Ea Energy Analyses

gras

FINAL REPORT

Cowichan Valley Energy Mapping and Modelling

REPORT 2 – ENERGY CONSUMPTION AND DENSITY MAPPING

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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
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

This report is the second 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 a report entitled 'GIS Mapping of Potential Renewable Energy sources in the CVRD'.

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 as well as the on-going provincial TaNDM project of which the CVRD is a partner. The results of task two are documented in this report.

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.

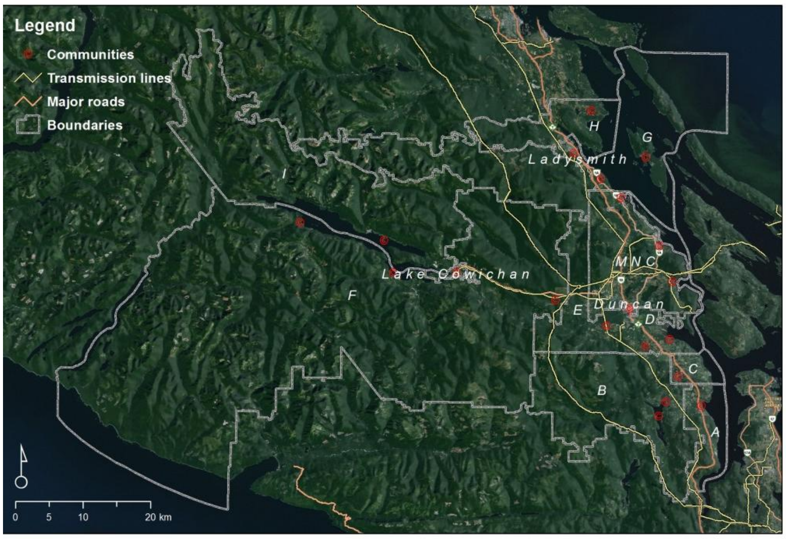

Figure 1: Map of the Cowichan Valley Regional District and its administrative areas (GRAS).

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.

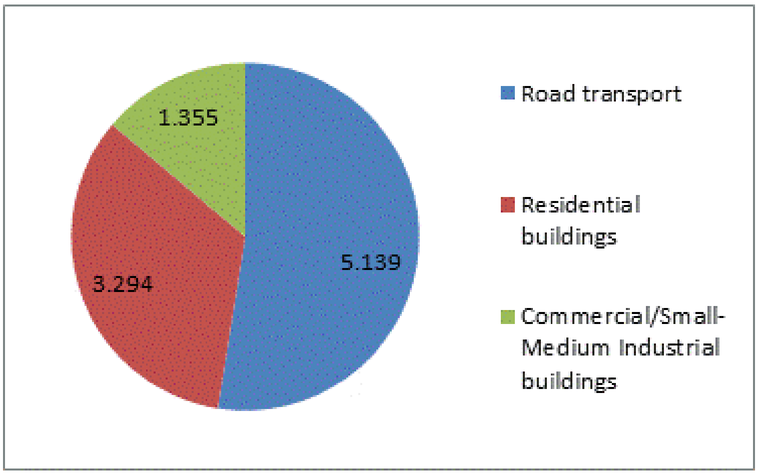

Figure 2: 2007 CVRD total energy consumption by sector (TJ) excluding large industrial users and Indian Reserves (BC Ministry of Environment, 2010).

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.

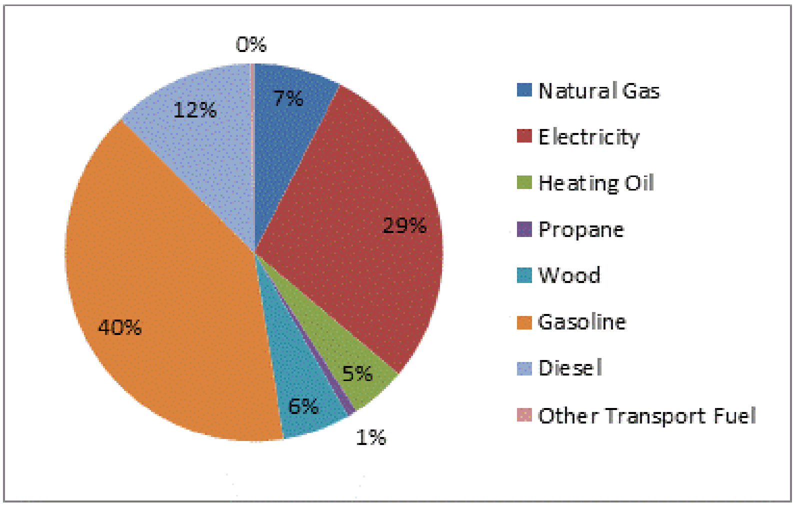

Figure 3: 2007 CVRD total energy consumption by source (TJ) excluding large industrial users and Indian Reserves (BC Ministry of Environment, 2010).

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.

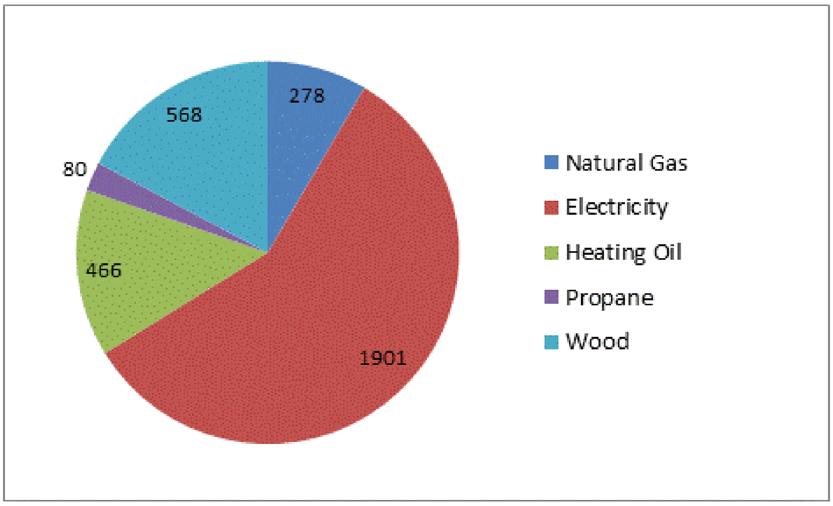

Figure 4: 2007 CVRD residential sector energy use (TJ) (BC Ministry of Environment, 2010).

