City of Revelstoke
District Energy Expansion Pre-feasibility Study
FINAL REPORT

Prepared as part of the Revelstoke Community Energy and Emissions Plan (CEEP)

Prepared on Behalf of:

City of Revelstoke
John Guenther, Director of Planning
216 Mackenzie Avenue, PO Box 170
Revelstoke, B.C. V0E 2S0

Prepared by:
Compass Resource Management Ltd.
200 – 1260 Hamilton St.
Vancouver, B.C.
V6B 2S8 Canada

Consultant Contact:
Will Cleveland and Taylor Zeeg

CEEP developed in Association with:
thinkBright Environment Innovations
Enerficiency Consulting
Mountain Labyrinths Inc.

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Statement of Limitations

This report has been prepared by Compass Resource Management Ltd (Compass) for the exclusive use and benefit of the City of Revelstoke with respect to the potential expansion of district energy in Revelstoke. This document represents the best professional judgment of Compass Resource Management Ltd. based on the information available at the time of its completion and as appropriate for the scope of work. Services were performed according to normal professional standards in a similar context and for a similar scope of work.

Executive Summary

The City of Revelstoke is evaluating the long-term expansion potential of district energy. The City owns and operates an existing biomass system, which is operated by the Revelstoke Community Energy Corporation (RCEC). Compass Resource Management Ltd. conducted a district energy expansion pre-feasibility study as part of a broader Community Energy and Emissions Plan (CEEP) process. The purpose of the assessment is to identify opportunities for district energy expansion and provide strategic recommendations to guide implementation.

This analysis follows on the 2009 Official Community Plan, which established environmental and broader community goals. District heating has the potential to help Revelstoke accomplish these goals by increasing energy self-reliance, keeping energy dollars in the community, reducing greenhouse gas (GHG) emissions, reinforcing Smart Growth principles, and providing further support for directing development towards existing neighbourhoods.

The analysis is based on the best available population and floorspace projections provided by City of Revelstoke staff. Subsequent analysis of district energy opportunities in Revelstoke should use updated data if available.

For this analysis, we have focused on district heating and excluded district cooling. Due to very small cooling loads in Revelstoke, district cooling is challenging to implement economically. Furthermore, district cooling offers relatively little environmental benefits compared to business as usual (BAU) due to comparable equipment efficiencies.

Single family dwelling and existing buildings are not assessed as part of this analysis. These building types can be technically and economically challenging to connect and are better assessed on a case by case basis. RCEC is actively assessing eligible exiting buildings in the downtown area.

This report is a screening-level assessment to compare various district energy options with BAU. We assess district energy opportunities across 3 neighbourhoods (Highway Corridor, Central & South Revelstoke combined and the Revelstoke Mountain Resort lands) and the combined neighbourhoods over the next 20 years. A favourable screening suggests it is worth proceeding to more detailed analysis that would consider more detailed cost estimates, phasing of infrastructure, financing sources, and other operations and maintenance costs in greater depth.

As this assessment relies on high-level estimates of growth projections, the density and layout of future development is unknown. Because of this, distribution piping system (DPS) costs are excluded from the screening analysis. Instead, we estimate a residual value available from district energy service (the difference between BAU heating costs and district heating costs exclusive of

distribution). We then compare this residual value to a range of typical DPS costs to assess potential viability.

Any future district energy growth in Revelstoke could be implemented by RCEC, through another City entity, a third party, or a shared ownership model. This report examines feasibility and does not consider specific ownership options. System ownership is typically addressed once fundamental viability has been demonstrated.

Key findings of the analysis are summarized below. A summary table of the results is provided below the key findings. Recommendations follow.

- District heating systems may be viable in all scenarios (each neighbourhood separately and all neighbourhoods together). For the lowest-cost options, the residual value for DPS and phasing costs when compared to BAU are potentially large enough for district heating to be competitive. However, this is highly dependent on the density of future development. Concentrated nodes of development with a floor area ratio of at least 1.1 will likely be required to meet the target energy density of at least 800 MWH/hectare.

- Neighbourhood-scale plants likely have lower costs than one large, centralized plant. Link pipe costs to deliver heat to the Resort and Highway Corridor areas are too high to justify connecting these neighbourhoods to a central plant. As well, neighbourhood scale plants are easier to phase and less susceptible to financial risks associated with stranded or underutilized equipment.

- For biomass options, we assess sizing the alternative capacity to 35% or 85% of peak heating demand (85% is consistent with the design of the current RCEC system). Sizing heating-only biomass and biomass combined heat and power (CHP) systems to 35% of peak heating demand provides the lowest cost of heat in expansion areas. At 85% peak sizing, the savings from reduced propane consumption (under current propane price and carbon tax forecasts) are outweighed by the higher capital costs associated with larger biomass systems. The optimal sizing of biomass systems would need to be evaluated during a more detailed feasibility and design phase, taking into account actual load size and mix, phasing, and expected propane prices and carbon taxes or values.

- Significant GHG reductions versus BAU are possible using alternative thermal energy sources. Reductions relative to BAU range from 2,000 to 13,000 tonnes per year for alternative energy sources.

- District energy could reduce electricity consumption relative to BAU within the three screened neighbourhoods by as much as 15,700 MW.h/year. This assumes low rise apartments would otherwise use electric baseboard heating. If hotels would have installed electric baseboard heating, electricity savings from district heating could be even greater. However, ensuring buildings are hydronic will likely require strong policy direction from the City and/or incentives.

Screening Analysis Summary Table

Description	Units	All Neighbourhoods Combined	South and Central	Highway Corridor	Resort
BAU Cost of Heat	$/MW.h	$125 – $150 for all scenarios			
BAU GHG Emissions	t/yr	15,100	6,300	3,100	5,800
Lowest Cost Heat Source	n/a	Biomass CHP Sized to 35%	Biomass Heat Only Sized to 35%	Biomass Heat Only Sized to 35%	Biomass Heat Only Sized to 35%
Levelized cost of heat (excluding DPS, phasing, finance, etc)	$/MW.h	$110	$80	$95	$80
Absolute GHG Emissions	t/yr	5,800	2,700	1,000	2,200
GHG Emission reductions (compared to BAU)[1]	t/y	9,300	3,600	2,100	3,600
Electricity savings compared to BAU[2]	MW.h	15,700	9,500	1,000	5,200
Max node size to meet target energy density of 800 MW.h	ha	n/a	38	15	31
FAR Target	n/a	1.1	1.1	1.1	1.1

Recommended next steps include:

- Where compatible with broader community objectives, direct new development to density nodes in each neighbourhood, with target average FARs of 1.1 or higher within the maximum density node.

[1] Not including GHG emission reductions from RCEC's existing system.
[2] Assuming the alternative energy source is not an open-loop geoexchange system. Also, if the hotels at the Resort and Highway corridor opted for electric space heating, electricity reductions would be an additional 2,000 and 800 MW.h/year respectively (assuming biomass DE is the supply option).

- Develop policy tools to promote district heating development in the Highway Corridor area, potentially including a defined mandatory connection area for new buildings (i.e., a service area bylaw) and target densities.

