuels to replace nuclear is just not an option from a water quality standpoint and from a greenhouse gas emissions standpoint.

As a result of all of these factors, Ontario does not have many other options than to commit to some nuclear power for the foreseeable future. However, mining, purifying and transporting the uranium fuel, along with constructing and maintaining a nuclear power plant are very energy intensive. According to Hartmann (2004), the energy consumed for these activities during the lifetime of a nuclear plant is equivalent to the energy produced by the same nuclear power plant over an 18 year period. Looking to the longer term, investment is required to develop alternate ways of generating base load once the next generation of nuclear power plants is up for replacement.

According to Winfield et al (2006), Canada has only 40 years of proven uranium reserves left at current extraction levels. As more and more of the World’s uranium is mined, he remaining uranium will become more and more difficult to access. The amount of energy required for the mining and the wastes created will increase. This serves as another reason why Ontario should plan for replacing nuclear power in the longer term.

5.0 Conclusion

The Central Question for this paper is:

"Where should Ontario steer energy policy to ensure minimal impacts to water quality in the Great Lakes, while ensuring healthy economies?"

This paper has shown that, while some elements of the current energy mix have minimal impacts to water quality and quantity, keeping the status quo is an unacceptable approach. The impact to water from the use of coal, oil, nuclear and biofuels needs to be addressed to ensure the longterm health of the Great Lakes, so that future generations can use the source of water for life and to drive the economy, and so that other species can continue to live of the Lakes. Many of the ideas to reduce harm to the waters of the Great Lakes from energy are the same ideas that have been discussed to reduce greenhouse gas emissions, to improve air quality and to reduce environmental impact. This should be no surprise since all of these issues are interconnected.

The easiest and most effective way to reduce the impact to water from energy generation is to reduce the amount of energy that is required. Conservation, energy efficiency, peak shaving and efficient use of energy all play huge roles in improving water quality and ensuring water quantities are not impacted. Renewable sources of energy, such as solar, wind, hydroelectric and biomass should also be pushed where appropriate. For the time being, however, these energy sources are not able to provide the amount of energy and the reliability needed to keep the economy strong. However, a clear understanding of the impacts to water quality and quantity must be understood before developing any source of energy. Current generation biofuels and some hydroelectric power plants have major consequences on water. Nuclear power should be used as a transition fuel; the Province of Ontario must plan to end nuclear power generation after the next nuclear power plants run their course. Use of gasoline and diesel for transportation must be reduced.

The list of solutions presented in this paper to minimize the impacts to water quality and quantity is by no means an exclusive list. Many other ideas exist, and will be discussed, to reduce water impacts. All new ideas should be encouraged, and evaluated thoroughly to attain maximum benefits.

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Appendix

Appendix A: Per Capita Energy and Electricity Consumption for Several Nations

Table A1 lists the per capita energy consumption for several industrialized nations for the year 2000. Canada and the United States are the two top per capita energy consumers in the world.

Table A1: Total Per Capita Primary Energy Consumption in the Year 2000 (Measured as Tonnes of Oil Equivalent Per Capita) (Nation Master, 2000)

Country	Total Primary Energy Consumed (Tonnes of Oil Equivalent Per Capita)
United States	8.35
Canada	8.16
Finland	6.40
Belgium	5.78
Australia	5.71
Sweden	5.70
Norway	5.70
New Zealand	4.86
Netherlands	4.76
France	4.25
Japan	4.13
Germany	4.13
United Kingdom	3.89
Ireland	3.86
Switzerland	3.70
Denmark	3.64
Austria	3.52
Italy	2.97

Canadians and Americans are among the highest per capita electricity consumers in the world (Nation Master, 2007 and Frontier Centre for Public Policy, 2003). Ontario’s per capita electricity consumption is about 12,000 kWh (Conservation Bureau, 2008). The fact that the consumption is below the Canadian average may be a result of Ontario’s heavy reliance on natural gas for space heating and the warmer climate than most other regions of the country.

Table A2 provides a sample of the yearly per capita electricity consumption rates of several countries in the world.

Table A2: Yearly Per Capita Electricity Consumption Rates of Several Developed Countries (Nation Master, 2007).

Country	Per Capita Electricity Consumption (kWh/year)
Iceland	26,102
Norway	24,374
Canada	15,645
Sweden	15,258
United States	12,343
Australia	10,252
New Zealand	9,286
Austria	7,951
Belgium	7,930
Japan	7,426
Denmark	6,659
Russia	6,649
Germany	6,366
Netherlands	6,180
United Kingdom	5,680
Ireland	5,653
Portugal	4,327
Chile	2,979
Thailand	1,786

Appendix B: Impacts to Water Resources from Tar Sands Operations in Alberta

As the World deals with ever reducing reserves on conventional oil, and higher oil prices, unconventional oil sources, such as the Tar Sands (or Oil Sands) in Northern Alberta, are becoming more attractive to investors. The impacts of developing the oil sands on greenhouse gas emissions have been well documented by media over the last few years. According to Hatch and Price (2008), 40 million tonnes of carbon dioxide emissions were created by oil sands mining and processing in 2008. Development of the tar sands also has major impacts on freshwater resources both in the Athabasca region of Northern Alberta, where tar sands are located, and throughout North America.