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.

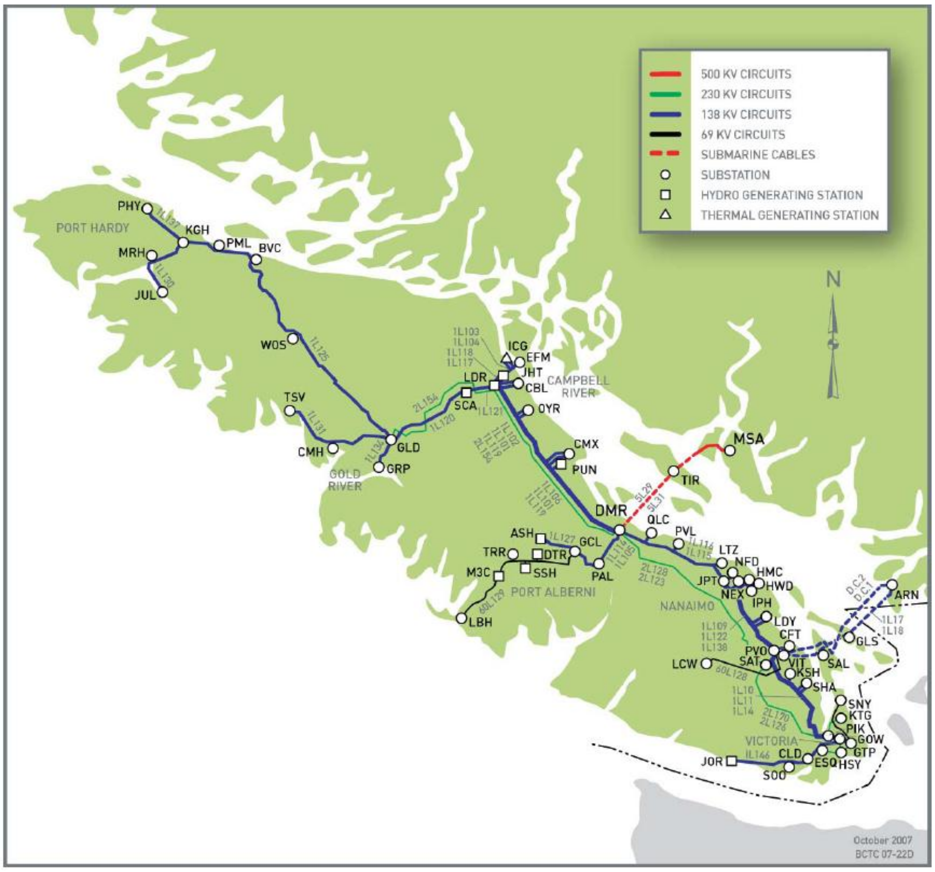

Figure 5: Vancouver Island Transmission network as of October 2007 (BC Hydro, 2007).

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.

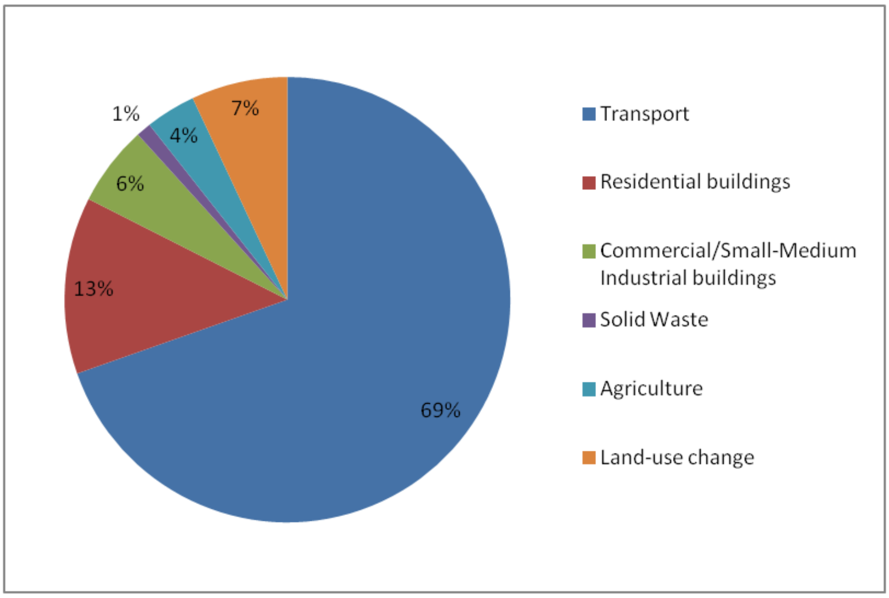

Figure 6: 2007 CVRD GHG emissions according to source excluding large industrial users and Indian Reserves. Total emissions were just over 503,000 tonnes of CO_2 (BC Ministry of Environment, 2010).

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 objective in mapping regional energy consumption density is to compare energy consumption density per area unit with renewable energy resource availability (cf. the first report in this series), as well as depict an energy baseline against which future energy planning activities can be evaluated.

