FINAL REPORT

Cowichan Valley Energy Mapping and Modelling

REPORT 1 – GIS MAPPING OF POTENTIAL RENEWABLE ENERGY RESOURCES IN THE CVRD

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Prepared by:

Ea Energy Analyses (lead)
Frederiksholms Kanal 4, 3. th.
DK-1220 Copenhagen K, Denmark
www.eaea.dk

GRAS
Øster Voldgade 10
DK-1350 Copenhagen K, Denmark
www.grasdk.com

Acronyms and abbreviations

AUC – Actual use codes
BAU – Business-as-usual
BC – British Columbia
BCAA – British Columbia Assessment Authority
BIMAT – Biomass Inventory Mapping and Analysis Tool
CEEI – Community Energy & Emissions Inventories
CIBEUS – Commercial and institutional building energy use survey
CRD – Capital Regional District
CVRD – Cowichan Valley Regional District
DEM – Digital elevation model
EE – Energy efficiency
EOSD – Earth Observation for Sustainable Development of Forests
ESRI – Environmental Systems Resource Institute
GHG – Greenhouse gas
GIS – Geographic Information System
HVAC – High voltage alternating current
JUROL – Jurisdiction and roll number
LIDAR – Light detection and ranging
MSW – Municipal solid waste
NEUD – National energy usage database
NRC – Natural Resources Canada
OCP – Official community plans
ODT – Oven dried tonne
O&M – Operation and maintenance
PRISM – Parameter-elevation regressions on independent slopes model
RDN – Regional District of Nanaimo
RE – Renewable energy
RMSE – Root mean square area
SSE – (NASA's) Surface meteorology and Solar Energy (dataset)
TaNDM – Tract and neighbourhood data modelling

Contents

1 Introduction

Overall project

The following report is the first in a series of six reports detailing the findings from the Cowichan Valley Energy Mapping and Modelling project that was carried out from April of 2011 to March of 2012 by Ea Energy Analyses in conjunction with Geographic Resource Analysis & Science (GRAS).

The driving force behind the Integrated Energy Mapping and Analysis project was the identification and analysis of a suite of pathways that the Cowichan Valley Regional District (CVRD) can utilise to increase its energy resilience, as well as reduce energy consumption and GHG emissions, with a primary focus on the residential sector. Mapping and analysis undertaken will support provincial energy and GHG reduction targets, and the suite of pathways outlined will address a CVRD internal target that calls for 75% of the region's energy within the residential sector to come from locally sourced renewables by 2050. The target has been developed as a mechanism to meet resilience and climate action target. The maps and findings produced are to be integrated as part of a regional policy framework currently under development.

GIS mapping of renewable potentials

The first task in the project was the production of a series of thematic GIS maps and associated databases of potential renewable energy resources in the CVRD. The renewable energy sources mapped were solar, wind, micro hydro, and biomass (residues and waste). Other sources were also discussed (e.g. geothermal heat) but not mapped due to lack of spatially explicit input data. The task 1 findings are detailed in this report.

GIS mapping of regional energy consumption density

The second task in the overall project was the mapping of regional energy consumption density. Combined with the findings from task one, this enables comparison of energy consumption density per area unit with the renewable energy resource availability. In addition, it provides an energy baseline against which future energy planning activities can be evaluated. The mapping of the energy consumption density was divided into categories to correspond with local British Columbia Assessment Authority (BCAA) reporting. The residential subcategories were comprised of single family detached dwellings, single family attached dwellings, apartments, and moveable dwellings. For commercial and industrial end-users the 14 subcategories are also in line with BCAA Assessment as well as the on-going provincial TaNDM project of which the CVRD is a partner. The results of task two are documented in the report 'Energy Consumption and Energy Density Mapping'.

Analysis of potentially applicable renewable energy opportunities	The third task built upon the findings of the previous two and undertook an analysis of potentially applicable distributed energy opportunities. These opportunities were analysed given a number of different parameters, which were decided upon in consultation with the CVRD. The primary output of this task was a series of cost figures for the various technologies, thus allowing comparison on a cents/kWh basis. All of the cost figures from this task have been entered into a tailor made Excel model. This 'technology cost' model is linked to the Excel scenario model utilised in task 4. As a result, as technology costs change, they can be updated accordingly and be reflected in the scenarios. Please note, that the technologies considered at present in the technology cost model are well-proven technologies, available in the market today, even though the output is being used for an analysis of development until 2050. Task 3 results are detailed in 'Analysis of Potentially Applicable Distributed Energy Opportunities', which presents an initial screening for various local renewable energies and provides the CVRD with the means of evaluating the costs and benefits of local energy productions versus imported[1] energy.
Analysis of opportunity costs and issues related to regional energy resilience	Based on the outputs from the above three tasks, a suite of coherent pathways towards the overall target of 75% residential local energy consumption was created, and the costs and benefits for the region were calculated. This was undertaken via a scenario analysis which also highlighted the risks and robustness of the different options within the pathways. In addition to a direct economic comparison between the different pathways, more qualitative issues were described, including potential local employment, environmental benefits and disadvantages, etc. The main tool utilised in this analysis was a tailor made Excel energy model that includes mechanisms for analysing improvements in the CVRD energy system down to an area level, for example renewable energy in residential buildings, renewable energy generation, and the effects of energy efficiency improvements. For the industrial, commercial, and transport sectors, simple and generic forecasts and input possibilities were included in the model. The Excel 'technology cost' and 'energy' models are accompanied with a user manual so that planners within the CVRD can become well acquainted with the models and update the figures going forward. In addition, hands on instruction as to how to link the Excel model with GIS maps was also provided

[1] The term 'imported' here refers to energy imported from outside of the CVRD

to both planners and GIS professionals within the CVRD and associated municipal organisations.

Task 4 results are detailed in a report entitled 'Analysis of Opportunity Costs and Issues Related to Regional Energy Resilience'.

GIS mapping of energy consumption projections

Task 5 focused on energy projection mapping to estimate and visualise the energy consumption density and GHG emissions under different scenarios. The scenarios from task 4 were built around the energy consumption density of the residential sector under future land use patterns and rely on different energy source combinations (the suite of pathways). In task 5 the energy usage under the different scenarios were fed back into GIS, thereby giving a visual representation of forecasted residential energy consumption per unit area. The methodology is identical to that used in task 2 where current usage was mapped, whereas the mapping in this task is for future forecasts. The task results are described in the report 'Energy Density Mapping Projections'. In addition, GHG mapping under the various scenarios was also undertaken.

Findings and recommendations

The final and sixth report presents a summary of the findings of project tasks 1-5 and provides a set of recommendations to the CVRD based on the work done and with an eye towards the next steps in the energy planning process of the CVRD.

1.1 Motivation for study

One of the motivations behind the overall study was to increase the resilience of the CVRD communities to future climate and energy uncertainties by identifying various pathways to increase energy self-sufficiency in the face of global and regional uncertainty related to energy opportunities, identification of energy efficiencies and mechanisms, and identify areas where local energy resources can be found and utilised effectively. Overall this strategy will reduce reliance on imported energy and the aging infrastructure that connects Vancouver Island to the mainland. Investigating future potential scenarios for the CVRD, and Vancouver Island as a whole, makes it possible to illustrate how this infrastructural relationship with the mainland could evolve in years to come.

This work supports the overall development of sustainable communities by:

- Increasing community resilience to price and energy system disruptions,

- Increased economic opportunities both at a macro energy provision scale and the development of local economies which support alternative energy systems and maintenance of those systems,
- Potential economic development by way of community based heat and power facilities which could be owned and operated by the community,
- Identification and exploitation of low cost low impact energy sources,
- Provision of a consistent overall strategic policy and planning framework for community planning,
- Incorporation of clearly defined energy policies in OCP and development permit and growth documents
- Developing early strategies for the development of energy systems and infrastructure programs, particularly with regards to district heat or heat and power programs.

1.2 CVRD overview

Geography

The Cowichan Valley Regional District is located on the southern portion of Vancouver Island in British Columbia, Canada and covers an area of nearly 3,500 km^2. It consists of 9 electoral areas, 4 municipalities, and aboriginal lands, and has a total population of roughly 82,000 people. It is bordered by the Capital Regional District (CRD) to the south, which while roughly 2/3 in size, has a population of approximately 350,000 and is home to the Province's capital, Victoria. To the northeast, the CVRD is bordered by the Nanaimo Regional District (NRD) which has a land area of just over 2,000 km^2 and a population of roughly 140,000. Lastly, to the northwest the CVRD is bordered by the Alberni-Clayoquot Regional District, home to just over 30,000 people spread over a land area of nearly 6,600 km^2.

Figure 1: Map of the Cowichan Valley Regional District and its administrative areas (GRAS).

The fact that the vast majority of the population centres within the CVRD are concentrated along the east coast, with very little along the western portion is of great relevance when identifying potential energy generation sources, both with respect to physical access to sites, and proximity to electricity transmission and distribution networks. Figure 1 on the previous page illustrates this.

Energy consumption

Based on 2007 data[2], the CVRD as a whole had an energy demand of nearly 10 PJ or 2.7 TWh (for reference purposes an energy conversion factor is included as appendix 1). As depicted in the figure below, well over half of this went to road transport, slightly over a third to residential buildings, and just under 14% was used by commercial and small-medium industrial buildings.

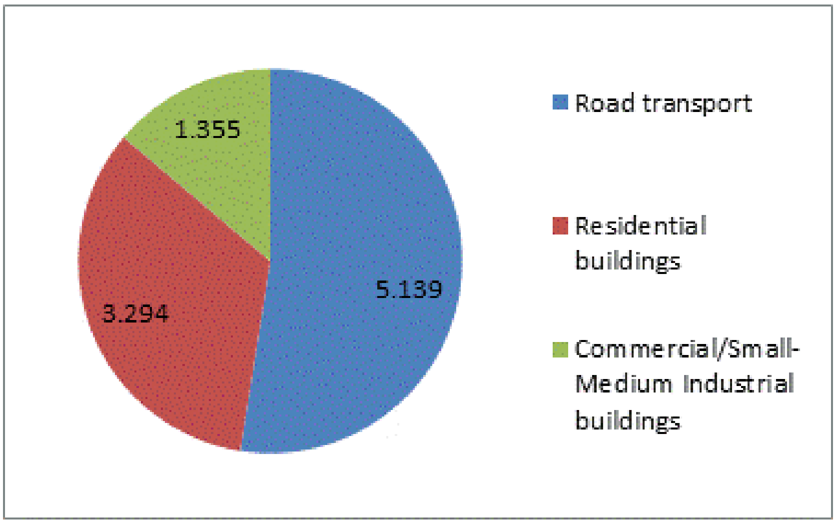

Figure 2: 2007 CVRD total energy consumption by sector (TJ) excluding large industrial users and Indian Reserves (BC Ministry of Environment, 2010).

In terms of fuel use by sector, it is thus not surprising that over 40% of the CVRD's energy needs are met by gasoline and 12% by diesel. Within buildings segment of consumption, the dominant sources are electricity, natural gas, wood, and heating oil. More specific breakdowns of these usages are displayed in the figure below.

[2] Excluding large industrial. Figures are withheld in CEEI publications when there are too few installations, as is the case with large industry in the CVRD.

