Ea Energy Analyses

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FINAL REPORT

Cowichan Valley Energy Mapping and Modelling

REPORT 4 – ANALYSIS OF OPPORTUNITY COSTS AND ISSUES RELATED TO REGIONAL ENERGY RESILIENCE

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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
RDF – Refuse derived fuel
RDN - Regional District of Nanaimo
RE – Renewable energy
RMSA – Root mean square area
SSE – (NASA's) Surface meteorology and Solar Energy (dataset)
TaNDM – Tract and neighbourhood data modelling

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1 Introduction

Overall project

The following report is the fourth 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 Resources 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 Assessment as well as the on-going TaNDM project. 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

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

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

The results of task 4 are documented in the present report.

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.

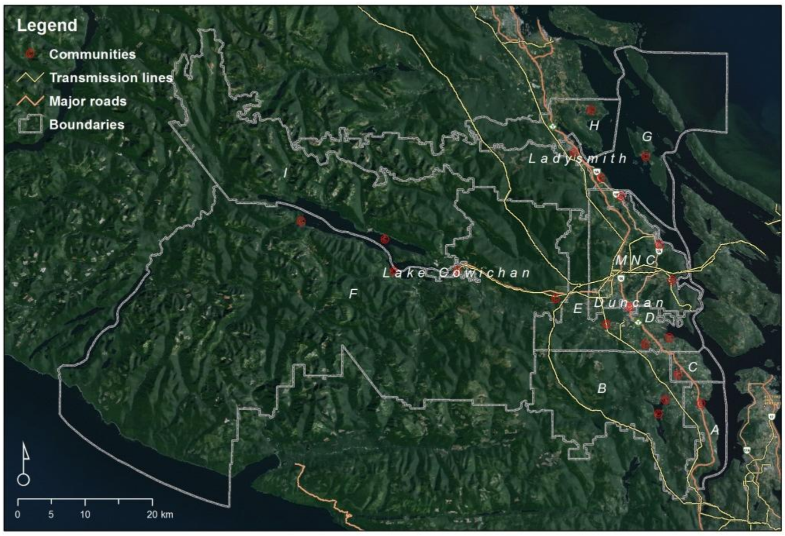

Figure 1: Map of the Cowichan Valley Regional District and its administrative areas (GRAS).

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.

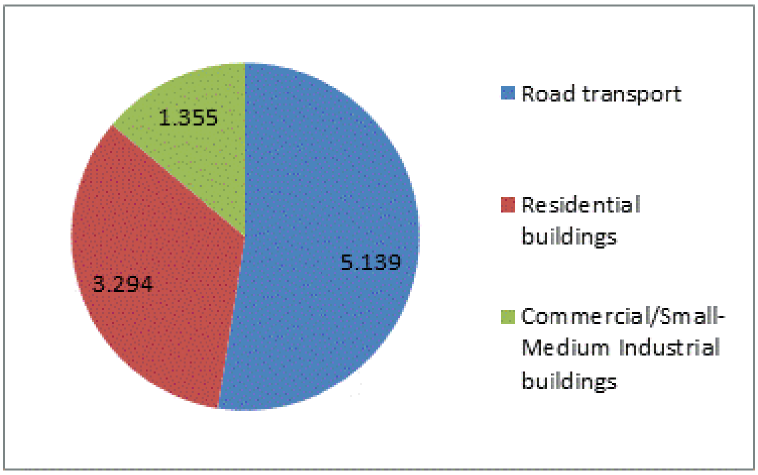

Figure 2: 2007 CVRD total energy consumption by sector (TJ) excluding large industrial users and Indian Reserves (BC Ministry of Environment, 2010).

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.

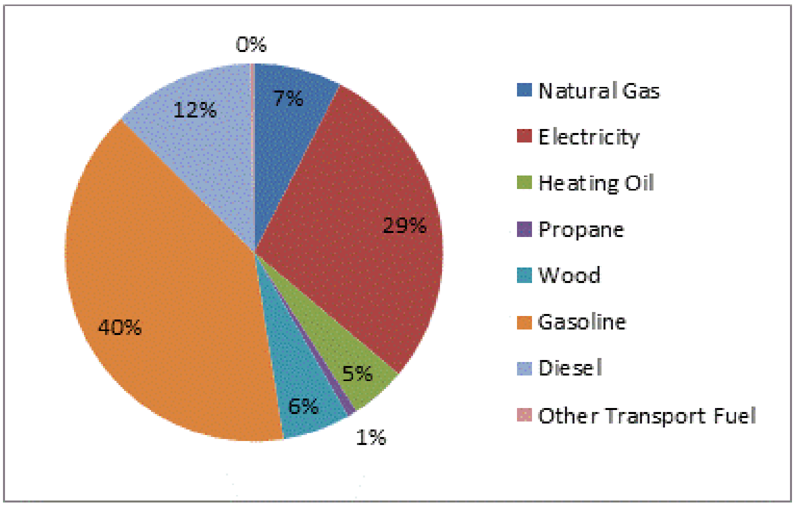

Figure 3: 2007 CVRD total energy consumption by source (TJ) excluding large industrial users and Indian Reserves (BC Ministry of Environment, 2010).

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.

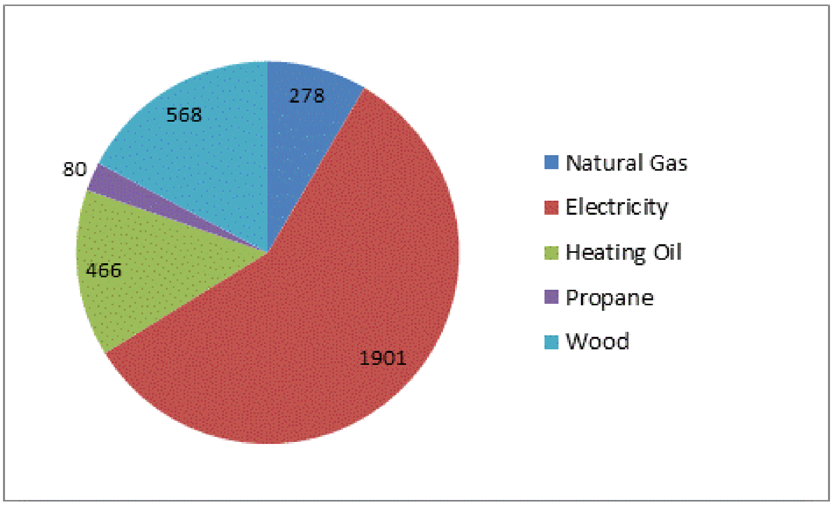

Figure 4: 2007 CVRD residential sector energy use (TJ) (BC Ministry of Environment, 2010).

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.

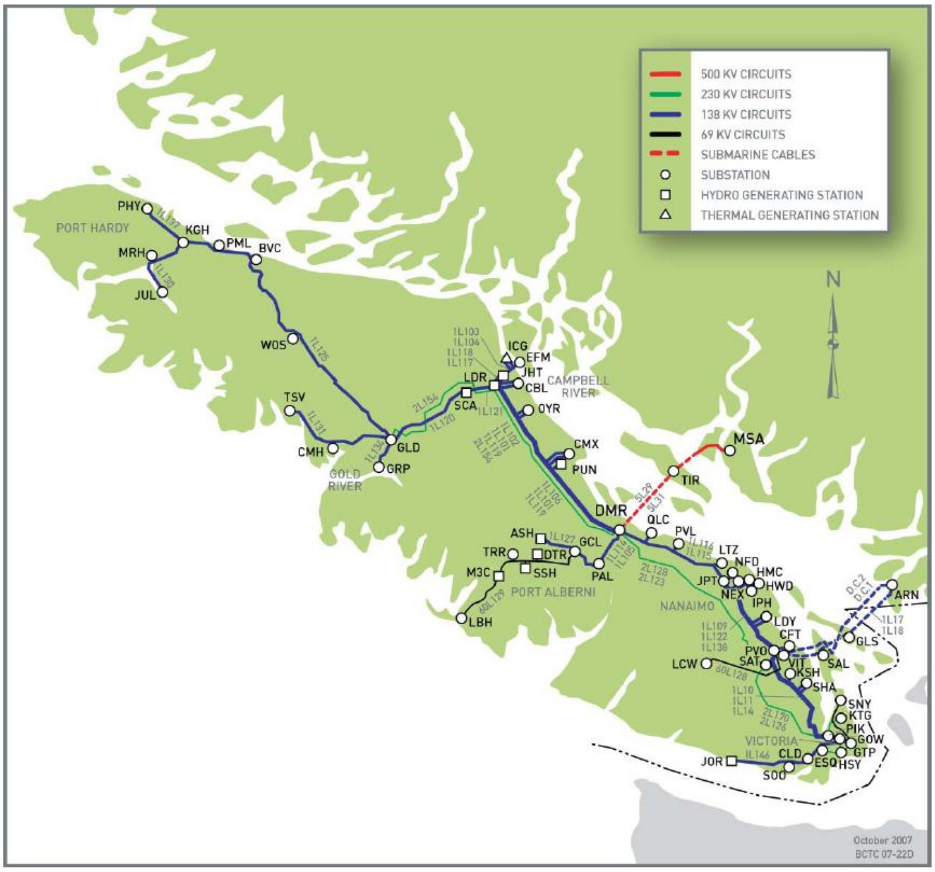

Figure 5: Vancouver Island Transmission network as of October 2007 (BC Hydro, 2007).

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.

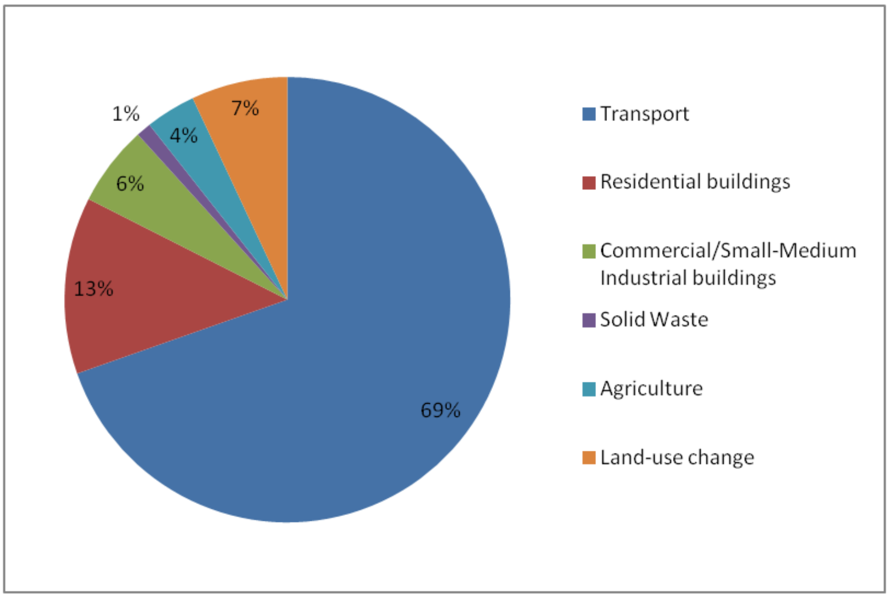

Figure 6: 2007 CVRD GHG emissions according to source excluding large industrial users and Indian Reserves. Total emissions were just over 503,000 tonnes of CO_2 equivalent (BC Ministry of Environment, 2010)

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 report starts with a brief discussion of energy resiliency from a CVRD perspective. This is followed by a description of the paths to achieve an increase in resiliency, as well as a brief description of the energy model that is used to generate the scenarios. The common assumptions for the scenarios are then presented before each of the four scenarios and their results are described. A sensitivity analysis on the most relevant elements is undertaken, followed by conclusions and recommendations.

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 Energy resilience

The term energy resiliency can encompass many aspects. For the CVRD in the context of this study it refers to:

1. Security of supply – The ability of the island and region to cope with extreme events or emergencies such as disruption of an electricity cable to the mainland. In this respect energy resiliency could be defined as the community's energy production capacity when in "island mode": the electricity production and heating capacity on the island and/or in the CVRD.

2. Robustness – The ability to guard against price shocks, general increases in fuel prices, and/or to provide climate benefits (locally or on a larger scale). In this case the focus would be on reducing the import of oil, natural gas, and electricity to the CVRD, and the subsequent reduction of energy costs to the community.[3]

These two perspectives are by no means mutually exclusive, but in discussing security of supply it makes more sense to consider Vancouver Island as a whole. Whereas with robustness, it is possible to focus more specifically on the CVRD while keeping in mind that many projects would benefit from inter-regional cooperation.

Resiliency targets

In consultation with the CVRD it was determined that the 2050 'resiliency' target within the residential sector should focus on addressing energy imports, as well as security of supply. As such the 2050 resiliency target includes:

- Phase out of fossil fuels for primary heating in the residential sector (oil, natural gas, and propane).
- Meet 75% of residential energy demand with local renewable energy (RE) sources.[4]

There are two ways to achieve these long-term targets, namely energy conservation and increased production of local renewable energy. As illustrated below, these can serve as stand-alone or combined strategies for improving resilience.

[3] It should be noted that the risk of price shocks also vary by fuel, and as such it could be appropriate to pinpoint particular fuels where energy resiliency is more relevant. For example, electricity generated from hydro is not susceptible to price shocks, while oil prices can be quite volatile. Future natural gas price variation is perhaps the most difficult to say something concrete about as it will largely depend on whether or not large scale development of shale gas takes places in North America.
[4] In calculating this figure, all RE produced electricity within the CVRD from non-industry is counted as being utilised by the residential sector, and firewood for non-primary heating is not counted.

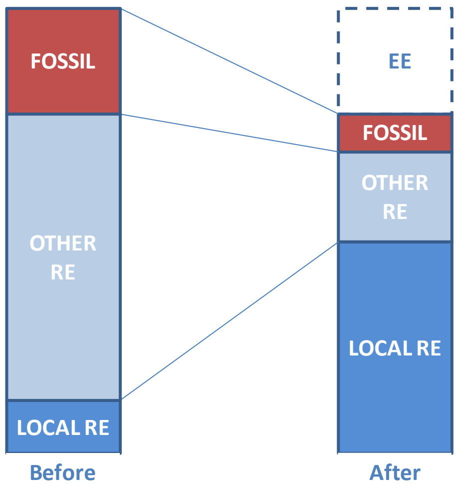

Figure 7: Illustration of how reducing energy use from fossil fuel based sources, and/or via increasing local RE production can increase resiliency, i.e. the ratio of local RE production relative to total demand.

Energy conservation

With respect to energy conservation, it is worth noting that roughly 60% of residential units in the CVRD today are heated via electric baseboard heating. While electricity has traditionally been a cheap and abundant resource in British Columbia, from an energy standpoint, baseboard heating is an inefficient use of a high value product. A conversion of these baseboard units to, for example, heat pumps would reduce the electricity consumption of these customers from somewhere between a half to a third of their current demand. Meanwhile, because roughly 2/3 of the heating provided from the heat pump comes from the local environment, this would at the same time increase the share of locally produced RE. This dual benefit is an example of the interplay between conservation and increased local RE production, as converting to a more efficient heat delivery system would also reduce the amount of investment in local electricity production in order for the CVRD to meet its long-term energy resilience targets.