Mapping energy consumption density for the CVRD has been divided into two main categories, residential and commercial, and then into further sub-categories that correspond with the Tract and Neighbourhood Data Modelling (TaNDM) project categories currently in development.

This report begins with a presentation of the overall methodology applied, followed by specific chapters detailing data, methods and results for each category. 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

2.1 Overview

Energy consumption was mapped following the general framework as proposed by the Tract and Neighbourhood Data Modelling (TaNDM) project (2011-2012), where building information obtained from BC Assessment is linked to their respective parcels.

In our adaptation of the TanNDM framework, building information was obtained from BC Assessment and served as the basis for classifying the building mass into a number of building archetypes. Thereafter, energy intensity factors for each building type were developed. The next step involved applying energy intensity factors to the individual area of each energy consuming building type to estimate a total per building energy consumption estimate. In a subsequent step, a refinement based on build year was made so that older buildings received a higher energy usage rating than newer buildings of the same type.

The final step involved generating the spatial link with the parcel layer through the JUROL (Jurisdiction Roll & Roll Number) identification key. The resulting output is presented both as total energy usage per parcel, and as energy usage per m^2 (i.e. total energy usage divided by parcel area).

2.2 Residential

This section details the specific steps and requirements for mapping residential sector energy usage.

Data

Input data for mapping residential sector energy usage was sourced from a residential inventory report from BC Assessment, as well as from GIS parcel layers obtained from the CVRD. Moreover, building and energy information from the energy guide database was used as input for estimating energy intensity factors for the building archetypes, along with information from the National Energy Usage Database[3] (NEUD).

Archetypes

The inventory report from BC Assessment classifies the building mass on the basis of 36 different Actual Use Codes (AUC). A cross-walk table relating AUCs

[3] http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/trends_res_bc.cfm

to building archetypes was used to divide the residential buildings into the four building archetypes as defined by the TaNDM project as being of relevance for energy consumption mapping (cf. Table 1:)

Category	Count of ID**	Average of area (m2)
Single detached	22,886	169
Single attached	2,341	129
Apartment	1,491	86
Moveable dwelling	1,290	90
Other residential	699	84
(Seasonal dwelling)*	(628)*	(76)*
Grand Total	**28,707**	**156**

* Sub-category of other residential; ** Excluding folios with no reported area

Table 1: Building archetypes, estimated counts and average area (source: BC Assessment).

Energy intensity

For each residential building type (i.e. Single detached, Single attached, Apartment and Moveable dwelling) energy intensity factors were developed using the CVRD energy guide database (this is a provincial database generated by the eco-energy retrofit program). This database reports among other things: house type, square footage (m^2) and total annual energy consumption (MJ), thus allowing us to calculate the energy intensity ($GJ/m^2/year$) as per housing type. As the database is heavily dominated by single detached housing, the intensity factors as reported in the NEUD were also considered in the evaluation of the final set of energy intensity factors. For example, there were no apartments listed in the energy guide database, and it was therefore important to have the NEUD as reference when assigning an energy intensity factor for this category.

Category	Energy intensity (GJ/m^2)	NEUD (GJ/m^2)	Comment
Single detached	**0.71**	0.61	Derived from CVRD building database
Single attached	**0.60**	0.56	Derived from CVRD building database
Apartment	**0.57**	0.54	Not in CVRD building database, so assumed only
Moveable dwelling	**0.91**	0.89	Derived from CVRD building database
Other residential	**0**	-	-
(Seasonal dwelling)*	**0.21**	-	30% of single detached Energy Intensity

* Sub-category of other residential

Table 2: Energy intensities for the residential building archetypes.

As seen from the table above, the energy intensity factors (bold numbers) are slightly higher than those reported by the NEUD, which can be explained by several factors. Firstly, the CVRD energy guide database includes houses that have applied for retrofits, which indicates this sample of houses represents less efficient houses. Moreover, the average square footage for the single detached houses in the building database is much higher than that of the average for the CVRD as whole (264 m^2 versus 169 m^2). This indicates that it is likely the larger and less efficient houses that generally apply for retrofits (these home owners generally have the means to pay for expensive renovations, and also have a larger total monetary incentive to do so), and as such the sample may not be representative of the CVRD as a whole.

On the other hand, the NEUD estimates energy intensity factors for British Columbia as a whole. It can therefore be expected that the reported numbers are biased towards the City of Vancouver area, and since the CVRD has a slightly colder climate, the energy intensity factors could be expected to be higher.

Moreover, iterative energy consumption modelling was performed with both sets of intensity factors, and both models returned a total energy usage well below the energy use as reported by the 2007 CEEI. It was therefore decided that given these comparisons with CEEI data, the use of the higher intensity factors developed from the CVRD energy building database were justified.

Adjustment for building age

The calculated energy intensity factors represent the average energy intensity across the entire suite of residential units belonging to a certain category. This average measure will, of course, disguise some internal category variation. Year of construction is perhaps the most important determining factor for energy efficiency, and as such the intensity factors were adjusted for building age using the build year information from the CVRD energy building database.

From the database a strong negative linear relationship (r^2=0.98) between build year and total energy usage for single detached buildings is visible in the graph below (cf. Figure 7).

