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Energy

Canadian outlook

Like most industrialized countries, Canada's energy consumption is high; this is compounded by its northern location. On a *per capita* basis, only the United States has a higher consumption rate than Canada. Overall energy use rose markedly from 1960 to 1973, the year oil prices increased significantly. There was a drop in global energy consumption after 1973 and again during the economic recession in the early 1980s.

Canadian energy consumption in 1994 was approximately 8,000 petajoules, or 8.0 x 10^{18} joules, corresponding to about 175 million ton oil equivalents (TOE)[1]. The highest energy demand in 1994 was for oil, which represented 37% of consumed energy as compared to 56% in 1971. Natural gas was next at 27% of energy used (19% in 1971). Electric power[2] provided 21% of energy in 1994 as compared to 9% in 1970, while 10% came from coal and 5% from wood (12% and 7% respectively in 1970). The use of oil has therefore decreased 33% in 24 years to the benefit of natural gas, hydroelectric and nuclear power. Finally, it should be mentioned that energy resources and production play a crucial role in Canada's economy, accounting for nearly 8% of the GDP.

Various forecasting models predict a 9,000 to 10,000 petajoule energy demand in 2010. This means that growth will be much slower between 1995 and 2010 than it was over the past three decades. Moreover, these forecasting models indicate that the share of each of these energy sources is stabilizing. Oil will therefore continue to play an important role, while new energy sources (solar, biomass and wind power, etc.) are not expected to make significant inroads.

Energy use in Quebec

From 1961 to 1997, total energy consumption in Quebec rose from approximately 17 million ton oil equivalents (TOE)[3] to nearly 34 million TOE in 1995, a 100% increase in 35 years. But this growth was not distributed evenly. The strongest growth period was recorded during the 13 years between 1961 and 1974 when consumption reached approximately 32 million TOE in 1974, meaning the annual growth rate was 7%. Growth was irregular after the oil crisis in 1973, and the economic recession in the early 1980s caused a marked decline in energy use in Quebec. A more normal growth rate of just over 2% per annum ensued, leading the ministère des Ressources naturelles du Québec (MRN) to predict that this rate will be stable until 2011 when a little over 45 million TOE will be used.

The dominant form of energy in Quebec in 1971 was oil. It represented 74% of demand, followed by electricity (19%) and gas (5%). By 1995, this situation altered dramatically: oil represented only 41.5% of Quebec's energy balance, followed very closely by electricity at 41.3%. The use of natural gas surged upwards from 5% in 1971 to 16% in 1995. According to MRN predictions, the use of electricity and natural gas should rise slightly between now and 2011 while oil dips to 34.5%. No major upheavals are expected to alter Quebec's energy picture the way the oil crisis did in 1973.

Primarily because of the transportation sector, oil should still represent at least a third of the province's energy consumption between now and the end of the 21st century. Looking at

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[1] One TOE equals the amount of energy contained in a barrel of Canadian crude oil.

[2] Includes hydroelectric power and electricity generated by nuclear or natural gas or coal-fired power stations.

[3] One TOE equals approximately 11 kWh (kilowatt hour).

consumption changes by sector, we see that oil accounted for 82% of home heating in 1971 and only 19% in 1995. Electricity, on the other hand, increased from 7% usage for domestic heating in 1971 to nearly 71% in 1995. It is important to specify that even though the use of non-traditional energy sources (wind and solar power, burning forest biomass and urban waste, etc.) rose 160% between 1975 and 1995, their contribution to Quebec's energy use is limited to four million TOE in 1995, or 11% of total consumption.

It is also noteworthy that energy conservation has helped reduce Quebec's energy demand. Excluding energy used in transportation, the average household energy consumption of approximately 2.65 TOE in 1984 declined to 2.51 TOE in 1994. This was one of the lowest rates in Canada, compared to Manitoba (4.0 TOE), Ontario (3.55 TOE), New Brunswick (2.9 TOE) and British Columbia (2.68 TOE).

In completing this outline, it must be said that the MRN feels that the use of non-traditional energy sources (wind and solar power, etc.) will fall from 9.6% of the Quebec energy balance in 1994 to 8.4% in 2011. Although it was predicted in the 1980s that these energy sources would become substitutes, technological hurdles and development costs have hindered their success.

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Hydroelectric dams

Extent of Quebec's production

Although there are some hydroelectric power stations in a few Canadian provinces, Quebec's development of its vast, harnessable hydraulic resources has resulted in the majority of this production being concentrated in Quebec since the early 1950s. The growth in the use of this form of energy obviously accompanied this development. In fact, if the transportation sector is excluded, electricity now meets most of the energy requirements of people and business, holding a 50% to 65% share of the markets involved.

Quebec is currently the world's third-ranking hydroelectric producer, with a power base of nearly 40,000 megawatts (MW), including the energy from Churchill Falls in Newfoundland's Labrador territory. Three-quarters of this power belongs to Hydro-Québec, which has built 83 power stations in the territory. Churchill Falls accounts for 12% of the total and private producers for just over 8%. With its total power of just over 15,000 MW, the La Grande complex is currently the world's leading hydroelectric installation.

