GREEN & ALTERNATIVE ENERGY DIVISION

EXECUTIVE REPORT ON THE GREEN ENERGY STUDY FOR BRITISH COLUMBIA

PHASE 1: VANCOUVER ISLAND

Prepared by:

Power Supply Engineering

ISO 9001 Registered

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BC hydro

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SYNOPSIS

New energy resources are needed to serve the future electricity needs of British Columbians. BC Hydro is exploring the potential contribution of green energy resources in part by conducting a BC Green Energy Study to quantify and characterize potential resources.

The first phase of the study focused on Vancouver Island since some of the earliest capacity additions will be required to reinforce the peak supply. BC Hydro anticipates the need to further reinforce the electricity supply to Vancouver Island due to the planned retirement of the High Voltage Direct Current terminal equipment (HVDC) in 2007. Of particular concern is the reliability of supply to meet the *peak load demand* on VI, which occurs during cold winter months. Dependable capacity is required to meet peak load demand.

The first phase of the BC Green Energy Study focused on Vancouver Island and identified an installed (nameplate) capacity of over 1600 MW, and an annual energy estimated at over 3500 GWh from green energy resources. The technologies examined included energy derived from wind, small hydro, landfill gas, municipal solid waste, woodwaste, wave, and tidal barrage. Resource Smart options (additions to BC Hydro existing powerplants) and energy storage by means of low impact closed-circuit hydro electric pumped storage were also examined.

This study was not an exhaustive inventory since it was based primarily on available information using estimated levelized costs in year 2000 dollars, and each energy source also had specific goals and objectives for capacity identification.

Phase 2 of the BC Green Energy study will see the extension of green resource assessment to the rest of British Columbia. The form and shape of future studies will include the requirements of the 2002 Electricity Plan. For example, land use requirements for technologies and other attribute definitions would be included in Phase 2 studies.

Costs estimated for Phase 1 study were estimates of production costs only. Consistent assumptions for key financial variables were applied across the portfolio of green energy resources and no evaluation of "value" items, such as dispatchability, Green House Gas credits, or social issues was conducted. The unit cost of energy of these new energy sources was estimated to be in the range of 4 to 9 ¢/kWh at the generation site including an allowance for transmission to the main grid.

The study energy and capacity results were combined with the Demand/Supply forecast for Vancouver Island to examine the energy/capacity balance on an annual basis until 2020. Green energy developments were anticipated to be staged additions, with considerations for realistic development timelines, lowest cost options, and meeting the forecasted energy/capacity deficit for Vancouver Island, if possible.

Results indicated that the Vancouver Island green energy resources do not provide the necessary dependable capacity to meet the winter peak demand without some storage, back-up or firm supply option to support the green resources. Low impact, closed circuit pumped storage was investigated as a potential storage option to provide dependable capacity supplementing green resources. Vancouver Island green resources could provide significant energy on an average basis, with the balance of energy provided by the existing 500 kV transmission system.

Intermittent energy sources such as wind and wave energy cannot be relied on to be available when required. As well, the output from small hydro installations may be limited during cold winter temperatures. Pumped storage is an option that could therefore provide the majority of the dependable peak capacity requirements for Vancouver Island. Biomass, Resource Smart upgrades, and small hydro together would provide less than 30% of the peak load deficit.

Demand Side Management (DSM) efforts to reduce winter peak demand were outside the scope of this study.

This Executive Report on the Phase 1, Vancouver Island Green Energy Study, highlights the pertinent components of the study without the technical and commercial details.

SECTION 1.0 - INTRODUCTION

The Phase 1, Vancouver Island study presented the results of the pre-feasibility investigations for the B.C. Green Energy Study. It supported the decision to proceed with more detailed investigations and the development of the Green Energy Demonstration Projects on Vancouver Island (VI).

New energy resources are required to serve the future electricity need of British Columbians. BC Hydro is interested in exploring the potential contribution of green energy resources. In particular, new energy and capacity resources are required to meet growing energy demand on VI. BC Hydro anticipates the need to further reinforce the electricity supply to VI due to the planned retirement of the High Voltage Direct Current terminal equipment (HVDC) in 2007. Of particular concern is the reliability of supply to meet the *peak load demand* on VI, which occurs during cold winter months. Dependable capacity is required to meet peak load demand.