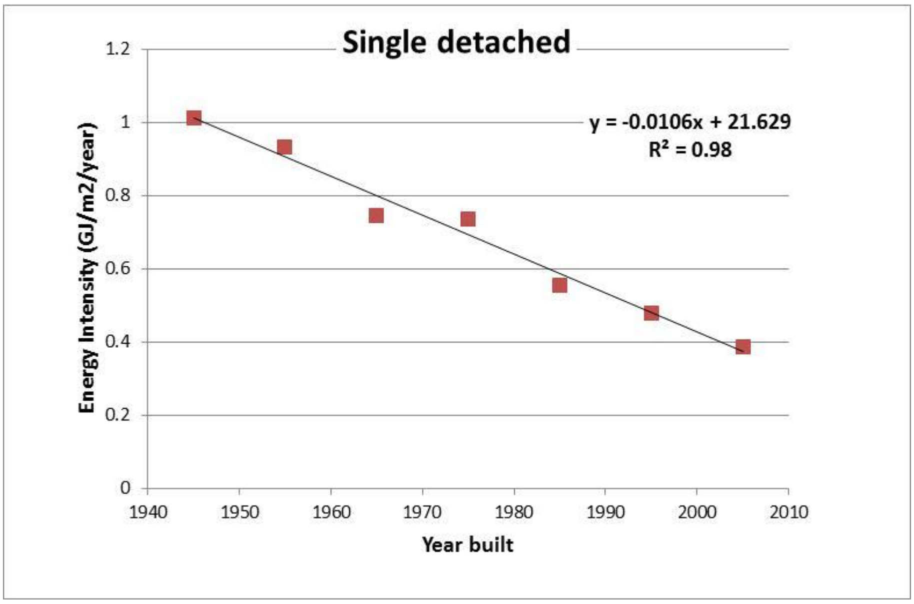

Figure 7: Relationship between energy intensity and build year, the latter being grouped into 10 year intervals (source: CVRD energy guide database).

As a result, the energy intensity for single detached houses was adjusted for building age using the following formula:

$$\mathbf{EI_{adj} = -0.0106*}\boldsymbol{yr.b}\mathbf{ + 21.629}$$

where EI_{adj} is the adjusted energy intensity and *yr.b* is year built. The database only has sufficient numbers to build a robust relationship for single detached houses, but it was expected that this relationship would be equally valid for single attached housing. However, the relationship was not applied to apartments and moveable dwellings, which represent very different building architectures, and in lieu of any better reference information these categories were not adjusted for building age.

Spatial linking

The resulting adjusted energy intensity factors were subsequently used to estimate the total annual building energy usage by multiplying the factor with the reported square footage from BC Assessment.

To map out the energy usage, a link between the tabular calculations and locations on the ground is needed. BC Assessment includes information about jurisdiction and roll number that can be combined into a unique code (JUROL), and used as the spatial link between the table and the parcel map. This also includes information about jurisdiction and roll number for each parcel.

In principle the spatial linkage is thus straightforward, however, matters are complicated by the fact that one parcel may contain several BC Assessment

JUROLS e.g. apartment blocks where each apartment has a JUROL but the block itself resides within just one parcel. The opposite may also happen (albeit rarely) i.e. where one BC Assessment property resides over two or more parcels.

Further complications arose in the mapping exercise, due to the fact that no single and harmonised parcel layer exists for the CVRD as a whole. In fact, five different parcel layers were collected (i.e. the CVRD, Ladysmith, Duncan, Lake Cowichan and North Cowichan), but in four cases the jurisdiction and roll number information was insufficient to develop a robust spatial link via the JUROL code. Therefore, the BC Assessment Fabric was also obtained to act as the spatial unit representative in those areas (i.e. Ladysmith, Duncan, Lake Cowichan and North Cowichan).

In addition, as will be explained in section 2.4, special conditions apply for First Nations lands.

2.3 Commercial/Industrial

This section details the specific steps and requirements for mapping energy usage by the commercial/industrial sector.

Data

Input data for mapping the energy usage by the commercial/industrial sector was an Inventory report from BC Assessment as well as GIS parcel layers for the CVRD. In addition, information from the Commercial and Institutional Building Energy Use Survey (CIBEUS)[4] was used as input for estimating energy intensity factors for sector archetypes. Lastly, location data on commercial and industrial addresses and associated lots was obtained for First Nations areas.

Archetypes

The inventory report from BC Assessment classifies the commercial/industrial building mass on the basis of approximately 170 different Actual Use Codes (AUCs). A cross-walk table relating AUCs to building archetypes was used to divide the residential buildings into twelve building archetypes, which are defined by the TaNDM project as being of relevance for energy consumption mapping (Table 3).

[4] http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/data_e/cibeus/tables/cibeus_10_2_4.cfm

Energy Intensity

Each Commercial/Industrial building archetype was compared with the categories given in the CIBEUS database. The energy intensity factors from the latter were transferred to the building archetypes on a best fit basis (cf. Table 4).

Category	Count of ID	Average area (m2)
Accommodation	464	933
Arts entertainment and recreation	137	387
Education	114	415
Healthcare	53	232
Information and cultural	66	426
Light industrial	29	515
Mixed use	138	253
Office	153	503
Other commercial/institutional	45	398
Restaurant/Pub	58	343
Retail	318	667
Warehouse	236	813
Grand Total	**1,860**	**624**

Table 3: Commercial/Industrial building archetypes, estimated counts and average area (source: BC Assessment).

Category	Energy intensity (GJ/m2)	CIBEUS*
Accommodation	1.72	Commercial and Institutional acc.
Arts entertainment and recreation	1.97	Entertainment and recreation
Education	0.65	Education
Healthcare	2.96	Health care
Information and cultural	0.8	Public assembly
Light industrial	2.00	NA
Mixed use	1.50	NA
Office	1.36	Office
Other commercial/institutional	0.80	Public assembly
Restaurant/Pub	3.36	Food service
Retail	2.58	Food and non-food retails
Warehouse	0.87	Warehouse/wholesale

Table 4: Energy intensity factors for the commercial/industrial sector.