- Multi-unit residential buildings that would otherwise be electrically heated must be hydronically heated for district energy compatibility. Hydronic conversion is a capital cost premium for developers. BC Hydro is offering developer incentives for hydronic conversion. The City and RCEC should continue discussions with BC Hydro about the applicability of the incentive program to Revelstoke. A mix of City policy tools that promote connection and capital incentives for hydronic conversion would enable greater connection rates, increasing energy self reliance as well as reducing GHG emissions and electricity consumption.

- Initiate discussions with the Revelstoke Mountain Resort about the pace and scale of future development at the Resort, and identify any nodal opportunities for district energy system development.

- Collect information on possible future nodes of development in the Central and South Revelstoke areas, and consider developing policy tools to promote district heating in these neighbourhoods, including mandatory connection policy and density targets (provided this is compatible with other community objectives).

- Work with experienced operators and equipment providers to develop a strategy for using cedar hog as boiler fuel, and explore other biomass fuel source options as required.

- Develop a general policy and an ownership, financing and operating strategy to support cost-effective expansion of district energy in Revelstoke.

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1.0 Introduction

The City of Revelstoke is undergoing a Community Energy and Emissions Planning (CEEP) process, which includes both evaluating a community's energy consumption and greenhouse gas (GHG) emissions and outlining strategies for reducing energy use and emissions. Strategies typically include land use and transportation planning, building-scale efficiency measures, and infrastructure and utility development. The CEEP process is being led by thinkBright, a consulting group with experience in planning and climate change adaptation and mitigation, with support from Compass Resource Management, Mountain Labyrinths and Enerficiency Consulting.

This CEEP process follows on the 2009 Official Community Plan, which established several environmental and broader community goals, including energy conservation, reducing emissions from the community, promoting smart growth principals and a more compact urban form, and promoting infill development in existing neighbourhoods. It also follows from the 1997 Community Energy Plan, which recommended the development of a biomass based district energy system.

As part of the CEEP process, Compass is responsible to complete a pre-feasibility analysis of district energy expansion opportunities in several Revelstoke neighbourhoods, as well as business planning support for Revelstoke's existing district heating system, the Revelstoke Community Energy Corporation (RCEC).

The City of Revelstoke currently owns and operates the RCEC district heating system. Operating since 2005, the system provides heating energy (space heat and domestic hot water) to ten downtown buildings and process steam for Downie Timber's drying kilns. RCEC uses a 1.5 MW biomass boiler for baseload heating needs and a 1.75 MW propane boiler for peaking and backup. The heating plant is adjacent to Downie Timber's mill in central Revelstoke. Downie has committed to a 20 year biomass fuel supply agreement, beginning in 2005. There is currently far more biomass available than RCEC requires.[3]

This pre-feasibility report assesses expansion opportunities for district energy in Revelstoke based on projected floorspace estimates provided by the City. Any future growth in district energy in Revelstoke could be implemented by RCEC, through another City entity, by a third party (with City policy support), or through some sort of joint venture between the City and the private sector. This report examines potential feasibility and does not consider specific ownership options. System ownership is typically addressed once fundamental viability has been demonstrated.

[3] Downie Mill is on interruptible service, so during peak demand periods, energy is supplied first to other customers, with any remaining energy provided to the mill.

2.0 Report Structure

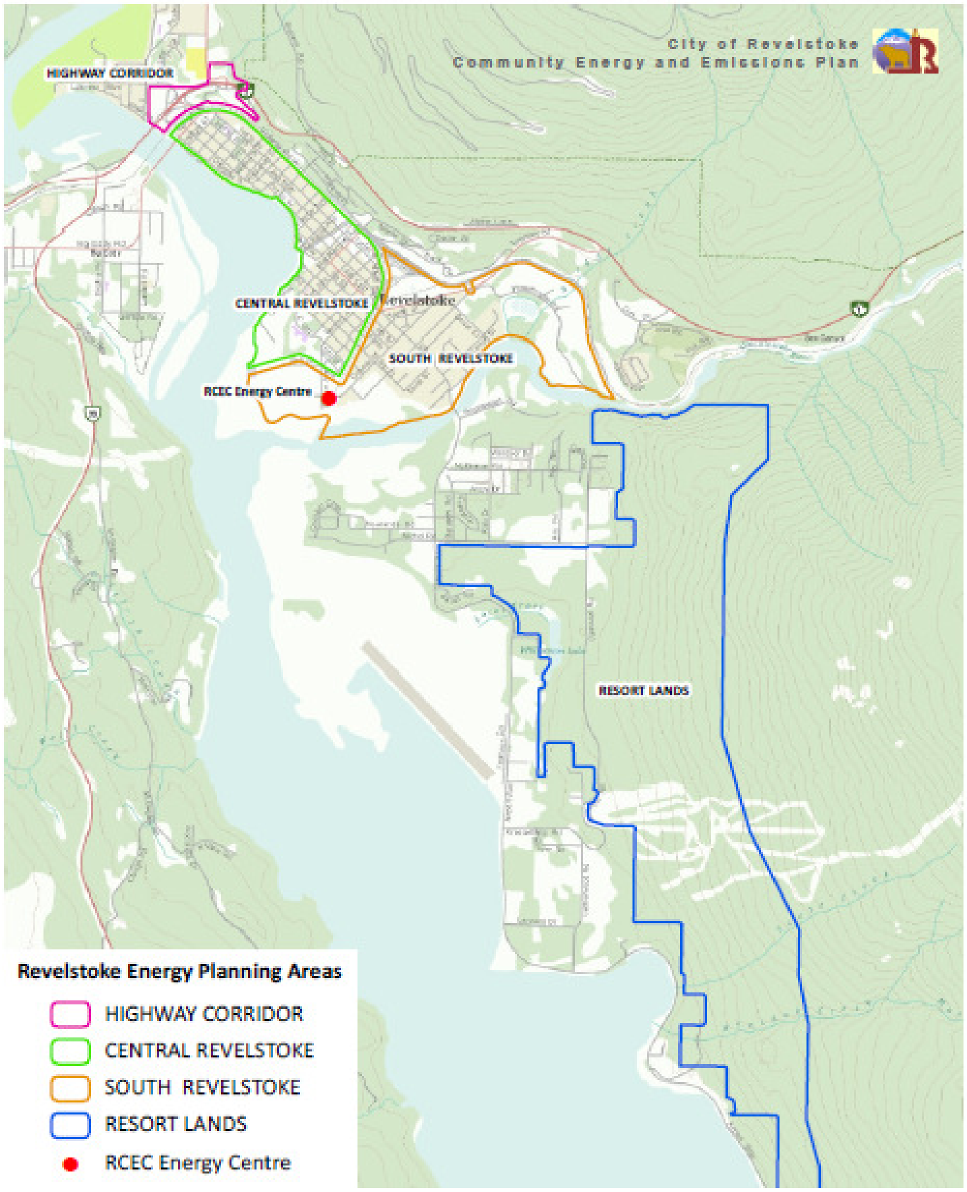
Section 3 of this report describes the study area. Sections 4 and 5 include background information on district heating systems and the rationale for advancing such systems. Section 6 outlines our general approach to the analysis. The heat energy demand forecast is outlined in Section 7. The financial and environmental screening of each option and the effects of density are discussed in section 8. Section 9 provides strategic recommendations.