It should be emphasized that this study is a "pre-feasibility level" study, which uses available information and limited additional studies to identify and provide rough cost estimates for potential green energy resources.

BC Hydro engaged the services of consultants to assist with the identification of sites and preliminary energy and cost analysis of alternative resources for new electricity supply requirements. The study, prepared by BC Hydro with consultants' assistance, detailed the results found to date. This Executive Report highlights the pertinent components of the study without the technical and commercial details.

1.1 OBJECTIVES

The objectives of the pre-feasibility study were to:

(a) Identify a number of viable alternative green energy resources that could provide information for future energy planning and support decision-making around future generation options for VI. However, it was not a comprehensive inventory of potential green energy resources on VI; and

(b) Provide specific input for the development of a 20 MW demonstration project for green energy on VI.

1.2 METHODOLOGY

In order to meet the objectives of the study a number of potential sources of green energy and capacity were evaluated, including:

(a) **Wind energy** up to 500 MW in five to ten locations.

(b) **Small "Green" Hydro** up to 50 MW in various locations that meet 'Green Energy' requirements. [1, 2]

(c) **Biomass**: Woodwaste co-generation in selected locations, landfill gas, solid waste energy and waste treatment plant gas.

(d) **Wave energy**

(e) **Tidal energy**

(f) **Resource Smart opportunities** at existing BC Hydro dams and powerplants that could provide additional energy.

(g) **Miscellaneous** sources including Solar Energy.[3]

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1 Requirements that must be met for "Green Energy" designation are currently being developed on a technology basis.

2 Previously proposed storage hydro projects were not included in this study.

3 The sole respondent to the miscellaneous RFP indicated that there were no other proven energy sources that could contribute on a large-scale at the price threshold as defined and so further study was not conducted.

(h) **Pumped Storage** (closed circuit loop) locations previously identified and studied, intended to provide dependable capacity.

The study focused on near commercial technologies that could be applied on a utility scale. In order to achieve the study objectives for the first phase consultants were asked to focus their studies to identify, within each of these technology areas:

- only green energy resources with an estimated unit energy cost less than approximately 7 ¢/kWhr,
- developable sites, considering accessibility to transmission grid connections, and
- sites that would satisfy a specified target-installed capacity (i.e. not every possible site was considered, only enough to reach a specific MW target).

The above bounds and limitations were subjectively selected in order to limit the scope of the study. As a result, the study was not a complete inventory of green energy resources on VI, and there may be additional resources, particularly for wind and pumped storage, that have not been included.

The study was based primarily on available information using levelized costs in year 2000 dollars and consistent assumptions for key financial variables applied across the portfolio of green energy resources. Each energy source also had specific goals and objectives for capacity identification. The general scope of work, for all energy sources in this study, was for each site to:

- indicate the potential installed capacity, annual energy, and winter dependable capacity available (MW and GWh);
- estimate the cost of development, unit energy cost, and unit capacity cost;
- identify suitable locations with highest potential installed capacity;
- consider general transmission requirements (e.g. nearest transmission line);

- identify limitations/constrictions including expected technical or cost changes over time; and
- provide a timetable and list of activities for development.

Preliminary assessments on environmental impacts and regulatory requirements are being undertaken in separate studies.

SECTION 2.0 - RESULTS

The potential of each green energy resource examined in this study is briefly described below. It should be noted that the qualification of each resource as "green" would need to be confirmed on a site by site basis.

2.1 WIND

Many areas on VI have a good wind resource potential, with a predicted annual average wind speed of 6 to 8 metres per second (m/s). Generally, in North America a site with an annual average of 7 m/s is considered economically viable. Candidate sites were identified utilizing a screening exercise consisting of model-predicted wind speeds, topographic map (1:50 000 scale) reviews and helicopter flyovers. Areas identified have a total installed capacity potential of over 650 MW. There may be additional opportunities for wind development on VI.

The identified sites are located on relatively high elevation forested terrain well separated from populated areas. In general, potential issues and challenges that will be faced in the development of wind energy on VI are related to the remote locations and ruggedness of the terrain. Also, the wind resource needs to be confirmed with on-site monitoring for up to one year, as the energy production is highly dependent on wind speed.