Adjustment for building age

The calculated energy intensity factors represent the average energy intensity across the entire suite of units belonging to a certain category. This average measure will of course disguise some variation within the category. Construction standards, techniques, materials and types vary considerably from one decade to the next, but in all cases they exert a direct impact on energy usage. The CIBEUS data clearly illustrates that the buildings with the lowest energy efficiency are those constructed prior to 1980. Overall the energy intensity of these buildings is 20% higher than those constructed from the 1980s and onward (NRCAN 2001).

This information was used to adjust the intensity factors so that pre-1980 buildings had an intensity factor that was 10% higher than the average value, while post-1980 buildings were given an intensity factor of 10% less than the average value.

Spatial linking

The estimation and mapping of total building energy usage was similar to what was done with the residential sector (cf. description provided above). As for the First Nations lands, details are given below.

2.4 Mapping First Nation's Energy Usage

BC Assessment does not include properties on First Nations land, and as such a different approach for mapping energy usage had to be applied. Input data for mapping the energy usage within First Nations land consisted of map layers of addresses and lots, as well as reference information from the Commissioned Energy Emission Plan (CEEP) as reported in the Cowichan Tribes Energy Action Plan (CEA 2011).

All addresses were coded according to general use (i.e. *residential*, *commercial*, *institutional*, *industrial*, *removed* and *not in use*). The general use classes are similar to those used in the BC Assessment model and as such the model for First Nation energy usage was based on the average building areas and intensity factors (with some modifications) from the BC Assessment model (cf. Table 5:).

General use classes	Count	Average building area*	Energy Intensity (GJ/m2)**	Total Energy usage (GJ)
Residential	547	90	0.91	44,799
Commercial	55	450	2	49,500
Institutional	32	450	2	28,800
Industrial	2	500	2	2,000
Total non-residential	***89***	-	-	***80,300***
Not in use	57	0	0	0
Removed	15	0	0	0

* Average of CVRD; ** Commercial/Industrial intensity factors are slightly higher than CVRD assuming buildings are generally older and less efficient.

Table 5: Input data and general assumptions for the modelling of energy usage of the First Nation building stock.

The Cowichan Tribe's CEEP reports a total energy usage for the residential sector of 45,000 GJ, while the corresponding number for the commercial/institutional/industrial sector is 85,000 GJ. Comparison to the energy intensity model shows a high level of correlation and performance.

3 Results

The energy consumption density mapping is presented in 42 separate maps, both as energy usage per parcel, and as energy usage per m^2. An index of these maps is presented below in Figure 8. For the region as a whole, the residential energy consumption density is extremely low. Areas such as municipalities do, however, have segments with consumption densities high enough to warrant, for example, district heating consideration. Consumption density is an important factor that would help to determine the feasibility of a potential renewable energy (RE) option.

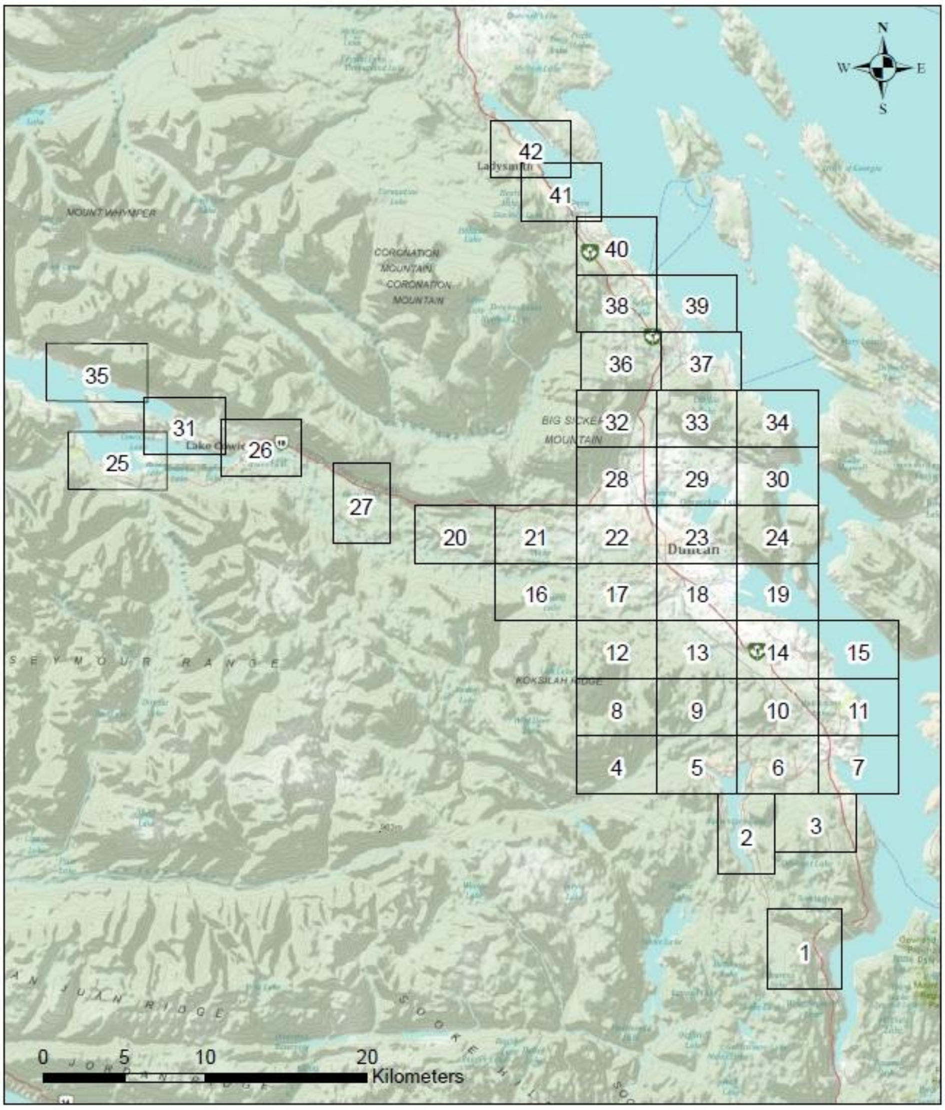

Figure 8: Index over 42 energy consumption density maps

Energy usage per m²

Using the previous methodology to determine average energy intensity by building type, energy maps can be produced which provide strategic and analytical infrastructure for policy and capital program development. It is important to note that the actual energy use is not mapped due to data limitations and privacy concerns.