Change in demand

The Quebec government wishes to continue harnessing various rivers and increasing power not only to meet the predicted Quebec demand, but also for export markets. Hydro-Québec's demand predictions are usually based on demographic, economic and energy outlooks. However, electricity demand forecasts made in the early 1990s have recently been revised downwards. The initial expected annual growth rate of 2.2% is now 1.5%, or half that of the period between 1980-1995 and only a quarter of that of the previous fifteen years.

The downward revision of the annual growth rate in electricity demand was one of the primary reasons for suspending the work scheduled for the 1990s on the Grande Baleine complex. Nevertheless, some medium-size projects have been started recently, such as the facility at the Sainte-Marguerite-3 River north of Sept-îles (nearly 900 MW). Moreover, the Quebec government has made it possible for private concerns to produce electricity and sell it to Hydro-Québec. These projects are normally new power stations but some stations abandoned several years ago are being refitted, such as those on the Chaudière River and at Sept-Chutes on the Ste-Anne River near Québec. These hydroelectric plants, however, must produce less than 50 MW of power, since Hydro-Québec remains the only company with authorization to manage projects with a greater output.

Socio-economic impacts

Because building a hydroelectric power station requires creating a reservoir behind a retaining structure (dam) made of rock fill (fill dam) or concrete, its location may result in significant socio-economic and environmental repercussions. For example, the installation of the La Grande complex in northern Quebec upset the traditional lifestyle of several Aboriginal groups.

Atmospheric impacts

Hydroelectricity is usually described as clean energy, since it is not produced from fossil fuels that emit gaseous atmospheric pollutants. Nevertheless, the construction of dams has led to questions about their contribution to the greenhouse effect. Tree loss in flooded areas could exacerbate the greenhouse effect because of vegetation decomposition (CO_2 and CH_4 emissions) and the loss of the carbon sink, since tree growth absorbs CO_2. However, the models used indicate a very low environmental impact in terms of greenhouse gases.

Terrestrial impacts

From an environmental perspective, priming a reservoir first causes the disappearance of terrestrial fauna habitats by destroying plant resources. Shoreline vegetation is most affected and for many years after an artificial reservoir is filled, the new banks often remain barren of this type of plant life because of the marling[4], which can be quite significant. Because of their limited ability to migrate, the smaller fauna are the most affected by the introduction of a new dam.

Aquatic impacts

The aquatic environment is subject to the greatest upheaval in the first few years following the priming of a reservoir. What was once a river becomes a lacustral environment in which the physical and chemical parameters are greatly altered. Submerging the vegetation produces large concentrations of organic material, which is broken down by microorganisms. There is

[4] Marling is the variation in the reservoir’s water level caused by periods of dry or rainy weather.

an increase in the biochemical oxygen demand (BOD) accompanied by a reduction in dissolved oxygen concentration. At the same time, nutrient elements (nitrogen and phosphorus) released by the decomposition of this organic material

foster the growth of phytoplankton. This is usually accompanied by an observable change in the composition of the ichthyological community. Some species of fish flourish while others diminish.

Mercury

One major problem caused by flooding the terrestrial environment is the transformation of inorganic mercury bound to the rocky subsoil into organic mercury (primarily methyl mercury), which can be biologically accumulated by aquatic organisms. The presence of water encourages the microbial activity producing this transformation. Since the mercury concentration in contaminated aquatic fauna is five to six times too high, restricted fish consumption represents a significant socio-economic repercussion for local human communities.

The level of fish flesh contamination varies with the species, but in all cases it is a gradual process, occurring over several years. In the La Grande 2 reservoir, for example, mercury concentration in flesh of the Northern sucker and lake whitefish reached 0.5 mg/kg by the fifth year after the reservoir was primed, and stabilized there until at least the ninth year. In the case of the carnivorous pike and northern pickerel, the concentration increased steadily until at least the ninth year when it reached 3 mg/kg. Since studies on the subject do not agree, it is difficult to predict how long mercury concentrations in fish will remain higher than normal, but a minimum of 15 to 30 years is considered realistic.

This situation obviously has repercussions on how Aboriginal communities who normally eat the fish will feed themselves. In its “Health Effects Assessment Summary Tables” (HEAST), the EPA states that the daily ingested dose of mercury should not exceed 0.002 mg/kg/d. Health Canada has established that fish for consumption should not contain more than 0.5 mg of mercury per kg. Given the level of contamination in Quebec fish, it is estimated that people should eat no more than eight meals (230 grams of fresh fish) per month of the insectivorous species and no more than two meals per month of the more contaminated fish-eating species. It must be said, however, that because of their traditional lifestyle, which includes eating large quantities of fish, these rules are not necessarily followed by the Aboriginal populations inhabiting Quebec’s northern regions. These people are therefore likely to bioaccumulate higher levels of mercury than are populations who consume less fish.

