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Running head: ELECTRIC POWER GENERATION OPTIONS

Electric Power Generation Options for Vancouver Island

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Abstract

British Columbia Hydro and Power Authority (BC Hydro) provides electricity to the residents, businesses, and industry of Vancouver Island. Electric power on Vancouver Island was supplied from local hydroelectric generators at the Ash River, John Hart, Jordan River, Ladore, Puntledge, and Strathcona stations until the mid 1950s. In 1956 a submarine power cable system between Tsawwassen and North Cowichan was put into service. A second submarine power cable system was built in stages from 1967 and 1979, along the same route. In the mid 1980s two more submarine power cable systems were opened between Powell River and Qualicum. BC Hydro is now proposing three natural gas-fired electric power generation plants to supply the expected future demand on Vancouver Island. What other options are available to supply electric power for Vancouver Island?

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Electricity Power Generation Options for Vancouver Island

In 1961 the Government of British Columbia purchased the privately owned *British Columbia Electric Railway Company*, better known as the *British Columbia Electric Company* (BC Electric) (1897-1962). Then in 1962 the government merged it with the *British Columbia Power Commission* (BCPC) (1945-1962), a crown corporation, to form the *British Columbia Hydro and Power Authority* (BC Hydro). BC Electric had been providing electric power for the two largest cities in the province, Vancouver and Victoria, while BCPC had been providing electricity for the rest of the province.

On Vancouver Island prior to 1962, BC Electric provided power south of the Malahat. The company was formed in 1897 with offices in Vancouver and Victoria, and had acquired the following Vancouver Island companies: *Victoria Gas Company*, 1861-1904; *Victoria Electric Illuminating Company*, 1887-1890; *National Electric Tramway and Lighting Company*, 1889-1944; *British Columbia Electric Railway*, 1897-1944; and the *Vancouver Island Power Company*, 1910-1944 (Wilson, 12-15).

On Vancouver Island prior to 1962, BCPC provided power north of the Malahat. BCPC was formed by the government in 1945 with the passage of the Electric Power Act. "The Commission's task was twofold. First, it would meld the existing hodgepodge of generation and distribution facilities spread across the province – and outside BC Electric's territory – into one system. Second, it would extend service to many communities that didn't have power at all" (Wilson, 73). It purchased small electrical utilities, provided electrification to small towns and rural areas, modernized existing plants, and built an electrical transmission system. It's first purchase was the *Nanaimo Duncan Utilities* (NDU) in 1945. By 1962, BCPC had 300,000 customers, 40 percent from acquired utilities and 60 percent from those receiving electricity for the first time. The Commission provided power to 251 BC communities (Wilson, 73, 102).

BC Hydro now proposes to build three natural gas-fired electric power generation plants to supply the expected future demand for electricity on Vancouver Island. These plants will be a joint venture with the Canadian subsidiary of an American company. A natural gas pipeline from Washington state to the island by an American company is also proposed. Why has BC Hydro proposed this costly option, and what other options are available to supply power to the island? This ex-post-facto research included a search of periodical articles on this subject as well as information available on the internet, to try and find answers to these question.

This paper includes the following; The BC Hydro Proposal, Fossil Fuel Power Generation, Hydro Electric Power Generation, Submarine Power Cables, Alternative Energy Power Generation, Environment and Health Issues, and the Cost of Producing Electricity.

The BC Hydro Proposal

BC Hydro claims that the proposed natural gas-fired electrical generators and the undersea natural gas pipeline to supply them, is the best option to supply the future power needs of Vancouver Island (Vancouver Island Generation Project).

Vancouver Island Generation Project (VIGP)

BC Hydro and *Calpine Canada* (Calgary, AB), a subsidiary of the American company *Calpine Corporation* (San Jose, CA), propose to build three 50/50 joint venture natural gas-fired electric generation plants on Vancouver Island. These facilities are expected to develop 265 MW (295 MW with duct firing). The plants will include "a gas combustion turbine generator with selective catalytic reduction (SCR) to reduce Oxides of Nitrogen (NO_x), a steam turbine generator (STG), a steam condenser, a heat recovery steam generator (HRSG) and auxiliary equipment that will be housed in a building on the site" (Vancouver Island Generation Project).

The first of these plants, the Island Cogeneration Project (ICP), was completed in September 2000, but due to technical difficulties has yet to be turned over to the operator, Calpine. It is located adjacent to the *Norske Canada* Elk Falls pulp and paper mill in Campbell River. The second plant is expected to be built at Duke Point near Nanaimo, and the third at a location that is still undetermined.

BC Hydro is searching the world in order to purchase greenhouse gas (GHG) offsets. A GHG offset is a reduction in emissions at one location to compensate for an increase in emissions at another location. The company plans to purchase GHG offsets for half of the expected 700,000 tonnes per year increase in GHG caused by each of the three plants (GHG Offsets).

The Georgia Strait Crossing Project (GSX)

BC Hydro and *Williams Gas Pipeline Company* (Houston, TX) propose to build a new natural gas pipeline system, from the interconnection point of Westcoast Energy and Williams' Northwest Pipeline, near the Canada-USA border at Sumas Washington, to the Centra Gas pipeline west of the north end of Shawnigan Lake on Vancouver Island (see Figure 1. Georgia Strait Crossing). This 137 kilometer long 41 cm diameter pipeline will cost $260-million, and is required to supply the gas for the proposed three new natural gas-fired electrical generating plants on Vancouver Island (Georgia Strait Crossing Project).

The underwater section of the pipeline runs from a point between Blaine and Ferndale, WA under Georgia Straight to a point on the Canada - United States border in Boundary Pass, then proceeds in a westerly direction, south of Saturna Island, South Pender Island, and Salt Spring Island, to a point near Cherry Point on Vancouver Island (Georgia Strait Crossing Project).

The proposed GSX pipeline is designed to carry 2.66 million cubic metres of natural gas per day, and will be the second to cross Georgia Strait. The Centra Gas pipeline (see Figure 2. Centra Gas Pipeline) runs between Texada Island and Courtney, and was completed in 1991 (Georgia Strait Crossing Project).