Local RE production

With regards to local RE production, three available options include:

1. Building integrated renewable energy production (i.e. heat pumps, wood pellet stoves, solar PV, etc.)
2. Stand-alone renewable energy production (i.e. wind or hydro)
3. Renewable resource-based district heating (i.e. wood chips).

The technical aspects of each of these categories are described in greater detail in report 3 ‘Analysis of Potentially Applicable Distributed Energy Opportunities’, where the assumptions underlying current and future cost factors are also detailed.

Modelled options

An overview of the options built into the technology cost model and the energy scenario model is presented in the table below.

Options	Reduced consumption	Building integrated RE	Stand-alone RE	RE based DH
Improved building codes	X			
Renovations per year	X			
EE improvement via renovation	X			
EE in auxiliary energy usage*	X			
Geo-exchange heat pumps		X		
Air-to-air heat pumps		X		
Solar water heating		X		
Wood pellets		X		
Photovoltaics		X		
Onshore wind			X	
Offshore wind			X	
Mini hydro			X	
DH – Wood chips				X
DH – Wood chips, CHP			X	X
DH – MSW, CHP			X	X

Table 1: Analysed RE technologies to increase energy resilience. DH = district heating. CHP = combined heat and power

**Auxiliary energy usage includes electricity for appliances, lighting, electronics, etc., as well as propane and firewood for non-primary heating.*

3 Energy scenario analysis

The vast majority of the CVRD's energy needs is met by resources imported from outside the region. By mapping the potential RE resources within the CVRD it becomes apparent that there are significant potential RE resources to be found locally.

With technological data, fuel prices, efficiency measures, as well as forecasted energy demand and growth development as additional inputs, this information helps to identify which resources are economically and politically feasible now , and what the tipping point may be in the future. Each factor serves as an input into the development of scenarios, as depicted in the figure below.

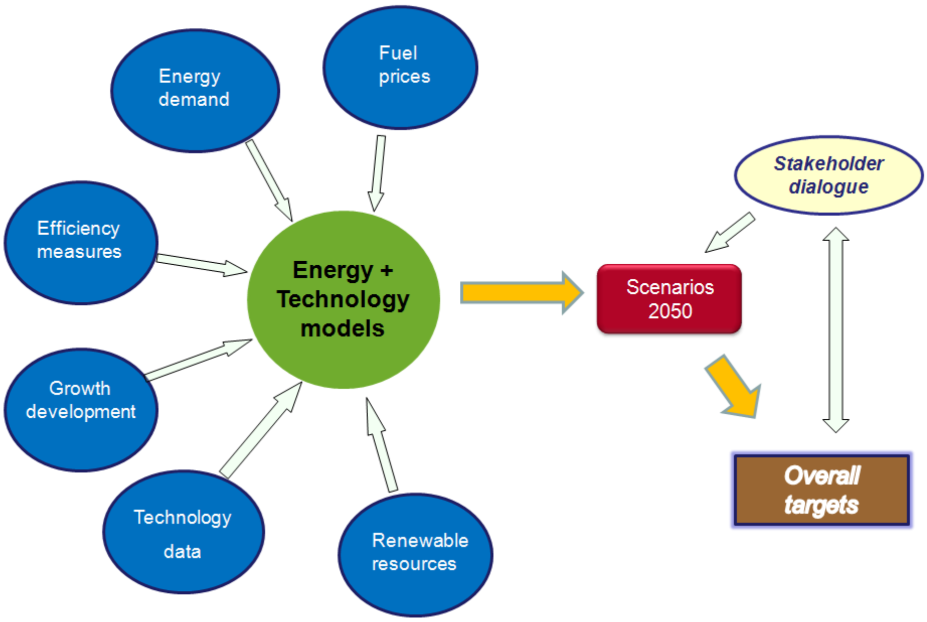

Figure 8: Scenario development

What are scenarios?

Scenarios are stories about how the future might unfold and as such are not predictions or forecasts. They are provocative and plausible accounts of how external forces can give rise to challenges and opportunities, including those related to policy development, scientific and technological development, social dynamics, and economic conditions.

Why energy scenarios?

Energy scenarios provide an overview and help to identify opportunities, threats and points of action. They usually include 'elements' that can be influenced and 'elements' that cannot be influenced. Scenarios assist in dealing with uncertainty by looking at a range of possibilities that allows deciding on a strategic direction in the face of present and future possibilities and uncertainties.

An additional benefit of scenario analysis is that it can be a means to involving stakeholders in long-term decision-making and help them reach a common point of reference. As such, stakeholder consultation is often an integral part of the scenario analysis work process. The dialogue established during the consultation process is often educational for all parties, including the scenario analysts, and often results in the identification of potential win/win situations for all stakeholders. This dialogue can also assist with the next steps in policy-making and create anchoring in the constituency (either public or political).

Different kinds of scenarios can be outlined, including:

- Predictive – what future seems most likely given the continuation of current trends?
- Explorative – what futures are possible and how do we prepare for sets of equally plausible futures?
- Anticipative – what future is preferable and how can we get there?

Anticipative scenarios

This project is focused on anticipative scenarios, as these help to highlight the different ways one can achieve a target. Such scenarios can, for example, help to determine whether achieving resiliency via a large-scale centralised approach is preferable to a small-scale decentralised approach, or vice versa. Through dialogue with relevant stakeholders, one can identify which pathways are economically, technically, and politically feasible, and those which are not feasible at this point in time. Anticipative scenarios are very useful tools for planners and politicians alike, as they may help to answer questions such as 'If we want to get here, what is the likely cost?' These scenarios therefore give politicians a better basis upon which to make their decisions as well as present their rationale for doing so.

It is worth noting that a high level of data detail and accuracy does not always provide additional value in scenario analysis. The main goal is to provide a reasonably accurate impression of the consequences for a set of alternatives and uncertainties. Great complexity in the development of a scenario (for example by attempting to include every single potential input, regardless of how significant the individual input may be for the overall result) may shift the focus to technical details rather than the broader perspectives.

Within the project, a series of training workshops and briefings where provided to each of the local governments within the CVRD on the use of the models as well as scenario development. For the purposes of this study a number of scenarios where chosen to illustrate various future pathways and impacts.

4 Modelled scenarios

Based on consultations with the CVRD, four different scenarios were developed and are detailed below. While the models used to explore the scenarios also include inputs for the commercial/industrial and transport sectors, the focus of the scenarios is on the residential sector.

Business-as-usual (BAU) – This scenario depicts a situation where current and anticipated trends, strategies, and policies take shape in the form of certain levels of energy efficiency, building codes, etc. It assumes that the primary heating source for residential dwelling remains unchanged relative to 2010.[5] This scenario provides:

- A picture of what the future may look like given current and anticipated growth trends, strategies, and policies.
- A point of reference for comparison with alternative scenarios.

Increased energy efficiency (EE) – This scenario could be referred to as a 'savings scenario' as it addresses questions such as:

- What cost savings can be achieved through increased energy efficiency alone?
- What fuel and CO_2 reductions can be achieved through energy efficiency improvements alone?

As the model does not have a direct cost for efficiency improvement measures and, like the BAU, assumes that the primary heating sources for residential dwellings will remain unchanged relative to 2010, this scenario will provide a cost savings figure that can then be used to determine whether the savings are enough to warrant the required investment in energy efficiency.

Increased local renewable energy production (RE) – This scenario assumes a business-as-usual development in energy efficiency, along with increased local energy production from renewables. To meet the CVRD's targets, technology options are primarily selected according to the lowest cost available, as laid out in the technology cost model. Technology selections are however not based solely on cost alone, as they are also tempered with assumptions regarding the feasibility of all units converting to a certain technology (i.e. not all residencies will be willing and/or able to implement a technology), resource availability, etc.

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[5] This is in reality likely an overly conservative assumption as even under a BAU scenario it could be expected that dwellings change primary heating source, for example from oil furnaces to cheaper alternatives.

Increased energy efficiency plus increased local renewable energy production (EE+RE) – A combination scenario where increased energy efficiency is equal to that of the EE scenario and then "topped up" by increased local renewable energy production, to the point where the overall resilience targets are met. As was the case with the RE scenario, the EE+RE scenario relies primarily on the lowest cost technologies from the technology cost model to meet the targets. However, these are not necessarily the same as those selected in the abovementioned RE scenario, as the energy savings through increased efficiency affects the relative cost of the various energy production technologies. This scenario thus allows for a comparison with the RE scenario to see:

- How much less local RE production is needed if energy efficiency improvements are also undertaken?
- Which technologies become more/less cost-effective when there is greater energy efficiency?

Additional targets

In addition to the overarching energy resiliency goals, the CVRD also set additional sub-targets:

- 95% renewable energy use by the residential sector by 2030[6].
- 75% reduction in residential GHGs in 2030 relative to 2010.
- A new home in 2030 is twice as efficient as a new home in 2010.

Developed models

The energy model used for the scenario analysis uses a bottom-up approach to model energy demand and gross energy consumption. Supply technologies that are available are described in the separate technology cost model, which serves as a catalogue of different technology options, and can be updated easily over time. A separate manual describes the models in greater detail.

The dwelling types, primary heating technologies, and energy sources included in the technology cost model and the energy model are shown in the figure below. The choice of energy resource in a given scenario is determined by the primary heating technology used in dwellings and the cost and availability of the energy resources required for the heating technology to operate.

[6] There may still be some secondary and luxury fossil fuel use, for example propane, natural gas, etc. for hot water heating, fireplaces, barbeques, etc.

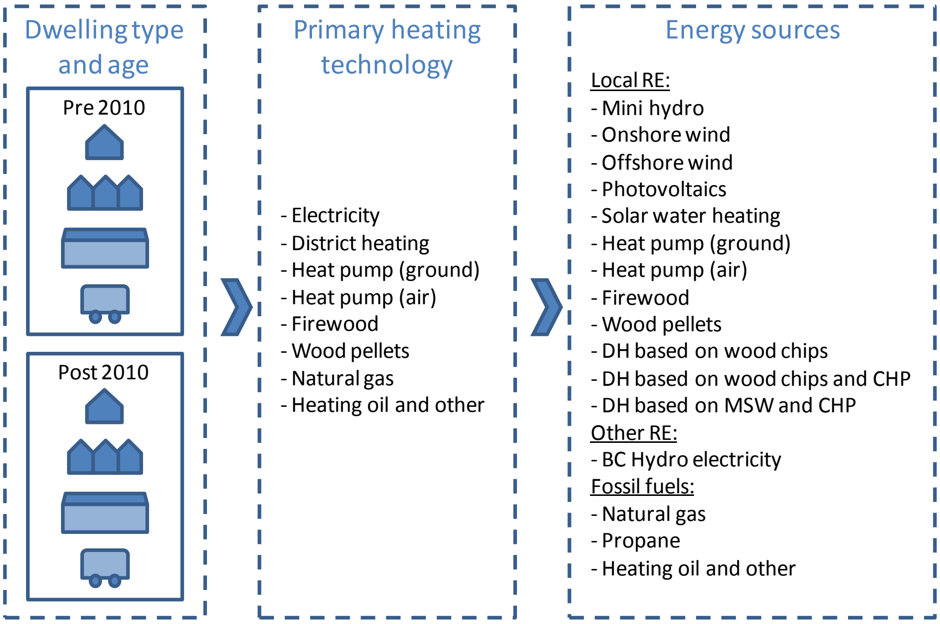

Figure 9: Illustration of the dwelling types, primary heating technologies, and energy sources included in the technology cost model and the energy model. DH = district heating. CHP = combined heat and power.

Future residential energy demand is modelled using simple energy efficiency multipliers that are based on building typologies (assumed equal over the CVRD) and the building's heating source. These multipliers can easily be altered to reflect different goals for energy efficiency amongst existing building stock (pre-2010) and/or new buildings (post-2010). This is illustrated in Figure 10.

Figure 10: Illustration of the driving elements of the modelled energy consumption.

Scenario assumptions

Efficient use of local resources

The scenario approach is built around the assumption that the CVRD wishes to promote efficient use of resources, and thereby CHP where cost-effective.

Residential unit type

CVRD residential units are divided into four categories and correspond with the local British Columbia Assessment Authority (BCAA):

- Single family detached
- Single family attached (row houses for example)
- Apartment
- Moveable dwelling

Number of units

The number of units for each building category in each of the 14 administrative areas has also been derived from data taken from the BCAA. This data shows that overall 82% of units within the CVRD are currently single detached, 7% are single attached and apartments and moveable dwellings constitute 5% and 6%, respectively. However, each administrative area has a unique combination based on its residential and urban mix as well as its development history and other variables.

Future projections for the number of residential units for each building type were calculated using population growth figures for the respective administrative areas, and by maintaining the current share by building type listed above. These variables can easily be modified by local government staff to keep the models updated and/or explore various planning and policy alternatives.

Size of residential unit and energy demand

The size of future residential units is not explicitly forecasted, but is instead incorporated into future end-use factors, which indicate how much energy a future residential dwelling will use relative to one in 2010. These factors incorporate expected BAU efficiency improvements that result in less energy use per dwelling, but also factor in anticipated growth in dwelling size and consequently, increased energy use. Based on overall BC trends for the past 10 years, an annual BAU decrease in energy use of 0.8% was applied to the scenarios. [7]

Residential heating type

Each residential unit has been classified according to its primary heat source[8]:

Primary heat source classifications	
• Electricity	• Heat pump (air)
• Natural gas	• Heat pump (ground)
• Heating oil and other	• Firewood (stove)
• Wood pellets	• District heating

Table 2: Primary heat source classifications used.

Current BCAA reporting does not include heating type, and as such the number of units in each heat source category was estimated based on feedback from local building inspectors, by administrative area. The estimated dispersion between heating types for 2010 is displayed in Figure 11 below.

[7] From 2000 to 2009 the energy use in GJ/m^2 for all BC residences on average decreased by 2% per year, while the size of the average residence increased by 1.2% per year over the same period, thus a net reduction of roughly 0.8 % per year in terms of total energy used.

[8] Each residential unit was assigned a primary heating source for the sake of simplicity. However, in practice many residential units have more than one type of heating source. This can be reflected in the modelling by altering the allocation between heating types.