Impacts downstream from the reservoir structure

There may be major repercussions downstream from the dam because of reduced water flow, particularly when the reservoir is being filled. The most obvious case is that of the anadromous fish in the area, which cannot swim upriver to spawn. The dam itself is also an insurmountable hurdle for these fish. Depending on its size, it is possible, however, to install a fish-pass to help them swim upriver. Some recreational usages may also be lost as a result of severe reductions in the rate of water flow and breadth of the watercourse, especially in the dam's initial post-construction years.

Construction period

The environmental disturbances occurring during a dam's construction must also be mentioned. Opening new temporary or permanent roads, heavy truck traffic and blasting all produce dust that falls on and pollutes the environment. Add to this the noise pollution and the esthetic degradation of the natural environment. As a secondary impact, the presence of roads leading to the dam may open a previously inaccessible natural environment, resulting in the too-familiar consequences of tourism

activities: destruction of wildlife or waterfowl habitats, over-usage of certain areas, pollution from litter and motor vehicles, wildlife disturbance, etc.

Dam failure

The disaster that is most feared is a catastrophic dam failure, resulting in the rupture of the retaining structure and the sudden, rapid and uncontrolled release of the reservoir water. This would cause a flood wave to swallow the valley downstream from the dam. The worst consequences would be loss of life and major damage downstream from the point of failure.

On a global scale, some 8,000 people have perished as a result of dam failures in the 20th century. In Quebec, dam management is subject to stringent criteria. Prior to the Saguenay floods of 1996, the only incident in which lives were lost was the 1966 failure of the Éboulements reservoir, when three died at St-Joseph-de-la-Rive in the Charlevoix region. Even without loss of life, dam failure can cause significant damage to the natural environment. A 1984 dam failure in the Laurentian Wildlife Reserve north of Québec laid waste to about 144 hectares of forest over a distance of 6 km and carried away more than 2 million m^3 of loose material, destroying one of the reserve's primary wildlife habitats.

The Saguenay incident occurred between July 19 and 21, 1996, when devastatingly high water levels after exceptionally heavy rains caused many rivers to overflow. Public and private property suffered extensive damage. In addition to the devastation of forest and agricultural lands, downtown Chicoutimi and part of the city of La Baie vanished under the rising flood waters. It was during those three days that the dams and levees overflowed and ruptured.

Sector: Energy Activity: Hydroelectric Dam Structure[5]

STRESSOR/ EXPOSURE	Type of Stressor	Environmental Impact	Affected Zone	Control Measures	Standards or Recommendations
Technological disaster	- dam failure	- destruction of terrestrial and aquatic habitats	- downstream from the dam (up to tens of kilometres away)	- regular dam inspection - preparation of evacuation plan	- Bill forthcoming, 1998 (Government of Quebec)
Gaseous or atmospheric emissions	- CO_2 (from the destruction of vegetation)	- greenhouse effect	- global	- none	- Rio (1992) and Kyoto (1997) commitments
Liquid or waterborne emissions	- organic mercury	- contamination of aquatic organisms	- reservoir (upstream	- none	1 Fg/L (Q-2, drinking water regulation.) 2 Fg/kg/d, HEAST 0.5 mg/kg in flesh[6]
	- decomposing organic material	- water pollution, reduction in dissolved oxygen	- reservoir	- recover vegetation prior to priming reservoir	- none
	- floating debris	- water pollution, insalubrity, esthetics	- reservoir	- recover vegetation prior to priming reservoir	- none
Solid or soil-borne emissions	- varied construction debris (boulders, sand, etc.)	- pollution, insalubrity, esthetics	- construction site vicinity - access roads	- recover waste materials - restore the sites - transplanting	- none
Disamenities	- upstream flooding	- destruction of terrestrial habitats	- reservoir zone	- adjustments	- none
	- downstream drought	- destruction of aquatic habitats (affecting fish)	- downstream riverbed	- adjustments, migration channels (for fish)	- none
	- noise, dust (during construction)	- insalubrity	- construction area		- noise???
Indirect impacts or other exposure	- depreciation - social conflict - exploitation of wildlife or other resources	- heritage, economic or tourist	- dam construction area and access roads	- communication - monetary compensation	

[5] Applicable to the construction of a concrete or fill dam that creates a reservoir flooding terrestrial habitats.

[6] According to Health Canada, fish for consumption should contain no more than 0.5 mg/kg of mercury.