A map corresponding to map 23 and a portion of 29, and covering much of Duncan, is displayed below in Figure 9.

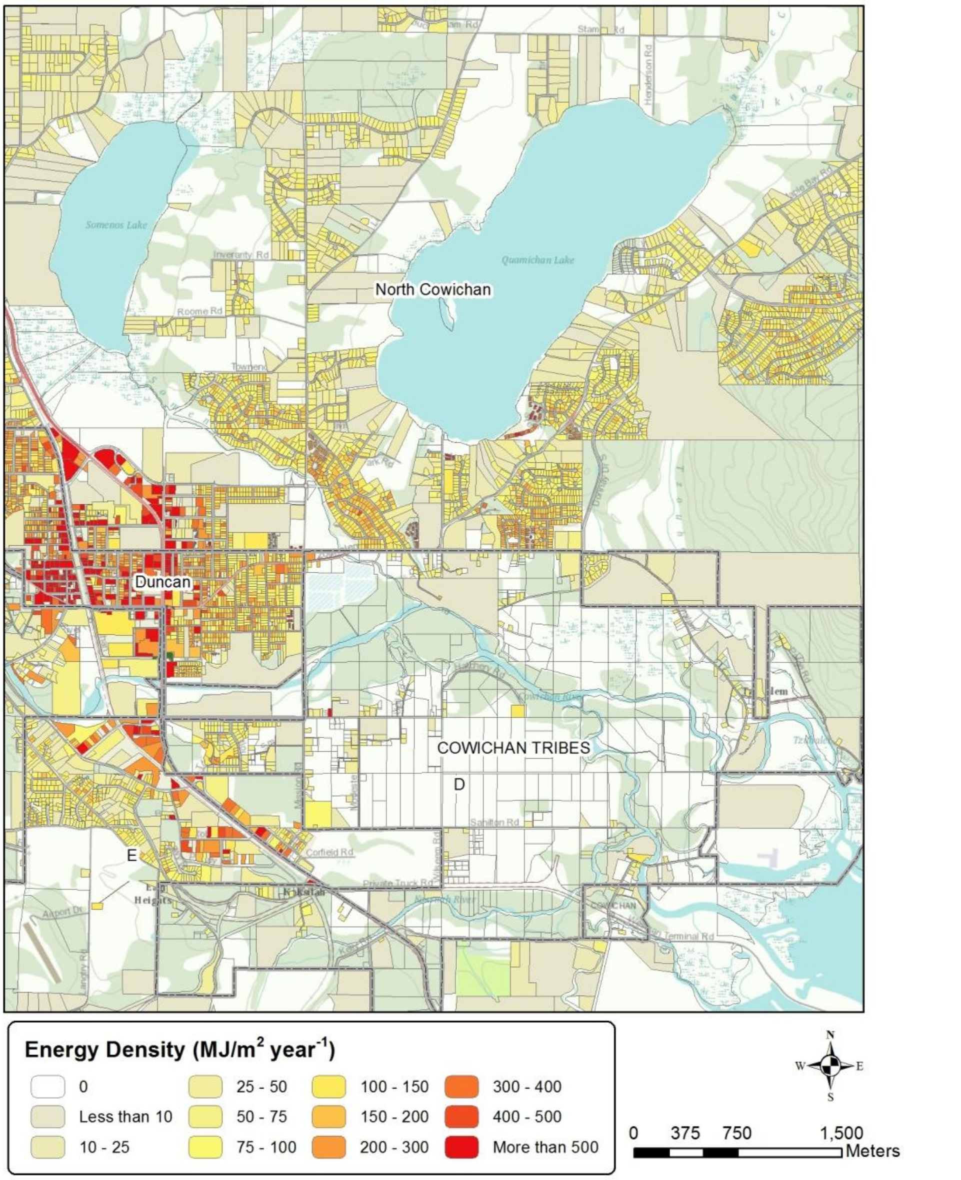

Figure 9: Residential energy consumption density for a portion of the Duncan area (MJ/m^e per year).

Figure 9 clearly highlights how the City of Duncan has the highest energy consumption density, which can be mainly attributed to the higher density of commercial and industrial properties. However, it is possible to find areas in residential areas with energy consumption densities considerably higher than the CVRD average. The map on the following page zooms in further on one of these central areas just south of Quamichan Lake.