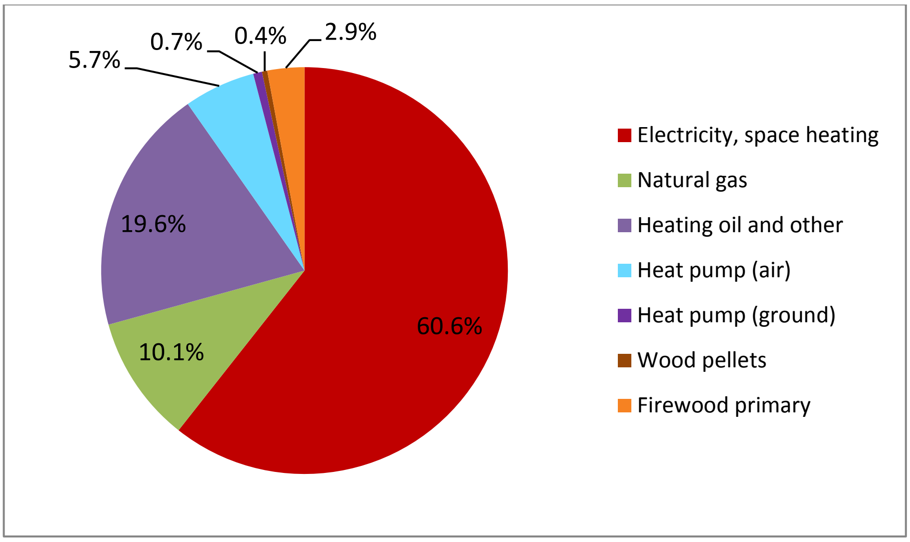

Figure 11: Current dispersion of primary heating types in residential units according to local estimates.

Fuel costs

Anticipated fuel costs for each heat source, for the analysed 40-year period are displayed below in Figure 12. Costs include CO_2 tax, delivery, and flat fees, but do not include HST.[9]

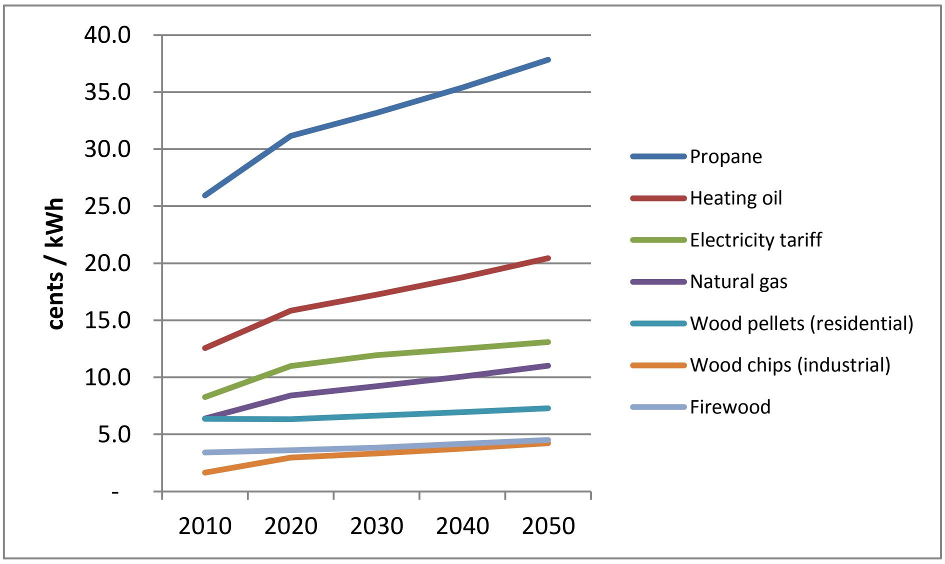

Figure 12: Fuel costs utilised in scenarios including CO_2 tax, delivery, and flat fees, excluding HST.

Energy supply costs

Anticipated heat and electricity supply costs are based on the technology cost model described in Report 3. The figures below give an overview of the cost inputs produced through the model and used in the scenarios.

[9] Assumptions and sources for the various costs can be found in the general assumptions worksheet of the technology cost model.

As an example, Figure 13 below illustrates the cost of energy supplied via each heating option on a per kWh basis in the BAU scenario.

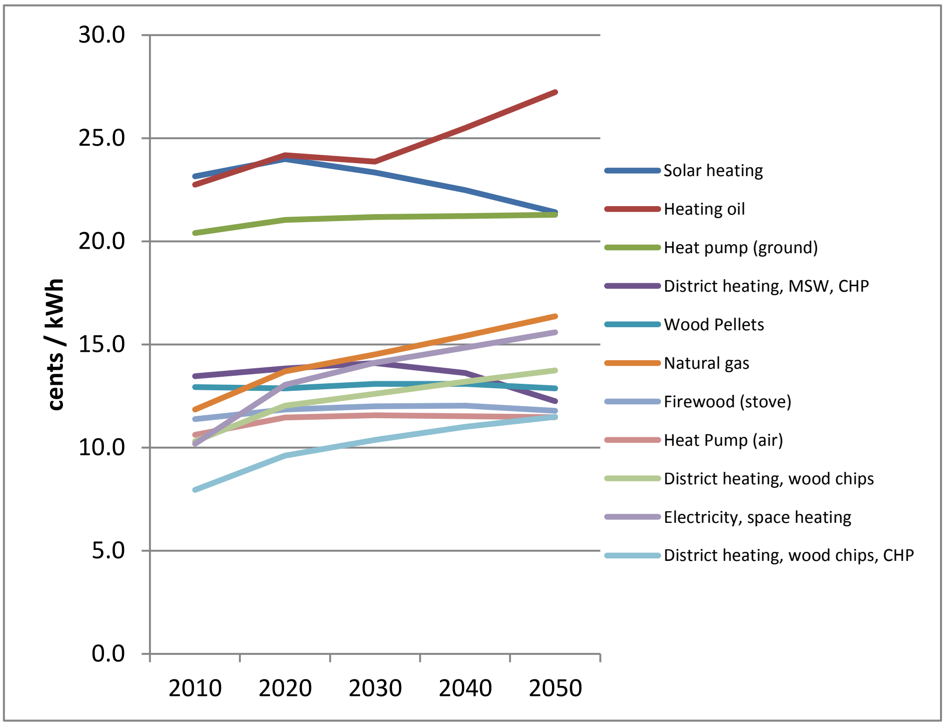

Figure 13: Cost of heat supplied to end-users, includes capital, O&M, and fuel costs. Excludes HST and technology rebates. The cost is a weighted average according to residential dwelling type and whether it is an existing or new dwelling. Costs for district heating in particular can vary substantially depending on building type, location, etc. For heat pumps, the existing fuel technology in place also affects the conversion cost.

Costs include capital, operation & maintenance (O&M), and fuel but excludes HST and technology rebates. As illustrated, solar heating, heating oil, and geo-exchange (ground source heat pumps) are the most expensive options, while wood chip-based district heating using CHP remains the cheapest throughout the period.

Meanwhile Figure 14 illustrates the anticipated cost of supplying locally produced electricity via the various technologies examined. Solar PV is initially about three times as expensive as the other options but falls steadily to reach approximately the same level as offshore wind by 2050.

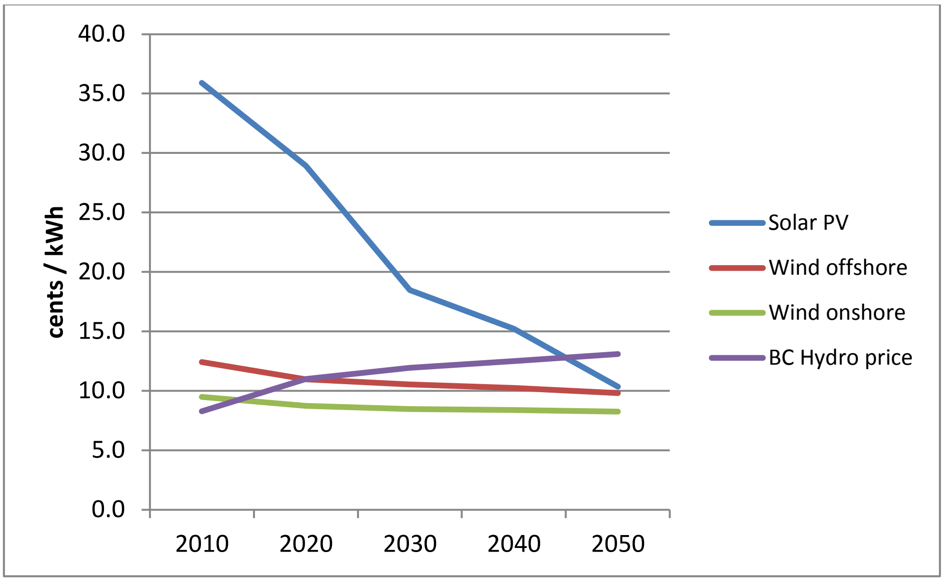

Figure 14: Cost of electricity supplied to residential end-users (BC Hydro price), vs. cost of locally produced and distributed electricity.[10]

GHG emissions from electricity

As was indicated in the introduction, 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).[11] When electricity imports are incorporated, i.e. the focus shifts to electricity *consumed* in British Columbia, this figure becomes roughly 84 g CO_2/kWh (Pembina, 2011). Looking beyond 2016, the electricity from BC production is meant to be carbon neutral, while the inclusion of imports is forecasted to raise the CO_2 intensity electricity *used* within the province to 60 g CO_2/kWh (Pembina, 2011).

Another important factor when considering the GHG emissions of electricity is the CO_2 intensity of marginal electricity, i.e. the last unit of electricity produced. It is the unit of electricity that will not be produced if electricity demand is lowered. This is relevant when discussing the federal or global impact of the CVRD increasing / decreasing its electricity consumption / production. The CO_2 intensity of marginal electricity in BC has been calculated to be 555 g CO_2/kWh[12] (Pembina, 2011). Including this figure when calculating the impact of a change in overall CVRD electricity usage would greatly alter projected GHG emissions, and should be kept in mind when considering the 'bigger picture' of various future energy alternatives. This is the case because if the CVRD lowers its import of high intensity CO_2 (through reducing its own

[10] Costs for mini hydro are not included as they are extremely site specific. Electricity costs from CHP plants are assumed to be the same as from BC Hydro, while the variation takes place on the heat side
[11] The term 'CO_2' is used for CO_2 equivalents.
[12] This could be due to the marginal electricity coming from a coal power plant in a neighbouring area

electricity demand or producing more RE electricity locally), and/or exports locally produced RE electricity, it will reduce the overall CO_2 emissions at rate dictated by the marginal CO_2 intensity.

For the purposes of scenario modelling, a CO_2 intensity of 24.7 g CO_2/kWh, equal to that used in the CEEI reports, was utilised for 2010. For future years this CO_2 intensity was gradually reduced so that it reaches 14.4 g CO_2/kWh by 2050. The reason for this reduction is BC Hydro's stated goal of reducing the average CO_2 intensity of electricity produced within the province.

g CO2/kWh	2010	2020	2030	2040	2050
Electricity from BC Hydro (figure used in CEII / after 2016)	24.7	0.0	0.0	0.0	0.0
Electricity including imports (before and after 2016)	84.0	60.0	60.0	60.0	60.0
Electricity (marginal)	550.0	NA	NA	NA	NA
Electricity used in model	**24.7**	**19.7**	**17.8**	**16.0**	**14.4**

Table 3: CO_2 intensity of electricity according to definition (g CO_2/kWh) (Pembina 2011, CEEI 2010).

Table 4 provides an overview of the main assumptions that are utilised in the four scenarios.

Parameter	BAU	EE	RE	EE+RE
Population growth rates	Growth rates for each admin area till 2020 based on previous 5-10 year average* Growth rates[13] from 2020-2050 for all admin areas of 1.1%**			
Residential unit type	The ratio of residential unit types from today is held nearly constant till 2050.			
Interest rate	An interest rate of 5% is used for private households, and 2% for the CVRD			
Renovations per year	4%	5%	4%	5%
Tear downs per year	2%	2%	2%	2%
Annual improvement in building code	0.5%	2.0%	0.5%	2.0%
Efficiency improvement via renovation	10%	12.5%	10%	12.5%
Reduction in non-heat electricity usage, propane and firewood (per year)	None	0.3% to 2020, 0.6% to 2030, 0.9% to 2040, 1.0% to 2050.	None	0.3% to 2020, 0.6% to 2030, 0.9% to 2040, 1.0% to 2050.

Table 4: Assumptions utilised in the scenarios.

* For the four municipalities, growth up to 2020 is forecasted to continue at an annual average equal to that from 2001-2011. For the nine electoral areas, previous Statistics Canada census figures are only available back to 2006. For the Indian Reserves a rate of 2.5% was used.

** For the Indian Reserves, an annual growth rate of 1.5% from 2020 to 2050 is implemented.

[13] In analysing the past population growth statistics it is apparent that growth rates across the respective administrative areas fluctuate a great deal over time, therefore an annual average population growth rate of 1.10% (equal to the CVRD average annual growth rate from 2001-2011) was applied for all 14 administrative areas from 2020 to 2050.

5 BAU scenario

Parameters

This scenario gives a picture of what the future may look like given current policies, growth projections, etc., and is used as reference point for the other scenarios. The scenario takes, as a baseline figure, the number of existing residential units in 2010 as per BCAA reporting. Based on the anticipated population growth rates for each administrative area, the number of residential units grows accordingly. Residential units are assumed to become more efficient, but also continue to grow slightly in size.[14] In this scenario it is assumed that relative to 2010, non-heat electricity demand (that is to say electricity for appliances, lighting, electronics, etc.) will stay constant as end-use efficiency gains will be mitigated by a larger number of electrical devices in the home. It is also assumed that supplementary propane and firewood demand are constant.[15]

Results

Number of units

The number of residential units, according to primary heating source under the BAU scenario, is displayed in Figure 15 below.

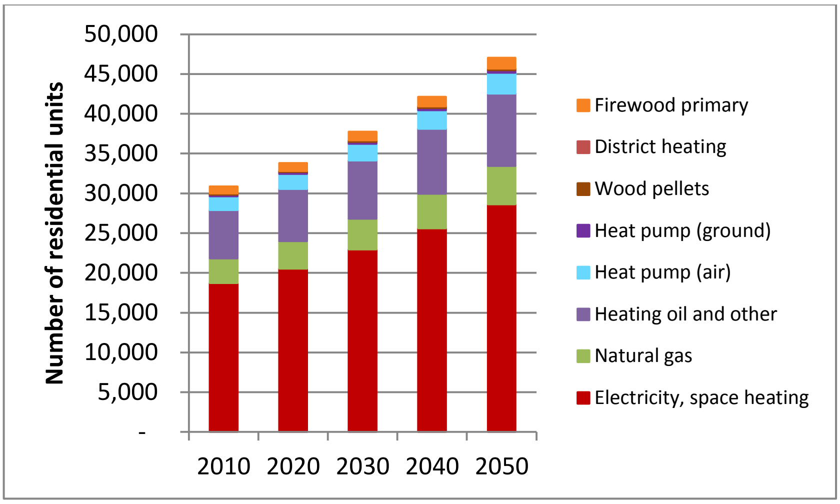

Figure 15: Number of residential units according to primary heating type in the BAU scenario.