STRESSOR/ EXPOSURE	Effects on Health	Population at Risk	Probability of Occurrence	Biological/ Environmental Monitoring Indicators	Information/ References
Technological disaster	injury, trauma, death	- communities downstream from the dam, particularly those on the banks of harnessed rivers	- very rare	- public safety reports - regular inspections	Boivin *et al* (1994)
Gaseous or atmospheric emissions	- climate changes	- global	- rare (in the case of dams)	- atmospheric CO_2 concentration	- Mysak (1994)
Liquid or waterborne emissions	- poisoning (behavioural and neurological disorders)	- people eating large quantities of fish	- rare to frequent	- Hg levels in blood and hair (15 to 30 mg/kg in hair[7])	Tremblay *et al* (1994), BAPE (1993) and
	- N.A.	- N.A.	- N.A.	- BOD level	Hydro-Québec (1993)
	- insalubrity quality of life	- neighbouring communities, people using the area	- occasional	- visual appearance of the area	BAPE (1993) and Hydro-Québec (1993) MEF and MSSS (1995)
Solid or soil-borne emissions	- N.A.	- N.A.	- N.A.	- N.A.	
Disamenities	- quality of life	- local communities	- occasional to frequent	- complaints/perception	BAPE, Report #60 (1993) Hydro-Québec (1993) Complexe Grande-Baleine, project brief
	- quality of life	- local communities	- occasional to frequent	- complaints/perception	
	- quality of life	- local communities	- rare to occasional	- complaints/perception	
Indirect impacts or other exposure	- quality of life - stress - changes to the Aboriginal diet = 8 cardiovascular disease, diabetes, etc.	- local and regional communities - Aboriginal communities	- occasional to frequent - occasional to frequent	- complaints/perception - morbidity/mortality indicators	

[7] This concentration is three times the limit recommended by WHO but has been impossible to apply to Quebec Aboriginal communities for whom fish is the dietary mainstay.

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Cogeneration power stations

Nature of cogeneration

Cogeneration means the simultaneous production of two types of energy, usually electricity and steam. This combined generation of two forms of energy also calls for one or more energy sources. Natural gas is the most commonly used, and the other source (which normally represents less than 10% of the energy contribution) may originate from the combustion of different biomasses, wastes, or even an alternative energy such as wind power. In reality though, most developers have chosen to use declassified oil or grade 2 oil as the alternative fuel.

SUGGESTION TO INSERT AN ILLUSTRATION SHOWING A TYPICAL (GENERIC) SCHEMATIC OF A COGENERATION PLANT

Natural gas and a fossil fuel source are usually used to drive the turbines that power the electricity-producing generators. The hot gases are recovered from the turbines, and in turn drive the steam turbines. The steam can be used by a variety of industrial clients or to drive yet another electricity-producing generator. Each developer has a number of possible combinations to assess, which depend on potential client needs. As a general rule, industrial clients buy the steam and Hydro-Québec buys the electricity.

Atmospheric emissions

Environmental constraints to operating cogeneration plants are essentially atmospheric. Even when the plant uses only natural gas, the full range of primary atmospheric pollutants can be observed: suspended particulates, sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen oxides (NO_x), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and volatile organic compounds (VOCs). While emissions of these substances are minimal when natural gas is burned, they increase markedly when fossil fuels are used. These pollutants include suspended particulates, several greenhouse gases (CO_2, CH_4 and N_2O), gases that cause acid rain (SO_2 and NO_x) and substances that are irritants or a source of ozone and urban smog (NO_x and VOCs). Burning heavy oil or fossil fuel can also cause the release of polycyclic aromatic hydrocarbons (PAH). Risk calculations in the latter scenario usually predict a 10^{-6} (or, one person per million) increase in the incidence of cancer in adults.

Wastewater

The wastewater discharged into the environment from cogeneration plants usually comes from routine purges of the boilers and residual steam condensers. More wastewater is also generated when machinery or piping is cleaned. As a general rule, this wastewater contains few pollutants, although the presence of some biocides employed to prevent the growth of bacteria in the machinery may give these liquid wastes toxic properties.

Vapour plume

The existence of a vapour plume may cause a variety of problems. For example, if the plume changes into ground-level fog, it can alter visibility, or in winter it can form ice on the road surface. In either case, road safety can be jeopardized.

Odours

Cogeneration power plants should not cause unpleasant odours unless they use large quantities of fossil fuels when the gas system breaks down. In this instance, the presence of NO_x and SO_2 is a potential source of odour.

Economic relevance

The Bureau d'audiences publiques sur l'environnement hearings have indicated that the cogeneration power plant issue was more socio-political than environmental. Many stakeholders actually question the relevance of building such plants when there is an energy glut and incentive to conserve energy.

Socio-economic impacts

If the arrival of a cogeneration plant has the potential to stimulate a sector's economy by creating jobs and increasing patronage of neighbouring businesses, there is nevertheless agreement that negative socio-economic impacts can also result. They can arise from a fear that some form of pollution, or just the presence of the plant, will cause degradation of the natural and human environment, or even a depreciation in the neighbourhood's economic value.