Details of the heat source analysis for each scenario are included as tables in Appendix A.

3.0 Study Areas

The study area is the City of Revelstoke, with a focus on neighbourhoods identified as likely candidates for significant new development. The neighbourhoods initially assessed are the Highway Corridor, Central Revelstoke, South Revelstoke, Clearview Heights, Arrow Heights, and the Resort area. We then focused on the Highway Corridor, Central and South Revelstoke, and Resort areas due to expected floorspace growth and building compatibility (Figure 1).

Figure 1: Revelstoke Neighbourhood Areas



4.0 Basic District Energy Concept

District energy refers to the central provision of heating and/or cooling. Heating typically encompasses both domestic hot water (DHW) and space heating, which includes heat for suites, common areas and ventilation air. As well, electricity may sometimes be produced as a by-product of district energy through the use of combined heat and power technologies (CHP). The waste heat from the CHP plant is used in the district energy system, while the electricity output may be used on-site and/or sold to BC Hydro under a long term agreement.

There are four main components to a district energy system (Figure 2).

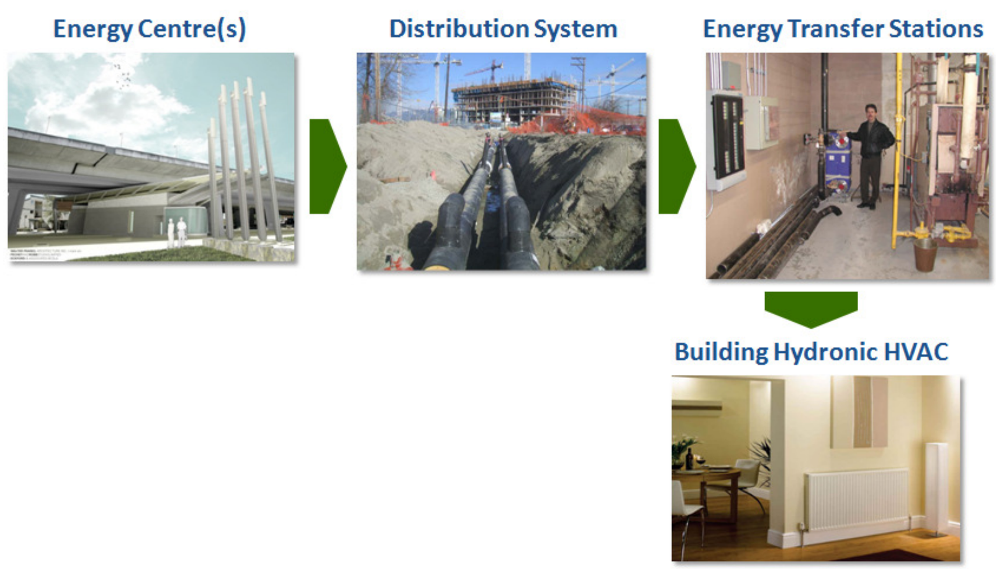
Central energy centre – One or more plants produce all of the heating and/or cooling energy required by customers.

Distribution system – Underground pipes (one supply and one return pipe each for heating and cooling) that distribute hot and cold water to individual buildings.

Energy transfer stations (ETS) - An assemblage of components located on the customer premises that meter and control the heat energy passed between the district energy system and the building.

In-building Hydronic HVAC Systems – To be compatible with district energy, the in-building HVAC system should be hydronic (i.e. thermal energy delivered via water in pipes). Connecting forced air systems is technically possible but at a lower level of efficiency for the district energy system.

Figure 2: Components of a District Energy System



Alternative forms of energy systems can also be implemented on a distributed basis within individual parcels or smaller collections of parcels (i.e. nodes). Although these distributed systems may not be interconnected, they could also be organized under a utility ownership model. The main benefit of such a delivery model is that the upfront capital costs, which tend to be higher for many alternative energy technologies, are absorbed by a utility and recovered over longer terms through rates. An example of the parcel scale distributed model is Sun Rivers near Kamloops, B.C. The utility installed and owns parcel-scale geo-exchange systems and charges residents an access fee for use of the energy system's services. To be compatible with distributed technologies, buildings' internal distribution systems should also be hydronic and meet specific design criteria. As an established utility, RCEC could expand services and develop parcel or nodal scale systems similar to the Sun Rivers model (currently owned by Corix Utilities).

5.0 Rationale for District Energy

From a customer perspective, district energy offers a variety of potential benefits, including:

- Improved quality of service –Hydronic heating and cooling is generally considered more comfortable than other forms of space conditioning. A utility can normally undertake more timely and regular maintenance of equipment than individual building owners.

- Improved environmental performance – Economies of scale and other cost savings from centralization of equipment can facilitate the use of more efficient technologies or technologies consuming alternative fuels for the same or in some cases lower costs than more conventional on-site technologies.

- Reduced risk and increased flexibility – In-building systems put more risk on individual building owners, even if they do not own the actual equipment. Financial and operating risks can be pooled across a larger number of customers in a utility model. Implementation of more efficient and alternative technologies can further reduce customer exposure to fluctuating fuel prices. Hydronic heating and cooling systems are also more adaptable to new technologies over time. A centralized utility will also typically have a higher level of design and operating standards, and ongoing professional management of systems.

- Reduced first costs / lifecycle costs – Centralization of equipment also offers possible cost savings through reduced equipment requirements (due to load diversification),[4] economies of scale in equipment costs, and savings in operating costs from more efficient equipment and optimized operations. A utility model helps to overcome the barrier associated with many sustainable technologies that have higher costs by eliminating the need for consumers to purchase equipment upfront. And a utility delivery model also offers the potential for lower financing rates and longer amortization periods for capital compared with consumer financing. These potential cost savings, however, must be weighed against any additional costs associated with centralization or creation of a utility, such as the cost of the neighbourhood heat distribution system and the

[4] Load diversification refers to the fact that the peak demand in different buildings will typically occur at slightly different times. As a result, the peak demand on the central system will typically be lower than the sum of the peak demands for individual buildings.