Given the assumed population growth rates, the total number of residential units grows by over 50%, from just under 31,000 units in 2010, to over 47,000 in 2050. In this scenario there are no conversions from one heating form to

[14] From 2000 to 2009 the energy use in GJ/m^2 for all BC residences on average decreased by 2% per year, while the size of the average residence has increased by 1.2% per year over the same period. (NRCan, 2011)

[15] This is perhaps a conservative assumption as higher propane prices would likely lead to reduced demand.

another, and as such the dispersion between heating types stays nearly constant through till 2050.[16]

Gross energy consumption

Total energy consumption for the CVRD residential sector under this scenario is displayed in the graph below. Despite slight efficiency gains in both buildings and heating technologies, population growth leads to an overall increase of energy consumption in the residential sector by 28%.

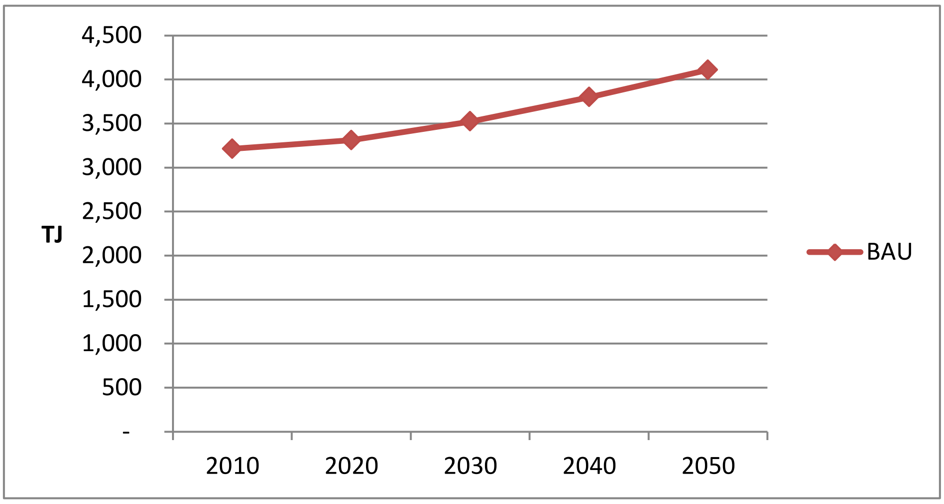

Figure 16: Gross energy consumption in the CVRD residential sector under the BAU scenario.

Figure 17 (below) breaks down the energy consumption by source.

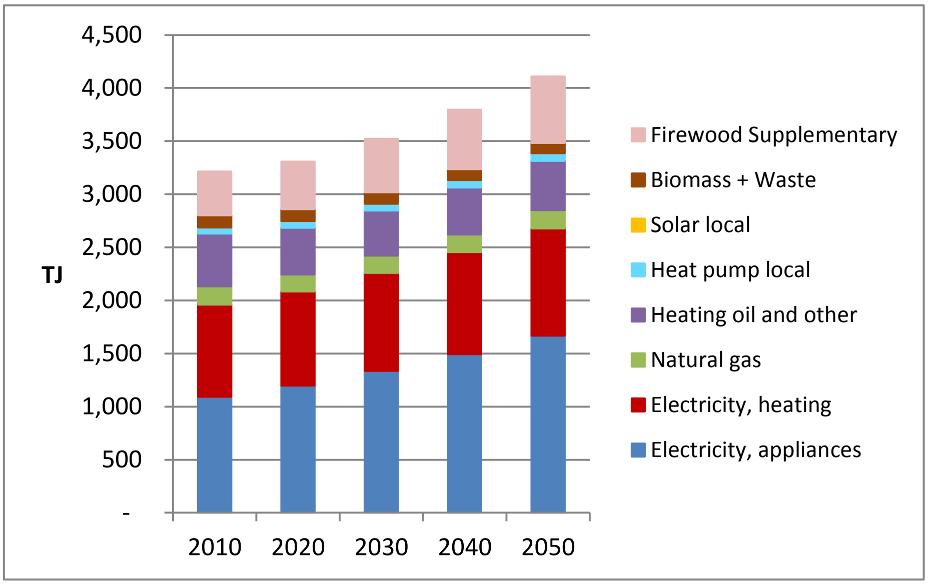

Figure 17: Gross energy consumption in the CVRD residential sector by energy source under the BAU scenario.

[16] Slight variations occur due to administrative areas having varying growth rates and building heat source compositions.

Electricity used in baseboard heating and appliances does not increase in efficiency (both are already at 100%), while biomass and fossil fuel based technologies do see technological improvements over the 40 years' span. As a result, from 2010 to 2050 the share of electricity grows from 60% to over 65% of total gross consumption. Meanwhile, the share of natural gas falls from 5% to 4%, while 'heating oil and other' (which benefits from the largest efficiency increases) sees a fall from 15% to 11%.

Comparison with CEEI

The most comprehensive energy consumption data for the CVRD comes courtesy of the 2010 Community Energy and Emissions Inventory (CEEI) reports. The BAU scenario was compared with this data from 2007, and the results for the residential sector are shown below.

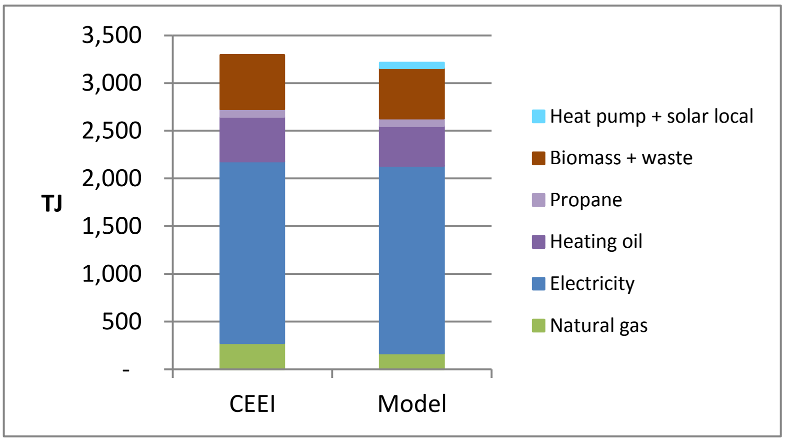

Figure 18: Comparison of 2010 CEEI and BAU residential consumption figures for the CVRD.

The largest difference can be seen for natural gas, where the BAU in the model uses roughly 100 TJ; nearly 40% less than that reported in the 2010 CEEI report. This could be due to the fact that secondary natural gas usage (i.e. hot water heating, fireplaces, etc.) is not included in the model, and/or because the percentage of residential units with natural gas may be higher than assumed in the model. The model also uses roughly 10% less oil, and 7.5% less biomass and waste.

On the other hand, the model uses roughly 60 TJ more electricity (ca. 3% more than the CEEI data), and the model also incorporates energy consumption from locally produced sources (such as that extracted from the air and ground by heat pumps, and from the sun via solar heating).

As a whole, this results in the model registering a gross energy consumption 2.5% less than that from the 2010 CEEI report. That the model registers a total energy consumption less than the CEEI could be due to a number of factors within the model (assumed efficiencies of heat systems, heat demand, electricity demand, etc.), or could be due to the fact that the BCAA input data may not include all residential dwellings within the CVRD.

GHGs

Total energy-related GHG emissions for the CVRD residential sector under the BAU scenario are shown in Figure 19 below.

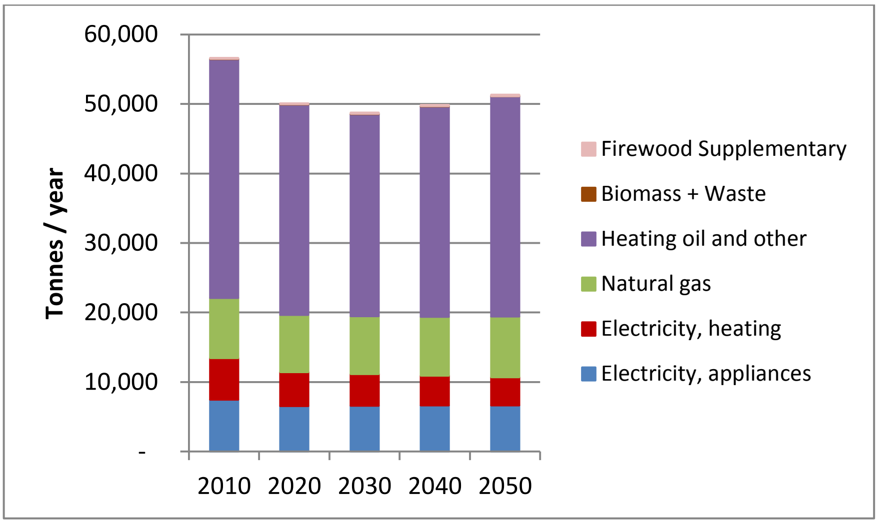

Figure 19: GHG emissions from the CVRD residential sector under the BAU scenario.

While the above figure displays the total energy-related CVRD GHG emissions, on a per resident basis they fall from 0.70 tonnes/capita in 2010, to 0.41 tonnes/capita in 2050.

In the BAU scenario the total residential GHG emissions fall through to 2030 due to the stock of heating oil and natural gas units becoming more efficient, as well as an anticipated fall in the GHG intensity of electricity produced in British Columbia. From 2030 to 2050, however, these efficiency gains and the drop in the GHG intensity of BC electricity are anticipated to be outpaced by population growth, and therefore total residential GHG emissions begin to increase slightly once again in 2040 and 2050.

Costs

The total energy costs for the CVRD residential sector are displayed in Figure 20 below. Costs include capital, O&M, and fuel costs, but exclude HST and technology rebates.

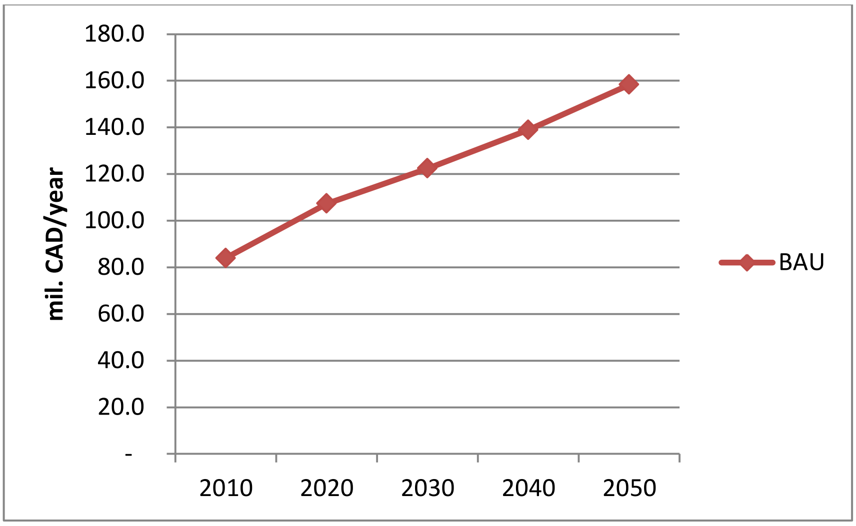

Figure 20: Total energy costs for CVRD residential sector in BAU scenario.

Despite slight efficiency improvements, and a population growth of roughly 50%, total annual energy costs for the residential sector nearly double by 2050. With the exception of a small CO_2 tax component, this cost increase is driven almost solely by increases in fuel prices, which are anticipated to increase for all fuel types.

Energy resiliency

The BAU energy resiliency trend for the CVRD from 2010 to 2050 is displayed below.

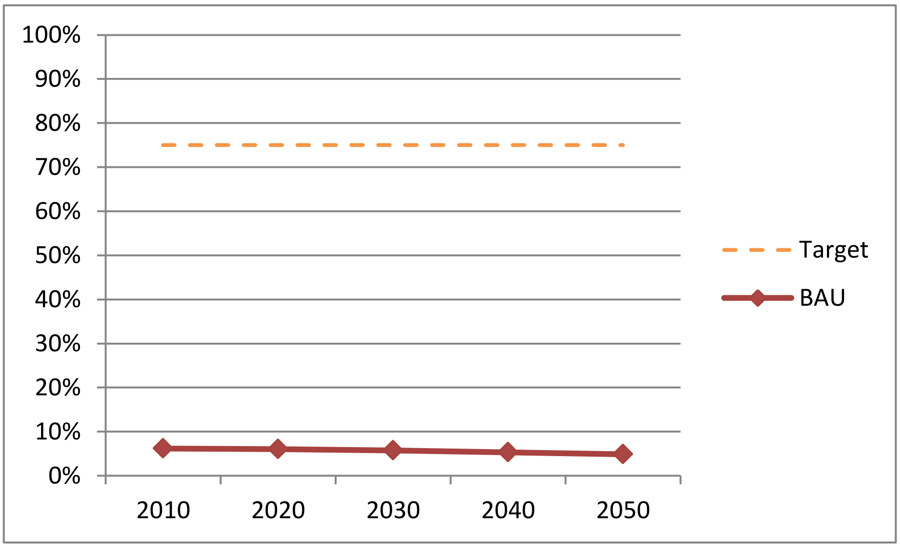

Figure 21: Energy resilience in the CVRD under the BAU scenario.

Energy resiliency within the context of this study is defined as the ratio of gross energy consumption that comes from local (within the CVRD) sources. This includes all electricity produced within the CVRD, energy derived from the air and ground via heat pumps, solar energy, and biomass. All biomass used within the CVRD is assumed to be locally sourced.[17]

The residential sector energy resiliency falls slightly over time in the BAU scenario (from 6.2% in 2010 to 4.9% in 2050) because the biomass utilising technologies become more efficient, and therefore use less biomass. Meanwhile, electricity usage for appliances and electric baseboard heating do not increase in efficiency, so they comprise a greater portion of the non-locally sourced gross energy consumption.

[17] There is a great deal of firewood used as a secondary heating source and/or in a supplementary fashion. This is not factored in to the energy resiliency equation as good deal of this may be used for external campfires, additional 'luxury' use, etc., and including it could artificially inflate the resiliency figure due to the extremely large amounts used.

6 EE scenario

Parameters

Energy efficiency

The parameters that were altered in this scenario were the end-use efficiency of residential units, as well as the auxiliary energy demand for non-heat electricity usage, and supplementary propane and firewood usage. The rate of renovations per year was increased from 4 to 5%, while the average improvement via these renovations was increased from 10 to 12.5%. Meanwhile, the average annual increase in the building code required efficiencies was increased from 0.5% to 2.0%

In terms of auxiliary non-primary heat demand, (electricity for appliances, computers, lighting as well as propane, firewood, etc.), the EE scenario incorporates a 3% reduction in 2020 relative to 2010, a 6% reduction from 2020 to 2030, a 9% reduction from 2030 to 2040, and a 10% reduction from 2040 to 2050. It is assumed that greater reductions will take place at the end of the period as fuel prices continue to rise, and because efficiency gains in the short term may be largely mitigated by increased use of electrical devices in the home.

Results

Gross energy consumption

The total energy consumption for the CVRD residential sector under the EE scenario is displayed in the graph below. Despite a population growth of over 50% by 2050, efficiency gains result in a modest increase in gross energy consumption of only 2.9%. This raises consumption to just over 3,300 TJ in 2050, which is 800 TJ less than in the BAU scenario.