Sector: Energy Activity: Cogeneration power plant burning primarily natural gas

STRESSOR/ EXPOSURE	Type of Stressor	Environmental Impact	Affected Zone	Control Measures	Standards or Recommendations
Technological disaster	fires, explosions	deposits, smoke, destruction	site and perimeter	confinement, capture	CSA Z731-95, emergency measures planning NFTA 850
Gaseous or atmospheric emissions	- suspended particles	- photosynthesis inhibition (deposits on leaves)	- site and perimeter	- dust collector	- 150 Fg/m^3 (24h), Q-2, atm. qual. reg.
	- NO_2	- ground-level smog and ozone formation	- regional	- catalytic reduction	- 0.2 ppm (1 hour) and 0.1 ppm (24h); Q-2, atm. qual. reg.
	- VOC	- ground-level smog and ozone formation	- regional	- recovery (biofiltration)	- none
	- CO_2	- greenhouse effect	- global	- reduce combustion	- Rio (1992) and Kyoto (1997) greenhouse gas commitments
	- CH_4	- greenhouse effect	- global	- none	
	- SO_2	- acid rain, toxic to vegetation	- vicinity and community	- recovery and absorption	- 0.5 ppm (1h) and 0.1 ppm (24h); Q-2, atm. qual. reg.
	- CO	- pollution	- site and perimeter	- recovery and combustion	- 0.3 ppm (1h) and 13 ppm (8h average); Q-2, atm. qual. reg.
	- PAH	- pollution	- site and vicinity	- recovery	- 0.2 Fg/m^3 (8h), total PAH (MUC)[8]
Liquid or waterborne emissions	- suspended materials	- insalubrity and turbidity	- captor watercourses	- holding and sedimentation tank	- 0.5 mg/L (Env. Canada raw water criterion)
	- anti-corrosive substances and biocides in coolant water	- toxicity to aquatic organisms	- captor watercourses	- none	- none
Solid or soil-borne emissions					
Disamenities	- noise and	- salubrity	- vicinity	- absorbent zone, better technology	- L_{eq} 45 dB (night) and 50 dB (day)
	vibrations	- salubrity, visibility, safety	- site and perimeter	- condensation inside stack	- none
	- vapour plume - odours	- salubrity	- vicinity	- filtration	- municipal reg.
Indirect impacts or other exposure	depreciation	economic and social value	perimeter and vicinity	compensation citizen participation	Q-2, section IV

[8] Standards taken from the Montreal Urban Community air quality regulations.

STRESSOR/ EXPOSURE	Effects on Health	Population at Risk	Probability of Occurrence	Biological/ Environmental Monitoring Indicators	Information/ References
Technological disaster	respiratory irritation, burns, death	workers and neighbourhood	very rare	public safety report	CSPQ (1994)
Gaseous or atmospheric emissions	- respiratory tract irritation, asthma	- neighbourhood (asthmatics)	- rare	- epidemiological surveillance of level of atmospheric particles	BAPE (1993a, b) and BAPE (1994) CSPQ (1994) Levallois and Lajoie (1997)
	- respiratory tract irritants	- neighbourhood	- rare	- atmospheric level of NO_2	
	- none at predicted concentrations	- N.A.	- N.A.	- atmospheric emissions tonnage	
	- climate changes	- global	- frequent	- atmospheric emissions tonnage	
	- climate changes	- global	- frequent	- atmospheric emissions tonnage	
	- respiratory problems	- neighbourhood (asthmatics)	- rare	- atmospheric emissions tonnage	
	- 8 carboxyhemo-globinemia	- neighbourhood	- very rare	- atmospheric and blood CO_2 measurement	
	- cancers (mostly lung and bladder)	- neighbourhood	- very rare	- level of BaP and other ambient air PAH	
Liquid or waterborne emissions	- insalubrity, no direct effect	- users of polluted water (bathers, boaters, etc.)	- rare	- aquatic SPM measurement	BAPE (1993a, b) and BAPE (1994)
	- unknown	- N.A.	- N.A.	- N.A.	
Solid or soil-borne emissions					
Disamenities	- quality of life and sleep, stress	- neighbourhood	- unknown	- complaints, ambient noise measurement	BAPE (1993a, b) and BAPE (1994)
	- quality of life	-neighbourhood	- unknown	- complaints	
	- quality of life	- neighbourhood	- unknown	- complaints	CSPQ (1994)
Indirect impacts or other exposure	- stress, quality of life assessment role	- neighbourhood and community	- unknown	complaints, role of assessment and perception studies	CSPQ (1994)

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Transport and liquefaction of natural gas

Nature of project

The information used in preparing this grid was taken from the PAC-RIM LNG project submitted to the Government of British Columbia in 1995. The project involves exporting liquid natural gas to Asia using specially designed vessels called LNG tankers.

The project includes three components. The first is the construction of a pipeline (24 to 30 inches in diameter) from Prince George, B.C., to Prince Rupert or Kitimat on the Pacific coast; the pipeline, either 507 kilometres. (Kitimat) or 592 kilometres. (Prince Rupert) in length, would carry 14 million cubic metres (500 million cubic feet) of natural gas per day with a diameter of 24 inches.