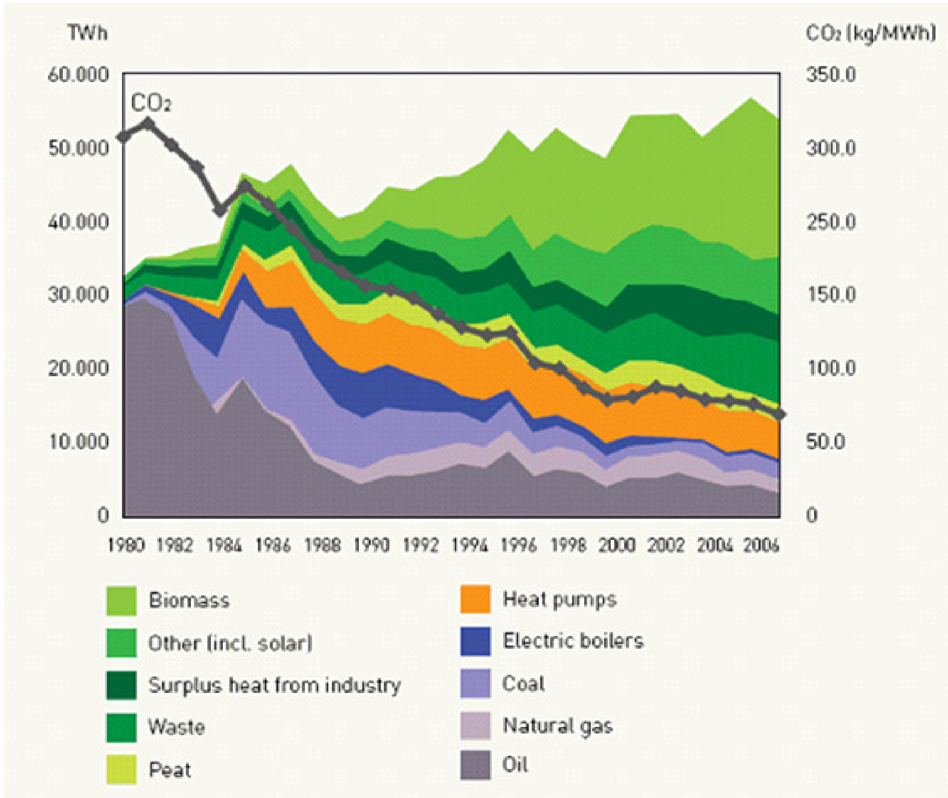
additional costs of management and administration for a utility (as well as any real or perceived incremental costs associated with hydronic heat distribution systems within buildings). In addition, some of the cost savings associated with centralization is often used in part to invest in more costly but environmentally-friendly forms of heat production.

For new district energy systems, the costs may be equal to or possibly slightly higher than conventional systems. A premium can be justified by the higher comfort, better service (including lower but difficult to quantify onsite maintenance costs), lower environmental impacts and reduced risk.

There are other benefits to district energy from a municipal perspective. District energy infrastructure is simple while providing a flexible platform for the adoption of new technologies and fuels within a community over time. The system also provides a platform for sharing the risks and benefits of adopting new technologies. It is more difficult to adopt new technologies and fuel sources (or take advantage of the economies of scale associated with larger installation or sources not located within individual building sites) when heating systems are located within individual buildings (particularly when those systems are of very different vintages and dispersed across many different owners).

The Swedish experience illustrates the potential flexibility of centralized systems (Figure 3). Since the 1980s, the penetration of district energy has almost doubled so that nearly 50% of the building area in Sweden is now supplied with district energy. Over this same period, district energy systems in Sweden have transitioned from relying almost entirely on imported fuel oil to relying on a diverse mix of resources, including biomass, refuse and waste heat. In between, there were periods in which coal and electricity were more dominant sources of heat. It is unlikely such a large and relatively rapid switch in fuels and technologies would have been possible if buildings had been heated by thousands of smaller plants. Also note the inverse relationship between district energy growth and GHG reductions in the chart below.

Figure 3: Swedish District Energy Fuel Sources (1980 – 2006)



Source: Bizcat Consulting

Mature district energy systems also offer an alternative revenue source to municipalities, either through direct ownership or municipal taxation of assets, particularly where the costs of district heat are less than alternatives. In addition, greater reliance on local resources can create local jobs and stimulate more local economic activity.

6.0 General Methodology and Assumptions for Screening

The screening consisted of the following steps:

- Estimate expected thermal energy demands from new buildings within each neighbourhood over the next 10 and 20 years.
- Estimate the likely optimal sizing of a central heating energy system to serve new and existing loads.
- Identify candidate alternative heating energy sources at the existing RCEC plant and/or in each neighbourhood to meet the target supply.

- Estimate the levelized cost of supply for each candidate alternative thermal energy source and compare to business as usual supply costs.[5]
- Estimate the remaining margin between the business as usual cost and the cost of centralized energy sources, if any. This is the amount available to pay for DPS, phasing, and other costs associated with district energy. Where the margin is small, centralized energy sources are unlikely to be viable without grants or other subsidies to offset capital and/or operating costs.
- Estimate electricity and GHG emission reductions.

6.1 Demand forecast assumptions

The study focuses on three high growth neighbourhoods identified by the City of Revelstoke. Growth assumptions were developed based on the City of Revelstoke's 2009 Transportation Study with input from the Planning department.

The Transportation Study states a total (permanent plus seasonal) buildout population of 27,250 by 2060. This expected growth is fairly close to the current OCP Low Scenario. However, at 4.2%/year[6] it is high with respect to current market conditions. Floorspace estimates were based on population projections and provided by the Planning department.

Growth is treated as linear from 2010 to 2060, and is apportioned between neighbourhoods based on expected development patterns. As these projections are based on best available information from the City Planning Department in September, 2010, any future changes in expected population growth or construction growth will affect the outputs of this analysis. Future policy decisions should reflect any updates to these projections.

Projected new commercial, institutional, industrial, and multi-unit residential buildings within each neighbourhood were included in our analysis. Given that single family dwellings (SFD) have small, dispersed loads, they are rarely economical to connect to district heating systems, and these loads have not been included in this analysis. However, recommendations to further assess the viability of connecting SFDs are in the CEEP.

Existing buildings are also not included in this analysis as they can be challenging to connect cost-effectively. Not all buildings have heating systems that are compatible with district energy. When they do, connection typically needs to be timed with the replacement of an existing boiler. As well, existing buildings which are good candidates for connection have relatively small loads compared to the potential heating energy loads from new development. This is not to suggest that existing loads should not be considered in future expansion plans, only that new growth is more likely to drive expansion followed by connection of existing loads on an

[5] Levelized refers to calculating the average life cycle costs of a generation alternative taking into account the time value of money (i.e. discount rate).
[6] Simple growth, not compounding.

opportunistic basis. Existing buildings which may be short-term candidates for connection to RCEC are shown in Figure 4. To connect existing buildings, RCEC will need additional capacity at the energy centre and possibly within its DPS.

Floorspace estimates for each neighbourhood are provided in the Demand Forecast part of the report (Section 7.0).

Figure 4: RCEC and Potential New Loads

Note: The Revelstoke Secondary and Elementary schools are being decommissioned and replaced with new facilities which will also be connected to the system after 2012.