Fossil Fuel Power Generation

In 1883, the *Victoria Electric Illuminating Company* used coal gas to power a 25 horsepower steam engine, manufactured by the Albion Iron Works, to produce the first commercial electricity in Canada. The electricity was used to power clusters of arc lamps on tall masts at three downtown Victoria locations (Wilson, 10).

The *Brentwood Steam Plant* was located at Brentwood Bay on Saanich Inlet, 16 km north of Victoria and was completed in 1912 (see Figure 3. Brentwood Steam Plant). It used fossil fuel to produce steam and generate electricity. It was decommissioned in

1965 (Wilson, 16).

Combustion Turbine Power Generation

Combustion Turbine Power Generation burns fossil fuels such as coal, oil, or natural gas, and the hot exhaust gasses from the combustion drive turbines, which then drive electric generators.

The *Georgia Generating Station* was located at Bare Point near Chemainus. It was opened in 1957 when the first of four gas turbines was placed in operation. Two of the turbines were simple-cycle, single-shaft machines, each producing 19,750 kW. The other two were regenerative-cycle, single-shaft machines, each producing 18,000 kW. All four turbines were built by General Electric Company (Schenectady, NY), and burn Bunker-C oil and compressed air for normal operation, but switched to diesel oil during startup and shutdown. The total output power was 75.5 MW and was used during peak electrical use periods. The station was decommissioned in 1970 (Kirby,1958).

The *Keogh Generating Station* consisted of two diesel-powered turbines with a total output power of 90 MW. The plant located 26 km east of Port Hardy, was built for the BHP Utah mine, but after the mine closed it was used by BC Hydro as back up power for the northern island. The first turbine was installed in 1975 and the second in 1977. The station was decommissioned in 2001 (BC Hydro's Keogh Generating Station to be Decommissioned).

Thermal Electric Power Generation

Thermal Electric Power Generation is the burning of fossil fuels such as coal, oil, or natural gas to produce hot gasses or steam which drives gas or steam turbines, and which in turn drive electric generators (Thermal Generation).

There are three general type of gas turbines, or combustion turbines, simple cycle, recuperated cycle, and combined cycle. The BC Hydro proposal is to build three 265 MW combined cycle gas turbine power plants on Vancouver Island.

Combined Cycle Gas Turbines, (see Figure 4. Combined Cycle Gas Turbine), exercise the concept of heat recovery by using exhaust steam in a device called a heat recovery steam generator (HRSG). The HRSG may contain a burner to increase the energy output. Energy from the HRSG drives a steam turbine which generates addition power to the main power turbine. Combined-cycle gas turbine power stations considerably increase power output and performance compared with the simple-cycle design. The efficiency is much higher for all cycles with heat recovery. Electrical efficiency increases for combined cycle turbines and generally is greater for larger turbine sizes (Gas Turbines for Distributed Generation).

Hydro Electric Power Generation

Hydro electric power is produced from the kinetic energy of falling water. The amount of electric power that can be produced at any location is a function of the volume of the water (flow) and the vertical distance that the water falls (head), the following equation can determine the power: power (kW) = 5.9 x flow (m^3 / sec) x head (m). A traditional hydroelectric station includes a dam, which creates a reservoir to store the water; penstocks or pipes, which channel water to the turbines; and a generator, which is driven by the turbine, and creates the electricity (Hydro Electric Power).

The *Goldstream River Generating Station* was the first hydroelectric generating station on Vancouver Island, and the first major hydroelectric station on the west coast (see Figure 5. Goldstream River Power House). It was built by BC Electric in 1898, at Japan Gulch on the Goldstream River, 21 km west of Victoria. It had a high head of 213 m which provided water pressure at 20 kg/cm^2 to the two Pelton water wheels, (see Figure 6. Pelton Water Wheel), which turned two 360 kW General Electric stationary field generators. In 1903 a 500 kW generator was added and in 1904 a 1,000 kW was also added. In 1912, when the Jordan River Generating Station was opened, the two original 360 kW units were shut down, and the plant continued with a power output of 1.5 MW. The plant was decommissioned in 1956 (Macfarlane, Summer 1971).

There are presently six BC Hydro owned and operated hydroelectric generating stations on Vancouver Island located at the Ash River, John Hart, Jordan River, Ladore, Puntledge, and Strathcona power stations. They provide 20% of the electricity available on Vancouver Island.

The *Ash River Generating Station* was built in 1958, and is located on the north shore of Great Central Lake north west of Port Alberni. The single Francis vertical shaft turbine with a maximum discharge of 13.97 m^3/sec, drives a vertical synchronous two-bearing conventional generator which produces 27 MW of power (see Figure 7. Francis Turbine). The Ash River system includes Elsie Reservoir with a capacity of 77 m^3 of water, and a normal water level range of from 320 m to 330.7 m. There is also a main dam and four saddle dams, each with a dam crest of 334.37 m. The Main Dam is earth fill, 189.2 m long with a maximum height of 30.5 m. Saddle Dam 1 is earth fill, 438.1 m long with a maximum height of 18.3 m, and has a low-level section to release water. Saddle Dam 2 is earth fill. 157.9 m long with a maximum height of 10.7 m. Saddle Dam 3 is earth fill, 130 m long with a maximum height of 3.0 m. Saddle Dam 4 is earth fill, 51.6 m long with a maximum height of 6.1 m (Ash River – Generating System Statistics).

The *Jordan River Generating Station* located 43 km west of Victoria was built by BC Electric and opened in 1911. It used three Pelton water wheels driving three generators which produced a total of 14.4 MW. A fourth turbine and generator were added in 1930 which increased power output to 26.4 MW. In 1971 the original four Pelton water wheels were replaced by a single Francis high head turbine driving a Mitsubishi generator which produces 170 MW of power (Macfarlane, Winter 1971-72).