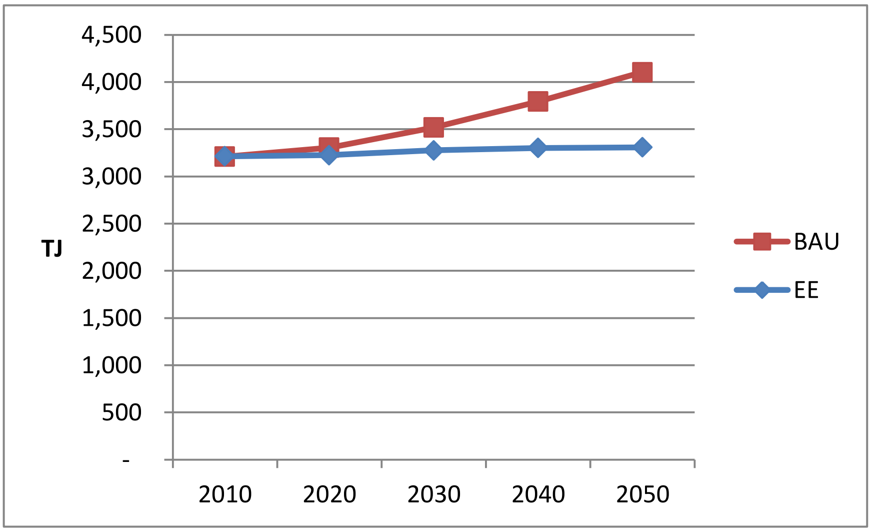

Figure 22: Gross energy consumption in the CVRD residential sector under the EE scenario.

Figure 23 below breaks down the energy consumption by source. Relative to the BAU scenario, electricity plays a slightly lesser role, largely due to the fact that energy efficiency gains result in lower percentage of total energy going to electrical appliances.

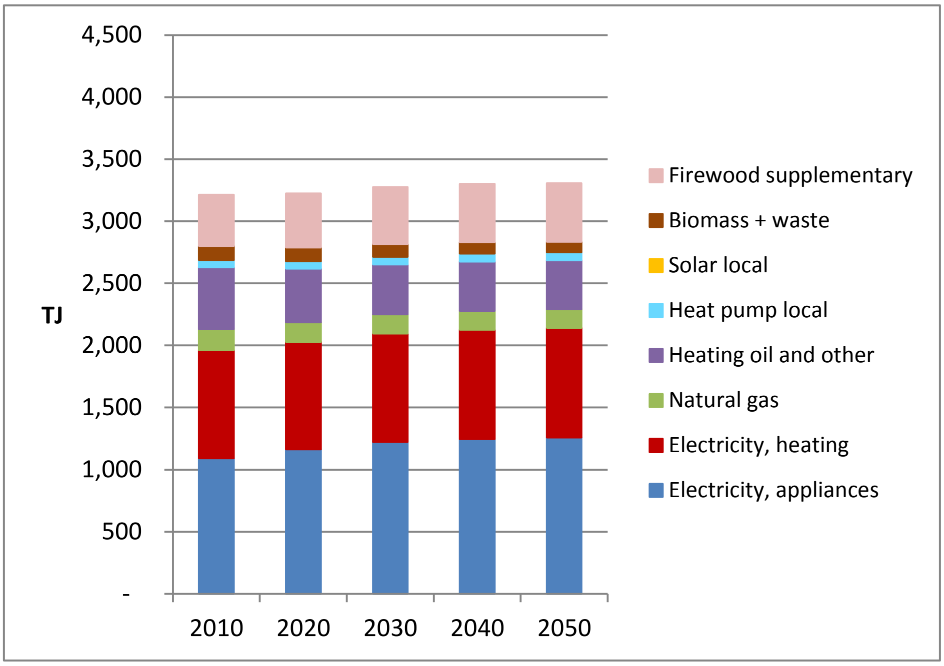

Figure 23: Gross energy consumption in the CVRD residential sector by energy source in the EE scenario.

GHGs

Total GHGs emissions for the residential sector under the EE and BAU scenarios are displayed in Figure 24 below.

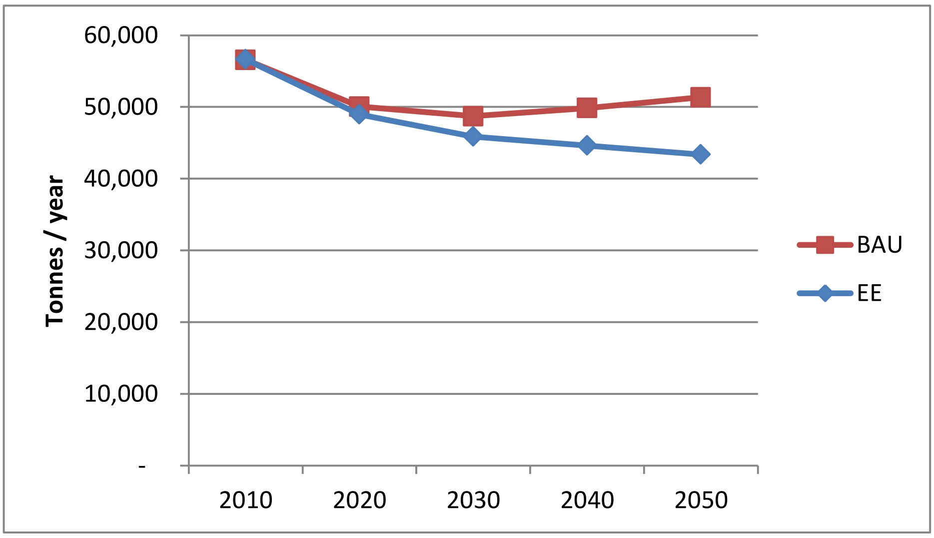

Figure 24: Residential GHG emissions in the CVRD under the EE and BAU scenarios.

The figure highlights the fact that energy efficiency measures allow for the CVRD to continue to reduce its GHG emissions from the residential sector beyond 2030, despite a large overall population growth.

While Figure 24 displayed the total emissions, on a per capita basis the GHG emissions fall from 0.70 tonnes/capita in 2010 to 0.35 tonnes/capita in 2050.

Narrowing in on the source of emissions in Figure 25 below, it becomes apparent that the largest reductions are made within the heating oil and other category, which is not surprising given that oil has the highest GHG coefficient of all the fuels used in the CVRD.

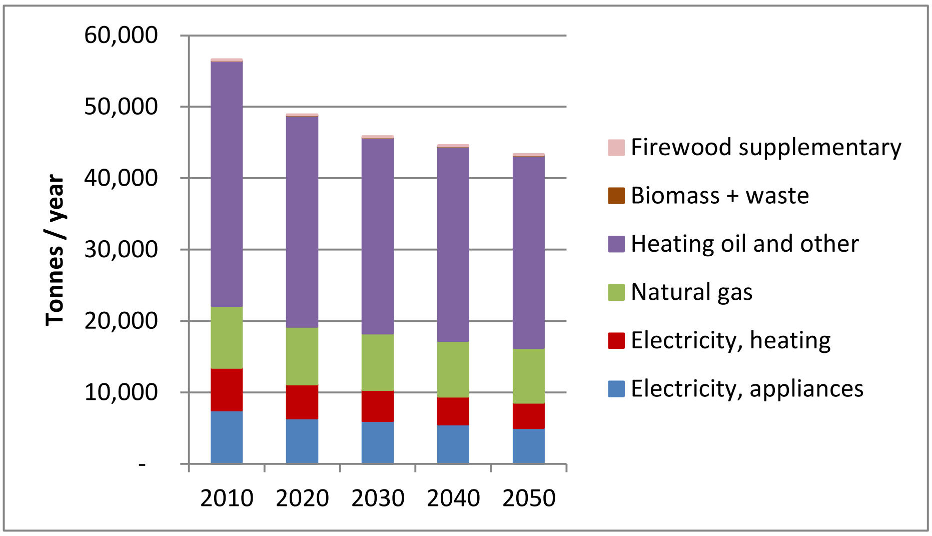

Figure 25: GHG emissions from the CVRD residential sector by source under the EE scenario.

Costs

Total energy costs for the residential sector under the EE and BAU scenarios are displayed in Figure 26. Relative to the BAU scenario, the efficiency improvements in 2050 equate to annual savings in the residential sector of 27.8 million CAD, or roughly 600 CAD/household in 2050. However, it is very important to note that within the modelling, there has not been a cost value associated with bringing about the efficiency improvements and reduced energy demand. As such it remains undetermined what the upfront cost of realising these future savings are, and therefore to what extent these efficiency improvement measures should be undertaken.

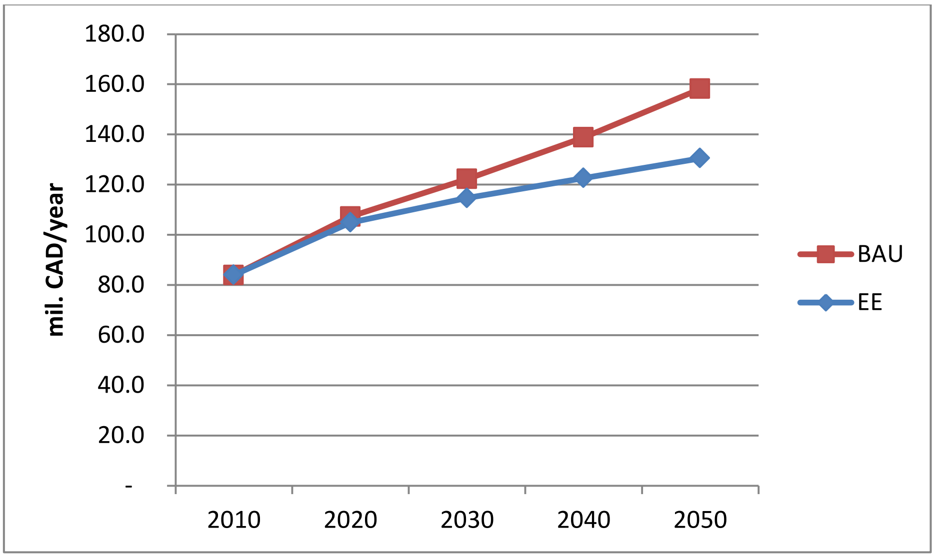

Figure 26: Total energy costs for the residential sector under the EE and BAU scenarios.

Energy resiliency

In the EE scenario, energy resiliency falls due to the same reasons as highlighted in the BAU scenario (the biomass utilising technologies become more efficient, and therefore use less biomass, while electricity usage for appliances and electric baseboard heating do not increase in efficiency, so they comprise a greater portion of the non-locally sourced gross energy consumption). However, as indicated in the figure below, the decline in resiliency is slightly less than in the BAU scenario, because while gross biomass consumption still falls (thus reducing resiliency) in the EE scenario, the consumption of other non-locally sourced energy sources decreases even more (thus increasing resiliency).

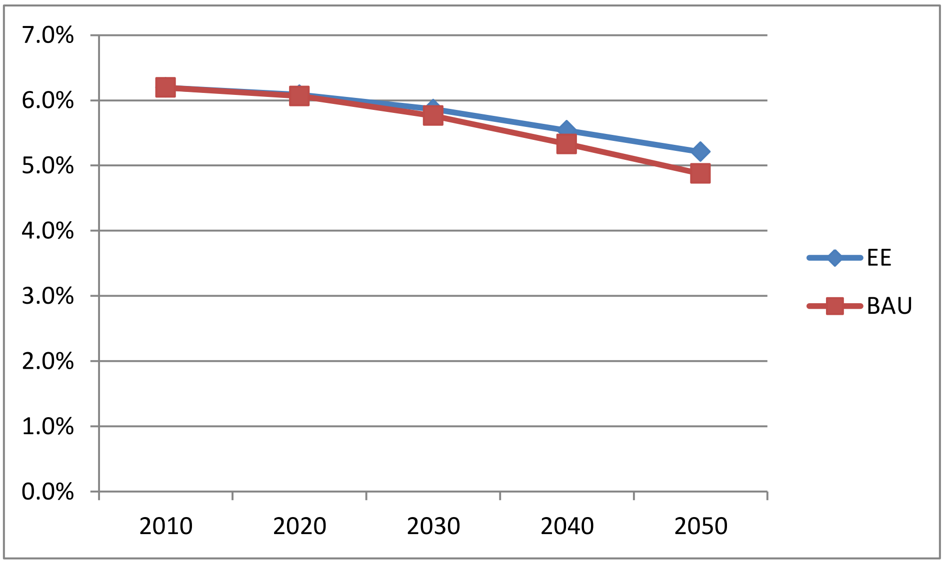

Figure 27: Energy resiliency in the CVRD residential sector in the EE and BAU scenarios.

One of the main observations that can be drawn from the EE scenario is that energy efficiency improvements alone do very little to increase overall energy resiliency. This is because energy efficiency does not result in fuel and technology shifting (keeping in mind that within this study energy resiliency is measured as the % of local consumption that is covered by local RE production).

7 RE scenario

Parameters

Energy efficiency

In order to provide a clear accounting of effects, relative to the BAU, end-use efficiency of residential units and auxiliary energy demand were not altered in this scenario.

Renewable energy production

CVRD-wide, 90% of dwellings that are currently using space heating, natural gas, or heating oil, switch to heat pumps (air) by 2050, and the other 10% switch to wood pellets. Heat pumps (air) are the cheapest individual heating alternative in 2050, and therefore in this scenario the majority of units will switch over to this technology. Wood pellets are the second best alternative cost wise, and thus it is assumed that those that cannot switch to heat pumps will select this option.[18]

The tables immediately below show the gradual shift in dwelling heating type towards the cheaper solutions, namely air-to-air heat pumps (top table) and wood pellets (bottom table).[19]

	Ambitious scenario - pre 2010 buildings					Ambitious scenario - post 2010 buildings				
	2010	2020	2030	2040	2050	2010	2020	2030	2040	2050
Electricity, space heating	0	25	50	80	90	0	25	50	80	90
Natural gas	0	45	90	90	90	0	45	90	90	90
Heating oil	0	45	90	90	90	0	45	90	90	90
Wood Pellets (boilers)	0	0	0	0	0	0	0	0	0	0
Firewood Primary	0	0	0	0	0	0	0	0	0	0

	Ambitious scenario - pre 2010 buildings					Ambitious scenario - post 2010 buildings				
	2010	2020	2030	2040	2050	2010	2020	2030	2040	2050
Electricity, space heating										
Natural gas	0	5	10	10	10	0	5	10	10	10
Heating oil	0	5	10	10	10	0	5	10	10	10
Wood Pellets (boilers)	0	5	10	10	10	0	5	10	10	10
Firewood Primary	0	0	0	0	0	0	0	0	0	0

Table 5: Percentage shift to air-to-air heat pumps (top table) and wood pellets (bottom table) from the respective current technologies.