Energy use intensity factors (EUIs) for each building typology are applied to floorspace estimates to calculate annual and peak heating requirements. In addition to space heat and domestic hot water (DHW) demand, cooling demand was also calculated but was not considered in the screening of district heating concepts. The annual cooling requirement in Revelstoke is very low relative to heating so it likely is difficult to recover the large capital investment required to provide a centralized cooling service. Further, the amount of electricity used to produce a given level of cooling is typically much lower than the amount of gas or electricity used to produce a similar level of heating due to onsite cooling equipment efficiency, so the environmental benefits of alternate cooling systems are proportionately lower. Finally, cooling demand can often be offset more cost-effectively through passive design elements (e.g., shading strategies, and natural ventilation), particularly in low- to mid-rise buildings. EUIs are shown in Table 1.

Table 1: Revelstoke New Construction EUIs

	Annual Space Heat kW.h/m2	Annual DHW kW.h/m2	Peak Heating W/m2	Annual Cooling kW.h/m2	Peak Cooling W/m2
Commercial	103	9	59	49	106
Hotel[7]	56	66	44	58	102
Multi-family residential	97	30	41	16	56

EUIs represent the annual heat energy load (kW.h/m2) and peak heating demand (W/m2) requirements of each building typology within a study area. EUIs are based on typical building practices and requirements under the current BC Building Code, previous Revelstoke district energy studies, and the BC Hydro Conservative Potential Review. We have assumed a constant efficiency standard over the 20 years. This is a reasonable screening assumption given the BC Building Code is relatively new and change has been very slow. Further, there is typically a lag between actual practices and the building code, and this lag can be significant in the absence of good enforcement.

6.2 Sizing of Alternate Energy System

For each neighbourhood, we identified an optimal target capacity for an alternative energy system under the full build out energy loads in 20 years. The capacity required in a district energy system is typically smaller than the collective capacity of individual (parcel-scale) systems because of the benefits of diversification across sites and types of loads. For the purposes of this analysis, we assume an 88% diversity factor[8].

In addition to the total capacity required for district energy, we also needed to make an assumption about the optimal size of an alternative energy module. Heating loads are very peaky. That means that peak heating demands occur in relatively few hours

[7] Hotel DHW EUI from BC Hydro 2007 Conservation Potential Review (Interior Hotel).
[8] This is consistent with RCEC's current diversification factor for existing operations.

of the year. Alternative energy capacity is relatively costly. As a result, it is typically best to size the alternative energy module below the peak heating demand and use propane boilers for peaking. These peaking boilers serve a dual function in that they also provide back-up in the event the alternative energy capacity is unavailable. Back-up is critical for meeting reliability objectives as well. Typically, an alternative energy system sized to between 30 and 50% of the peak heating demand will still meet 60 to 80% of the annual heat energy load, providing significant environmental benefits while offering a higher likelihood of economic viability.

We selected a target size for each technology and neighbourhood based on the specific characteristics of neighbourhood loads and technologies under consideration. Given the availability of free biomass fuel currently, RCEC's existing alternative energy system (a biomass boiler) is sized for 88% of peak heating demand. For biomass and biomass CHP options, we compare a range of alternative energy capacities to test the effects of free fuel and higher capital costs.

Peak loads and backup capacity are typically met with conventional boilers. Given the high-level nature of this analysis, we assume that all screened energy sources would include propane boilers sized to 125% of diversified peak demand to account for backup needs. A full feasibility analysis for an expanded district energy system may include actual equipment sizes, which would allow detailed sizing of backup equipment.

6.3 Alternative energy comparison and BAU

Alternative energy sources were compared to business as usual (BAU) on a levelized life cycle cost basis. The levelized life cycle cost is the full cost of generating thermal energy (annualized capital + fuel + non-fuel operating costs) on a per MW.h basis taking into account equipment life, the carrying costs of capital (financing), long-term fuel price, and average maintenance costs. . This is how utilities like BC Hydro compare generation alternatives. The main benefit of levelized costs is that allows a fair comparison of generation technologies with different life spans and annual energy outputs.

Alternative energy system costs are based on data from a variety of full feasibility district heating assessments in British Columbia. Additional information on biomass CHP equipment was provided by Wellons Canada. Cost estimates for ground-water heat pump systems and resource capacity were provided by Hemmera.

Business as usual costs will differ depending on whether potential customers are multi-unit residential buildings (MURBs) or non-residential buildings.

In multi-unit residential buildings (MURBs), BAU space heating is a mix of electric baseboard heating (in suites) and propane DHW and ventilation air. The space heating ventilation is provided by a propane-fired make-up air unit (MAU). The MAU provides heating to the corridors and ventilates the individual suites by pressurizing the corridors and forcing air flow through the suites. In a recent study completed by

RDH Engineering that examined 38 actual multi-unit residential buildings in the lower mainland area of B.C. it was found that the MAU accounts for 35-70% of a buildings space heating load. The warm air from pressurized corridors enters the suite under apartment doors. We assume the MAU will meet 50% of the space heating load under the business as usual scenario. The rest of the space heating load in MURBs is met with electric baseboard heaters. For non-residential floorspace, we assume propane heating for all space heating, DHW and ventilation.[9]

BAU capital cost estimates for non-residential buildings are based on term sheets for buildings recently connected to the RCEC system. For multi-family residential buildings, capital cost estimates are based on studies recently completed in the lower mainland of a similar equipment mix. Capital costs are annualized at a real customer discount rate of 10% and converted to a $/MW.h basis for ease of comparison.

BAU maintenance costs are calculated at 20% of capital. Maintenance costs are based on term sheets for recent RCEC connections.

Fuel costs for business-as-usual are a mix of propane for DHW, ventilation and space heating and electricity for in suite space heating in MURBs. We assume a lifetime efficiency of 75% for new propane boilers. All fuel prices are based on forecasted prices and levelized at a customer discount rate of 10%.

Table 2: BAU Costs ($/MW.h of heating)

BAU Cost	Non-residential	Multi-family Residential
Capital	$42	$27
Non-fuel O&M (20% of capital)	$8	$6
Fuel	$100	$92*
Total	**$150**	**$125**

*Assumes an overall 40/60 blend of electricity and propane for all heating loads (space heat, ventilation, DHW). Electricity would account for approximately 50% of the space heating load.

The BAU costs for each neighbourhood is a blend of avoided costs, based on the proportion of residential and non-residential floorspace for each neighbourhood.

6.4 Fuel prices

For the fuel price assumptions, we use levelized fuel prices (Table 3). Levelized fuel prices are a forecast of future fuel prices converted to an equivalent constant annual price assuming a given discount rate.[10]

[9] Hotels are considered commercial in this study. Resort condos could opt for electric baseboard but to date the hotel condos at the resort have installed propane heating systems.

[10] For BAU electricity prices we assume a 10% real customer discount rate. For fuel prices that apply to

Electricity prices are based on BC Hydro's recent electricity price forecast. A blended Residential Inclining Block is applied to electric baseboard heaters. We assume 80% of the in suite heating load is at the Step 1 rate and 20% at the Step 2 rate based on a MURB energy consumption analysis Compass completed for another client.

The new Large General Service rate is applied to electricity used by heat pumps. This is an inclining block rate, so we have used a blended rate based on a sample monthly profile. The carbon tax is internalized in all electricity prices.