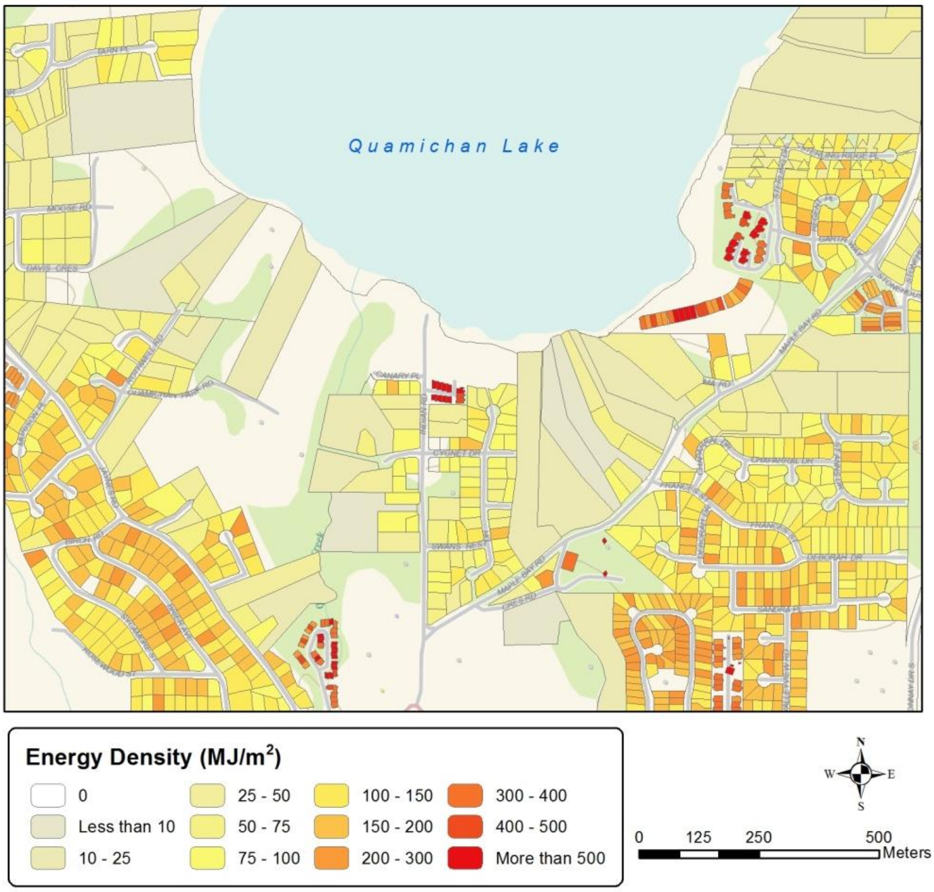

Figure 10: Annual residential energy consumption in MJ/m^2 for an area south of Quamichan Lake.

The above figure reveals the fact that there are a number of residential areas with energy densities greater than 200 MJ/m^2 per year, and some pockets with densities greater than 500 MJ/m^2 per year.

Energy usage per parcel

An alternative approach to mapping the consumption density is to map according to energy consumption per parcel. As parcel size varies greatly this gives a different picture altogether. A map for the same area as that in Figure 10, this time depicting energy usage according to parcel size, is displayed below. This approach is particularly useful in integrating into Official

Community Plan (OCP) development and updates as it allows for a zoning based analysis.

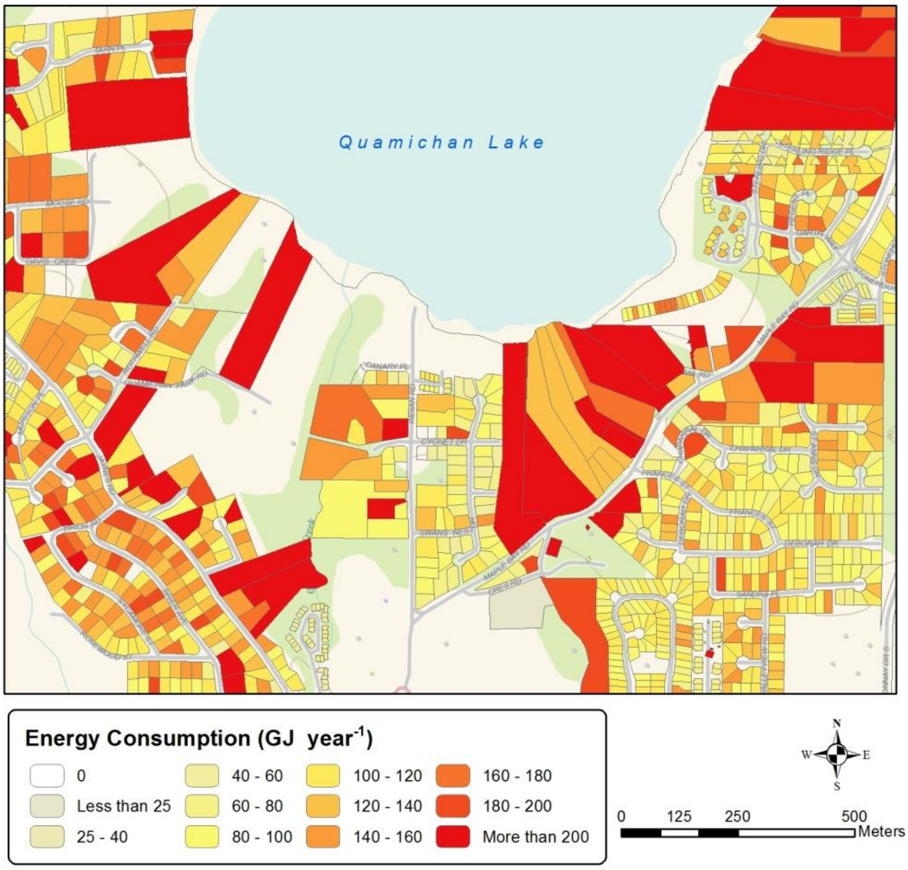

Figure 11: Annual residential energy consumption in GJ/parcel for an area south of Quamichan Lake.

When comparing Figure 10 and Figure 11 it is important to note that the energy consumption in the first figure is in MJ/m^2, while in the second is in GJ per parcel, and 1 GJ = 1,000 MJ.