The second component is a plant for liquid natural gas (LNG) production. With a production capacity of 3.5 million tons of LNG per year, the plant (in Prince Rupert or Kitimat) would liquefy the gas by cooling it at -160 ^{o}C (-260 ^{o}F) in a cryogen tower. When liquefied, natural gas is reduced 625 times in volume for transport by an LNG tanker. Transformation involves the removal of carbon dioxide (CO_2) followed by removal of the water contained in the gas. Liquefaction is achieved through cooling with compressed propane gas and a mixture of pressurized nitrogen, methane, ethylene and propane. Refrigeration system operations require 300,000 litres of sea water per minute to cool the compressed gases. After liquefaction, LNG would be stored in four double-walled pressurized reservoirs measuring 95,000 cubic metres (600,000 barrels) each, at a temperature of - 160 ^{o}C.

The third component is the construction of a deep water port (Prince Rupert or Kitimat) to transsship LNG in tankers with double-walled pressurized holds and carrying capacities of 125,000 to 135,000 cubic metres. Sixty vessels a year would be loaded with LNG for transport to Asian countries like Korea and Japan.

Pipeline construction was estimated at $575 to $725 million, and plant and port construction at about $850 million. Total costs would be $1.3 to $1.5 billion and would employ 3,000 persons/year. The promoters estimate that the project would add about $12 billion to Canada's gross national product during its useful life, estimated at 20 years.

Environmental impacts

This is a major project in a northern setting with environmental impacts on water and air quality, soil, water fowl, bird life and large mammals (caribou and bears). The living patterns and hunting and trapping zones of the Aboriginal people of the region would be affected. Impacts are described for each of the project components: the pipeline, the factory and the deep-water port.

Impacts resulting from the construction and operation of the pipeline

A pipeline has little impact on air quality unless there is a leak. However, gas pumping stations operating with fossil fuels release low amounts of combustion gases into the atmosphere: carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NO_x) and volatile organic compounds (VOC) (see section on the liquefaction plant for the description of the effects of these pollutants).

The 18-metre-wide pipeline right-of-way would impact on vegetation and on aquatic and terrestrial fauna, and would cross about 200 watercourses of varying sizes along with several wetlands. Shoreline destruction and wetland drainage draining on an 18-metre swathe are major disturbances. Suspended solids and petroleum products could be introduced into the water during construction. These disturbances would impact on fish life, especially the five species of salmon found on the West Coast of Canada.

Pipeline construction would also impact on migratory and non-migratory bird life by destroying habitats through forestry and leading to nest abandonment. Ungulates (caribou, moose, deer, etc.) could be disturbed by construction machinery, while the the pipeline could alter the migratory habits of species like the caribou. The habitats of large carnivores (black bears, grizzlies and cougars) could also be disturbed, especially in cases where their food source (like salmon) is affected as well. The corridor defined by the pipeline route could facilitate hunting access and increase those pressures on various species.

The pipeline would run through the lands of various native tribes, and changes on wildlife habitats could have a negative impact on the Amerindians, since several animal species play a major role in their diet. Increased hunting could result in supply problems for Amerindian populations. The promoter's impact study finds that Amerindian quality of life would improve through job creation and economic benefits. However, the negative effects of such a major industrial installation must be factored into the equation.

More direct impacts on the health of native populations could result from food source contamination (plant or animal) through the spillage of petroleum products, or through herbicides used to maintain a free zone in part of the corridor. Changes in diet could also occur through disturbances to the animal resource or increased access to foods brought in from urban regions. Past studies have shown that seemingly minor changes in a traditional diet can lead to a variety of health problems.

Breakages can occur in pipeline transportation, with the potential ignition of escaped gas. Natural gas is highly flammable, and the heat generated by breakages can be enough to start fires. There is a permanent risk of human injury or death in the vicinity of an area where this type of disaster could occur.

Impacts related to the construction and operation of the natural gas liquefaction plant

With an oil or gas complex there is always the possibility of hydrocarbon leaks and explosions. The greatest risk here would be leaked natural gas leak or LNG, which is flammable in the atmosphere at a concentration of 6 to 13%. Depending on the size of the leak and the direction and strength of the wind, the natural gas plume could travel toward inhabited areas in a flammable concentration, with potentially disastrous results.

Several polluting gases would be released into the atmosphere during the plant's operations. Carbon dioxide (CO_2) removal, the use of burners (flare stacks) to dispose of surplus methane or various hydrocarbons and minor leaks from the numerous valves would release carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NO_x), volatile organic compounds (VOC) and methane (CH_4).

Carbon monoxide (CO) is an odourless gas that can increase carboxyhemoglobin. Concentrations would not be high enough to be a problem, however, and it is not considered a pollutant here.