The BC Hydro purchase price is applied to the electricity sales from the biomass combined heat and power (CHP) option. A CHP facility in Revelstoke could sell power under the recent Community-based Biomass Call. The biomass call is underway and, as a competitive process, no definitive price is established, but there is an upper-bound of $150 per MW.h. The average price from BC Hydro's most recent clean power call was $120, so we used these two values as upper and lower-bound estimates for electricity sales prices.

Propane costs are based on the US Energy Information Administration's Annual Energy Outlook price forecast. Delivery and midstream costs are assumed to remain flat in real terms. The levelized prices below include commodity, delivery and the B.C. carbon tax.

Considerable amounts of biomass are available through the Downie Mill. We have estimated the amount of biomass currently available on-site at Downie at approximately 11,000 bone dry tonnes[11], and have assumed a price of $55/bdt ($10/MW.h) for all additional biomass. For context, the current RCEC system uses approximately 2,000 bdt/year.

district energy options, we assume a 6% real discount rate (8% nominal).

[11] This is in addition to the biomass currently used by the existing RCEC heat plant. It does not include red cedar bark, which has been found to clog the fuel loading mechanism. CHP plant operators at another BC mill reported similar issues with cedar bark.

Table 3: Levelized Fuel Prices

Fuel	Unit	Levelized Unit Price
Propane		
Rate 2 Gas Burner Tip	$ / MW.h	$71
Rate 3 Gas Burner Tip	$ / MW.h	$73
Electricity		
Blended Residential Inclining Block	$ / MW.h	$81
Large General Service	$ / MW.h	$72
Standing Offer	$ / MW.h	$120 – $150
Biomass	$ / MW.h	$0 – $10

6.5 Biomass supply

The security of biomass fuel supply arises often in discussion with City staff, stakeholders and potential customers. Energy customers will generally expect certainty of price and certainty of supply. Real or perceived concerns about biomass fuel supply influences customer confidence in RCEC services.

The most convenient biomass supply for RCEC's system is residue generated at Downie's mill. The current estimated residue supply from Downie is 45,000 green tonnes per year or 22,500 bone dry tonnes (bdt) assuming 50% moisture content (Table 4).[12]

Table 4: Downie Residue Mix

	Residue Mix	Bone Dry Tonnes (bdt)
Hog	50%	11,300
Sawdust	25%	5,600
Shavings	25%	5,600
Total	100%	22,500

RCEC is currently using an estimated 2,000 bdt of sawdust per year. Downie is under contract to provide up to 10,000 green tonnes (5,000 bdt) of fuel to the RCEC plant

[12] Based on a high heating value of 5.5 MW.h per bone dry tonne, 22,500 bone dry tonnes is equivalent to approximately 124,000 MW.h of biomass fuel. Common estimates for the heating value of wood residue range from 5.4 to 5.6 MWh per bone dry tonne. Western red cedar, which makes up much of the volume at Downie, has a higher heating value, making this estimate conservative.

at no cost through 2025. There is currently enough sawdust available at Downie to meet more than double RCEC's entire annual biomass demand.

Wood shavings from Downie are another source of readily available biomass fuel. However, to use shavings the operator needs to adjust the biomass combustor's air flow, a relatively easy adjustment.

The Downie cedar hog fuel is currently not an option. There are operational challenges with getting the hog into the combustion chamber. The cedar hog is stringy and clogs the feed mechanism. Most mills which have successfully used cedar bark as fuel have used it in a mixture with other bark types. Downie has recently been processing 60 – 100% red cedar, with red cedar often making up 100% of the mill's volume, so a fuel mixture may not always be possible. Grinding the cedar bark a second time may make it more useable – the Tolko mill in Armstrong, BC has used this approach to include cedar bark in the facility's fuel mix.[13]

Beyond Downie, there are other possible sources of biomass in the region. The Revelstoke Community Forest Corporation (RCFC), a municipally-owned forest company, manages TFL 56 north of Revelstoke. The annual allowable cut is approximately 100,000 m^3 with typical recent cuts of ~60,000 m^3 per year. Western Red Cedar trees provide the most valuable logs on TFL 56, but the harvest also includes significant amounts of hemlock and balsam trees, which are less suitable for milling and are often sold for pulp to the Celgar mill in Castlegar. Celgar chips the logs and converts all but the tree bark into pulp. Depending on Celgar's opportunity costs, the bark chips could be sold back to RCEC as fuel for the biomass system in the event of a shortage from Downie. The City, RCEC or a private interest could also chip the logs in Revelstoke, sell the pulp stock to Celgar and keep the bark chips for RCEC's biomass system. Such a scheme would involve additional capital and some risk. Considering the hemlock bark is a backup option, buying the chips back from Celgar in the unlikely event of a Downie supply shortage is likely the more feasible option.

Hemlock and balsam pulp logs make up ~30-40% of the logs harvested from TFL 56.[14] Estimating the amount of potential residue is difficult, but based on a conservative estimate of 15% bark, roughly 2,500-3,300 m^3 could be available annually to RCEC.[15] This is equivalent to 1,300 – 1,700 bdt/year, or 65-85% of RCEC's current biomass consumption. [16]

In addition to harvesting from RCFC north of Revelstoke, 230,000 m^3 are harvested from the Revelstoke Timber Supply Area, by Downie, Stella Jones, BC Timber Sales and Joe Kozek Sawmill, as well as 90,000 m^3 from TFL 55, owned by Louisiana Pacific Canada. This wood would have to be debarked and chipped at an additional cost.

[13] Staff at Tolko emphasized that they avoid using cedar bark whenever possible. Ben Van Ryan, personal communication.
[14] RCFC Annual Report 2009.
[15] 15% bark and other residue by weight provided as a low-end estimate by Ron Racine of Trace Resources. Final bark volume estimates based on above values from RCFC Annual Report 2009.
[16] There may be hemlock bark available from other forestry operations in the area.

Assuming 30% of the harvest is hemlock and balsam, an additional 320,000 m^3 could be available.

There are also significant amounts of slash generated by forestry operations in the area. In 2009, RCFC disposed of slash on 269 hectares of harvested land, much of it through burning.[17] No survey of available slash has been undertaken, but it likely represents a significant source of biomass. In smaller operations, the cost of gathering the slash typically makes it prohibitive. In Sweden, slash from forestry operations is regularly collected for use in biomass plants but for operations at much larger scales.

Another possible source is the tenure south of Revelstoke, on the west side of the River and beyond Nakusp within TFL 23. This license is managed by Interfor, though is not active right now. The amount of hemlock on this tenure is unclear at this point.

Lastly, RCEC suggested Joe Kozek Sawmills, Stella-Jones pole yard, and the Revelstoke landfill could be a local source of an additional 4,000 bdt /year at a cost to RCEC.