The Jordan River system includes three dams and reservoirs. The Bear Creek Reservoir has a capacity of 9.3 million m^3 of water with a normal water level of 411 m. The Bear Creek Dam was built in 1912 and upgraded in 1994. it is earth fill, 337 m long with a maximum height of 19 m, and a dam crest of 420 m. It has a spillway with a concrete overflow section and two outlet valves to release water. The Diversion Reservoir has a capacity of 28.4 million m^3 of water, with a normal operating water level range of from 368 m to 386 m. The Diversion Dam was built in 1913, it is concrete buttress, 232 m long, with a maximum height of 39.9 m, and a dam crest of 390 m. It has an overflow spillway, a controlled low level outlet, and an emergency low level outlet.

m long. The spillway has three steel vertical lift gates with a total discharge capacity of 1220 m^3 /sec (Campbell River – Generating System Statistics).

The *Ladore Generating Station* was built in 1949 and put in service in 1957. Two turbines drive two generators which produce 54 MW of power. The Ladore Dam is concrete gravity and 94.5 m long. The spillway has three steel vertical lift gates with a total discharge capacity of 1925 m^3 /sec (Campbell River – Generating System Statistics).

The *John Hart Generating Station* was built in 1947. Six Canadian Dominion Works Francis type turbines, drive six Canadian Westinghouse generators which produce 126 MW of power. The John Hart Dam is concrete and earth fill, 746 m long, with a maximum height of 30 m. It is equipped with three vertical lift spill gates, each 9 m high and 9 m wide, with a total discharge capacity of 1557 m^3 /sec . Six intake gates 4.4 m high and 4.4 m wide with two per penstock, feed three 3.7 m diameter pipelines which move the water down 119 m to three 90 m high by 9 m diameter surge towers at the power house. The pipelines upper 1097 m section is made of wood and the lower 670 m section is made of steel (Campbell River – Generating System Statistics).

Submarine Power Cables

There are presently four submarine power cable systems providing electricity from the British Columbia mainland to Vancouver Island. They provide 80% of the electricity available on Vancouver Island.

Tsawwassen to North Cowichan Cables

The *HVAC Tsawwassen to North Cowichan Cable System* was opened in 1956. It is 119 km long and is comprised of two three-phase parallel circuits, each consisting of three high voltage alternating current (HVAC) 138 kV submarine cables, which provides a total of 200 MW of power. There is also one spare cable, The route runs by overhead transmission lines from the Arnott Terminal Station to the Tsawwassen Beach Cable Terminal near Point Roberts. Then undersea 26.5 km across Georgia Strait to Taylor Bay on Galiano Island and by overhead transmission lines across Galiano and Parker Island.

Then undersea 6.4 km across Trincomali Channel to Salt Spring Island and by overhead transmission lines across Salt Spring Island and Vancouver Island to the Vancouver Island (Stratford) Terminal, north of Duncan. The 11.3 cm diameter submarine cables supplied by British Insulated Callender's Cables Ltd., (England), and layed by the SS Ocean Layer, reached a maximum depth of 366 m. The cables are of a hollow core design to allow nitrogen gas pressurization to 136 kg. The cables are buried for protection near the cable terminals (Our undersea cable underway).

The *HVDC Tsawwassen to North Cowichan Cable System* was built in stages between 1967 and 1979. It is comprised of five (4 in service and 1 spare), high voltage direct current (HVDC) 300 kV submarine cables that provide a total of 840 MW of power. The route (see Figure 8. 300 kV Cable Route) runs by overhead transmission lines from the Arnott Terminal Station near Ladner, where the 230 kV AC is converted to 260 kV DC, to the Tsawwassen Beach Cable Terminal near Point Roberts. Then undersea 26.5 km across Georgia Strait to the Galiano Island, and by overhead transmission lines across Galiano and Parker Islands. Then undersea 6.4 km across Trincomali Channel to Salt Spring Island. Then by overhead transmission lines across Salt Spring Island and Vancouver Island to the Vancouver Island (Stratford) Terminal, north of Duncan, where it is converted back from DC to AC. The mercury-arc valve conversion equipment was supplied by ASEA (Sweden) and the solid state conversion equipment by General Electric (USA). The 9 cm oval shaped cable with a 4 cm centre copper conductor is wrapped with paper insulation, lead sheath, polyethylene, steel tapes, and an outer steel wire covering. The first three cables were manufactured by Cables-de-Lyon (France), and layed by the French government owned cable ship Marcel Bayard. The last two cables were manufactured by Pirelli Industries (Milan, Italy) (Macfarlane, Fall 1969).

Powell River to Qualicum Cables

The *Powell River to Qualicum Cable System* consists of two parallel circuits, each consisting of three high voltage alternating current (HVAC) 525 kV submarine cables for a total power of 2400 MW. The first circuit was placed in service in 1983 and the second circuit in 1984. The route (see Figure 9. 525 kV Cable Route) runs by overhead transmission lines from the Cheekye Terminal Station on the mainland to the Nelson Island Cable Terminal, undersea 9 km across Malaspina Strait to the Texada East Cable Terminal, by overhead transmission lines across Texada Island to the Texada West Cable Terminal, undersea 30 km across Georgia Strait to the Nile Creek Cable Terminal, and then by overhead transmission lines to the Dunsmuir Terminal Station on Vancouver Island, a total distance of 148 km. The submarine cables reach a maximum depth of 400 m. They are of a conventional central oil-duct design, with the insulation kept pressurized by eight oil pumping stations, one at each cable terminal. The cables were buried for protection from the cable terminals to a low tide depth of 20 m. The cables (see Figure 10. 525 kV Submarine Power Cable) were manufactured by two companies, STK (Norway) and SCP (Italy), and were layed by the cable ship Skagerrak (Norway) (Bjorlow-Larsen, 1985).

Power Transmission on Vancouver Island

BC Hydro's 500 KV power transmission line runs half the length of Vancouver Island. It extends between the Dunsmuir Terminal Station west of Qualicum Bay in the north, to the Pike Lake Terminal Station in the Highlands area north west of Victoria, in the south.