Nitrogen oxides (NO_x) include nitric oxide (NO) which transforms rapidly into nitrogen dioxide (NO_2); a brownish gas with a sharp, irritating odour that can oxidize cell membranes. This gas can decrease odour perception, alter pulmonary function and in cases of severe exposure, can lead to pulmonary edema. One of the most significant effects of chronic exposure is emphysema and a reduction in forced expiratory volume. NO_2 reacts with VOCs to form photochemical smog (see below).

Volatile organic compounds (VOCs) are hydrocarbons that evaporate at ambient temperature and exist in vapour form in the atmosphere; they number in the thousands, and some are relatively toxic. The principal VOCs produced by combustion engines are polycyclic aromatic hydrocarbons (PAHs) that form in almost all types of incomplete combustion and contain several carcinogenic components like benzo[a]pyrene (BaP); oxygenated hydrocarbons including aldehydes (e.g.: formaldehyde), cetones (acetone), alcohols (e.g.: methanol) and organic acids (formic acid) are all respiratory tract and mucous membrane irritants. Some VOCs, including benzene, chloroform and formaldehyde, are considered carcinogenic.

The photochemical reaction of NO_x with VOCs forms secondary pollutants collectively known as photochemical smog. This smog includes ozone (O_3) on the ground (tropospheric), various free radicals, oxygenated hydrocarbons like aldehydes, and peroxyacetyl nitrates (PAN). All can be respiratory irritants, and some are mutagenic (PAN) or carcinogenic (formaldehyde). Smog is a concern because of the health problems it causes and because it is an urban atmospheric pollutant that is on the rise in Canada.

CH_4 is one of the principal greenhouse effect gases. Although generally released in far smaller quantities than CO_2, its warming effect is 25 to 30 times greater and so its overall effect on global warming is not negligible. In Canada, oil and gas exploitation is the second most important source of methane emissions, after the biogas from sanitary landfill sites and dumps.

Plant construction and operation of the plant could cause noise disburbances for animals or humans in the vicinity. Noise is generally defined as any acoustic energy likely to alter physical or psychological well-being. The standard measure is the mean value of equivalent noise level (L_{eq}) per time unit (24 hours, for example). It is measured using the decibel scale, a logarithmic scale, meaning that noise doubles in intensity with each increase of 3 decibels.

The World Health Organization (WHO) proposes an indoor residential limit of less than 45 dB(A) during the day and 35 dB(A) at night. Its outdoor daytime limit is 50 dB(A) L_{eq} and 45 dB(A) L_{eq} at night. Over 55 dB(A), the nuisance level in a residential neighbourhood is considered serious. In industrial zones or work environments, a level of 75 dB(A) L_{eq} (8 hours) is considered acceptable. These standards are currently under review. The main problems of noise are loss of sleep, communication problems, effects on the performance and behaviour of students and a feeling of decreased quality of life. Chronic exposure can cause increased blood pressure.

Construction would inevitably result in a loss of land fauna habitats (mammals and birds) and aquatic habitats (water fowl, fish, invertebrates) over an area of at least 64 hectares (surface cleared for installation) as well as potential soil and water pollution through accidental hydrocarbon spillages.

Construction near the marine shore would impact on this ecosystem, causing pollution and increased turbidity through runoff and the destruction of benthic habitats essential to animals living on the ocean floor. Plant operation could impact negatively on the marine ecosystem, since 300,000 litres of seawater per minute would be used to cool the refrigeration gases. Water returning to the ocean would be 0.5 ^{o}C higher in temperature. This increase would not be likely to disturb large marine animals or fish, but could affect benthic fauna and flora.

The surface required for the plant and its perimeter would necessitate the destruction of plant and animal habitats used as food resources by the native population. Accidental spillage of petroleum products during construction or of various chemical products during operation could contaminate land and water resources in a larger area if restraining basins and protective dikes around reservoirs and channels are not able to retain the liquids.

Impacts linked to the construction and operation of a deep-water transshipment port

The construction of a deepwater port would increase water turbidityin the port, and ship movements would increase turbidity within an area of a few hundred metres from the dock. Turbidity and the displacement of the seabed by the turbulence of ship propellers would impact on the benthic fauna, in some cases seriously. Sediments in the water would also create various problems for fish by burying habitats and interfering with respiration and reproduction. These effects would be negligible among marine mammals, which have a broader habitat base and can avoid affected regions. The spillage of LNG or tanker fuel could have major impacts, depending on the extent of the spill. Bird life is generally the most severely affected, as has been proven by numerous oil spills since the 1960s.

Human health is not directly threatened by the construction and presence of a deepwater port. However, there is always the risk of LNG leaks and explosions. Port zone workers would be at the greatest risk of potential injuries and fatalities A Quebec study on the transshipment of propane gas estimated that the annual risk of accident associated with faulty ship-loading systems operation would be about 10^{-4} with a mortality rate of about 10^{-2}/year. Human health would be indirectly affected if occasional spills of petroleum products contaminated the sea water through a bioaccumulation of certain substances in the last links of the food chain - in this case, carnivorous fish and marine mammals that may be part of the human diet.