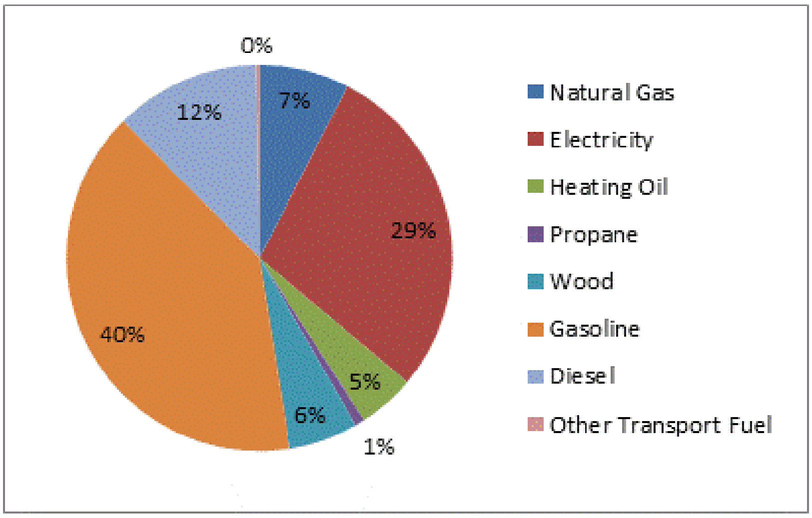

Figure 3: 2007 CVRD total energy consumption by source (TJ) excluding large industrial users and Indian Reserves (BC Ministry of Environment, 2010).

If we look at the residential sector which is the major focus of this project and is depicted in the figure below, the dominant inputs are electricity, wood, heating oil, and natural gas. It is worth noting that roughly 60% of residential dwellings are today heated via direct electric heating (i.e. electric baseboard heating), a phenomenon that is largely explained by the relatively cheap electricity that has historically been available in BC.

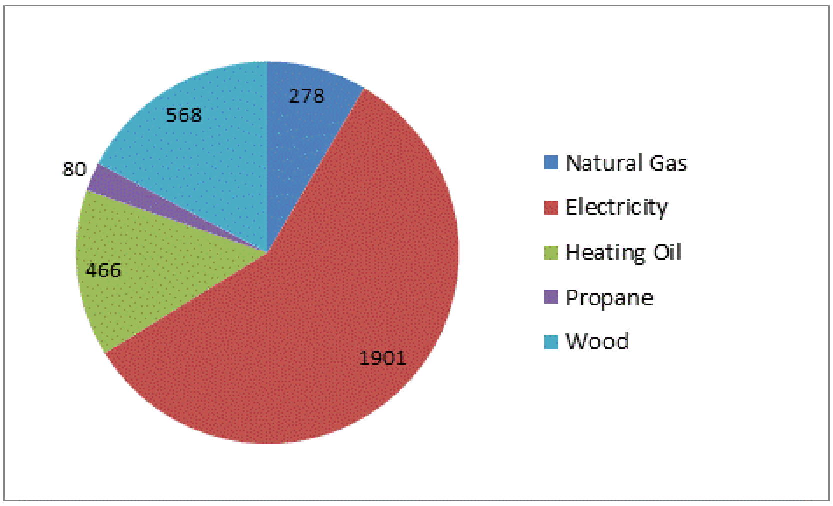

Figure 4: 2007 CVRD residential sector energy use (TJ) (BC Ministry of Environment, 2010).

Vancouver Island energy supply

Vancouver Island as a whole produces less than a third of its electricity consumption, with the remainder being supplied via undersea cables from the mainland. The largest of these connections is referred to as the 'Cheekye-Dunsmuir' which consists of two 500-kV HVAC lines and has an operational capacity of 1,450 MW (the red lines in the figure below). The other major connections are the 'HVDC Pole 2' connection from the Arnott (ARN) terminal station near Ladner on the mainland to the Vancouver Island Terminal (VIT) station located near Duncan with an operational capacity of roughly 240 MW, and the '2L129' connection also from ARN to VIT with an operational capacity of roughly 243 MW. (BC Hydro, 2011) The figure below displays the Vancouver Island transmission system as of October 2007, and as a result the new 2L129 connection is not depicted on the map.

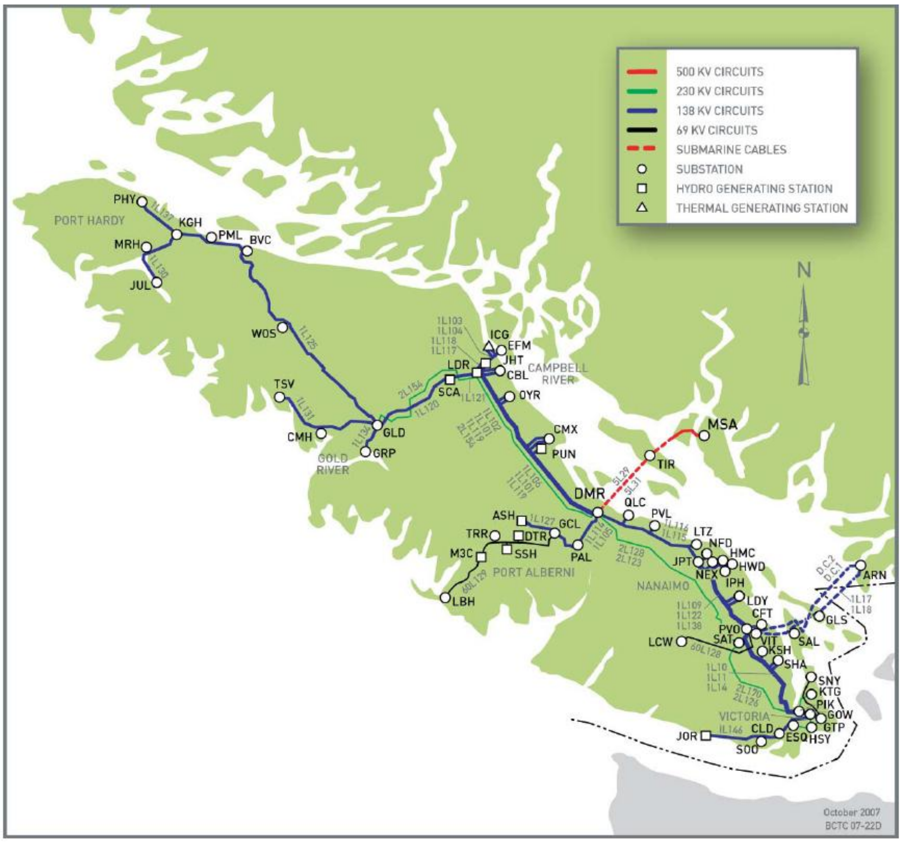

Figure 5: Vancouver Island Transmission network as of October 2007 (BC Hydro, 2007).

The majority of Vancouver Island's electricity is produced north of the CVRD, with the sole exception being the Jordan River facility located on the southern coast of the island. With the exception of the Elk Falls natural gas fired facility near Campbell River, all the electricity production on Vancouver Island currently comes from hydro, although new wind farm projects are in development in the Northern portion of the island.

CVRD energy supply

The CVRD therefore imports all of its electricity, some of it produced on the northern portion of the island, but a great deal of it is produced on the mainland. In addition all gasoline, diesel, natural gas, heating oil and propane are also imported from outside of the CVRD. As such roughly 95% of the CVRD's total energy demand is currently imported, with wood being the only local energy source.

GHG emissions

In terms of GHG emissions, the vast majority of the CVRD's GHG emissions can be attributed to road transport. Transport accounted for over 350,000 tonnes of CO_2 equivalent in 2007, or roughly 70% of the CVRD's total (503,000 - excluding large industrial emitters). In this report the term 'CO_2' is used synonymously to CO_2 equivalents.

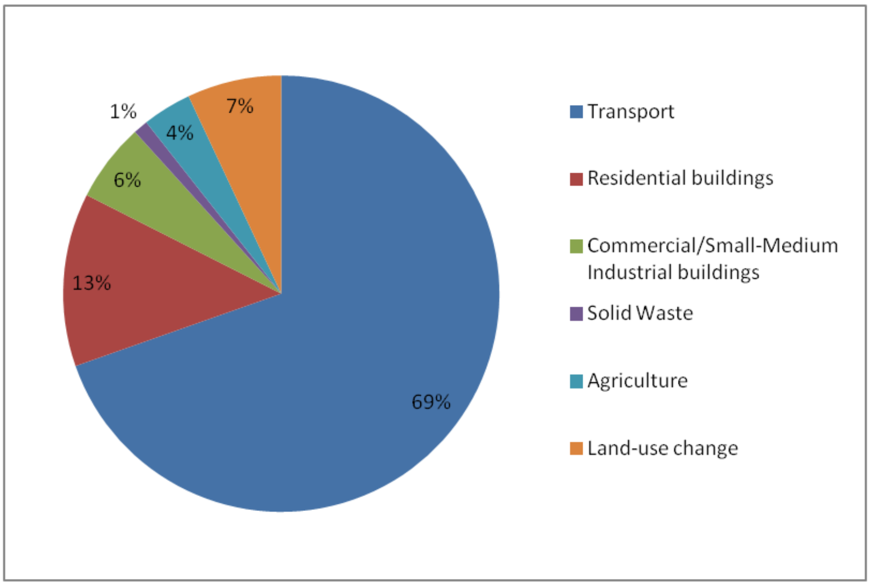

Figure 6: 2007 CVRD GHG emissions according to source excluding large industrial users and Indian Reserves. Total emissions were just over 503,000 tonnes of CO_2 (BC Ministry of Environment, 2010).

When calculating GHG emissions from electricity in British Columbia the CEEI reports utilise a CO_2 intensity of 24.7 g CO_2/kWh, as this represents the average amount of CO_2 found in electricity produced in British Columbia (CEEI, 2010). However, BC also imports and exports electricity, and when this is factored into the equation the average CO_2 intensity of electricity flowing through the power lines is over 3.5 times higher, at roughly 84 g CO_2/kWh (Pembina, 2011). It could be argued that using this latter figure when calculating GHG emissions is a more accurate representation of the actual carbon footprint from the use of electricity in BC. Doing so would increase CVRD residential sector emissions by roughly 50%, but transport related emissions would still be the most dominant source with well over 60% of CVRD emissions.

1.3 Report structure

The overall GIS methodology applied is presented first, followed by specific chapters detailing data, methods and results for each renewable energy source. As a reference for the reader, a table in appendix 1 gives an overview of the various energy related terms and units that are utilised throughout the report.

2 Methodology

The renewable energy resource potential for any given region is a function of both availability and applicability i.e. if the energy availability is high and the applicability is high the energy potential is high. On the other hand if the applicability is low it does not matter if the availability is low or high; the potential will always be low.

2.1 CVRD Ecosections

According to The British Columbia Ecoregion Classification (Demarchi, 2011) the CVRD is divided into three ecosections: (1) the Windward Island Mountains, (2) the Leeward Island Mountains and (3) the Nanaimo Lowland.

The Windward Island Mountains is an area on the western portion of Vancouver Island that consists of lowlands, islands, and rugged mountains. Pacific storms can bring intense rainfall and storms to these mountains as they rise and move to the east. Warm summer temperatures mixing with the cold Pacific water can bring heavy fog along the coast. Wet Coastal Western Hemlock forests dominate the lowlands and valleys at lower to mid–elevation slopes, while wet Mountain Hemlock subalpine forests are restricted to the very few higher summits along the eastern portion of the ecosection. Many of these forests have escaped significant disturbance, and there are a wide variety of representative protected areas in this ecosection. However, extensive clearcut logging has occurred in many of the more accessible valleys and lower slopes outside the protected areas. No major communities are found in this ecosection.