In addition, with their higher energy consumption densities, district heating from CHP is implemented in North Cowichan, Duncan and Ladysmith for the purposes of this scenario, meaning that approximately 5,600 units are provided with district heating. As a result, some of the CVRD wide conversion to heat pumps and wood pellets are instead replaced with district heating in

[18] Primary heating from firewood stoves is a slightly cheaper alternative, but it is assumed that due to the extra effort required, and local environmental effects, large numbers of conversions to this technology would not take place with only modest savings.

[19] The column to the left indicates the technology that is currently employed and will be switching to another specific technology (in the case of the top table, to heat pumps, and in the case of the lower table, to wood pellets). As an example, in 2050, 90% of homes (both pre and post 2010) that currently use electric space heating switch to air-to-air heat pumps, and the remaining 10% of homes (both pre and post 2010) that currently use electric space heating switch to wood pellets.

these three areas. A breakdown of the number of units per administrative area using district heating in 2050 is provided in the table below.

District heating dispersion	Duncan	North Cow.	Ladysmith	Total
Single detached	554	2,367	785	**3,707**
Single attached	74	443	115	**632**
Apartment	737	424	96	**1,257**
Total	**1,366**	**3,235**	**996**	**5,597**

Table 6: Distribution of the units furnished with district heating in 2050.

Lastly, to reach the overall target of 75% energy resiliency in the residential sector within this scenario, 130 MW of onshore wind turbines are installed in electoral area G by 2050. If these turbines produce roughly 2,700 full load hours per MW, this gives an electricity production of just over 350 GWh by 2050. Along with the electricity from the CHP district heating, this results in the CVRD's residential electricity demand equalling just under 64% of its RE-based electricity production in 2050.

Results

The number of residential units according to primary heating source under the RE scenario is displayed in Figure 28 below.

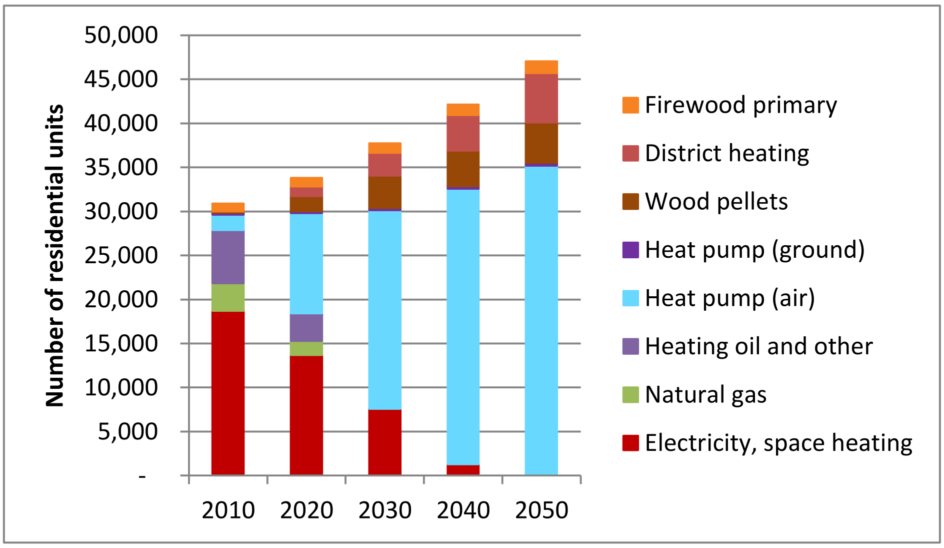

Figure 28: Number of residential units according to primary heating source in the RE scenario.

Gross energy consumption

The total energy consumption for the CVRD residential sector under the BAU, EE, and RE scenarios as depicted in Figure 29, highlights that total gross energy consumption will be only marginally less in the RE scenario than in the BAU scenario. This small difference is due to higher production efficiency of the involved technologies.

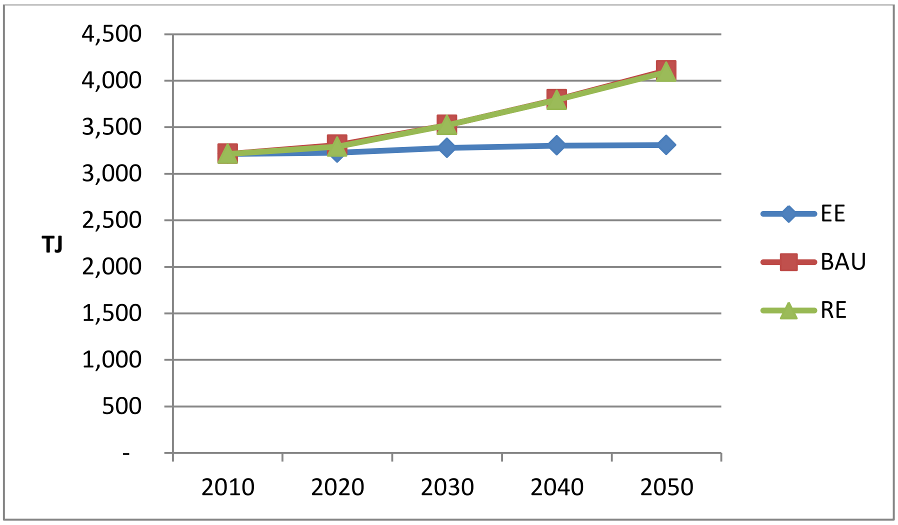

Figure 29: Gross energy consumption under the BAU, EE, and RE scenarios

However, when examining the breakdown by energy source, there are significant differences between the BAU and RE scenarios (see below).

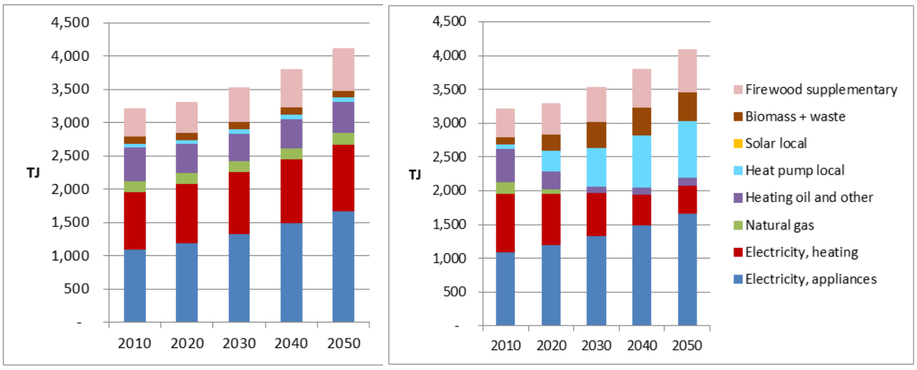

Figure 30: Gross energy consumption according to fuel source in the BAU (left) and RE (right) scenarios.

Most notable is the phasing out of natural gas and oil by 2030, with only the secondary usage from propane remaining. These fossil fuels are replaced by heat pumps (air) and CHP district heating, and by wood pellets for those dwellings that cannot install a heat pump or access district heating. It is also worth noting the large drop in electricity usage within the heating sector. This is largely the result of switching from electric baseboard heating to heat pumps, which have efficiencies 2-3 times higher than electric baseboard heating.

GHGs

Total GHGs emissions for the CVRD residential sector are drastically reduced already by 2030, largely due to the phasing out of oil and natural gas for individual heating. The largest remaining portion comes from supplementary propane use, which is not addressed in this scenario, but given its high price, reductions in usage would likely follow.

Relative to 2010, total residential GHG emissions are 82% lower in 2050 under the RE scenario.

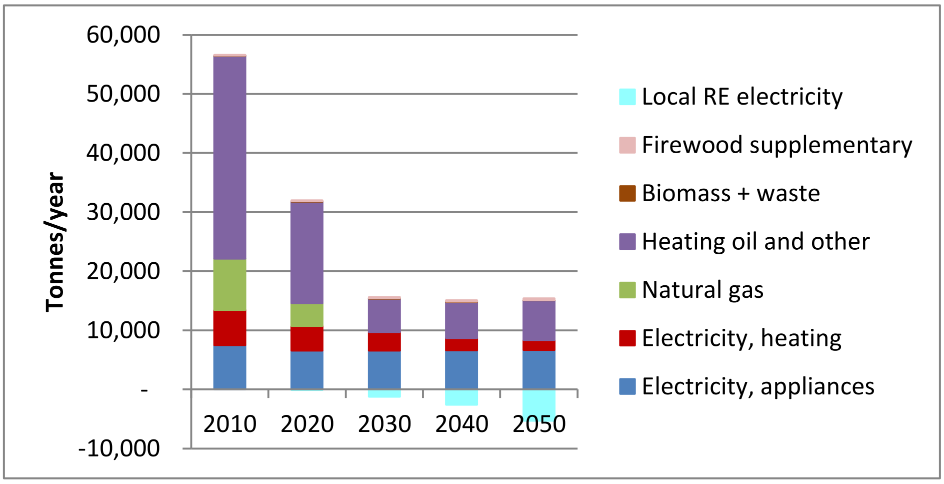

Figure 31: GHG emissions in the residential sector by source.

Meanwhile, the GHG emissions per inhabitant fall from 0.70 tonnes/capita in 2010 to 0.08 tonnes/capita in 2050.

Assuming that the electricity used in this scenario is produced from onshore wind within the CVRD, this usage would be carbon neutral. Meanwhile, the electricity that this replaces from BC Hydro has a small CO_2 content (as indicated in Table 3), which in 2050 is 14.4 g CO_2/kWh. These CO_2 savings are represented by the light blue portion as negative values in the figure above, subtracting from the total GHG emissions from the navy blue and red electricity portions. If we take 2050 as an example, these savings represent roughly 5,000 tonnes, and assuming these savings can be attributed to the residential sector, bring the total residential emissions down to roughly 10,000 tonnes. Compared to the BAU scenario the residential GHG emissions are thus 80% lower in 2050, with the big drop coming from 2010-2030 when oil and natural gas furnaces are replaced.

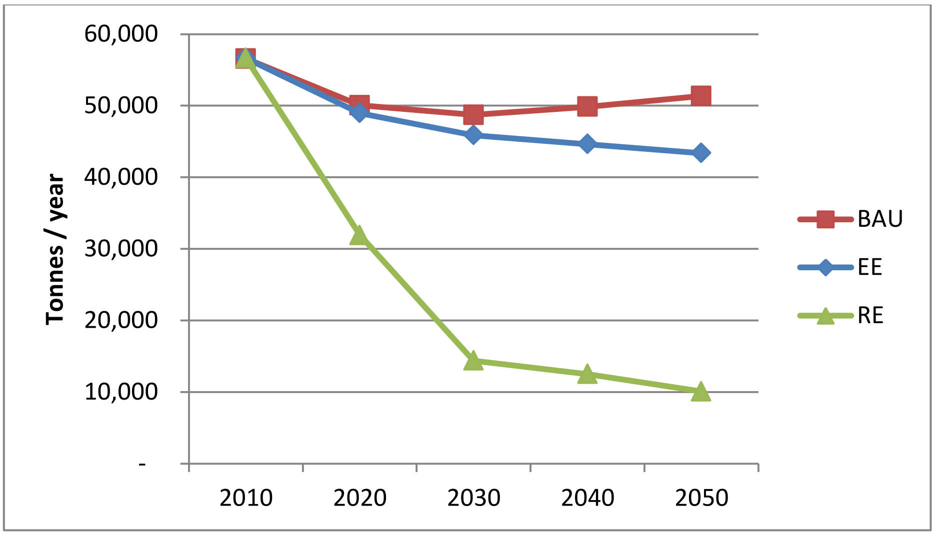

Figure 32: Residential GHG emissions in the CVRD in BAU, EE, and RE scenarios.

When comparing GHG emissions between the RE scenario and the EE scenario, the RE scenario results in over 33,000 tonnes less emitted annually by 2050.

Costs

Total energy costs for the residential sector under the BAU, EE, and RE scenarios show that relative to the BAU scenario, investing in local RE under the given assumptions will lead to significant cost savings for the CVRD.[20]

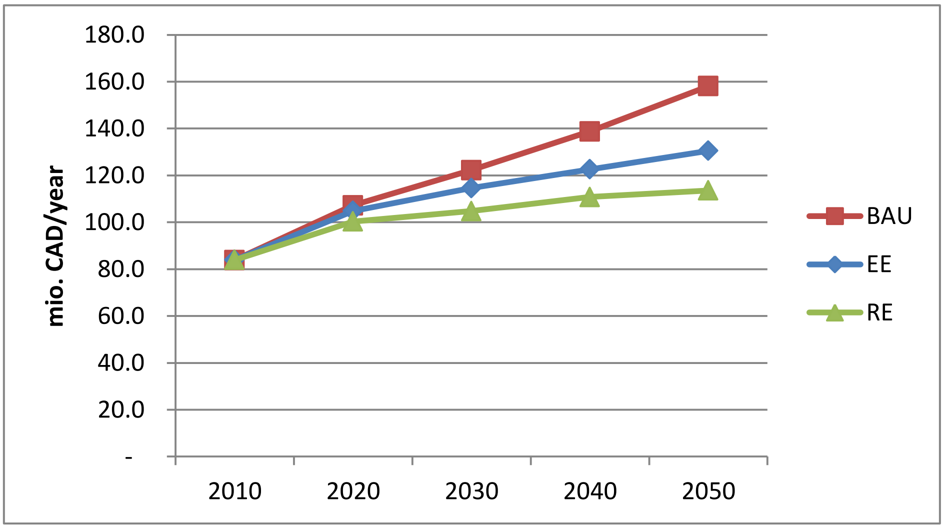

Figure 33: Total energy costs for the CVRD residential sector under the BAU, EE, and RE scenarios.

While residential energy costs still increase by 35% in 2050 relative to today, they result in costs savings of nearly 45 mil. CAD/year when compared with

[20] Some of the cost savings will accrue to the end-users, and some will accrue as profits to those investing in RE technologies. The overall cost figure is seen from the perspective of the CVRD residential sector as a whole.

the BAU scenario. On a household level this would translate into an annual costs savings of roughly 950 CAD/household in 2050.

Energy resiliency

Energy resiliency for the residential sector is not surprisingly much higher in the RE scenario than in the BAU and EE scenarios, with the target of 75% by 2050 being reached.