Alternative Energy Power Generation

There are many alternative sources for the production of electric power. They include; biomass, coal, fuel cells, geothermal, nuclear fission, nuclear fusion, passive solar energy, photovoltaic cells, and wood. But this paper will discus only micro and small hydro, tidal, wave, and wind power generation.

Micro and Small Hydro Power Generation

Micro hydro generators have a power output less than 2 MW, while small hydro generators provide a power output between 2 and 50 MW. These plants operate with small dams on small rivers and streams, to divert water through penstocks to a turbine which drives an electric generator. They are generally located on small steep streams that are impassable to fish, so do not flood land, or affect the habitat of fish and wildlife. These plants commonly generate electricity only 60 percent of the time (Micro and Small

Hydro).

BC Hydro has selected 18 green energy projects to demonstrate their Green Independent Power Producers (IPPs). Four micro and small hydro power generation plants are located on Vancouver Island. They are: (1) Innergex Inc. *Tsable River Small Hydro* near Courtney that will produce 4.5 MW; (2) Synex Energy Resources Ltd. *ZZ Creek (76145) Project* near Gold River that will produce 3.8 MW; (3) Synex Energy Resources Ltd. *McKelvie Creek Project* near Tahsis will produce 2.9 MW; and (4) Raging River Power & Mining Inc. *Raging River Project* near Port Alice will produce 1.75 MW (Green Independent Power Producers).

Wind Power Generation

A wind turbine converts the kinetic energy of the wind into mechanical energy which then is converted into electric power. There are two main types of wind power turbines; vertical-axis, and horizontal-axis machines, (see Figure 11. Wind Turbine Types). The horizontal-axis turbines are the most common, and comprise about 95% of the 100 kW capacity and larger turbines. Wind turbine systems include: (1) a rotor, or blades, that convert the wind's kinetic energy into rotational mechanical shaft energy; (2) a nacelle or cover that contains the generator, a drive train, and sometimes a gearbox; (3) a tower, which supports the rotor and generator; and (4) the electronic equipment and controls (Wind Energy),

Canada, and especially British Columbia have been slow to develop wind power. At present there are no wind farms in this province, but BC Hydro and *Axor Group* (Montreal QC) are planning a 10 MW joint venture demonstration project on Vancouver Island (Wind Energy Demonstration Project). One 700 MW wind farm is proposed for the Queen Charlotte Islands. There are active wind farms in Prince Edward Island, Québec, Ontario, Saskatchewan, Alberta, and the Yukon (see Table 1). Wind Power in Canada 2001 states that there were 197.7 MW of power generated at Canadian wind farms by the end of 2001 (Wind Energy Production in Canada).

The *Nai Kun Wind Farm* is a joint proposal of Uniterre Resources (Vancouver BC) and ABB (Berlin, Germany), to construct a 350 wind turbine power project in shallow water 30 km off the northeast coast of the Queen Charlotte Islands. Electricity from the wind farm will be connected to a BC Hydro grid substation near Prince Rupert by submarine power cable. An application for the 700 MW project was submitted to the federal and provincial governments in February 2002. Construction is expected to start in 2004, and take four years to complete (Wind Power Farm Proposed Near QC Islands).

The *Cowley Ridge Windplant* was the first commercial wind farm in Canada, and is located near Cowley Alberta. It was completed in two phases, the first in 1993, and the second in 1994. It is comprised of 52 US Windpower (Kenetech) KVS-33M 360 kW (USA) turbines. An expansion was completed in 2000 with the addition of five more US Windpower (Kenetech) KVS-33M 375 kW turbines. These 57 turbines produced 20 MW of power. There was further expansion in 2001, when Cowley North was completed. It consisted of 15 Nordex (Denmark) N60 turbines, each rated at 1.3 MW, with a further five Nordex N60 wind turbines planned. The present power output is 40 MW (Cowley Ridge Technology).

The United States has been developing wind power for decades and has many wind farms in operation, located in in 26 states. By the end of 2001 the installed capacity of wind turbines produced 4,258 MW, which supplied almost 6% of the total electricity used in the United States (News from AWEA).

The *Vansycle Ridge Wind Farm* is located on 5 ha about 40 km northeast of Pendleton Oregon and was placed in operation in 1998. It consists of 38 Vestas-American Wind Technology (North Palm Springs, California) 660 kW wind turbines and produces 29.9 MW of power. The turbines with a blade length of 23 m are mounted on 50.6 m towers. Power is produced for wind speeds between 4.4 km/h and 35 km/h. At 35 km/h the variable-pitch blades are feathered and the turbine is shut down (McFall, 1999).

The *Foote Creek-1 Wind Farm* was opened in 1999. It is located on 872 ha between Laramie and Rawlins in Wyoming at an elevation of 2377 m, where the temperature can drop to $-35^{\circ}C$ for extended periods. It uses 69 Mitsubishi Heavy Industries (Nagasaki, Japan) wind turbines of 600 kW each, that produce 41.4 MW of power. The three fiberglass composite heated blades of each turbine have a rotor diameter of 42.6 m and are mounted on 39.6 m high tubular towers. The turbines start with a wind speed of 7 km/h, produce full power at 12.5 km/h, and automatically feather the blades and shut down at 40.6 km/h. The turbines operate at a constant 24 rpm. Foote Creek-2 consisting of three turbines with a power output of 1.8 MW, and Foote Creek-3 consisting of 30 NEG Micron (Randers, Denmark) 750 kW turbines with a power output of 24.7 MW are now in operation (McFall, 1999).

Europe has a mature high-tech wind power industry that manufactures 90% of the wind turbines operating in the world. This industry generates over one-billion Euro's. There was 12,822 MW of power produced by wind energy in Europe in 2000 (See Table 2. Wind Power in Europe 2000). Forecasts indicate that this will increase to 60,000 MW (5,000 of which is offshore) by 2010, and 150,000 MW (50,000 of which is offshore) by 2020 (Wind Energy in Europe).