Leeward Island Mountains is a mountainous area in the central portion of the CVRD. Here moist Pacific air that has moved over the western side of Vancouver Island gives rise to rain shadows and a drop in precipitation, although still bringing heavy cloud cover. Due to its elevation this ecosection has the harshest winter climate within the CVRD. This ecosection is dominated by Coastal Western Hemlock in lowlands and valleys, while moist Mountain Hemlock subalpine forests dominate at higher elevations. Clearcut logging has been extensive throughout the ecosection for the past one hundred years and within this area there are many forest access roads. The Town of Lake Cowichan is the largest population centre in this ecosection, while smaller communities include: Youbou, Honeymoon Bay and Caycuse.

The Nanaimo Lowland is a coastal plain that is situated on the eastern portion of Vancouver Island. This ecosection has the mildest climate in the CVRD and is characterised by dry forests historically dominated by Douglas-fir and Garry oak. The majority of the CVRD population lives in this ecosection and most of the agriculture in the CVRD is concentrated here as well. It should also be noted that logging practices were such that very little of the old growth forest types remain today.

2.2 Methodology

The approach to mapping the renewable energy resource potential in the Cowichan Valley Regional District is built on a composite analysis of the factors affecting each renewable energy resource's potential. This is done via a geographical information system (GIS) platform that is able to combine and analyse several sources of spatial (mapped) information. The various factors are compiled and portrayed on individual maps and then overlaid and combined via simple mathematical expressions to show, in the final output maps, areas with high renewable energy potential (cf. Figure 7).

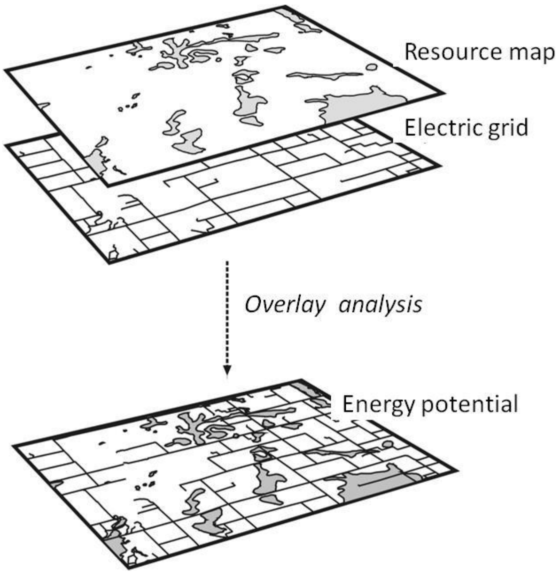

Figure 7: Conceptual sketch of the GIS approach to mapping renewable energy potential.

Apart from mapping the energy potential of individual energy sources it is important to expand the model so that it can represent the consideration of several energy sources as a single map output. As such, the output not only includes a set of individual GIS maps, but also an integrated representation of renewable energy potential looking across the various types of renewable energy. The resulting map will indicate total renewable energy potential as well as the most economically viable energy source at any given location within the CVRD.

Mapping Energy Resource Applicability

Resource applicability is a composed measure of the cost involved in collecting, harnessing, and transporting energy so it can become useful for human usages. The energy that can be produced from any given source is bound by the level, characteristics and cost-effectiveness of the selected energy production technology. While this technological/economical potential is not a spatial variable in itself, it is relatively easy to input this value into GIS as a weighted factor applied to each energy source i.e. higher weights representing more mature and efficient energy production.

The approach to mapping potential renewable energy resources in CVRD was based on a composite mapping analysis where several spatial data layers are combined using simple arithmetic expressions. The distinction between resource availability and resource applicability suggest a two-tier approach to the mapping of renewable energy resource potential. In other words, for any given resource the potential can be calculated as:

$$EP_i = R_{i,ava} + R_{i,app}$$

Where *EP* is the energy potential, *i* is the denotation for the different energy sources, $R_{i,ava}$ is the availability map of resource *i*, and $R_{i,app}$ is the applicability of resource *i*.

Resource applicability can be mapped in GIS using the following formula:

$$R_{i,app} = C_i w_i v_i$$

Where C is a travel cost measure that captures the spatial variability in energy exploitation and transportation as a function of landscape attributes (e.g. slope), proximity to existing infrastructure (e.g. transmission lines) and distance to existing nodes (e.g. residential, commercial and industrial areas); *w* and *v* are weights that represent the technological and economic potential for resource *i*, respectively.

In order to estimate the total renewable energy potential (EP_{total}) for a given area we take the sum of the resource potential for individual resources within that area:

$$EP_{total} = \sum_{i=n}^{n} EP_i$$

Another relevant output is a map that shows the optimal energy potential ($EP_{optimal}$) of RE option, designed to depict the energy source with the highest potential within each mapping unit.

$$EP_{optimal} = MAX[EP_i].$$

Text Box 1: Composite mapping analysis.

3 Solar energy

The total amount of solar radiation that is available at a site over the course of the year is the foremost statistic of interest to the solar energy developer. Since most solar equipment performs proportionally to available sunshine, average annual insolation (insolation being a measure of solar radiation) is a good indicator of the long-term performance of solar energy systems. The scarcity of traditional measurements of solar radiation data in the CVRD makes it difficult to accurately quantify average annual insolation across the District from observational data, and therefore a GIS modelling approach was used in the project.

3.1 Methodological approach

The solar power map for the CVRD is established using the solar analyst tool in ArcGIS. The tool generates a hemispherical viewshed (i.e. a view of the entire sky from ground level) which is used to calculate the insolation for each location via a Digital Elevation Model (DEM)[3]. The Solar Analyst can produce an accurate insolation map for any time period taking into account site latitude and elevation, surface orientation, shadows cast by surrounding topography, daily and seasonal shifts in solar angle, and atmospheric conditions.

The tool's parameter settings are for the most part fixed (being determined by geographic location and the terrain) but the settings for atmospheric conditions (i.e. transmittivity and diffuse proportion), need careful attention as atmospheric conditions vary over time for any given region. Given the lack of specific data for the CVRD monthly insolation data from Nanaimo was applied to optimise the settings for atmospheric conditions. The optimisation was an iterative process where different values for transmissivity (*t*) and diffuse proportion (*d*) were tested on a monthly basis. Clearness index values from NASA's Surface meteorology and Solar Energy (SSE) dataset were used to define the logical range of values for transmissivity. Due to the fact that there is an inverse relationship between transmissivity and diffuse radiation we could approximate values for diffuse proportion using the equation of Caroll (1984):

$$d = 1.11 - 1.16 * t \text{ (average for all cloud conditions)}$$

[3] Please refer to Box 1 for a detailed description of the DEM used in the calculation of sun and hydro power as well as being a modifier of the wind speed maps.

The final solar model was established by combining transmissivity and diffuse proportion, providing the closest match with insolation data from Nanaimo.

The average monthly insolation data from Nanaimo as derived from the ArcGIS solar analyst is shown in Figure 8 along with insolation data measured in situ.

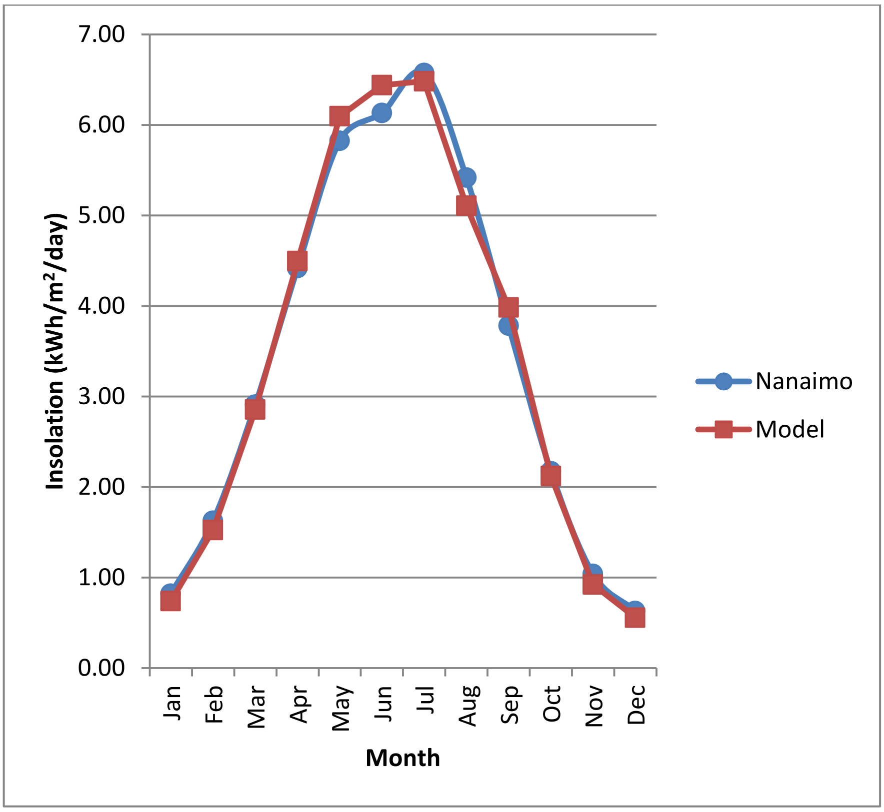

Figure 8: Measured solar insolation data from the Nanaimo weather station versus modelled solar insolation data.

Results for the CVRD as a whole were also evaluated against the solar resource maps of Canada available from Natural Resources Canada.[4] The maps give estimates of the mean daily global insolation (in kWh/m^2) on a monthly basis for any location in Canada on a 300 arc seconds ~10 km grid (cf. Figure 9).

[4] https://glfc.cfsnet.nfis.org/mapserver/pv/index_e.php

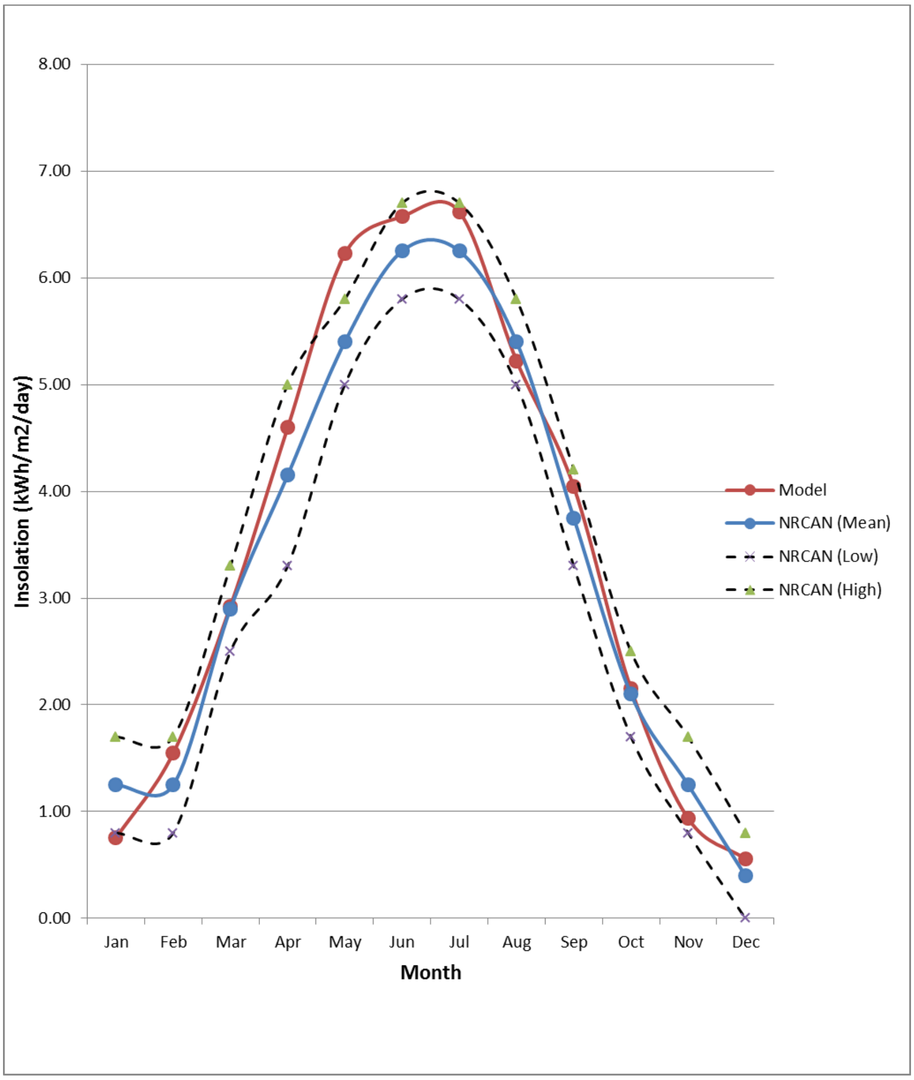

Figure 9: Modelled monthly average insolation for CVRD as whole compared to the solar resource maps of Canada available from Natural Resources Canada (NRCAN).