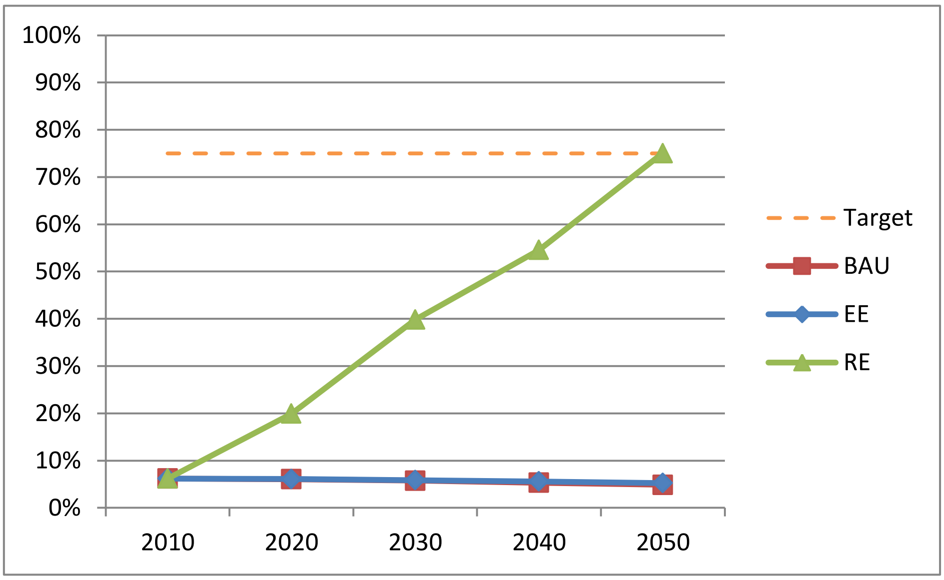

Figure 34: Energy resiliency in the CVRD residential sector under the BAU, EE and RE scenarios.

In terms of the RE production composition, a little under half is made up of residential heating, while the remaining is generated by RE electricity production (primarily from onshore wind).

8 EE + RE scenario

Parameters

Energy efficiency

Relative to the BAU scenario, end-use efficiency of residential units, as well as the auxiliary energy demand for non-heat electricity usage, and supplementary propane and firewood usage were altered in the same fashion as in the EE scenario.

Renewable energy production

As was the case in the RE scenario, CVRD-wide, 90% of dwellings that are currently using space heating, natural gas, or heating oil, switch to heat pumps (air) by 2050, and the other 10% switch to wood pellets. Heat pumps (air) are still the cheapest individual heating alternative in 2050, and therefore in this scenario the majority of units will switch over to this technology. Wood pellets are the second best alternative cost wise, and thus it is assumed that those that cannot switch to heat pumps will select this option.[21]

As is also the case in the RE scenario, district heating from CHP is implemented for just under 5,600 dwellings spread over North Cowichan, Duncan, and Ladysmith, thus reducing the number of units that would otherwise shift over to heat pumps or wood pellets.

Due to increases in energy efficiency, the district heating demand from these 5,600 dwellings is less in this (EE+RE) scenario than others, resulting in less electricity being produced via CHP. The result is a slightly higher district heating cost on a per kWh basis. Relative to the BAU scenario and the RE scenario, on a per kWh demand all technologies become more expensive in the EE and EE+RE scenarios, but particularly the more capital intensive technologies such as heat pumps and solar heating.

To reach the overall target of 75% energy resiliency in the residential sector, a little less than 100 MW of onshore wind turbines are installed in electoral area G by 2050. Assuming production of roughly 2,700 full load hours per MW, this gives an electricity production of just under 265 GWh by 2050. Along with the electricity from the CHP district heating, this results in the CVRD's residential electricity demand equalling 62% of its RE electricity production in 2050.

[21] Primary heating from firewood stoves is a slightly cheaper alternative, but it is assumed that due to the extra effort required, large numbers of conversions to this technology would not take place with only modest savings.

Results

Gross energy consumption

The total energy consumption for the CVRD residential sector under the EE+RE scenario is displayed in the graph below.

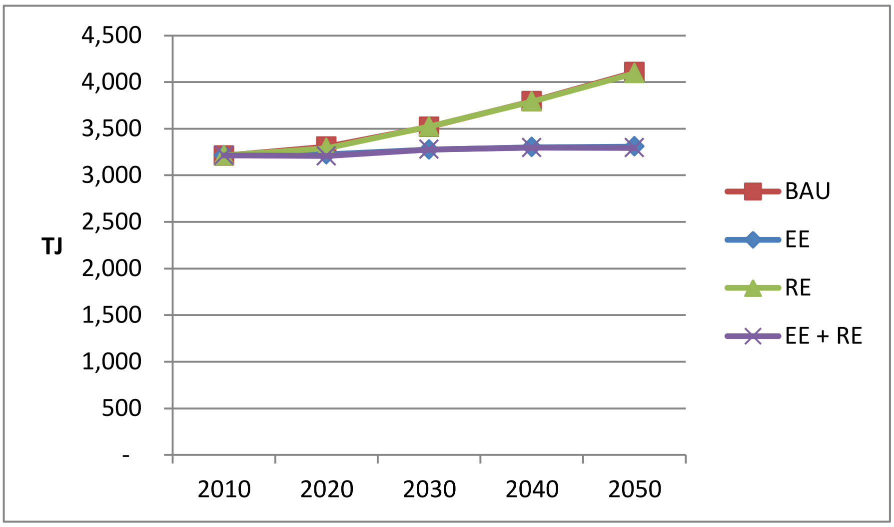

Figure 35: Gross energy consumption in the CVRD residential sector under the four scenarios.

The total gross energy consumption in the EE+RE scenario is nearly the same as in the EE scenario, however, as outlined in the next figure, the composition is quite different.

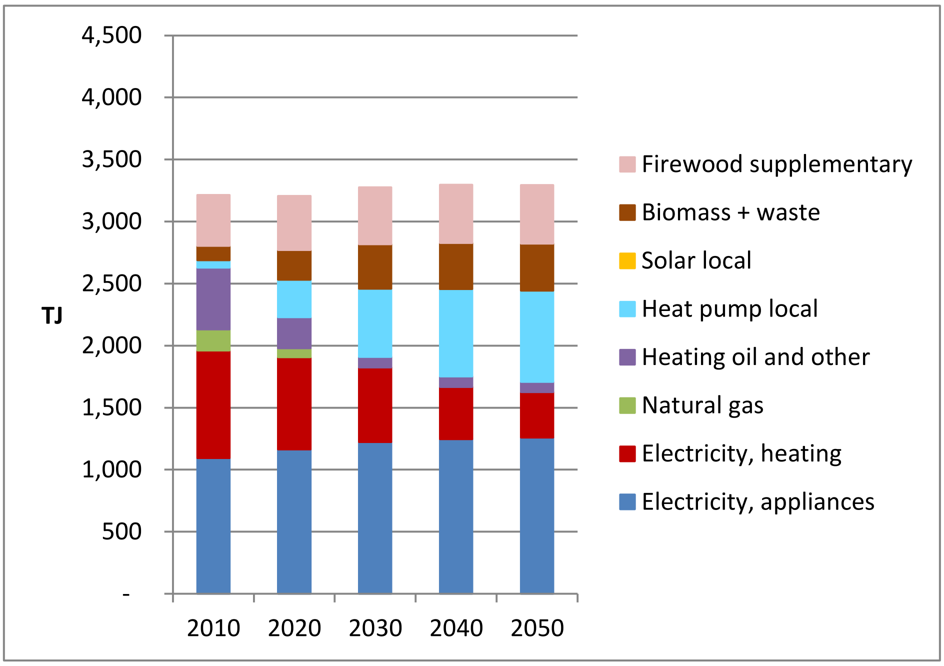

Figure 36: Gross energy consumption in the CVRD residential sector by energy source in the EE+RE scenario.

GHGs

Total GHGs emissions for the residential sector under the four scenarios indicate that some additional GHG emission savings can be made relative to the RE scenario, particularly from 2030 till 2050. The GHG emissions per inhabitant fall from 0.70 tonnes/capita in 2010 to 0.06 tonnes/capita in 2050.

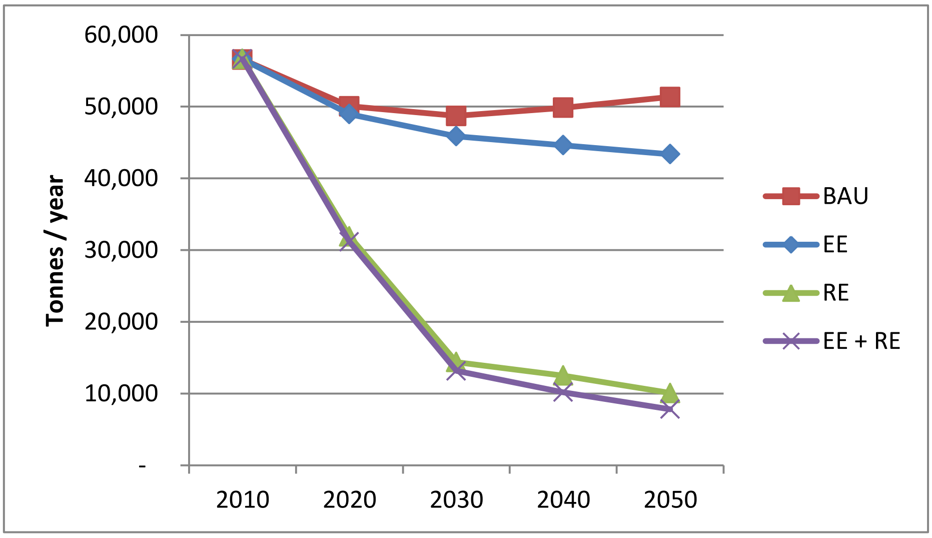

Figure 37: Residential GHG emissions in the CVRD under the four scenarios.

Costs

Relative to the BAU scenario, the EE+RE scenario in 2050 shows annual residential sector costs that are 63.5 million CAD lower, or roughly 1,350 CAD/household. However, it is again important to mention that the cost savings related to efficiency improvements were brought about 'for free', and the cost of implementing these policies would have to be subtracted from this total.

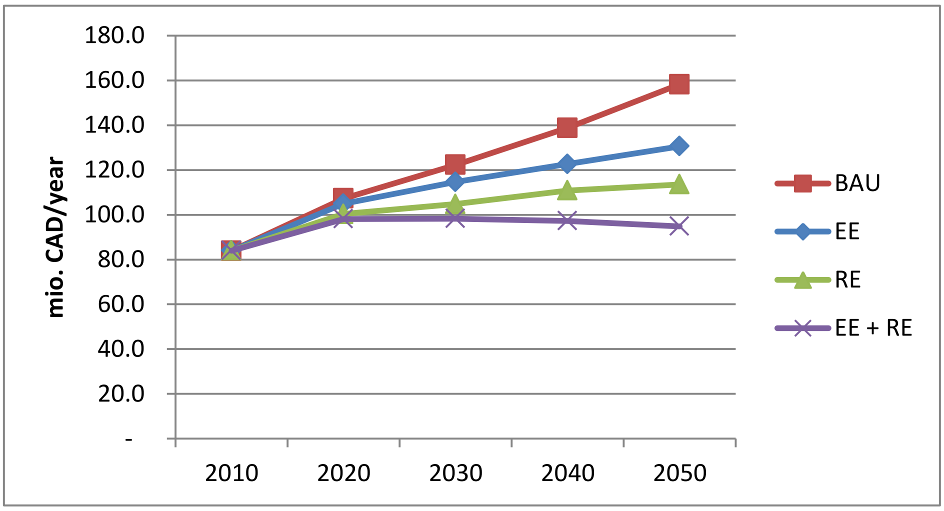

Figure 38: Total energy costs for the residential sector under the four scenarios.

Energy resiliency

In the EE+RE scenario the 75% energy resiliency target is again met, but thanks to reductions in end-user consumption, the total amount of RE electricity production from within the CVRD that is required to meet this target is reduced by nearly 25%.

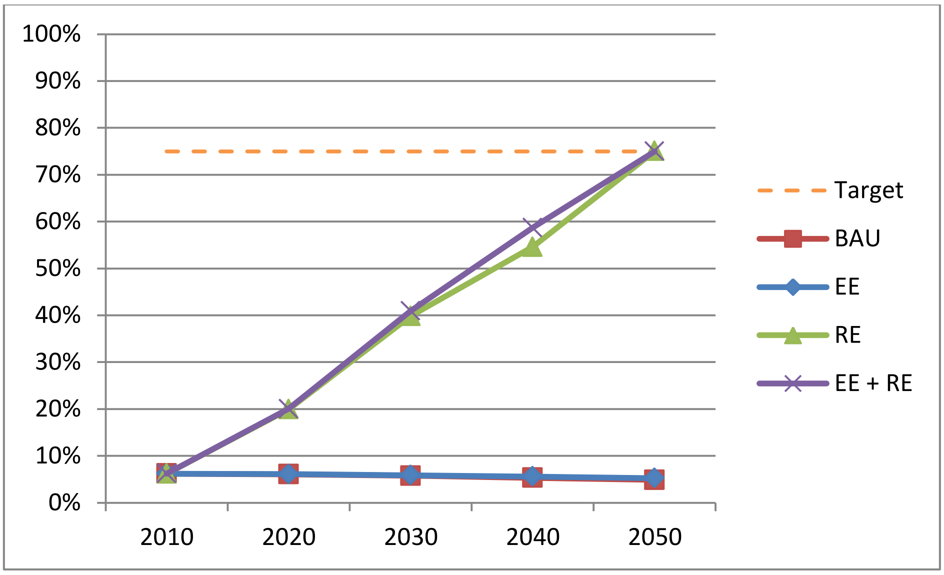

Figure 39: Energy resiliency in the CVRD residential sector in the four scenarios.

9 Summary 2050

In the RE and EE+RE scenarios the building stock according to primary heating source is drastically different from the BAU and EE scenarios. In the RE and EE+RE scenarios, air-to-air heat pumps are the dominant technology, with the remaining dwellings being biomass based in one form or another. In reality one technology may not come to dominate so extensively, but given the assumptions made in the modelled scenarios (i.e. air-to-air heat pumps are the cheapest heating alternative), air-to-air heat pumps represent the preferred technology, particularly in new dwellings where the dwelling can be designed with ventilation systems in mind.

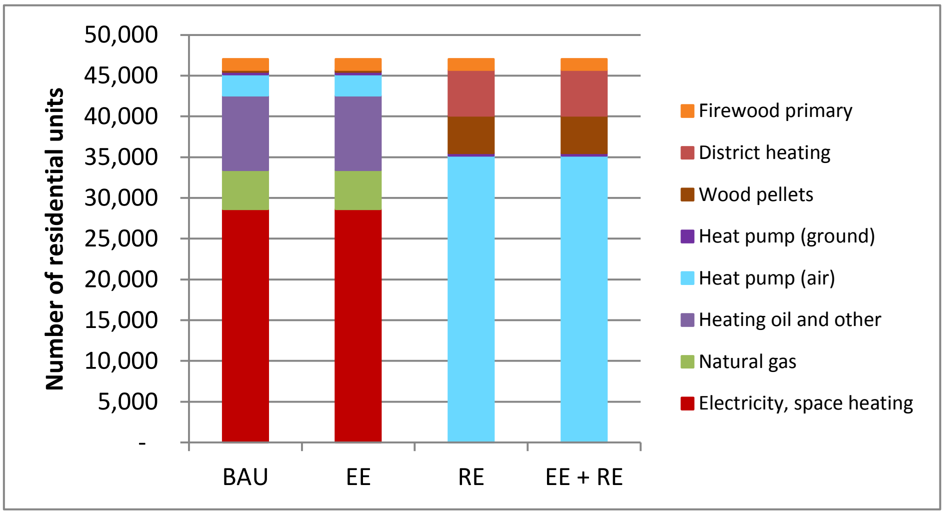

Figure 40: Dispersal of residential units according to primary heating source in 2050 under the four scenarios.