4 Corroboration of energy use figures

In order to provide some credibility to the energy maps, the final energy usage output is summarised for each community and compared with the numbers provided by the 2007 Community Energy and Emissions Inventory (CEEI) (cf. Table 6, Table 7, and Table 8).

Admin area	CEEI 2007 (GJ)	Model (GJ)	Deviation
CVRD (unincorporated areas)	1,973,132	1,724,661	-12.6%
North Cowichan	1,578,689	1,496,246	-5.2%
Duncan	382,109	388,048	1.6%
Ladysmith	532,714	429,004	-19.5%
Lake Cowichan	182,295	192,138	5.4%
Building Total	**4,648,939**	**4,230,098**	**-9.0%**

Table 6: Modelled total building energy usage compared with building totals as stated in the 2007 CEEI.

Admin area	CEEI 2007 (GJ)	Model (GJ)	Deviation
CVRD (unincorporated areas)	1,482,735	1,257,979	-15.2%
North Cowichan	1,085,664	1,071,138	-1.3%
Duncan	198,700	166,982	-16.0%
Ladysmith	380,598	319,869	-16.0%
Lake Cowichan	145,860	132,409	-9.2%
Residential Total	**3,293,557**	**2,948,377**	**-10.5%**

Table 7: The residential model outcome compared with actual residential energy use as stated in the 2007 CEEI.

Admin area	CEEI 2007 (GJ)	Model (GJ)	Deviation
CVRD (unincorporated areas)	490,397	466,682	-4.8%
North Cowichan	493,025	425,109	-13.8%
Duncan	183,409	221,067	20.5%
Ladysmith	152,116	109,135	-28.3%
Lake Cowichan	36,435	59,729	63.9%
Commercial/industrial Total	**1,355,382**	**1,281,721**	**-5.4%**

Table 8: The commercial/industrial model outcome compared with actual commercial/industrial energy use as stated in the 2007 CEEI.

The difference between the modelled total energy usage of buildings in the CVRD versus the actual energy usage is less than 10% (cf. Table 6). This is deemed quiet reasonable considering the assumptions and number of variables included in the modelling work. Nevertheless this rather close *overall* fit between modelled and measured energy usage masks some rather large individual area differences, ranging from a near perfect match between values for the city of Duncan, to an almost 20% difference for Ladysmith (cf. Table 6).

These area differences can be further scrutinised via a sectorial break down. For example, as shown in Table 7, the residential sector model returns an almost perfect fit for North Cowichan, but underestimates residential energy usage by about 15% in Duncan, Ladysmith and the unincorporated areas. The fact that the residential model consistently underestimates (i.e. across multiple administrative areas) indicates that model shortcomings could be addressed with some general modifications, for example changing the intensity factors, which the CVRD may choose to do the in the future.

This is in contrast to the commercial/industrial sector where the close match between actual and modelled overall energy usage actually appears to be the result of some significant underestimations in energy usage (North Cowichan and Ladysmith), and overestimations in Duncan and Lake Cowichan (cf. Table 8)[5]. A 64% overestimation in case of the latter is a cause for concern, but since total commercial/industrial energy usage in Lake Cowichan is limited relative to the CVRD as a whole it has little impact on total model performance. A physical review of the energy maps by staff at the City of Duncan and Town of Lake Cowichan may identify some parcel based issues or model archetypes. Edits and updates to the base fabric or archetypes can easily be accomplished after review.

Since each business is quite unique in terms of energy usage, and the building archetypes represent rather broad groupings, it is clear why the commercial/industrial model is not as consistent as the residential model. However, it does imply some difficulties in terms of improving the commercial/industrial model since it may not be as simple as changing the intensity factors. On the other hand, the sector is not overwhelmingly large for the CVRD so it would be plausible for the local administration to manually review and tune the model on a business by business level.

[5] The words 'underestimations' and 'overestimations' are used in reference to the CEEI data. Whether it is in fact the CEEI data that is under/over estimated is also a possibility.

5 Conclusion

The energy consumption mapping as presented in this report represents a highly qualified depiction of the spatial variation in energy usage across the CVRD. However, the maps should not be regarded as being static and there is certainly a scope for improvement as data sources are expanded or become available.

1. Firstly, it should be stressed that the energy intensity factors are changeable variables. Currently, the energy intensity factors are developed using the most objective measures as possible, and then compared to the CEEI. A different approach could be to calibrate the model against the CEEI and in which case the resulting intensity factors would be those that provide the closest fit to the CEEI. However, this is problematic if the CEEI data is inaccurate relative to the regional boundaries or administrative units. It also highly possible that individuals with local expertise (planners, building inspectors, local BCCA analysts, etc.) could improve the model inputs and parameters, thus representing a third way to fine tune the energy intensity factors.
2. Even if energy intensity factors are changed/improved it will not hide the fact that these factors represent a mixed stock of buildings, and this is particularly the case for the commercial/ industrial sector. Therefore, local experts are advised to carefully review data from BC Assessment regarding estimated energy usage to identify and change obvious anomalies.
3. As for North Cowichan, Duncan, Ladysmith and Lake Cowichan, local GIS managers may also be able to develop spatial linkages between the BCAA model and the official parcel layers, thus replacing the BC Assessment fabric as the spatial unit.
4. Mapping could be more easily done if a harmonised parcel layer for the CVRD was developed, from where clear indications of jurisdiction and roll number can be developed. In addition, local government could collect data to update the CVRD energy database consistently and across a more statistically meaningful cross section of the housing stock.

In the next report the findings from this and the previous report will be used to perform an analysis of potentially applicable distributed energy opportunities. In practice this will be achieved by analysing the supply side relative to the demand side as portrayed in this report.

6 References

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7 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	