3.2 Results

A solar radiation map for the entire CVRD is presented below. The majority of the CVRD sees between 1,200 and 1,500 kWh/m^2 per year, with the more densely inhabited lowland areas to the east situated at the lower end of this range (1,200-1,300 kWh/m^2). Areas with potentials greater than 1,500 kWh/m^2 per year are at higher elevations and for the most part located some distance from existing building mass and transmission lines (cf. Figure 10).

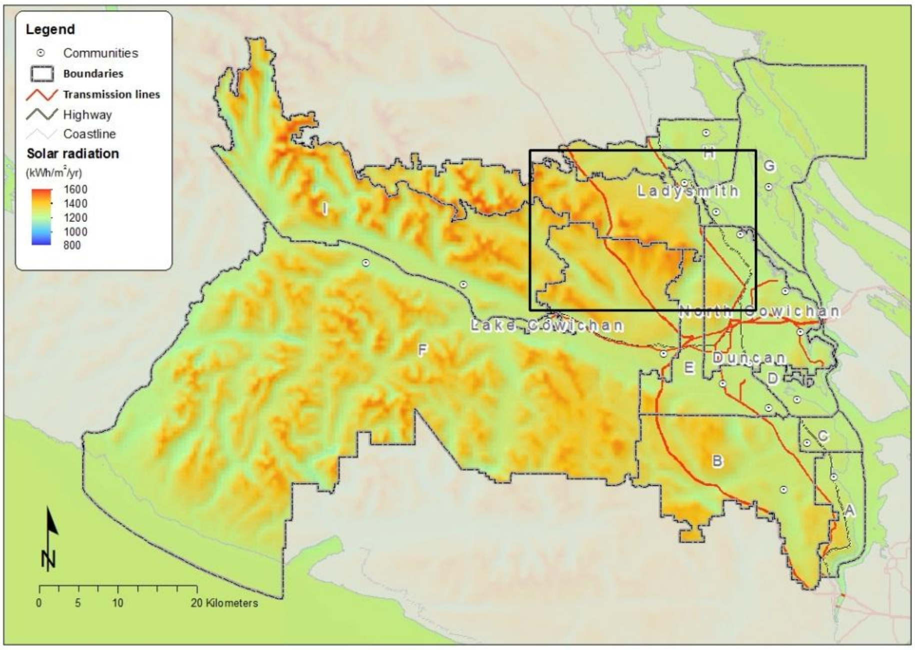

Figure 10: Solar resource map for the CVRD with annual solar potential measured in kWh/m² on a horizontal surface.

Notable exceptions are located southwest of Ladysmith in the Saltair/Gulf Islands and Cowichan Lake South/Skutz Falls electoral areas, where the annual solar energy potentials exceeds 1,500 kWh/m² and existing transmission lines are relatively close by (cf. Figure 11).

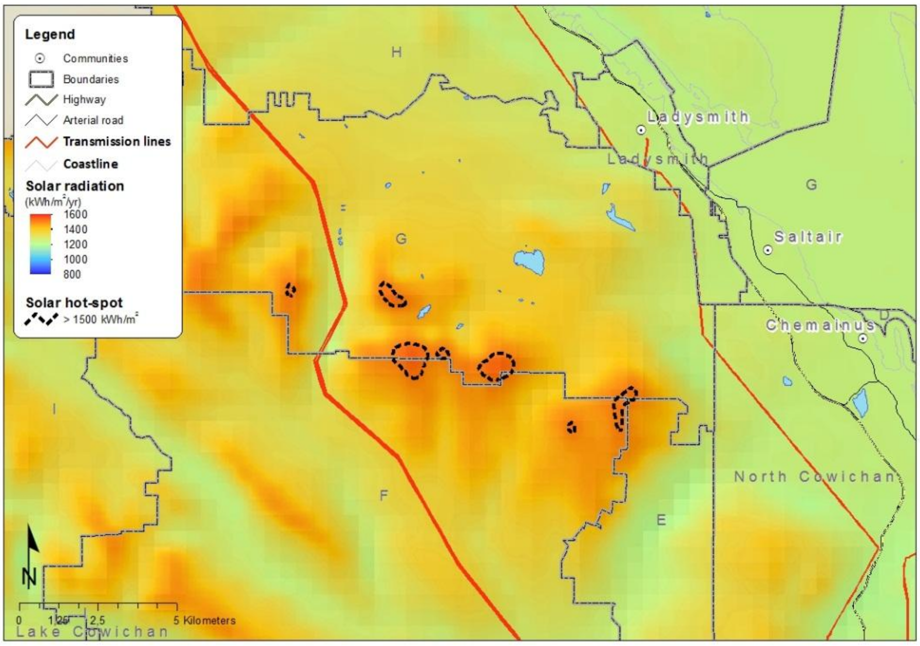

Figure 11: Solar energy potential in the western half of the Saltair / Gulf Islands electoral area (cf. black frame in Figure 10).

3.3 Seasonal variation

Even within areas of high potential, there is a great deal of seasonal variation in solar radiation, with the summer months having average monthly potentials over 7 times higher than those found in winter months (cf. Figure 8). Solar energy therefore benefits from working in conjunction with other renewable energy sources, such as wind, which has higher potential in the winter months and reservoir-based hydro, which has greater storage capacity. In addition, transmission capacity to neighbouring areas that allows for export during times with excess production, and import during periods with lacking production, can also be used to balance production variation.

3.4 Summary

Solar energy potential in the CVRD has been mapped using a digital elevation model and a GIS modelling tool. With an average annual solar radiation around 1,200 to 1,500 kWh/m^2, the potential for solar power is limited in CVRD with the current technology. This issue will be further elaborated on in the third report in this series, where the solar radiation maps will be fed into a photovoltaic cost analysis along with a set of assumptions on costs and efficiency of "typical" grid connected PV systems suitable for the CVRD setting).

4 Wind Energy

Wind energy describes the process by which the wind is used to generate mechanical power or electricity. Wind power production is a function of the site specific wind regime, which varies according to season, time of day, elevation and terrain.

4.1 Methodological approach

Accurate information about wind resources and wind energy potential for the CVRD was needed to evaluate the potential for wind energy exploitation. As a starting point, a slightly modified version of the Wind Atlas data from Environment Canada was utilised to obtain this information (Environment Canada, 2008). The Canadian Wind Atlas has been produced using a statistical-dynamical downscaling procedure of low resolution global climate simulations made from reanalysis. A reanalysis is essentially a combination of a model ("background") forecast and observations. If we assume we know the three-dimensional properties of the atmosphere at a given point in time, we can conduct a short forecast, e.g. for a six hour period, of the weather conditions using a global circulation model. With a perfect model to run this forecast, direct observations would not be needed. The model however, is not perfect, and should be considered a "first guess" to be corrected by applying observed data. Having completed this 'first guess', the next forecast step is undertaken where corrections based on observations are incorporated. The resulting product, called reanalysis, is a mixture of modelled and observed data for regions where observations are possible, or just modelled data for regions where observations are not possible. For reanalysis to be successful it is essential that the data used in the model is as realistic as possible (Stendel, M. 2011). For the development of the Canadian wind atlas the "original" reanalysis data from the U.S. National Centers for Environmental Prediction/National Center for Atmospheric Research (NCAR/NCEP) was used (Kalnay et al., 1996).

For the production of the wind atlas the Canadian territory is sliced into 65 tiles. On each tile, climate is characterised by a large set of weather conditions, providing over 200 different possible atmospheric states. The climatic modelling then consists of finding a spatial solution for the wind flow in each of those states. Results were then post-processed with a statistical model representing the seasonal dominant winds at three levels (30, 50 and 80 meters) in order to obtain weighted average of wind velocities and wind power in a 5x5 km spatial grid.

Given that local observations show a reasonable match with the Canadian Wind Atlas for wind speed (cf. Figure 12), the Atlas is an appropriate tool for developing preliminary feasibility studies of new wind energy projects.

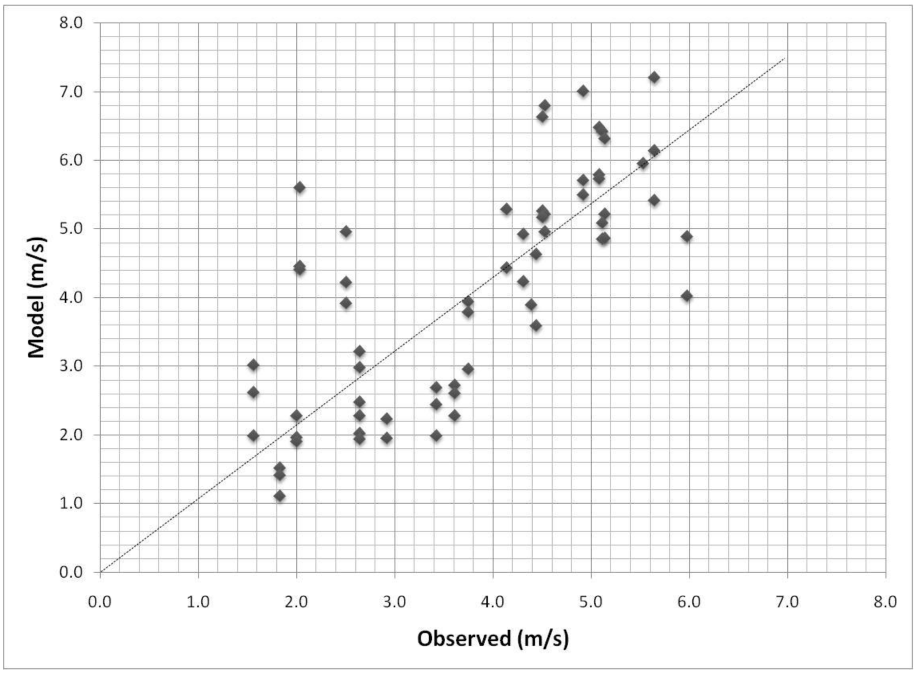

Figure 12: Relationship between observed wind speed at locations in the Vancouver/Vancouver Island greater region and modelled wind speed from Canadian Wind Atlas (see appendix for location map of observed wind speeds).