The earth in the tar sands contains 10-15% bitumen (Kunzig, 2009). Bitumen is a tar-like petroleum substance that must be upgraded to produce synthetic crude oil, and then refined in traditional refineries to produce gasoline and diesel fuel. Bitumen contains higher levels of contaminants than most other sources of petroleum; it is composed of 5% sulphur, 0.5% nitrogen, 100 ppm heavy metals, and other toxic substances, such as naphthenic acid and polycyclic aromatic hydrocarbons Nikiforuk (2008, p. 30). Many of these contaminants are released into the air and water during the different phases of processing tar sands bitumen. Huge amounts of energy and water are required to mine the earth, and separate the bitumen from the surrounding soil and sand. Every barrel of synthetic crude oil from the tar sands consumes an average of 2-4 barrels of water and 21.2 m^3 of natural gas (Nikiforuk, 2007).

Much of the water consumed by tar sands mining is stored in massive tailings ponds, covering a total area of 55 km^2 along the banks of the Athabasca River (Price, 2008). The Athabasca River flows northward, feeding the Mackenzie River, Canada's longest River, that flows all the way to the Arctic Ocean. Tailings are created at a rate of 2000 – 2500 L per barrel of bitumen, and are composed of water, sand, residual bitumen, and many toxic chemicals including mercury, cadmium, lead, naphthenic acid and polycyclic aromatic hydrocarbons (Price, 2008).

The tailings ponds are a risk for wildlife, including birds; they are unable to differentiate between natural water sources and the tailings ponds. Birds that land in the tailings ponds get covered with the hydrocarbon mixture that disables their ability to fly and often leads to death (Wells, Casey-Lefkowitz, Chavarria & Dyer, 2008).

The larger risk associated with the tailings ponds is that there will be an accidental spill into the Athabasca River, polluting the entire Mackenzie River Delta, including Northern Alberta and a large section of the Northwest Territories. According to Price (2008), it is estimated that the tailings ponds are already leaking into the Athabasca River, and into groundwater sources, at a rate of 4 billion litres per year, due to the fact that they are built on ground that conducts water. Signs of this contamination are already present in the areas downstream of the tar sands along the Athabasca River. The town of Fort Chipewyan, located just north of the tar sands, has been dealing with disturbing levels of rare diseases and forms of cancer (The International Boreal Conservation Campaign, 2008). In the same area there have also been fish found with deformities and tumours. One fish was found with 2 jaw bones (The International Boreal Conservation Campaign, 2008).

Appendix C: Impacts to Water Resources from Uranium Mining and Milling in Saskatchewan

Uranium used at Ontario's nuclear power facilities is mined in Northern Saskatchewan (Winfield et al, 2006). The majority of US Uranium is mined in Wyoming, Texas and Nebraska (US Department of Energy, 2006, p.56). According to Winfield et al (2006), mining of uranium can take place in either open pit or vertical shaft mines. Once removed from the earth, the uranium ore is transported to the milling facility, where it is ground into fine particles, mixed with an acidic or alkaline solution to remove the ore from the residual rock, and then concentrated. Wastes from mining and milling include waste rock from the earth that is moved to gain access to the uranium ore, and tailings, a mixture of sand, water and chemicals used in the milling process. Uranium mining for Canadian nuclear power plants produces 90,000 tonnes of tailings and 2.9 million tones of waste rock per year (Winfield et al, 2006, p. 23).

Like any other mining process, uranium mining has significant environmental impacts, including major impacts to water sources. When developing the mine, groundwater and surface water sources are often disrupted or removed from the landscape. For every 77 kWh of power generated from nuclear power, 1-6L of water are consumed during the mining process, with higher amounts required for surface mines (US Department of Energy, 2006, p.56). According to Winfield et al (2006, p.23), Uranium mining in Canada removes 16 Billion litres of groundwater per year. Milling of uranium also produces air pollutants, such as nitrogen oxides and sulfur dioxide, which are known to cause acid rain and impact local waterways. Annual nitrogen oxide emissions from uranium mining and milling are approximately equal to that of 100,000 cars (Winfield et al, 2006).

Waterways are contaminated due to water runoff from mills, waste rock and mines (Winfield et al, 2006). Tailings are also a potential source of water contamination. Tailings contain radioactive materials and heavy metals found in the earth with the uranium ore, and toxic chemicals used in the milling process (Winfield et al, 2006). They are usually acidic due to the milling process. Since some of the radioactive elements have half-lives of thousands of years, the storage and containment of tailings is a major issue. Any tailings leakage would contaminate water sources located in the area surrounding the tailings storage facilities. As of 2003, there were 213 million tones of uranium tailings at 24 different sites in Canada, located in Ontario, Saskatchewan and the Northwest Territories (Winfield et al, 2006).