Tidal Power Generation

The most practical sites for tidal power generation are those with exceptionally high tides on narrow bays or inlets. A barrage (dam) is built across the tidal bay or inlet with gates and turbans along the length. When there is an adequate difference in water elevation (hydrostatic head) from one side of the barrage to the other, the gates are opened and the water flow drives the turbines, which drives the generators (See Figure 12. Tidal Energy). Electricity is generated as water flows into the bay and as water flows out of the bay. The maximum amount of electricity is generated at the two high tides per day, and the minimum at the two low tides per day. The turbines can also be used to pump extra water into the bay inside the barrage at off peak times to be uses to produce more power at peak times. There are 12 tidal power stations in operation (See Table 3. Statistics for Tidal Power), (Tidal Energy).

There are no tidal power plants in British Columbia, and only one in North America. The *Annapolis Tidal Generating Station* in Nova Scotia was constructed in 1984, and is located in Annapolis Royal on the Bay of Fundy, where the tidal range is 6.4 m. It uses the worlds largest straflo turbine to produce 20 MW of power (Tidal Power

Generation).

The *La Rance Tidal Power Plant* is the oldest and largest in the world. It is located in the estuary of the La Rance river near St. Malo, France and supplies 90% of Brittany's electricity. It was built in 1966 and has 24 turbines and generators which produce 240 MW of power. The turbines are located in a 0.8 km long barrage which is also a highway bridge between the towns of St. Malo and Dinard (Statistics for Tidal Power).

<u>Wave Power Generation</u>

There are wave power installations in Norway, Portugal, Scotland, and the United States, but at present there are no wave power generation plants in British Columbia. This could soon change, as BC Hydro and *Energetech Australia Pty. Ltd.* (Randwick, NSW), have recently signed a memorandum of understanding to develop a 3 to 4 MW ocean wave demonstration project on Vancouver Island. Energetech uses an oscillating water column ocean waves technology to generate electricity . The design uses a parabolic wall to direct incoming waves, increasing wave height, and a unique designed turbine which increases the generation efficiency (BC Hydro Ocean Wave Energy Demonstration Project).

Environment and Health Issues

<u>Fossil Fuel Power Generation</u>

The generation of electricity by the burning of fossil fuels such as coal, oil, diesel, gasoline, or natural gas, causes harm to the environment, by the generation of greenhouse gases (GHG). These cause global warming by increasing the amount of gases that are trapped in the atmospheric greenhouse. The major greenhouse gases are water vapour (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone (O_3), and halocarbons (CFCs, HFCs, etc.). Carbon dioxide, is the largest producer of greenhouse gases, and due to the burning of fossil fuels, it is the main contributor to climate change, due to the huge quantities released. "When fossil fuels are burned, the carbon content is oxidized and released as carbon dioxide; every tonne of carbon burned produces 3.7

tonnes of carbon dioxide" (Climate Change).

Global warming increases the temperature of the planet and has a vast effect on all forms of life. The sea level will rise due to melting of the polar ice caps and glaciers, damaging coastal areas through erosion and flooding. The climate could change worldwide causing the extinction of many plant and animal species. Harsh and unpredictable weather conditions, such as heavy rain, unusual high and low temperatures, droughts, and extreme storms could happen more often (Climate Change).

The generation of electricity by the burning of fossil fuels causes acid rain. This is caused when sulfur dioxide (SO_2) and nitrous oxides (NO_x) are released into the atmosphere and them combine with water vapour to form weak sulfuric acid and nitric acid. Acid rain causes damage to terrestrial and aquatic ecosystems. It can also cause health problems in humans (Acid Rain).

The generation of electricity by the burning of fossil fuels also causes harm to the health of the population. Fine particulates are emitted into the air we breath which cause lung diseases. Research reported in the Lancet concluded that air pollution is directly linked to asthma in children and that the effect of air pollution is likely to be substantial on public health (Boezen, 1999).

A study in the Journal of the American Medical Association (JAMA) concluded that, "long-term exposure to combustion-related fine particulate air pollution is an important environmental risk factor for cardiopulmonary and lung cancer mortality" (Pope III, 2002).

<u>Hydro Electric Power Generation</u>

Hydro electric dams can cause the flooding of large areas that may have been previously the home of first nation people or used for forestry or agriculture. The amount of water and silt downstream of the dam can also be changed, and the migration of fish can be prevented. Regulations requiring a minimum water flow and the building of fish ladders can reduce these concerns (Hydro Electric Power).

<u>Wind Power Generation</u>

Wind farms require large areas of land, cause noise, affect birds, and cause radio interference. Environmental impacts can be reduced by building the plants in rural areas, away from heavy bird populations, and away from airports or other areas which rely on radio communications (Wind Energy).

Tidal and Wave Power Generation

The environmental affects of each specific site must be determined individually. But, the environmental impact of the La Rance barrage has been negligible and the local tides were only slightly changed (Tidal Energy).

Cost of Producing Electricity

The cost of producing electricity on Vancouver Island has been estimated for the three most probable power options, using various news stories. Since the media has published different costs for the same projects, an average has been used for this paper. Some costs such as the volatile world price for natural gas, or the cost of carbon credits are unknown.

Vancouver Island Generation Project and Georgia Strait Crossing Project

The capital cost for the Vancouver Island Generation Project (VIGP): three generating plants at $900-million; plus the Georgia Strait Crossing Project (GSX) undersea pipeline to supply natural gas at $260-million.

The operating costs for the Vancouver Island Generation Project (VIGP): the cost of natural gas which is unknown as the world price is very volatile; the purchase of carbon credits to offset greenhouse gas emissions also unknown as it has never been done before; and the hidden costs to the environment and health.

Replacement Submarine Power Cable

The capital cost of a replacement submarine power cable similar to the *Powell River to Qualicum Cable System* is estimated to be between $350-million to $400-million. The *HVAC Tsawwassen to North Cowichan Cable System* that was opened in 1956 cost $5.7-million. The *HVDC Tsawwassen to North Cowichan Cable System* second stage consisting of two cables built in 1973 cost $13-million plus $20-million for the conversion equipment at each terminal.

The operating cost of a replacement submarine power cable: surplus electricity from hydroelectric power on the mainland has an average cost of $0.061/kWh.