The 5 km grid cells used by the Canadian Wind Atlas, however, provide limited spatial variability. In particular, the local topography is believed to cause wind speeds that differ substantially from the predicted average values. As such, a first order adjustment was performed in order to better reflect the local topography. The rationale for the adjustment is the anticipation that points that lie above the average elevation within a 5x5 km grid cell will generally be somewhat windier than points that lie below it. The following equation accounts for the fact that every 100 m increase in elevation above the average will result in an increase in the mean wind speed of 0.25 m/s:

$$\Delta v = 0.0025 * \Delta z$$

In this equation *v* is wind speed and *z* is elevation height in meters.

However, elevation alone is not enough for successful wind power exploitation, and the surrounding landscape should also be considered. Elevated spots in a gently rising landscape will be more suitable for wind energy than elevated spots in a complex terrain with steep slopes. It should be noted that in this case surface roughness is not reflected in the downscaled map, as the purpose of downscaling is to create a smoother and more visually appealing output rather than to develop map that can be used for micro-siting. Therefore the resulting map should be used with caution and verified further with field observations.

4.2 Results

Maps depicting the annual mean wind speeds at 30, 50, and 80 meters above ground level have been generated for the entire CVRD. The map for 80 meters is displayed below as an example.

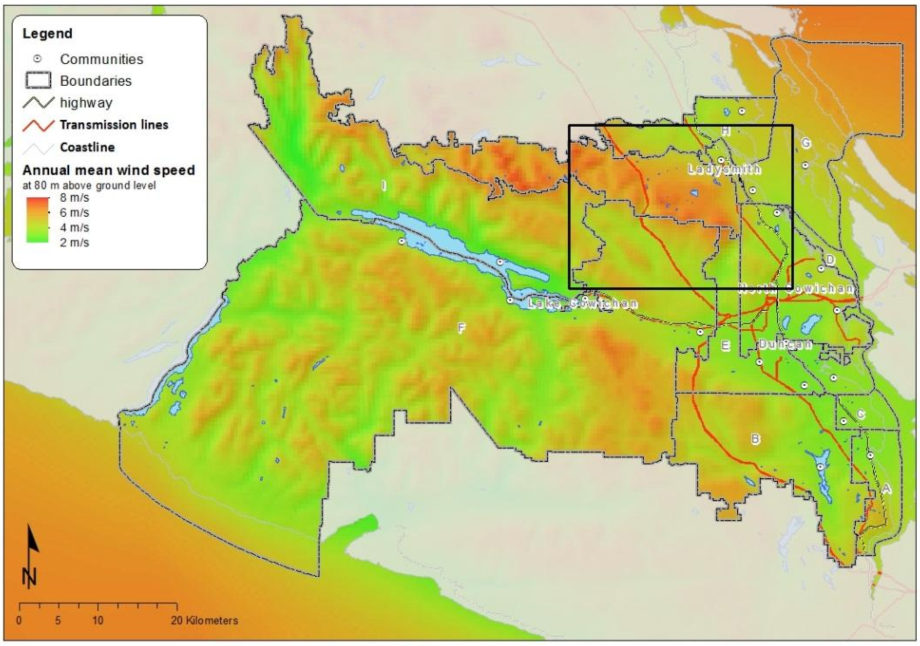

Figure 13: Annual mean wind speed in m/s in the CVRD at 80 meters above ground level.

Figure 13 indicates that the majority of the CVRD has relatively uninteresting wind regimes with annual average wind speeds of less than 5 m/s. Areas with average mean wind speeds greater than 6 m/s, however, can be found in the south-eastern corner of the Cowichan Lake South / Skutz Falls electoral area, as well as the western half of the Saltair / Gulf Islands electoral area. The latter area has the highest annual mean wind speed (> 6.5 m/s) in the CVRD, as illustrated below in Figure 14.

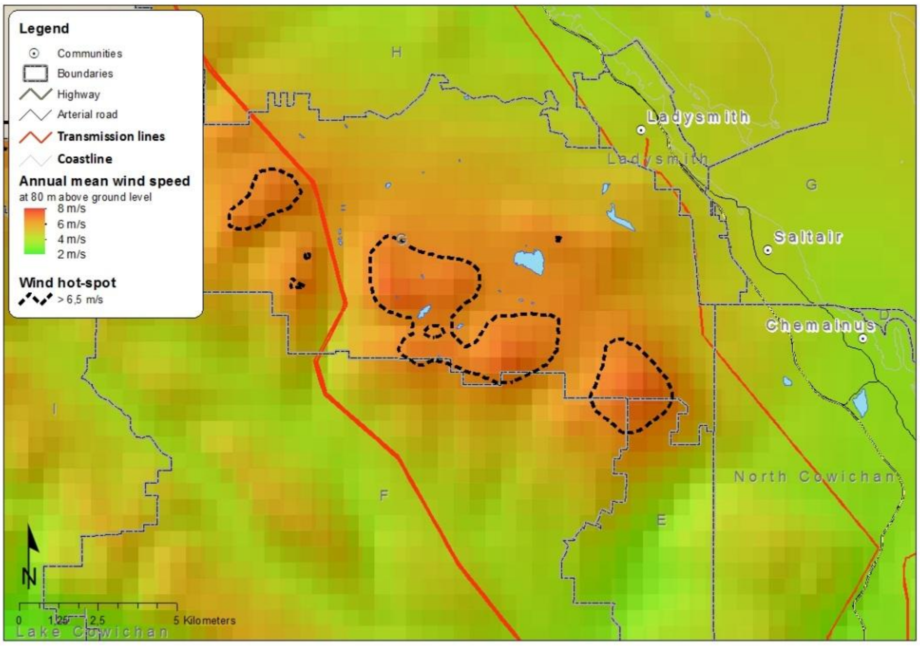

Figure 14: Annual mean wind speed in m/s in the western half of the Saltair / Gulf Islands electoral area (cf. black frame in Figure 13).

Transmission lines are located on either side of this area, making it favourable for wind power applicability. Moreover, the area is characterised by a gently sloping terrain varying from roughly 300 m southwest of Ladysmith, to a little over 1 km in the central and south-western portions, which further enhances its potential for hosting wind power (cf. Figure 15).

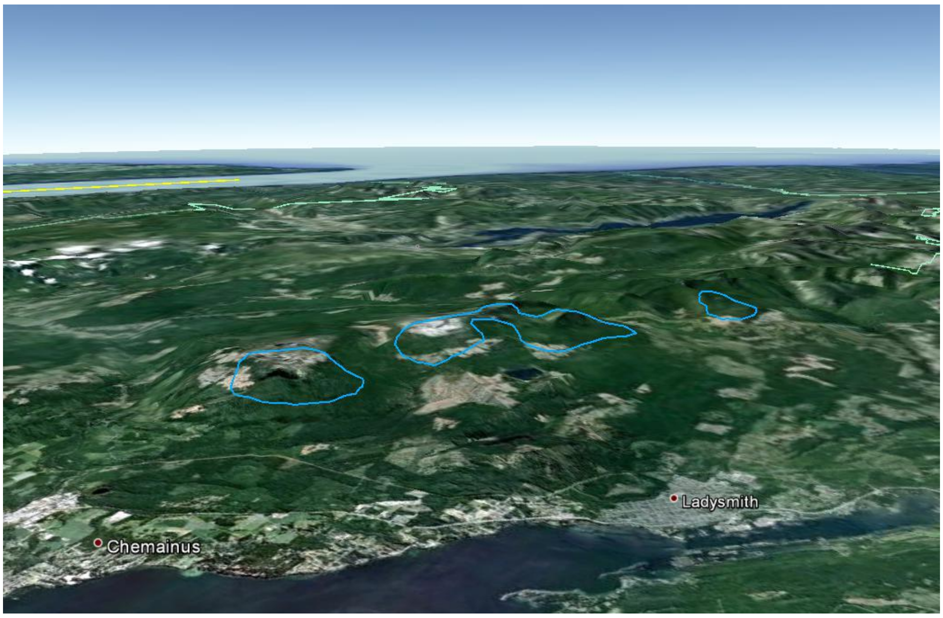

Figure 15: Area southwest of Ladysmith with favourable annual mean wind speeds and suitable gently sloping terrain (Google Earth, 2011).

4.3 Seasonal variation

As with solar energy in the CVRD, there is also a good deal of seasonal variation in wind speeds. In the case of wind the variation is somewhat smaller, but of greater relevance is the potential that winter months bring for wind energy (cf. Figure 16). In this regard, from a seasonal viewpoint, solar and wind potentials complement each other (recalling from the previous section that for solar the summer months have much more potential).

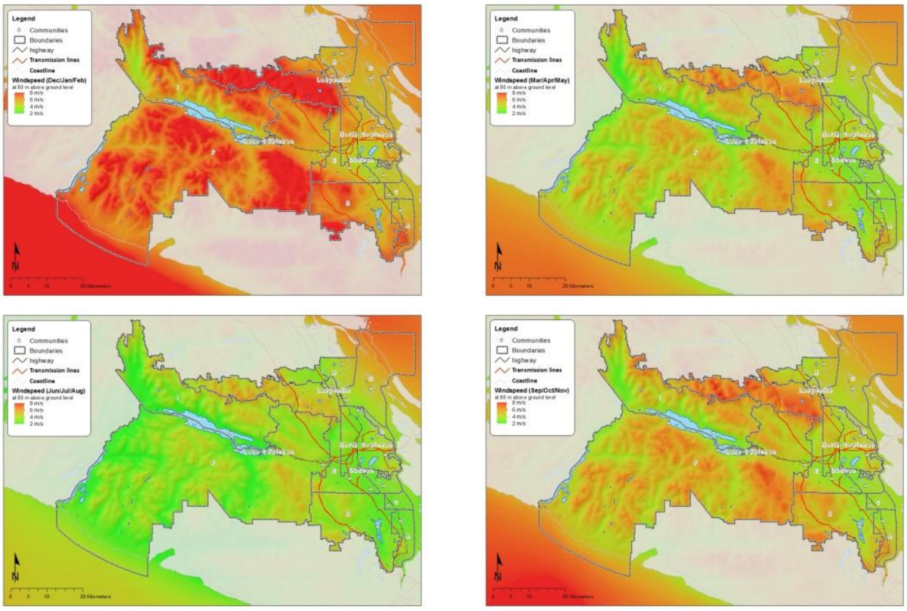

Figure 16: Seasonal wind variation in CVRD: Dec/Jan/Feb (upper left), Mar/Apr/May (Upper right), Jun/Jul/Aug (lower left) and Sep/Oct/Nov (lower right).

4.4 Offshore wind

As offshore turbines are more costly than onshore turbines, this option should only be considered for sites with higher wind speeds than onshore wind speeds, i.e. for annual average wind speeds of more than 7 m/s. Moreover, potential offshore wind sites should be located in relatively shallow waters, i.e. less than approximately 60 meters, which is the critical depth for fixed bottom foundations. Higher water depths require floating structures, a technology that is still currently at an early stage of its development.

The offshore wind isotachs (i.e. lines on a given surface connecting points with equal wind speed) for the CVRD and its neighbouring regions are shown in Figure 17 along with water depth. From the wind isotachs it is clear that offshore wind potential is limited to an area just north-east of the CVRD and close to Gabriola Island.