Sector: Energy Activity: Natural Gas Transportation and Liquefaction

STRESSOR/ EXPOSURE	Type of Stressor	Environmental Impact	Area of Influence	Control Measures	Standards or Recommendations
Technological disaster	- rupture in pipeline, conduits or reservoirs	- destruction of land, aquatic and marine habitats	-primarily site and perimeter, may also be regional	- regular inspection, emergency measures planning - confinement	- appropriate CSA standards like Z184 and Z276-M1994
	- explosion				
	- fire				
Gaseous or air emissions	- CO_2	- greenhouse effect	- global	-containment of CO_2 extracted from natural gas	- none
	- CH_4	- greenhouse effect	- global	- prevention of leaks	- none
	- No_x	- toxicity, formation of smog and ozone on ground	- local and regional	- antipollution systems	- 200 $\mu g/m^3$ (24h) for NO_2
	-VOC	- toxicity, formation of smog and ozone on ground	- local and regional	- containment or 8 combustion performances	- none
Liquid emissions or discharge into water	- suspended solids	- unhealthiness, disturbance of aquatic life	- downstream waterways or marine perimeter	-preventive measures, but hard to monitor	- for pollutants overall: Fisheries Act (Canada); Cdn Environmental Assessment Act; applicable provin-cial laws (B.C. Environmental Assessment Act)
	- hydrocarbons	- unhealthiness, toxicity for aquatic life	-downstream waterways or marine perimeter	- confinement, but hard to monitor	
	- diversion or drainage of waterways and wetlands	- destruction of wildlife habitats	- waterways or wetlands, site and perimeter	- mitigation measures	
Solid emissions or discharge into soil	- destruction of forest and land habitats	- loss of wildlife habitats, wildlife disturbance	- site and perimeter	- reduction of destroyed surfaces, appropriate mitigation measures	- Migratory Birds Act (Canada); Cdn Environmental Assessment Act; B.C. Env. Assessment Act.
	- hydrocarbon spillage	- appearance, toxicity for animals	- site and perimeter	- prevention and confinement	
Nuisances	-noise and dust	- wildlife disturbance, unsanitary	- site and perimeter	- noise mitigation measures and dust control	- L_{eq} 45 dBA(night) and 55 dBA (day) (WHO standards); Canadian Environmental Assessment Act; B.C. Env. Assessment Act
Indirect impacts or other exposures	- social conflict	- economic	- local and regional communities	- financial compensation, communication	- Indian Act, treaty concluded with Amerindians
	- loss of ancestral and archaeological sites	- heritage and cultural value	- local and regional Aboriginal communities	- communication, artifact displacement, project modification	-Heritage Conservation Act (B.C.)

	- modification in traditional Aboriginal diet	- N.A.	- local and regional Aboriginal communities	- mitigation measures, communication, project modification	-???

STRESSOR/ EXPOSURE	Effect on Health	Population at Risk	Probability of Occurrence	Environment/ Biological Indicator (Monitoring)	Information/ References
Technologica l disaster	- respiratory irritations, burns, trauma, death	- primarily workers, also population inhabiting the perimeter	- very rare, about 10^{-7} to 10^{-2} deaths per year	- accident, morbidity and mortality reports - explosimeter	
	- unknown	- global	- frequent	- measure in ambient air, average annual temperature	
	- asphyxia, unknown for climatic change	- workers (asphyxia) and global (climatic change)	- rare and frequent	- measure in ambient air, explosimeter, average annual temperature	
Gaseous or air emissions	- irritation of respiratory tracts, smog provoking inflammation	- urban zone residents	- occasional during very hot periods	- measure in ambient air	
	- irritation of respiratory tracts, smog provoking inflammation	- urban zone residents	- occasional during very hot periods	- measure in ambient air	
	- N.A.	- N.A.	- N.A.	- N.A.	
	- toxicity, potentially carcinogenic if presence of PAH	- consumers of drinking water	- rare or unknown	- measure of concentration in water	
Liquid emissions or discharge into water	- N.A.	- N.A.	- N.A.	- N.A.	
	- N.A.	- N.A.	- N.A.	-N.A.	
	- toxic, potentially carcinogenic effects	- workers handling soil	- rare or unknown	- measure of concentration in soil	
Solid emissions or discharge into soil	- quality of life, sleep disturbance, stress, aggressiveness, hypertension	- workers and peripheral residents	- rare to frequent	- measure of external and internal ambient noise, complaints, medical follow-up	
	- individual and group stress	- neighbours and communities	- occasional	- property assessment follow-up, perception studies	
Nuisances	- quality of life, stress	- local and regional communities	- occasional and frequent	- complaints, community perception	
Indirect impacts or other exposures	- lifestyle changes, health problems like cardiovascular disease	- local and regional communities	- occasional and frequent	- community perception, long-term medical follow-up, epidemiological studies	

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