Wind Power Generation

The capital cost of a wind farm depends on the size and location of the project. Large wind farms in the United States cost US$1-million per MW.

The operating cost for wind power in the United States has been decreasing dramatically and in recent years has declined to US$0.04/kWh. The cost of the *Foote Creek Wind Farm* is US$0.045/kWh, and the estimated cost for the *Nai Kun Wind Farm* is $0.066/kWh.

Conclusion

Why has BC Hydro proposed the most costly option to supply power to Vancouver Island, and why has the provincial government not opposed this project, when they are opposed to a similar project south of Abbotsford? Will the citizens of Vancouver Island be subjected to dirty power, so that clean power can be sold to California?

The Vancouver Island Generation Project and the Georgia Strait Crossing Project are the most expensive power option to build, the most expensive to operate, the most damaging to the environment, and the most damaging to human health.

With the North American Free Trade Agreement (NAFTA), any attempt to close an American owned plant for any reason, including massive pollution output, could result in hefty loss of income penalties charged to British Columbia. Since the natural gas is transported through the United States, the cost will certainly be higher than natural gas supplied from within Canada. There is also the possibility that a shortage of natural gas in the United States will result in the shut off of gas returning to Canada.

Will the regulating bodies turn down this power option?

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Figures

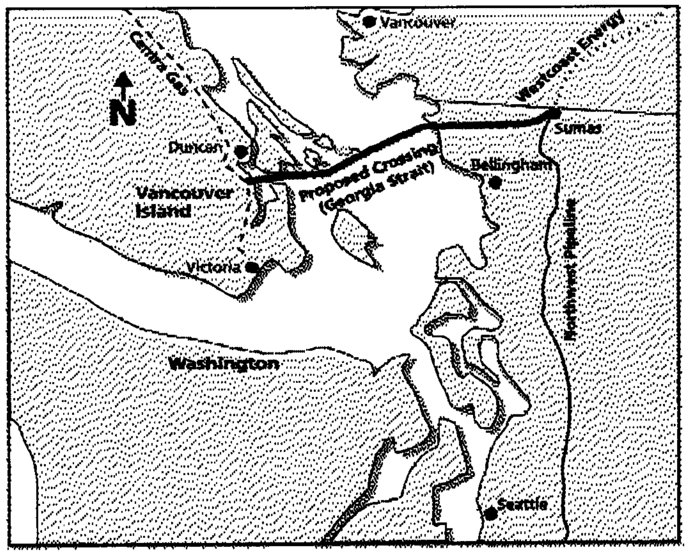

Figure 1. Georgia Strait Crossing

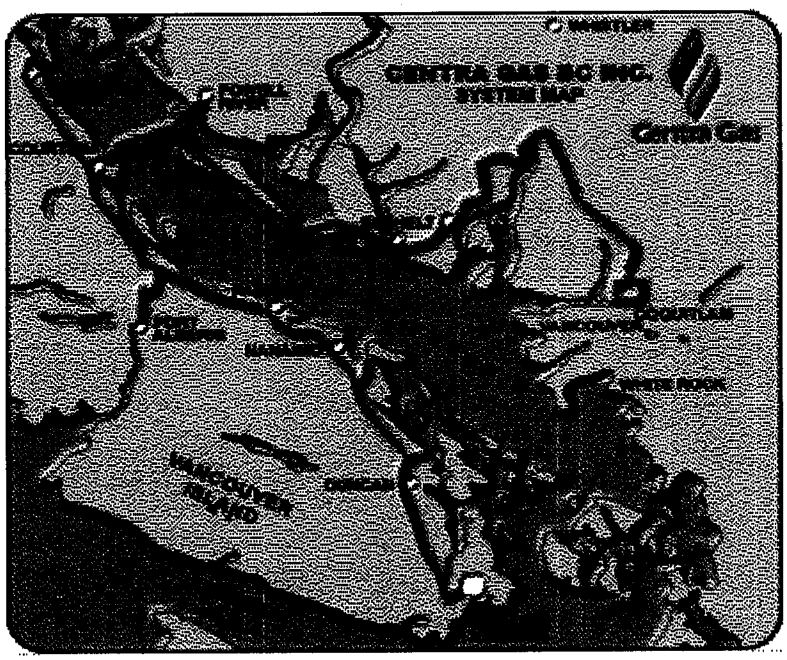

Figure 2. Centra Gas Pipeline

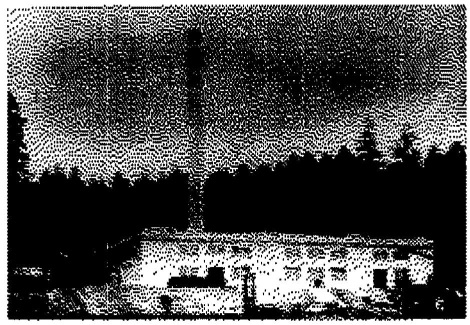

Figure 3. Brentwood Steam Plant

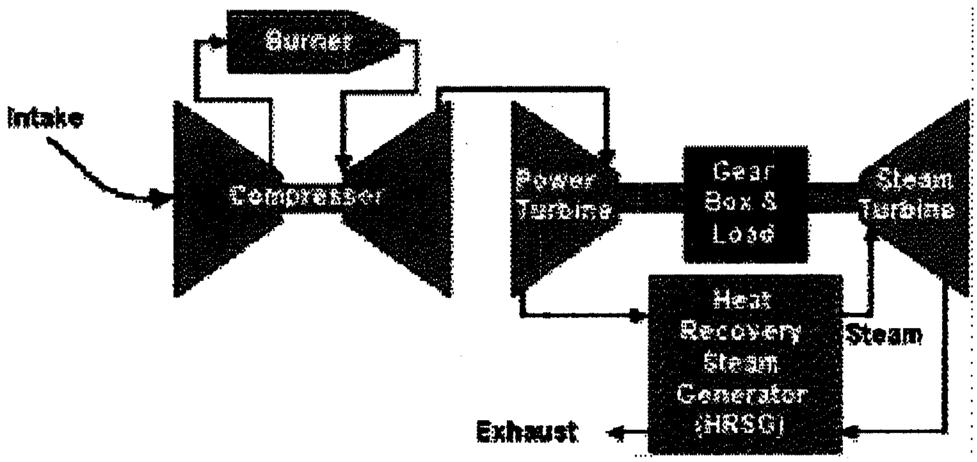

Figure 4. Combined Cycle Gas Turbine

Figure 5. Goldstream River Power House

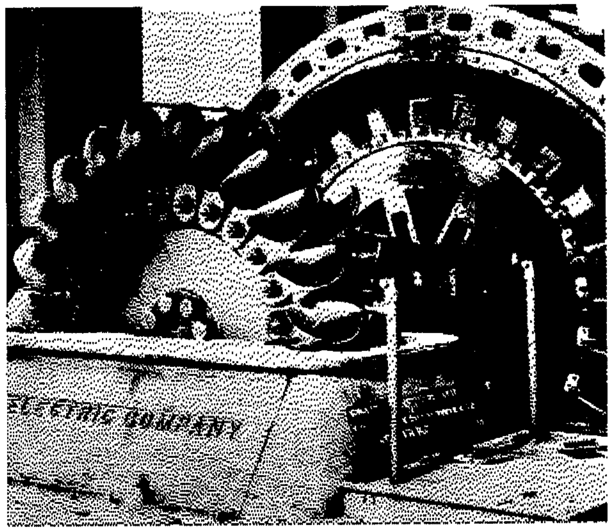

Figure 6. Pelton Water Wheel

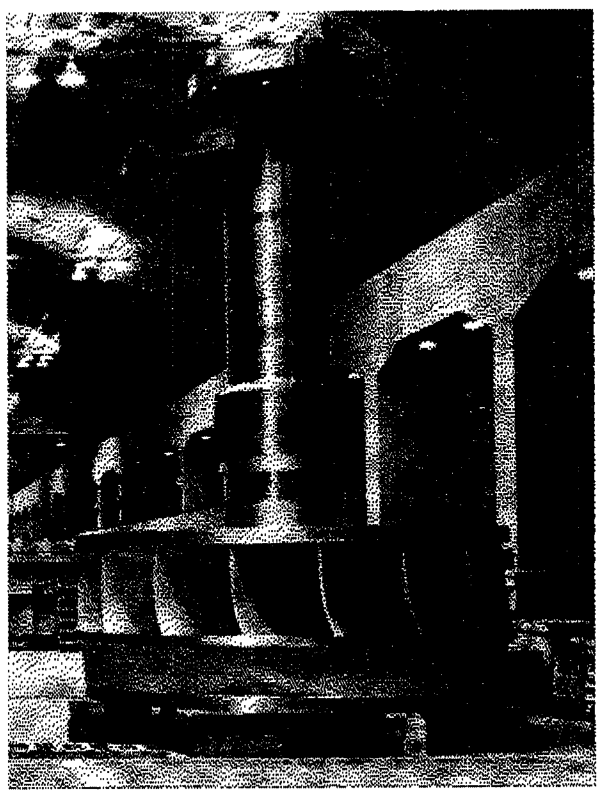

Figure 7. Francis Turbine

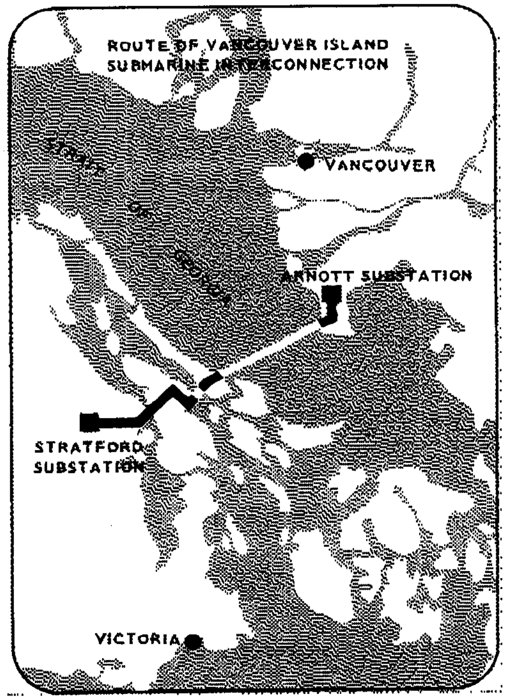

Figure 8. 300 kV Cable Route

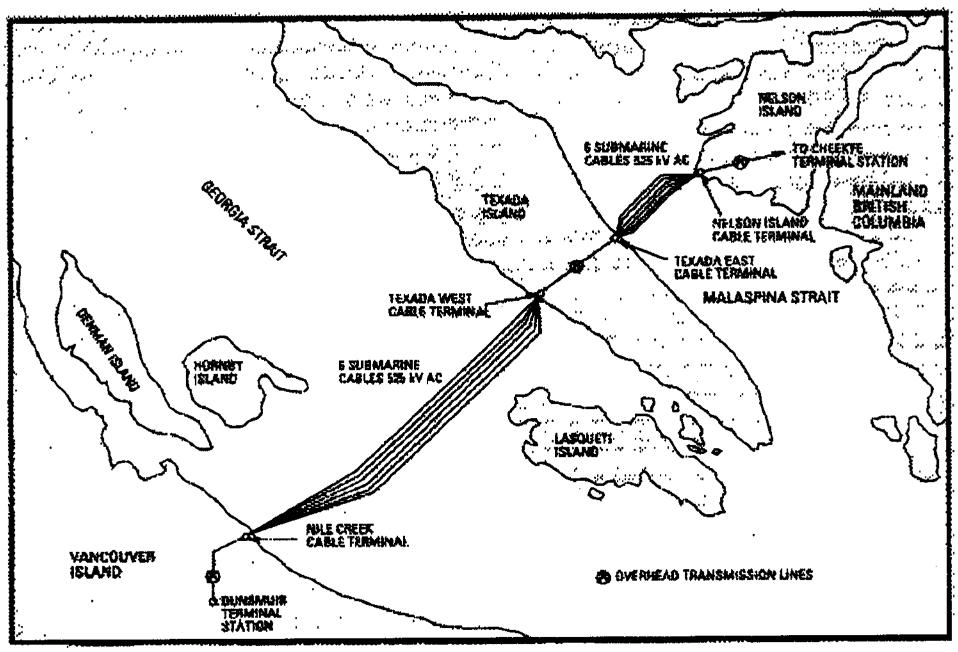

Figure 9. 525 kV Cable Route