2.2 SMALL HYDRO

VI provides many opportunities for small hydro development. Potential projects range in size from 500 kW to about 18 MW and they are located throughout VI. Due to differing terrain, capacities and hydrology, the projects also have a range of unit energy costs. Approximately 60% of the project sites are developable at less than 7 ¢/kWh (which comprises about 80% of the total developable energy).

2.3 LANDFILL GAS, REFUSE AND WOOD RESIDUE

In B.C., several landfills have installed landfill gas (LFG) wells and collection systems, but no power production. On VI, there are several possible locations for LFG recovery and power generation. LFG has an average cost of electricity generation of 6 ¢/kWh assuming that a collection system is in place. Most potential projects are based on traditional reciprocating ignition spark engines.

In addition to power generation from LFG, it is possible to directly generate power utilizing sorted municipal refuse. The biomass portion of municipal waste is utilized in many European countries, the United States, Japan and Australia for power and heat production. Typically, the municipal solid waste (MSW) is sorted into organic and inorganic streams. The organic portion can be compacted and densified into fuel pellets. This refuse derived fuel (RDF) is then most often used to produce steam and generate power using steam turbines.

Power generation from sawmill residues has been used for decades by VI pulp mills to meet a portion of their energy needs. The opportunity to expand this power production is significantly limited by wood residue availability from coastal sawmills, however there are some possibilities on the northern end of VI. Several B.C. based companies are developing wood residue gasification technologies that could significantly lower the cost of power generation at relatively small scales. These technologies provide a fuel substitute for diesel and gas fired turbines.

2.4 WAVE

The locations with the best wave resource are generally those in the mid to high latitudes. The eastern side of the North Pacific, in the vicinity of VI, certainly falls into this category. The results of this study indicate that the west coast of VI has an excellent wave energy resource with approximately 8.25 GW of wave power incident on the western VI. Two specific sites have been identified, each with over 200 MW of potential wave power installed capacity. The technology examined is the Oscillating Water Column (OWC), which, in terms of the science of wave energy, is the most widely accepted.

Currently around the world the majority of actual wave energy projects in-service, or soon to be in-service, are of the OWC type. These include the Energetech project at Port Kembla, the Wavegen LIMPET at Islay in Scotland, the EU sponsored Azores project on the island of Pico, the Indian National Institute of Ocean Technology project at Triviandrum in the south of the country, and the Japanese Might Whale project (a floating OWC).

2.5 TIDAL

The mean tidal range at several locations around the coast of VI varies from 1.9 m to 3.8 m. Generally, a mean tidal range of 4 m or greater is required for practical tidal energy exploitation. A commissioned study outlining the economic, environmental and social impacts of tidal energy was not received. In the absence of this study, and given the structural requirements for a tidal barrage energy source, it is difficult to ascertain the environmental impacts and regulatory requirements for this type of technology. Due to this, tidal power generation was not assessed as part of this study.

2.6 RESOURCE SMART

Since 1989, BC Hydro has been developing attractive Resource Smart options to improve the efficiency and more fully develop the potential of its existing dams and hydro projects.

There are six existing BC Hydro production facilities on VI, all with opportunities for improvement. Each system has a unique combination of facilities including dams, generating stations, and diversions. Through Resource Smart options there are potential energy gains of over 100 GWh/year and nearly 20 MW of increased capacity from VI facilities. Theses include turbine runner replacements and adding generation to existing discharges.

SECTION 3.0 - ENERGY STORAGE FOR DEPENDABLE CAPACITY

Some green energy resources, such as wind and wave, are intermittent and provide little or no dependable capacity. In order to meet the winter peak demand on VI, a storage option for intermittent energy or additional firm capacity is required. Additional firm capacity options include transmission additions and gas fired generation.

Closed-circuit pumped storage was examined as part of this study as potential low impact energy storage or back-up to meet the winter peak demand capacity requirements. There are other storage options available, but they were not examined as part of this study.

A role of pumped storage in a hydro system is to use lower cost off peak power to pump water from a low elevation reservoir to a high elevation storage reservoir. The stored water is then used to generate hydro electric power during the peak hour periods when demand is high.

A pumped storage plant does not create new energy, rather it is a net consumer of energy. Approximately 25% of the energy used to pump water is not regained on the generation cycle, due to equipment efficiencies and hydraulic losses during the pumping and generating cycle.