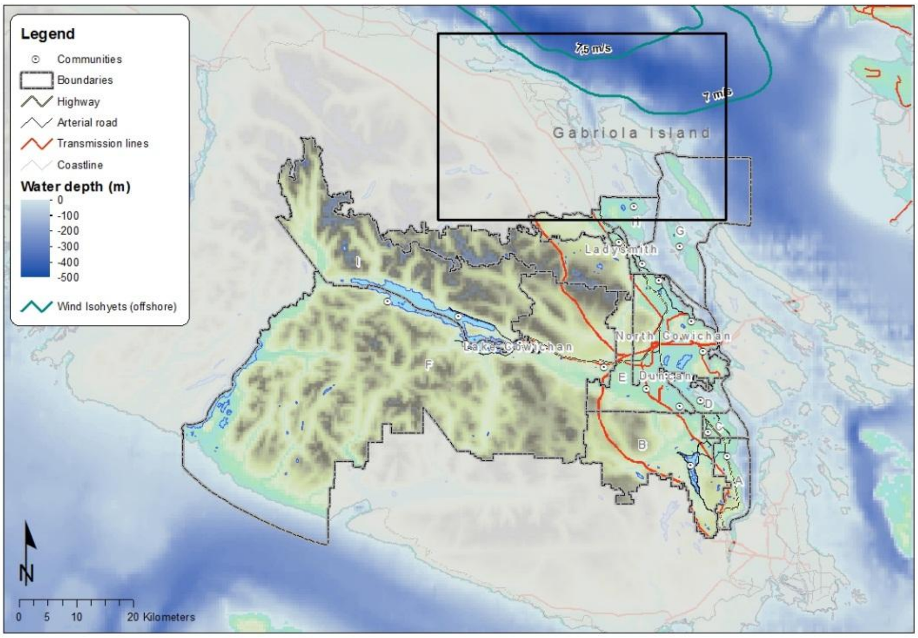

Figure 17: Water depths surrounding the CVRD, shown with offshore wind isotachs equal to or larger than 7 m/s.

Although the area with the greatest offshore wind potential is located outside the CVRD, it is relatively close to the main transmission line system. At closer inspection it can be seen that the 7 m/s isohyet and the 60 meter depth contour run almost parallel to each other in this area, in addition to a few pockets where the isohyet extends into shallower waters. This could be an indication of actual potential, although on site investigations would be needed to fully document whether the wind regime and bathymetry could justify the development of offshore energy in this region.

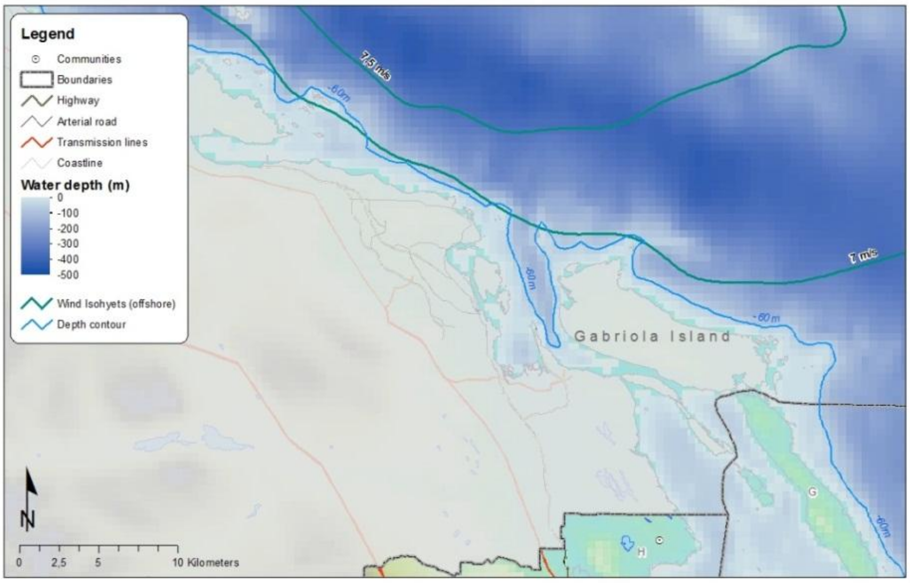

Figure 18: Area north of Gabriola Island with offshore wind energy potential (cf. black frame in Figure 17).

4.5 Summary

The Canadian Wind Atlas was instrumental in approximating and illustrating the spatial variation in wind speeds across land and sea areas of the CVRD, revealing sites that may have wind energy development potential.

As a follow-up to this initial screening, it would be beneficial to calculate total potential wind energy that could be produced within the CVRD after excluding obvious areas where wind farms cannot be established, including urban areas, water bodies and national parks. The next step would be to take into account wind turbine costs and efficiency as well as current capacity for distribution and transmission (cf. report 3).

5 Small-scale hydro power

Hydro power availability is a function of both water resources and land features, as the best sites for hydroelectric plants are fast-moving rivers or streams, mountainous regions, and areas with consistent rainfall and/or snowfall. For the purpose of identifying potential small-scale (up to maximum of 10 MW, but generally much smaller) hydro power sites in the CVRD a map screening approach was developed using GIS modelling techniques and available data on rivers, topography, land cover and topography. The mapping outcome provide a regional screening of hydro power opportunities, though it should be recognised that some local and site specific opportunities may be obscured by the relative coarse scale of the input data.

5.1 Methodological approach

The assessment of the hydro power potential in the CVRD is undertaken by estimating actual energy potential as calculated from digital maps of slope and runoff. The approach adopted was to look for an ideal combination of sustainable high flow rates and steep gradients, which would be required to create the necessary head for micro-hydro power generation.

Hydro-power is calculated using the following equation::

$$P_{ann} = g*\rho*Q*H$$

Where:

P_{ann} = Annual energy potential (kW/year)

g = Gravity (9.8 m/s^2)

ρ = Density of water (1,000 kg/m^3)

Q = Flow rate (m^3/s)

H = Head (m)

It follows that in order to determine annual energy potential we need to determine the head and the flow rate for any given site.

Head

The head was determined using the stream network in 1:20,000 scale from the Provincial Corporate Watershed Base and the ASTER Global Digital Elevation Model (DEM)[5]. For each river segment the potential head was

[5] ASTER GDEM is an easy-to-use, highly accurate DEM covering all the land on earth, and available to all users regardless of size or location of their target areas (http://www.gdem.aster.ersdac.or.jp/)

calculated as the difference between the highest and lowest elevation value along that segment. To avoid bias aginst longer segments we normalised all stream segments longer than 1,000 meters using the following equation:

$$H_{norm} = H/(L/1{,}000)$$

Where H is the head before normalisation and H_{norm} is the head after normalisation and L is the length of the river segment.

Thereafter all stream segments with a head higher than 20 m were selected and converted into a point theme to be used as our target points for flow rate estimation (cf. below).

Flow rate

The flow rate (Q) for any given site is a function of surface runoff (R) and watershed area (A).

$$Q = R*A$$

Surface runoff

Runoff volume is often taken as the precipitation modified by a coefficient reflecting basin recharge i.e.

$$R = C*P$$

Where:

R = runoff volume
C = runoff coefficient
P = precipitation

For our calculations of runoff we used the precipitation data from ClimateBC, an initiative of the Centre for Forest Conservation Genetics. This initiative extracts and downscales PRISM[6] (Daly et al. 2002) monthly data (2.5^o x 2.5^o) for the reference period (1961-1990), and calculates seasonal and annual climate variables for specific locations based on latitude, longitude and elevation (optional) for British Columbia, Yukon Territories, the Alaska Panhandle, and part of Alberta and US. The ClimateBC precipitation data (Daly et al. 2002) comes in a 400 meter spatial resolution in annual, as well as quarterly sums. The runoff coefficient was derived by simplifying the EOSD land cover classification map from the Canadian Forest Service into three classes: Forest (C=0.1), shrub (C=0.2) and herbaceous/exposed land (C=0.3).

[6] PRISM (Parameter-elevation Regressions on Independent Slopes Model) is a an analytical tool that uses point data, a digital elevation model, and other spatial data sets to generate gridded estimates of monthly, yearly, and event-based climatic parameters, such as precipitation, temperature, snowfall, degree days, and dew point.

Watershed area

Having determined the surface runoff, the next step is to calculate the watershed area. A watershed is the upslope area that contributes water to a common outlet as concentrated drainage. It can be part of a larger watershed and can also contain smaller watersheds, called sub-basins. The boundaries between watersheds are termed drainage divides. The outlet, or pour point, is the point on the surface at which water flows out of an area. It is the lowest point along the boundary of a watershed (cf. Figure 19).

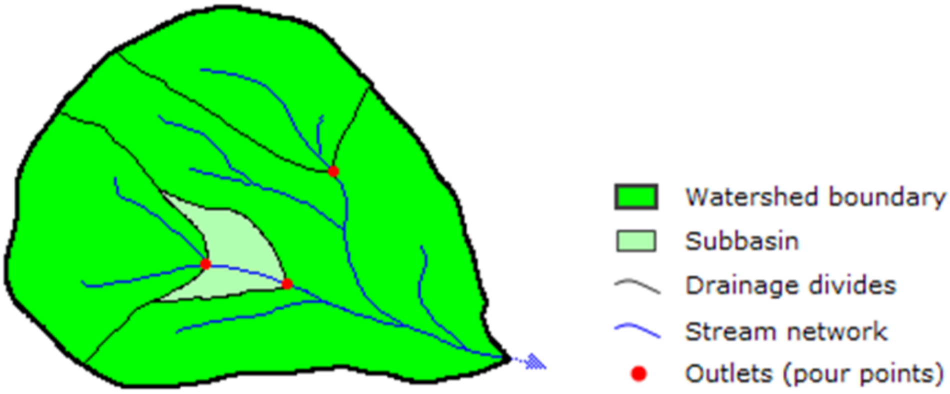

Figure 19: Watershed components (ESRI 2012).

Watersheds and sub-basins can be delineated from a digital elevation model (DEM) using the hydrology toolset in ArcGIS. First, a raster representing the direction of flow must be created from the DEM and using the *Flow Direction tool*. In addition, the outlet locations for the contributing areas to be determined must be specified, e.g. dams, stream gauges, or as in this case, potential sites for hydropower utilisation. Based on these input parameters the watershed can be determined using the ArcGIS *Watershed tool.*

Model outcome

Where possible the model outcome was compared with sites listed in BC Hydro’s “Inventory of Undeveloped Opportunities at Potential Micro Hydro Sites in BC”. The BC Hydro inventory includes only a few sites from the CVRD and its closer surroundings and as such we were only able to match four of the modelled sites with the inventory (cf. Figure 20).

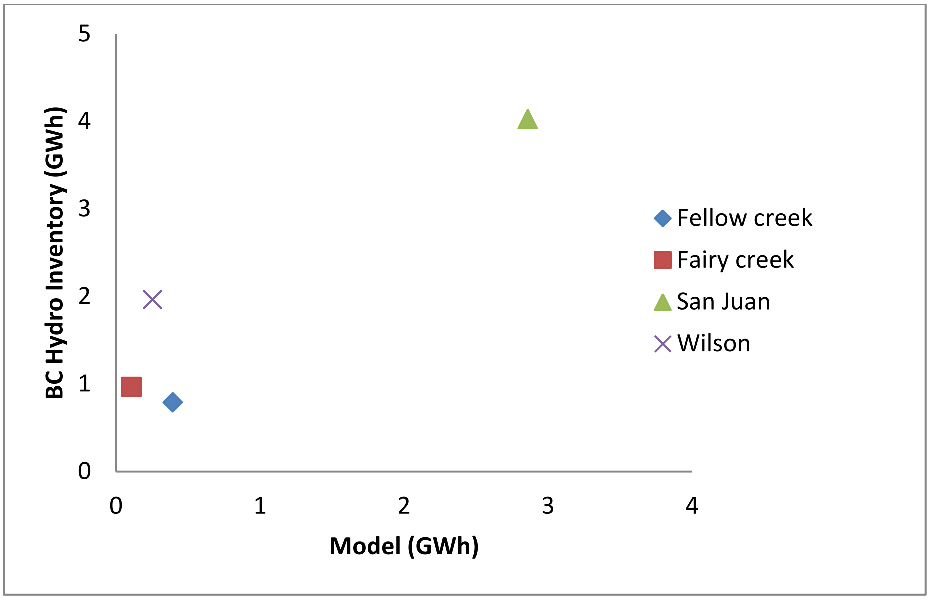

Figure 20: Modelled energy potential versus energy potential estimated by the BC Hydro inventory.