How the dispersal of primary heating units affects the gross energy consumption is highlighted in the RE and EE+RE scenarios in the following figure. Natural gas, heating oil, and a part of electricity to heating are replaced with biomass and local heat pump energy, thus completely eliminating fossil fuels from primary heating, with only residual propane use left. Meanwhile, in the scenarios involving EE, the gross energy consumption of all fuels is reduced considerably.

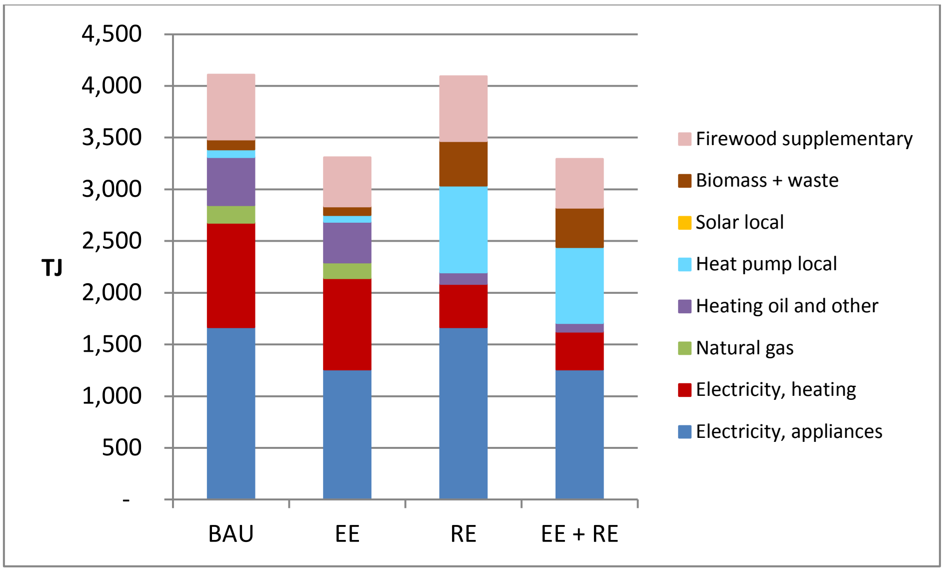

Figure 41: Gross energy consumption in the CVRD residential sector by energy source in 2050 under the four scenarios.

Comparing the GHG emissions in 2050 under the four scenarios illustrates that the largest reductions are made when fuels with high CO_2 intensities (heating oil and natural gas) are replaced with renewables and/or low CO_2 intensive electricity.

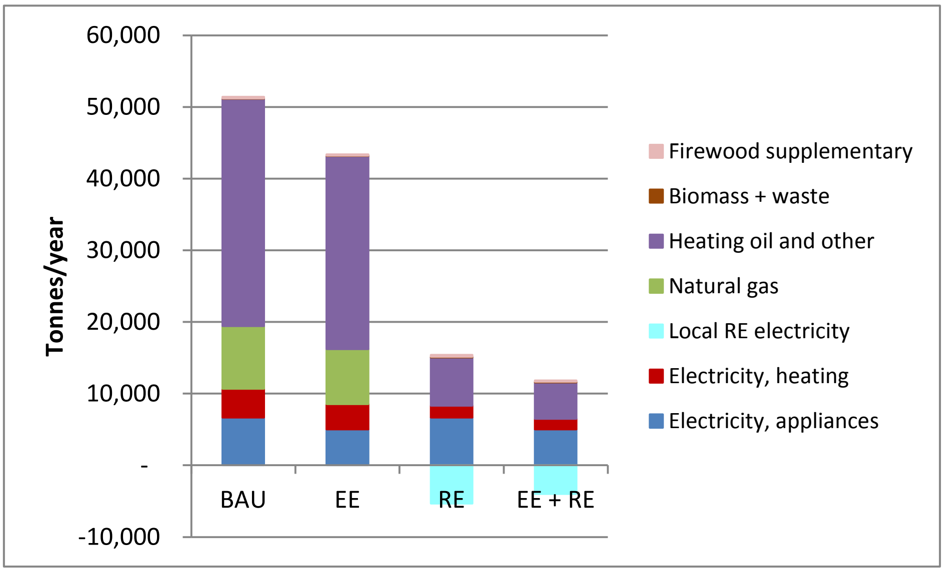

Figure 42: GHG emissions from the CVRD residential sector by source in 2050 under the four scenarios. The electricity that is produced from onshore wind within the CVRD is assumed to be carbon neutral. Meanwhile, the electricity that this replaces from BC Hydro has a small CO_2 content (as indicated in Table 3), which in 2050 is 14.4 g CO_2/kWh. These CO_2 savings are represented by the light blue portion in the figure.

Once heating oil and natural gas are replaced, increased efficiency does not result in large CO_2 savings. However, this is in large part due to the very low

CO_2 intensity of electricity utilised in the calculations. If a higher CO_2 intensity value were used, for example reflecting the marginal CO_2 intensity (see discussion of CO_2 intensity proceeding Table 3), then EE would bring about greater GHG emission savings.

9.1 Additional aspects

In addition to cost and GHG characteristics, other outcomes resulting from the scenarios should be highlighted. Firstly, in the RE and EE+RE scenarios, large-scale conversions to heat pumps would provide local employment, particularly when existing dwellings convert from other technologies. This is also the case with district heating, not only in the large infrastructure developments, but also with respect to local sourcing of the wood chips.

One potential disadvantage to heat pumps however, particularly in very densely populated areas, could be noise pollution. This is not assumed to be a major barrier as heat pumps have become increasingly quiet in recent years, and the vast majority of dwellings in the CVRD are single detached.

9.2 Sensitivity analysis

In carrying out the scenario work there are a number of parameters that are particularly sensitive to change:

- Rates at which money can be borrowed are extremely important, particularly for more capital intensive technologies.
- Due to their high efficiency, heat pumps will be the least affected by large changes in fuel and/or electricity prices. They are, however, greatly affected by interest rates.
- Even if large amounts of cheap natural gas are available, heat pumps are still likely to be a cheaper alternative.
- Municipal solid waste fed CHP is greatly influenced by the % of heat that can be sold, and the interest rates at which money can be borrowed. If there is a global run on biomass, wood chip-based CHP will become more expensive, thus making heat pumps relatively more attractive, but even a wood chip price 50% higher than assumed in the scenarios in 2050 would yield cheaper heating alternatives than those available via fossil based fuels.

10 Target achievement

In addition to the overarching energy resiliency target, each scenario has been assessed with regards to additional sub-targets listed below:

- 95% renewable energy use in the residential sector by 2030.[22]
- 75% reduction in residential GHGs in 2030 relative to 2010.
- A new home in 2030 is twice as efficient as a new home in 2010.

The results of this assessment are presented in Table 7. Only the RE and EE+RE scenarios meet the 95% renewable energy use target. The BAU scenario shows first a slight increase and then a larger decrease in GHG reductions relative to 2010. The RE and EE+RE scenarios on the other hand show a significant improvement – as expected. In the EE and EE+RE scenarios energy usage of new homes in 2030 relative to new homes in 2010 improves by over 30%, whereas new homes in 2030 in the BAU and RE scenarios improve by less than 10%.

Target	BAU	EE	RE	EE+RE
Sustainable energy use in residential sector (%) [23]				
- 2010	76.2%	76.2%	76.2%	76.2%
- 2020	78.9%	78.9%	88.3%	88.3%
- **2030 (95%)**	**80.5%**	**80.3%**	**96.9%**	**97.0%**
- 2040	81.2%	80.6%	96.9%	97.0%
- 2050	81.7%	80.8%	96.8%	97.0%
Reduction in residential GHGs relative to 2010 (%):				
- 2020	12%	14%	44%	45%
- **2030 (75%)**	**14%**	**19%**	**75%**	**77%**
- 2040	12%	21%	78%	82%
- 2050	9%	23%	82%	86%
Energy usage of new homes relative to 2010 (%):				
- 2020	95.1%	82.0%	95.1%	82.0%
- **2030 (50%)**	**90.5%**	**67.3%**	**90.5%**	**67.3%**
- 2040	86.1%	55.2%	86.1%	55.2%
- 2050	81.9%	**45.3%**	81.9%	**45.3%**

Table 7: Statistics regarding additional CVRD sub-targets under the various scenarios, red figures indicate targets met, while blue indicates target met in a later year.

[22] There may still be some secondary and luxury fossil fuel use, for example propane, natural gas, etc. for heating of warm water, fireplaces, barbeques, etc.
[23] It is assumed that all electricity comes from RE sources. In 2010 a slight portion of BC electricity does not come from RE sources. Secondary firewood is not included in these calculations.

11 Conclusions

EE scenario

The EE scenario shows that energy efficiency efforts alone can contribute to moderate GHG emission reductions. Relative to the BAU scenario, these efforts also result in lower direct energy costs. Further analysis regarding the cost of implementing energy efficiency is required to quantify the net value of investing in these efforts.

With respect to energy resiliency, within this study it is measured as the % of local consumption that is covered by local RE production. As such, energy efficiency alone does very little to increase overall energy resiliency because energy efficiency does not result in fuel and technology shifting.

It is recommended to investigate the cost and feasibility of measures that directly or indirectly lead to:

- Accelerating the renovation rate,
- Requiring efficiency improvements during renovations,
- More stringent building codes for new buildings, and
- Reduced supplementary electricity, propane, and natural gas usage.

The CVRD and its administrative areas are best suited to determine the most feasible options for implementing these measures, but potential measures include building codes, information campaigns to inform residents about potential cost outlays and savings, subsidies for renovation work, and zoning regulation with renovation requirements.

RE scenario

The RE scenario is more predicated on market prices, as it is primarily the lowest cost options that are implemented. It is assumed that end-users shift technologies because it is in their financial best interest to do so. There can be substantial capital costs included in these transformations, and as such these changes will not occur overnight, but instead over a running period as heating systems near the end of their product lifetime. If future heating technology options are considered when building new homes and/or undertaking renovations, then the capital costs related to a technology conversion can be greatly reduced. A prime example is air-to-air heat pumps, where a conversion to this technology is considerably less expensive if ducts are already in place.

As such, an additional recommendation is to look into a requirement that new developments must be heat pump ready.

In addition to lack of public awareness regarding the total lifecycle cost of a heating technology, end-users can also be deterred from overall lower costs options due to high upfront costs. Potential tools to deal with these challenges could be information campaigns regarding the expected total life-cycle costs of various technologies, as well as providing information and perhaps assistance for homeowners regarding financing options.

EE+RE scenario

In the combined EE+RE scenario, the reduced energy consumption results in technologies becoming more expensive on a per kWh basis (there is less consumption over which to spread the capital costs). This is particularly a problem for capital-intensive heating technologies (for example district heating), and as such selecting a heat technology should not only be based on current heat demand figures, but also consider the future demand expectations.

Conversely, it will be important to determine the long term strategy for areas where district heat may be feasible so as to not require either efficiency or energy upgrades which may not be cost effective for the end-user, or detrimental to the overall strategy.

The focus should be on the technologies that are cost-effective in all three alternative scenarios. For example, despite their relatively high capital costs, air-to-air heat pumps were amongst the cheapest options in all scenarios, due to their high efficiencies, thus illustrating the robustness of this technology given the cost assumptions used.

Big picture

The completed scenario analysis was undertaken for the CVRD alone, however, it is important to keep in mind that the CVRD is part of a larger energy infrastructure that includes the whole of Vancouver Island, the BC mainland, and beyond, and therefore planning decisions should take into account this bigger picture. A perfect example of this in the scenario work was the decision to not select the MSW CHP option in the RE and EE+RE scenarios despite the fact that it was a cheaper alternative. The reason for doing was that the 'Tri-Regional District Solid Waste Study' had earlier found that a facility serving both the CVRD and the neighbouring CRD and NRD areas would not be optimally placed inside the CVRD (AECOM 2011). This is not to say that the CVRD should not consider the possibility of a MSW plant within its borders (quite the contrary, the CVRD should continue to explore options for its MSW), but a more inter-regional perspective with respect to its optimal placement should be maintained.

It is also important to consider a wider perspective when considering the broader climate effects of changes within the CVRD. For example, reducing the demand for electricity 'imported' from outside the CVRD, either through savings or local RE electricity production, would allow for a greater amount of low CO_2 intensive electricity to be exported (or less imported) from BC to areas that have a higher electricity CO_2 content (Alberta, for example). Seen from a global climate perspective, there is a greater GHG incentive to reduce and/or produce RE electricity locally than is reflected in the current GHG intensity factors for BC electricity.

District heating

District heating from CHP is one of the options highlighted in the RE and EE+RE scenarios due to its high energy efficiency and flexibility. It is important to highlight the fact that actual prices for district heating are extremely site specific, and vary considerably depending on size of the system, number of connections, etc. It is therefore recommended that the CVRD investigate this option further, keeping in mind:

- How will the demand evolve over time as increased energy efficiency reduces loads?
- Are there commercial/industrial/institutional end-users that will be large stable users for a long time to 'anchor' the network?
- What price stability and availability of feedstock can be expected?
- Starting with small pilot projects as opposed to an over-dimensioned system is inherently less risky.

Wind

Based on the wind resource mapping it appears as though there may be areas with pockets of wind with average annual wind speeds high enough to produce electricity at costs around 8-10 cents/kWh. It is important to note that this is based on an initial screening, and local wind conditions are extremely important in refining these costs. If the CVRD is interested in exploring wind resources, it should first be determined whether it is feasible to erect wind turbines in these areas, whether public acceptance is an issue, and most importantly undertake onsite measurements as part of any (pre-) feasibility study. Another factor to consider is the local transmission systems' ability to integrate wind production, and as such consultation with BC Hydro is of course an important part of any (pre-) feasibility study as well.

Model upkeep

Lastly, with respect to the scenario models, in order to maximise their value it is recommended that the CVRD ensure that there is capacity in the CVRD to maintain them. The technology cost model is essentially a technology catalogue that, with periodic updating, and when combined with updated BCAA input data in the energy model, can provide a very dynamic picture and basis for future analysis.

12 References

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13 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	

Notes on scenarios

Industrial users

Large industrial users have not been included in the scenario modelling due to the fact that:

- These figures are not available via BCAA as they are commercially sensitive
- The majority are from pulp and paper mills, which are struggling in the province, thus there is some uncertainty if they will be in operation in 2050.
- While not used in the scenario analysis, we have included estimates of their energy usage. However, because they are only estimates, and the figures are quite large, any deviation will skew the overall figures considerably.