In 1977, BC Hydro identified 43 potential sites in the lower, more mountainous southern portions of B.C. The sites on Vancouver Island were screened on a geographical, economic, and construction basis. The investigations concluded with the selection of two high head pumped storage projects and one low head installation on VI.

For VI, pumped storage may be a feasible supply of dependable capacity. Energy for the pumping cycle would need to be provided from on-island generation and/or from mainland generation via submarine transmission. Further studies regarding the feasibility and timing of pump/generation cycles need to be conducted.

SECTION 4.0 - COST ESTIMATES

For each technology investigated, consultants provided capital costs, annual operation and maintenance costs, unit energy costs, and unit capacity costs for each site proposed, excluding transmission and distribution connection (T&D) costs. BC Hydro provided rough cost estimates for interconnection requirements.

4.1 GENERAL COST ESTIMATE

The costs provided are estimates, based on desk-top studies with no investigations. In addition, the capital cost and unit energy costs capture production costs only and no "value" items such as dispatchability, or greenhouse gas (GHG) credits are included in this study.

4.2 TRANSMISSION AND DISTRIBUTION COST ESTIMATES AND LIMITATIONS

Distribution from T&D provided connection cost estimates for sites that had a installed capacity of 25 MW or less. This included all of the small hydro and LFG and woodwaste development sites. Transmission from T&D provided cost estimates for sites with an installed capacity greater than 25 MW, which included the wave, wind, pumped storage, and RDF development sites.

4.3 COST SUMMARY

Items in the cost estimates for each of the green energy sources included:

- Site specific capital cost of the generation unit,
- Operation and maintenance costs for the period of operation as a fixed percentage of capital cost,
- Transmission and connection costs.

The unit energy costs of each green energy source were estimated to be in the range of:

Wind Energy	5 to 7¢/kWh
Small Hydro	4 to 7¢/kWh
LFG/MSW/Wood	5 to 9¢/kWh
Wave Energy	4 to 9¢/kWh
Resource Smart	2 to 5¢/kWh

The costs of pumped storage, a net user of energy, were not estimated in this study.

SECTION 5.0 - ENERGY AND CAPACITY ANALYSIS

5.1 ASSUMPTIONS AND LIMITATIONS

Resource Management, within Power Supply, provided the October 2000 Demand/Supply balance forecast for VI. The resource forecast included Existing and Committed Resources, i.e. the Island Cogen Plant (ICP 240 MW) and Port Alberni (260 MW). The analysis assumed that the HVDC to VI would be fully retired by August 2007. It was assumed that the energy supply from the mainland to VI would be as required up to the capacity of the transmission lines.

The energy and capacity results provided by the consultants for each technology were combined with the Demand/Supply balance forecast to examine the energy and capacity balance on an annual basis over the next 20 years. The objective of this exercise was to examine the energy/capacity of varying resource mixes and development strategies, and determine what mix of the green energy alternatives could be produced to meet the winter peak loads on VI.

Technologies were assumed to be added in an incremental manner using realistic development timelines, lowest cost options, and meeting the forecasted energy/capacity deficit for VI. It was assumed that development would begin slowly with a few demonstration technologies coming on line in April 2003, and then conservative development in the following few years. Development would then increase once the technologies have been established in the system. Pumped storage could be brought on line only to satisfy the dependable capacity requirements of VI, but further examination of the storage/capacity opportunities is required if a complete analysis is to be conducted.

5.2 ENERGY AND CAPACITY BALANCE

Table 5.1 shows the Demand/Supply Balance for Vancouver Island, including the retirement of the HVDC by August 2007. The forecast capacity deficit during winter peak load hours in 09/10 is 245 MW, contingent on the addition and operation of ICP and Port Alberni gas fired generation. In 2019/20 the forecast deficit during peak load hours is forecast to be approximately 700 MW.

VI green resources, as illustrated by the consultant studies, do not provide the necessary dependable capacity to meet the winter peak demand without some storage, back-up, or firm supply option to support the green resources. Low impact, closed circuit pumped storage was investigated as a potential storage option to provide dependable capacity supplementing green resources. The amount of pumped storage capacity that would be required is provided in Table 5.1.

The inefficiency of the pumping cycle in Pumped Storage has not been included in the forecast energy balance in Table 5.1. Approximately 25% of the energy used to pump the water is not regained in the generation cycle.