As a result, the comparison with BC Hydro is somewhat inconclusive. While the two approaches seem to return results that to a certain extent vary along the same relative scale, it is also evident that the model results are an order of magnitude lower than the BC Hydro inventory. The lack of accurate in-situ data, however, makes it impossible to judge which of the two approaches is more accurate. It is therefore recommended that the results should be tested against on-site investigations.

5.2 Results

A map of the micro hydro potential for the CVRD is displayed below.

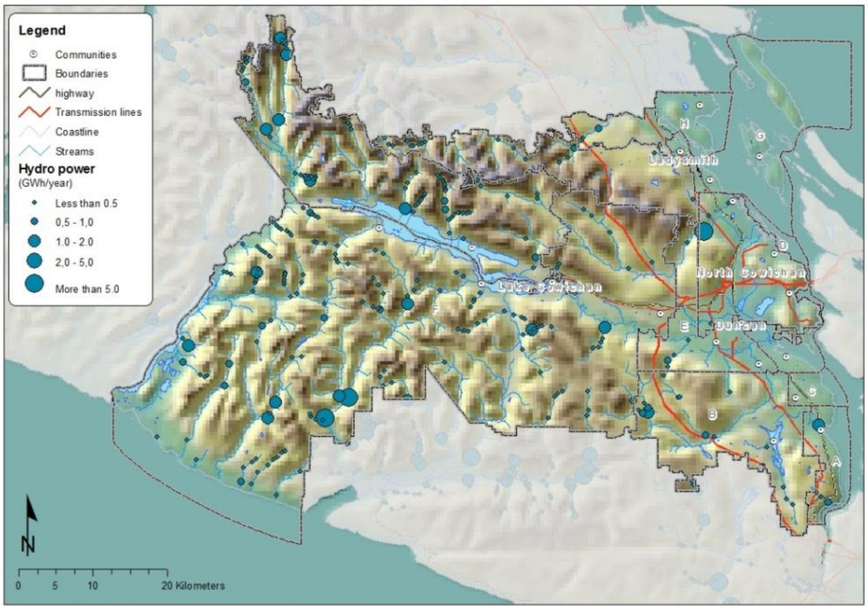

Figure 21: Annual micro hydro potential for the CVRD .

Figure 21 indicates that the greatest anticipated hydro potential are in the western portion of the CVRD, and thus quite some distance from existing transmission lines and demand centres. This is further emphasised in Figure 22 where only sites with an annual energy potential larger than 1 GWh are shown. The details of each of the sites are further elaborated in Table 1, and as previously stated these sites could serve as a starting point for some in-field assessment of actual on-site hydropower potential.

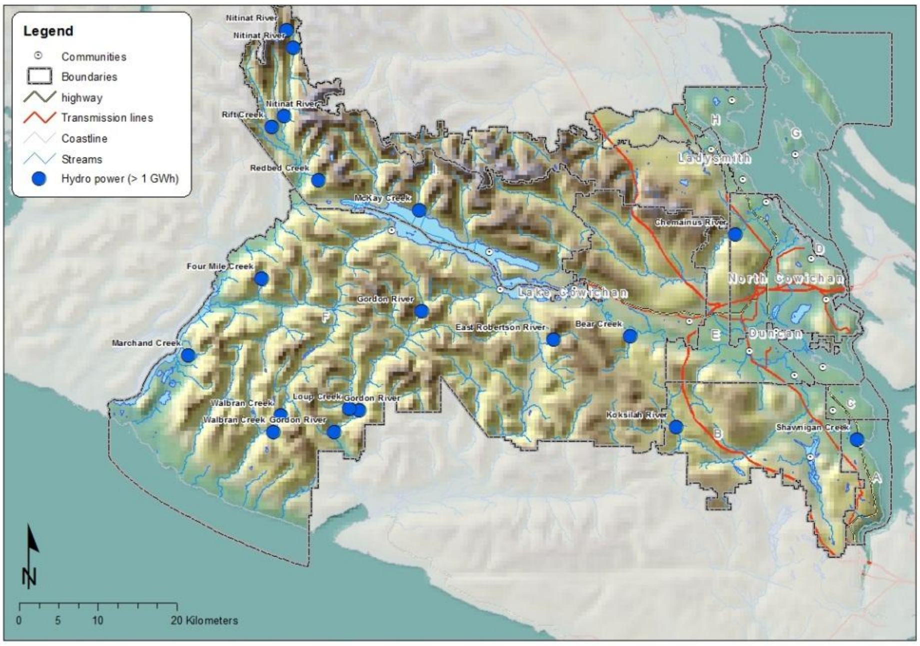

Figure 22: Sites with an annual micro hydro potential larger than 1 GWh.

While it appears that the hydropower map provides a realistic picture of the variability in micro-hydropower potential across CVRD, this cannot substitute for more detailed and in-field assessments of hydro power generating capacity. Moreover, only sites with an estimated head of more than 20 meters were investigated. The 20 meter threshold is dictated by the accuracy of the input DEM, which holds a relative vertical accuracy around 20 meters (~ 10 meter RMSE) and thus does not warrant analysis of sites with lower heads. As the new Light detection and ranging (LIDAR) elevation model becomes available for the CVRD, better head estimates as well as more accurate watershed analyses will be possible.

Name	Head (m)	Area (m^2)	Runoff (mm)	Flow (m^3/s)	Power (kW)	Energy (MWh/year)	Distance to grid (km)
Gordon River	26	212	671	4.50	1,146	10,042	34.7
Chemainus River	20	306	354	3.43	673	5,897	1.6
Gordon River	20	147	636	2.96	579	5,076	30.5
Nitinat River	21	47	877	1.32	271	2,373	39.0
Loup Creek	21	51	764	1.23	253	2,214	31.5
Walbran Creek	22	50	734	1.17	252	2,206	39.7
Walbran Creek	20	56	711	1.26	248	2,170	41.4
Rift Creek	27	33	849	0.90	237	2,080	41.0
McKay Creek	38	26	758	0.62	232	2,034	21.7
Nitinat River	92	7	909	0.21	185	1,620	40.5
Koksilah River	53	32	310	0.31	162	1,419	2.2
East Robertson River	47	18	590	0.34	155	1,360	6.3
Shawnigan Creek	25	104	182	0.60	147	1,284	2.5
Gordon River	20	32	686	0.70	138	1,210	19.2
Four Mile Creek	92	4	1,026	0.14	126	1,104	39.1
Marchand Creek	55	11	663	0.23	126	1,101	49.2
Nitinat River	29	16	871	0.43	123	1,078	38.9
Bear Creek	40	26	370	0.31	121	1,063	3.5
Redbed Creek	67	6	1,027	0.18	120	1,050	35.1

Table 1: Input parameters for estimating annual hydro power potential (note: only sites with a potential larger than 1,000 MWh is shown).

5.3 Conclusion

Through this study, a method has been developed to estimate hydropower potential using a map of the stream network, a digital elevation model and some GIS modelling tools. The third report in this series will provide further analysis of the hydropower potential by taking into account the design and infrastructure costs of small-scale hydropower generation. Further evaluation of potential sites utilising enhanced DEM (such as LIDAR) is recommended in proximity to communities and or infrastructure when it is available.

6 Biomass and waste

The CVRD has a large biomass resource base which could be managed for the production of energy. The main source of potential biomass energy in the CVRD is residues from forestry/forest products, but agriculture and urban sources (i.e. municipal wastes) also hold potential.

6.1 Methodological approach

Biomass from wood

From the Biomass Inventory Mapping and Analysis Tool (BIMAT), estimates of total forest residue biomass (softwood roadside harvest residue[7]) were obtained within a 40 km radius covering the majority of the CVRD region (cf. Figure 23) (Agriculture and Agri-Food Canada, 2008). Total forest cover area with the same radius was estimated using the EOSD land cover map as a basis. This allowed us to estimate the average amount of roadside forest residues available per hectare of forest in the CVRD (cf. Table 2).

Parameter	
BIMAT circle area	4,800 km^2
Forest cover proportion	61%
Total forest roadside residues	180,000 odt/year
Forest cover area	292,800 ha
Mean forest roadside residues	0.61 odt/ha/year

*Table 2: Input parameters for estimating mean roadside residues per hectare forest in the CVRD. * odt = oven dried tonnes.*

Lastly, to estimate the total forest biomass residue inside each CVRD administrative area we calculated the forest cover area within each administrative division and multiplied with the average residue production.

Biomass from agriculture

Potential renewable energy resource opportunities in the agricultural sector result from either livestock manure or from crop residues. In the CVRD it is mainly the former which is of interest. With the help of the Ministry of Agriculture, information was gathered to build a database of the number and location of farms and their approximate numbers of livestock. This information was coupled with assumptions on manure and slaughterhouse waste volumes, which along with a set of conversion factors, (cf. Table 3) was used to estimate the biogas potential on a farm-by-farm basis (cf. Table 5).

[7] Roadside Residues is a spatially-explicit estimate of the location and volume of forest harvest residues produced annually at roadside landings within the commercial forest land base in Canada

Assumptions	
Dairy = milk cows	
Layer = egg laying hens in cages	
Broiler = egg laying hens via broiler	
Assumptions on manure:	
38.69	tonnes per cow - kept inside
16.7	tonnes of manure per 1,000 broilers a year
4.48	tonnes per 100 "year hen" for layer
Assumption on biogas production per ton manure	
22.5	m^3/tonne cow manure (20-25 m^3/tonne)
75	m^3/tonne poultry manure (50-100 m^3/tonne)
Assumption regarding slaughterhouse waste	
0.544	tonnes of slaughter output per cattle
42	waste % of total slaughter output
0.23	tonnes of waste per slaughter unit
Assumption on biogas production per ton slaughterhouse waste	
100	m^3/tonne fatty slaughterhouse waste (>100 m^3/tonne)
50	% - of waste is fatty slaughterhouse waste
60	m^3/tonne gastrointestinal slaughterhouse waste (40-60 m^3/tonne)
50	% - of waste is gastrointestinal slaughterhouse waste
Conversions	
35.88	MJ / normal cubic meter methane
65	methane content of biogas (%)
23.32	biogas energy (MJ/normal cubic meter of biogas)
Cross-Check	
860	Annual biogas production (m^3 biogas) per freestall dairy cow [8]

Table 3: Assumptions used to convert agricultural manure and waste into biogas potential.

[8] Government of Alberta, 2010

Biomass from waste

Within the CVRD there are significant amounts of Municipal Solid Waste (MSW), which are currently transported out of the CVRD. In addition, both the adjacent Regional District of Nanaimo (RDN) and Capital Regional District (CRD) have MSW that is currently being disposed of in landfills. Report 3 will further investigate this potential with a focus on: heat only boilers or combined heat and power (CHP) for district heating, a waste incineration plant, and/or a plant that can utilise both wood chips and MSW.

6.2 Results

The EOSD forest cover map of the CVRD is shown in Figure 23 along with the location of biomass units and relative forest residues for the area.