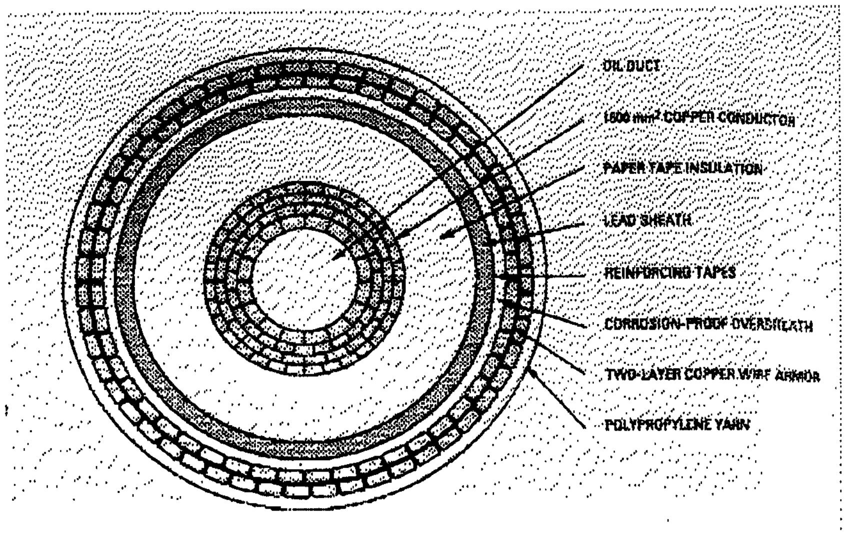

Figure 10. 525 kV Submarine Power Cable

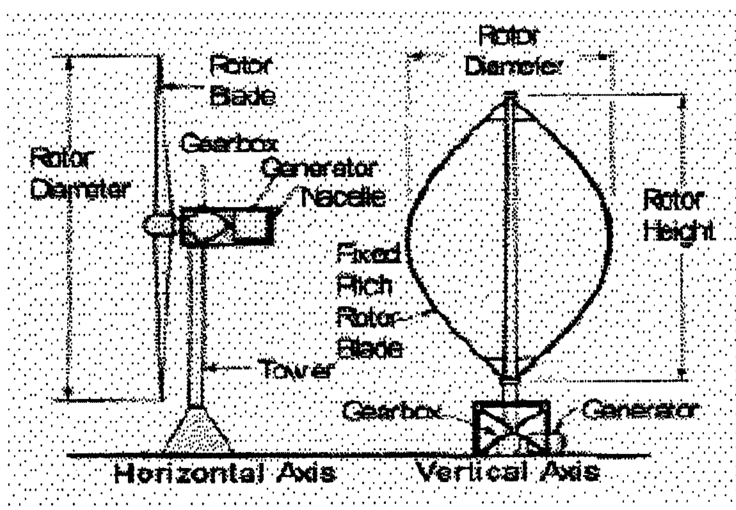

Figure 11 Wind Turbine Types

Wind Energy Capacity Installed in Canada in MW (2001-12-31)			
Province	MW	Province	MW
Québec	102.0	Ontario	2.4
Alberta	83.3	Saskatchewan	3.9
Prince Edward Island	5.2	Yukon	0.8
Total = 197.6 MW			

Table 1 Wind Power in Canada 2001

Wind Energy Capacity Installed in Europe in MW (2000-12-31)					
Country	MW	Country	MW	Country	MW
Germany	6113	Greece	189	Belgium	13
Denmark	2300	Ireland	118	Norway	13
Spain	2235	Portugal	100	Czech Republic	12
Netherlands	446	Austria	77	Luxembourg	10
Italy	427	France	66	Poland	5
UK	406	Finland	38	Switzerland	3
Sweden	231	Turkey	19	Romania	1
Total = 12,822 MW					

Table 2. Wind Power in Europe 2000

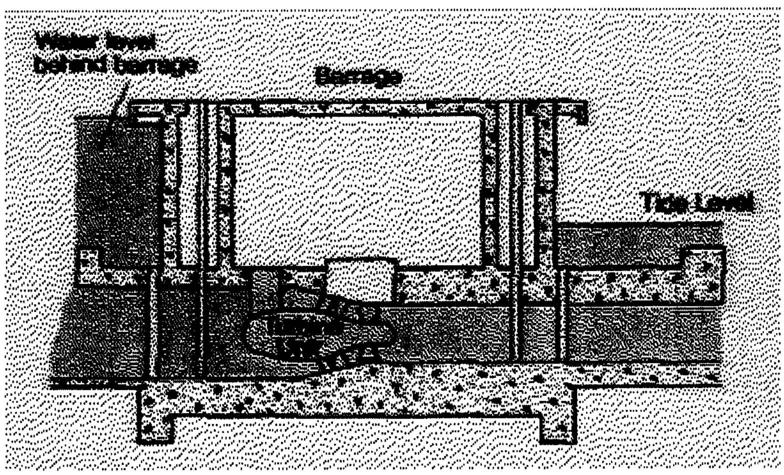

Figure 12. Tidal Energy

Comparison of World Tidal Schemes				
Year Built	Name	Country	Tideal Range	MW
1966	La Rance	France	8.0 m	240.0
1968	Kislaya Guba	Russia	2.4 m	4.0
1980	Jiangia	China	7.1 m	3.2
1984	Annapolis	Canada	6.4 m	20.0
1961-89	8 others	China	1.2-3.5 m	

Table 3. Statistics for Tidal Power