6.6 Greenhouse Gas Emissions

Environmental evaluation consisted of comparing the GHG emissions of each alternative heat source to business as usual. Each alternative option consists of a mix of alternative energy capacity and gas or propane boilers for peaking and backup. Heat pumps require an electricity input and therefore have a GHG impact. Biomass is GHG neutral. The GHG emission factors for BC Hydro electricity and propane are 22 kg/MW.h and 215 kg/MW.h, respectively. For biomass-fired CHP, there is a GHG emission credit for avoiding the emissions associated with typical electricity production in BC.[18]

For BAU GHG calculations we assumed propane for all non-residential space heating and domestic hot water. For residential we assume propane for 50% of space heating and 100% of DHW.

6.7 Residual Value Analysis

The life cycle cost of each alternative energy option was subtracted from the BAU life cycle cost to determine a residual value, or the amount left over to cover other costs associated with a district heating system. Examples of additional district energy costs include DPS, property taxes, effects of financing, and depreciation[19].

[17] RCFC Annual Report 2009.

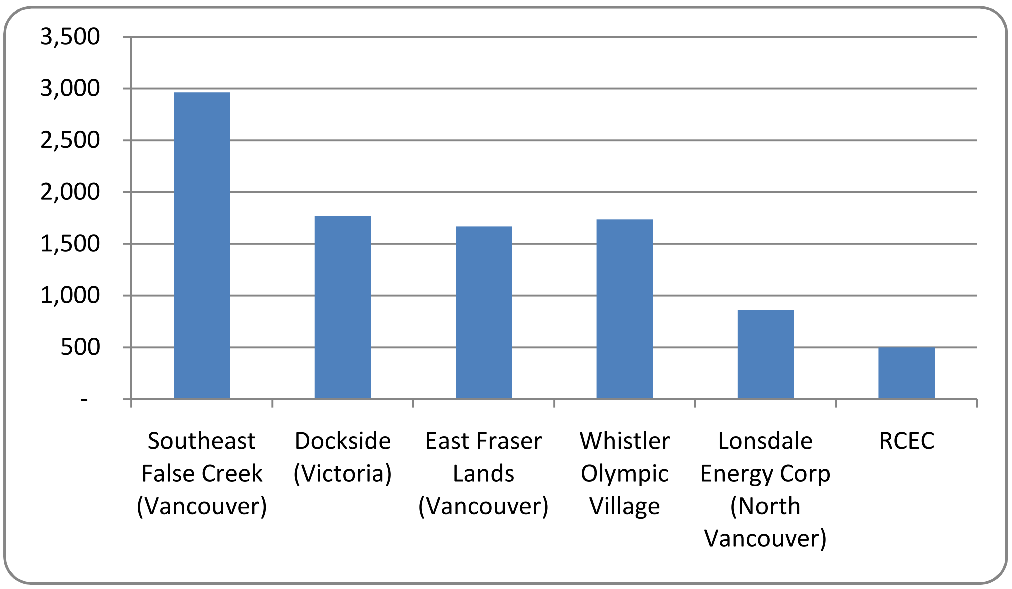
[18] It should be noted that in the Standing Offer and Clean Power Call, BC Hydro retains ownership of all environmental attributes. The Biomass Call appears to be similar, though the wording is not as clear as previous calls.

[19] Life cycle costs include energy transfer station costs.

Of these costs, DPS is the largest, and typically makes up 5 – 12% of total costs for a hot water district heating system. Variations in DPS costs are largely driven by a project's energy density, which is one of the key factors that effects district heating viability. Energy density in this case refers to the total annual heat energy load for an area divided by the land area hectares, or MW.h/ha. Energy densities for several existing and proposed district energy systems are shown in Figure 5.

Energy density is just one indicator of potential viability. BAU heating costs, the rate of development, and the cost of available heat sources are also important factors to assess.

Figure 5: Heat Energy Density (MW.h / ha)



For this district energy expansion pre-feasibility analysis, the specific development patterns in each scenario are unknown. If development is evenly dispersed throughout each assessed area, energy densities will be extremely low and system viability is highly unlikely. To give a sense for the density required for a district heating system, we have estimated how densely new development must be clustered in each scenario to achieve an energy density of 800 MW.h per ha, which is equivalent to North Vancouver's LEC energy density. We would suggest the current RCEC density is an absolute minimum and suggest an energy density target of at least 800 MW.h/ha.

While an energy density within this range does not guarantee system viability, it is comparable to some other systems in B.C. and illustrates the interplay between land use regulation and district heating. Revelstoke may be able to absorb a slightly lower density than other communities that have lower heating costs (mild climate and access to lower cost natural gas) and do not have access to low-cost biomass fuels. Promoting future district energy nodes may require policies to encourage density in areas other than the downtown core, which complements the OCP goals of promoting Smart Growth principles and infill development.

DPS costs and energy density will be discussed in more detail in scenarios 2, 3 and 4.

7.0 Energy Demand Forecast

Future development projections were provided for six areas in the City of Revelstoke:

- Central Revelstoke
- South Revelstoke
- Highway Corridor
- Arrow Heights
- Clearview Heights
- the Resort area

The Arrow Heights neighbourhood is anticipated to have significant growth in coming decades, but these buildings will be primarily or entirely single family dwellings and have been excluded from this analysis. No significant growth is anticipated in Clearview Heights over the next 20 years, so that area was also not included in the study.

New floorspace estimates for each study area are shown in Table 6 and Table 7[20]. Floorspace estimates for 2030 are cumulative (i.e. include 2020 amounts). Due to the long-term nature of the transportation study, we have focused on this longer-term growth forecast. New floorspace growth trends are shown in

Figure 6. For reference, excluding SFDs there is currently approximately 380,000 m2 of floor space (total) in Revelstoke as shown in Table 5.

Table 5: Existing Development, 2010 [m2]

	MURB	Hotel	Industrial	Commercial	Restaurant	Total
All Revelstoke	245,000	44,000	34,400	54,000	1,700	380,000

[20] New institutional space is included in the Commercial column.

Table 6: Cumulative New Development to 2020 [m2]

	MURB	Hotel	Industrial	Commercial	Restaurant	Total
Resort	53,500	34,500	7,500	5,600		101,100
Central and South	87,900	1,300	4,700	13,000	100	111,600
Highway Corridor	20,400	13,800		25,500	600	60,200
Total	**161,700**	**49,600**	**12,200**	**44,000**	**700**	**272,900**

Table 7: Cumulative New Development to 2030 [m2]

	MURB	Hotel	Industrial	Commercial	Restaurant	Total
Resort	106,900	69,000	15,100	12,100		203,100
Central and South	196,100	2,600	9,300	39,000	200	247,300
Highway Corridor	20,400	27,600		50,900	1,100	100,000
Total	**323,400**	**99,200**	**24,400**	**102,000**	**1,400**	**550,400**

Figure 6: Cumulative New Non-SFD Floorspace 2010-2030 (m2)