The results of the studies suggest that VI green resources could provide significant energy to VI on an average basis, with the balance of energy provided by the existing 500 kV transmission system.

SECTION 6.0 - SUMMARY

The Executive Report on the Green Energy Study for B.C. Phase 1: Vancouver Island, indicates that green energy resources could provide at least 1600 MW of installed (nameplate) capacity and estimated 167 MW of dependable capacity, over 3500 GWh/year of energy. The majority of unit energy costs are estimated at less than 7 ¢/kWh after transmission. Intermittent energy sources such as wind and wave energy cannot be relied on to be available when required. As well, the output from small hydro installations may be limited during cold winter temperatures. Pumped storage is an option that could therefore provide the majority of the dependable peak capacity requirements for VI. Biomass, Resource Smart upgrades, and small hydro together would provide less than 30% of the peak load deficit.

SECTION 7.0 - PHASE 2 NEXT STEPS

Phase 2 of the B.C. Green Energy study has been scoped to extend the green energy resource assessment to the rest of British Columbia.

These studies are required to complete the assessment of the green resource potential in British Columbia. The scope includes studies to:

- provide generic supply cost curves for each green energy technology,
- confirm the dependable capacity available from pumped storage and existing generation plants,
- investigate in more detail the feasibility of pumped storage in the VI system, and
- provide a robust comparison against other portfolio options presented in the 2002 Electricity Plan.

The scope of future studies will by guided by information requirements of the 2002 Electricity Plan. Additional attributes such as land use requirements will need to be identified to characterize the resources for the Electricity Plan and will be included in Phase 2 studies.

TABLES

Table 5.1 VI Green Supply Scenario

	2004/05			2009/10			2019/20		
	Generating Capacity MW	Dependable Capacity MW	Average Annual Energy GWh	Generating Capacity MW	Dependable Capacity MW	Average Annual Energy GWh	Generating Capacity MW	Dependable Capacity MW	Average Annual Energy GWh
Existing and Committed Resources									
VI Hydro [1]	458	448	1963	458	448	1963	458	448	1963
ICP	240	240	1935	240	240	1935	240	240	1935
Pt. Alberni	260	260	2100	260	260	2100	260	260	2100
AC Transmission [2, 3]	1200	1200	a/r	1200	1200	a/r	1200	1200	a/r
HVDC [3]	240	240	a/r	0	0	0	0	0	0
Total Existing & Committed Resources	*2398*	*2388*	*5998*	*2158*	*2148*	*5998*	*2158*	*2148*	*5998*
Examples of Potential New Green Resources									
Wave	4	0	8	75	0	156	225	0	468
Wind	50	0	110	483	0	1154	653	0	1565
Small Hydro [4]	16	2	79	73	10	385	76	11	396
LFG [5]	4	4	32	4	4	31	4	4	31
RDF [5]	0	0	0	25	25	394	125	125	985
Woodwaste [5]	10	10	79	10	10	79	10	10	79
Resource Smart [4, 5]	6	6	35	18	18	109	18	18	109
Total of Example New Green Resources	90	22	343	688	67	2308	1111	168	3633

VI Supply Demand Forecast		Peak MW	Energy GWh		Peak MW	Energy GWh		Peak MW	Energy GWh
VI Demand + Losses (Oct 2000 Electric Load Forecast)		2247	10827		2393	11523		2846	13433
VI Existing & Committed Supply		2388	5998		2148	5998		2148	5998
Forecast Deficit (Demand - Supply)		**-141**	**4829**		**245**	**5525**		**698**	**7435**
Deficit Potentially Supplied by New Green Resources		*22*	*343*		*67*	*2308*		*168*	*3633*
Additional Dependable Capacity Required [6]		**0**			**178**			**530**	
Additional Energy Required (including supply from Mainland via existing AC Transmission)			**4486**			**3217**			**3802**

Notes:

1. Values from "Making the Connection", BC Hydro 2000.
2. AC Transmission system can achieve 1300 MW capacity, but for periods less than the potential winter peak period.
3. a/r = As required, energy will be supplied to Vancouver Island up to the capacity of the existing transmission lines.
4. Further studies required to confirm dependable capacity.
5. May not meet 'green' criteria, to be determined.
6. Additional Dependable Capacity required to meet the winter peak demand. Potential options: closed-circuit pumped storage, new transmission from Mainland, DSM, or new on-Island generation.