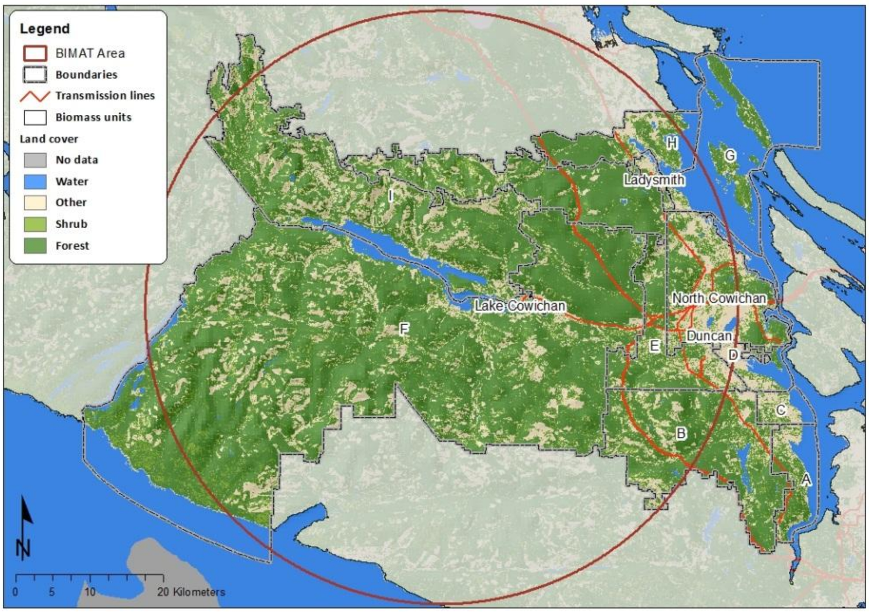

Figure 23: The EOSD forest cover map of the CVRD. The circle represents the BIMAT area used to calculate the input parameters for the estimation of mean roadside residues pr. hectare forest in CVRD.

Forest cover statistics along with estimated roadside forest residues and associated energy potential have been calculated for each administrative area in the CVRD (cf. Table 3). For the majority of the area it is clear that roadside residues from timber harvesting and wood processing operations can be considered a major biomass opportunity that warrant closer consideration.

It is also worth stressing that the calculated biomass represents a readily exploitable energy potential, since it is based on estimates of harvest residues produced annually at roadside landings within the commercial forest. In contrast, estimates based on the standing biomass would be much more theoretical since exploitation of the standing biomass is only viable if the resource is underutilised and if its removal is not leading to detrimental nutrient loss. However, neither of these conditions seem to apply for the CVRD, which has a long and extensive logging history, and much of the remaining forest is located in rugged terrain (Environment Commission 2010).

	Forest (ha)	Total area (ha)	Forest area (%)	Forestry roadside residue (odt/year)	Energy (TJ)*
CVRD (unincorporated areas)					
Electoral area A	2,530	5,185	49%	1,539	28
Electoral area B	19,780	31,211	63%	12,033	217
Electoral area C	543	2,330	23%	330	6
Electoral area D	656	3,237	20%	399	7
Electoral area E	8,096	14,535	56%	4,925	89
Electoral area F	125,619	178,957	70%	76,418	1,376
Electoral area G	21,619	30,472	71%	13,151	237
Electoral area H	6,038	9,620	63%	3,673	66
Electoral area I	28,339	50,620	56%	17,240	310
Subtotal	*213,220*	*326,166*	*65%*	*129,709*	*2,335*
Duncan	5	211	2%	3	0
Ladysmith	415	1,287	32%	253	5
Lake Cowichan	268	855	31%	163	3
North Cowichan	7,645	20,253	38%	4,651	84
Cowichan Tribes*	*888*	*2,514*	*35%*	*2,232*	*40*
Grand total	**221,553**	**348,772**	**64%**	**134,778**	**2,426**

Table 4: Forest cover statistics, estimated roadside forest residues and estimated energy potential as per administrative area in the CVRD. (1 oven dry tonne of woodfuel = approx. 5 MWh of energy = 18 GJ.) - Please note, that the Cowichan Tribes area is partially included as part of other administrative areas and is therefore not counted separately in the grand total.*

Biomass from agriculture

The table below provides a summarised listing of farming activities in the CVRD along with an estimate of their potential in terms of biogas production. Figure 24 illustrates how this is distributed within the region.

Farm#	Type	Scale	Tonnes manure per year	Biogas production (m^3)	Biogas production (m^3) per unit	Biogas (MJ)
1	Dairy	125	4,836	108,816	871	2,538
2	Dairy	75	2,902	65,289	871	1,523
3	Layer	5,000	224	16,800	3	392
4	Layer	15,000	672	50,400	3	1,175
5	Dairy	75	2,902	65,289	871	1,523
6	Dairy	80	3,095	69,642	871	1,624
7	Dairy	50	1,935	43,526	871	1,015
8	Dairy	70	2,708	60,937	871	1,421
9	Dairy	70	2708	60,937	871	1,421
10	Dairy	50	1,935	43,526	871	1,015
11	Dairy	70	2,708	60,937	871	1,421
12	Dairy	35	1,354	30,468	871	711
13	Broiler	40,000	668	50,100	1	1,168
14	Dairy	75	2,902	65,289	871	1,523
15	Dairy	75	2,902	65,289	871	1,523
16	Dairy	125	4,836	108,816	871	2,538
17	Dairy	40	1,548	34,821	871	812
18	Dairy	50	1,935	43,526	871	1,015
19	Dairy	80	3,095	69,642	871	1,624
20	Dairy	75	2,902	65,289	871	1,523
21	Dairy	70	2,708	60,937	871	1,421
22	Dairy	30	1,161	26,116	871	609
23	Dairy	200	7,738	174,105	871	4,060
24	Dairy	225	8,705	195,868	871	4,568
25	Dairy	30	1,161	26,116	871	609
26	Dairy	50	1,935	43,526	871	1,015
27	Layer	40,000	1,792	134,400	3	3,134
28	Layer	15,000	672	50,400	3	1,175
29	Layer	15,000	672	50,400	3	1,175
Sub Totals (annual)			**75,309**	**5,648,194**		**131,727**
Farm#	**Type**	**Weekly volume**	**Tonnes slaughter-house waste per year**	**Biogas production (m^3)**	**Biogas production (m^3) per unit**	**Biogas (MJ)**
30	Dairy, slaughter	20	566	45,261	44	1,056
Totals (annual)				**5,693,455**		**132,783**

Table 5: Farm activities in the CVRD and estimated potential for biogas production.

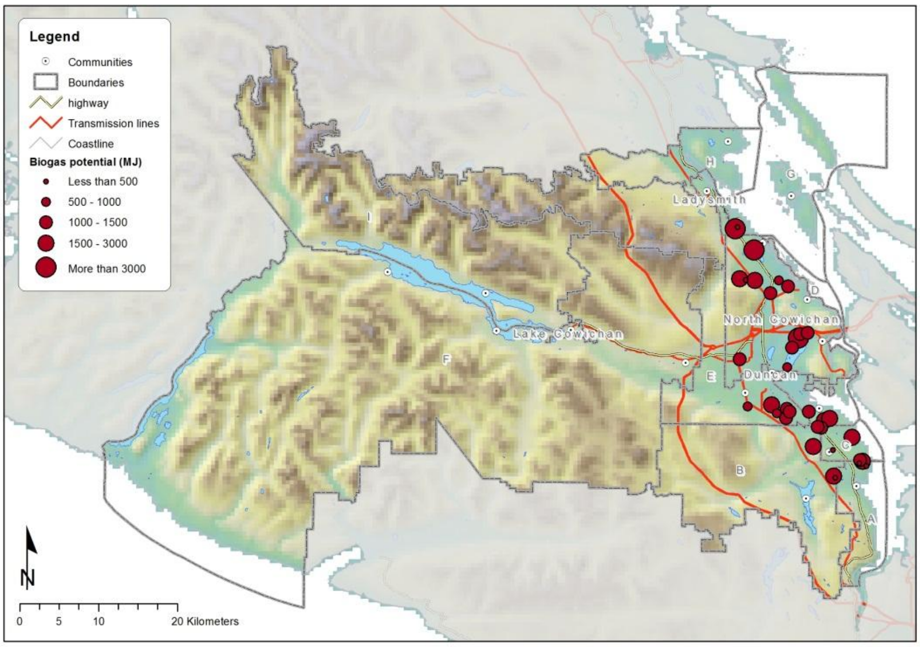

Figure 24: Farms in the CVRD evaluated in terms of biogas production potential.

6.3 Conclusion

Biomass energy potential from forest residues was mapped using a forest cover map and aggregated inventory data on forest harvest residues. The mapping reveals a significant potential for exploiting forest residues, which is further enhanced by the fact that it only represents residues produced at roadside landings. In other words if there is willingness and/or incentives to exploit this resource base it is there for the taking. Biomass from agricultural waste as a renewable energy source for human appropriation has a more limited total potential, but maintaining and updating this database as biogas technology evolves is nonetheless a worthwhile endeavour. In the third report of this series the biomass potential will be discussed further with emphasis on technology cost and efficiency.

7 Geo-exchange heat

Solar heat stored in the earth can be exploited using geo-exchange heat pump technology. As the ground retains relatively constant temperatures over the entire annual season, a heat pump is used to extract heat. In the summertime, a heat pump can also be used to provide air conditioning by moving heat from the building down to the earth.

Opportunities for heat pump systems are determined by site-specific characteristics. In general, any resident or business in the CVRD should be able to use heat pumps to harness this stored solar energy. However, site specific characteristics of the property and of the building would have an impact on the feasibility and the type of system that is required.

Variability in geology affects the suitability for geo-exchange potential as thermal exchange properties and ease of digging/drilling will vary for different geological materials. In addition, hydro-geology factors (e.g. soil moisture and ground water) are important for geo-exchange since the heat capacity of water is greater than for dry earth materials. A number of relevant hydro-geological factors were available (e.g. depth to water, aquifer media, soil media, and hydraulic conductivity) but only at a relative scale adapted to groundwater vulnerability and at a resolution which was not deemed sufficient for site specific characterisation. We have therefore not attempted to map out the CVRD's geo-exchange heat potential.

Nevertheless, geo-exchange heat systems have become popular in recent years and often represent a cost-effective and environmentally attractive heat provision option. As such, we consider geo-exchange to be highly relevant and it will be further discussed and analysed in the third report in this series.

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9 Appendices

Energy conversion factors

As a reference for the reader, the table below gives an overview of the various energy related terms and units that are utilised throughout the report.

Aspect	Symbol	Name	Value
Energy quantity Generally used to measure heat values	J	joule	1
	kJ	kilojoule	10^3
	MJ	megajoule	10^6
	GJ	gigajoule	10^9
	TJ	terajoule	10^{12}
	PJ	petajoule	10^{15}
Power Generally used to measure the output of a plant or device	W	watt	1
	kW	kilowatt	10^3
	MW	megawatt	10^6
	GW	gigawatt	10^9
	TW	terawatt	10^{12}
Energy quantity Generally used to measure the amount of electricity	Wh	watt hour	1
	kWh	kilowatt hour	10^3
	MWh	megawatt hour	10^6
	GWh	gigawatt hour	10^9
	TWh	terawatt hour	10^{12}
Conversion factors:	1 Wh	3,600 J	
	1 kWh	3.6 MJ	
	1 MWh	3.6 GJ	
	1 GWh	3.6 TJ	
	1 cent/kWh	10 CAD/MWh	

Wind station data

Figure 25: Location map of wind stations used for validation of wind speed map.