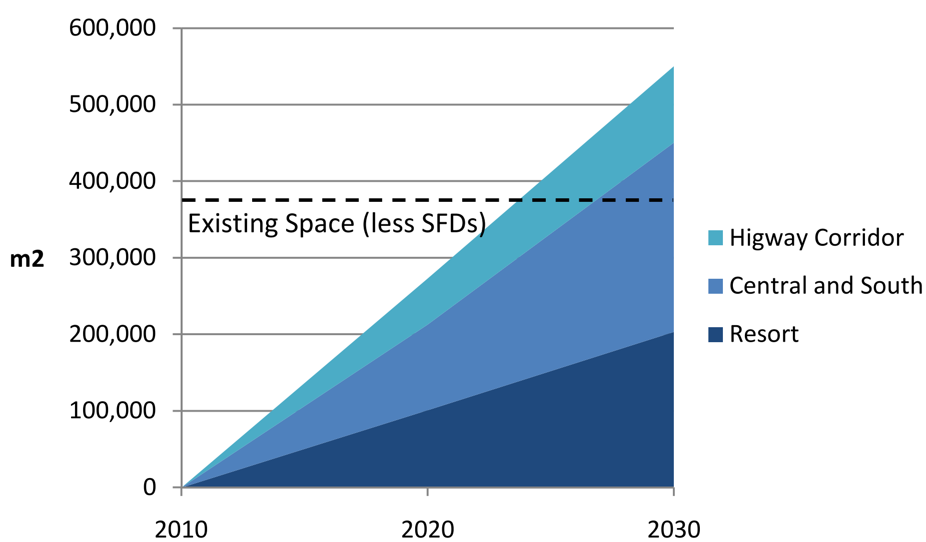


Table 8 summarizes the new building heating energy demand forecast for each neighbourhood based on the new floorspace projections above. The commercial EUI is used for commercial, hotel, industrial, restaurant, and institutional space. Peak heating demand estimates are non-diversified demands. For screening purposes, we assume the peak heating demand for district energy is approximately 88% of the non-diversified peak.

Table 8: Heating Energy Loads

Neighbourhood	Annual Heating Load MW.h	Diversified Peak Heat Demand MW
2020		
Resort	12,400	4.5
Central and South	13,800	5.0
Highway Corridor	7,200	3.0
2030		
Resort	25,000	9.1
Central and South	30,600	11.1
Highway Corridor	11,700	5.2

For comparison, the existing RCEC system has annual loads of ~11,000 MWh.

8.0 District Energy Opportunities

We assessed 4 scenarios - a base case and three alternative cases for future district heating projects in Revelstoke. The base case is a single centralized district heating system that serves all 3 neighbourhoods, including: Central / South Revelstoke combined, the Highway Corridor, and the Resort. The three alternative cases are for separate smaller district heating systems in Central and South Revelstoke; the Highway Corridor; and the Resort area. Examining these three nodal scenarios with the base case allows a high-level comparison of the costs and benefits of linking the Highway Corridor and Resort areas to a downtown energy centre. It also demonstrates the costs associated with various sizes of district heating systems. The screening thus provides the City with a number of benchmarks for implementing district heating given unknown future conditions.

We scanned these four neighbourhoods and surrounding areas for potential alternative energy heat sources that meet a minimum target capacity. We sought alternative energy heat sources that could satisfy a target of 65% of the annual heating requirements for the site. Typically, this target can be achieved with an alternative energy capacity of approximately one-third of the diversified peak heating demand for the site. For biomass options, we have also assessed larger alternative energy plants because of the availability of free fuel.

Potential heat sources for all areas and scenarios include centralized propane boilers, heating-only biomass, biomass combined heat and power, and open-loop geo-exchange (GWHP). Combined heat and power (CHP) options are assessed based on a heat load-following configuration rather than an electrical output maximizing configuration. Screened heat sources are shown in Table 9. The assumptions associated with each heat source are included in Appendix A (e.g. equipment efficiency, electrical output, fuel consumption, etc). Hemmera conducted a high-level assessment of geoexchange opportunities in Revelstoke, included in Appendix B. Please note that Hemmera's costs are for geoexchange fields only, and do not include heat pumps and link pipes.

Table 9: Heat Sources

Heat Source	Size / Peak Demand	Status
Centralized Propane	125% (with redundancy)	Assessed
Thermal-Only Biomass	35%	Assessed
Biomass CHP	35%	Assessed
Thermal-Only Biomass	85%	Assessed
Biomass CHP	85%	Assessed
Open Loop Geoexchange	35%	Assessed
Closed Loop Geoexchange	35%	Screened out
Sewer Heat	35%	Screened out

We did not do a detailed assessment of closed-loop geo-exchange. Closed loop geo-exchange is more expensive than open loop and will typically only be competitive with other district technologies when there are large cooling loads in buildings. The large cooling loads allow greater utilization of the geo-exchange equipment (thus greater ability to recover high capital costs). Cooling loads in Revelstoke are very low. Our approach is to screen open loop geo-exchange first, and if technically feasible and ranks highest among options, pursue that option. Where open loop geo-exchange does not rank well, a closed loop system will also be unattractive. Sewer heat was also screened out in all neighbourhoods as Revelstoke's small population means the total amount of available heat from sewage for the whole community, even under ideal conditions, would provide on the order of 1 MW of heat or less, which is too small for the scenarios considered.

Centralized propane boilers are sized to meet the full peak heating demand plus redundancy, and are included to show another reference point for comparing alternative energy systems. Biomass and biomass CHP systems are shown for the base case and each scenario in two configurations: sized to 85% of peak demand, which roughly corresponds to RCEC's current configuration, and sized to 35% of peak demand, which is a more typical assumption for alternative energy systems where there is a cost for biomass fuel. The two configurations are shown to allow comparison between both costs and GHG benefits for each approach. Open-loop geo-exchange systems for the base case and all scenarios are sized to 35% of peak diversified heating demand.

Life cycle costs include energy centre mechanical equipment, energy transfer stations, fuel, operations and maintenance. They do not include DPS, phasing costs, and other utility costs such as land rental or property taxes. The details for these calculations are provided in Appendix A.

8.1 Scenario 1 – Base Case

The Base Case includes new floorspace[21] for all four selected neighbourhoods, with allowances for link pipes to supply heating energy from the current RCEC energy centre[22] to the two outlying neighbourhoods – the Resort area and the Highway Corridor. Link pipe costs are based on a representative pipe cost of $1,600 per trench meter including installation, and a direct route via city streets. Costs were provided by RCEC. For the pipe to the Resort area, no extra allowance is included for a bridge over the Illecillewaet River, so this cost should be considered a lower bound.

The base case is the largest scenario, with peak diversified loads of 22.2 MW and 67,300 MW.h of annual heat energy load by 2030. The life cycle costs of the candidate heat sources for the Base Case are summarized in Table 10. Biomass and biomass CHP levelized costs are presented for equipment sized to 35% of peak demand and 85% of peak demand. Biomass CHP results are given for a range of electricity purchase prices.

Table 10: Base Case Levelized Energy Costs[23]

Energy Source	Centralized Propane	Biomass Heat Only	Biomass CHP $120/MW.h electricity price	Biomass CHP $150/MW.h electricity price	Open GX
Biomass sized at 35% of peak demand	$140	$110	$110	$110[24]	$150
Biomass sized at 85% of peak demand	n/a	$130	$145	$140	n/a

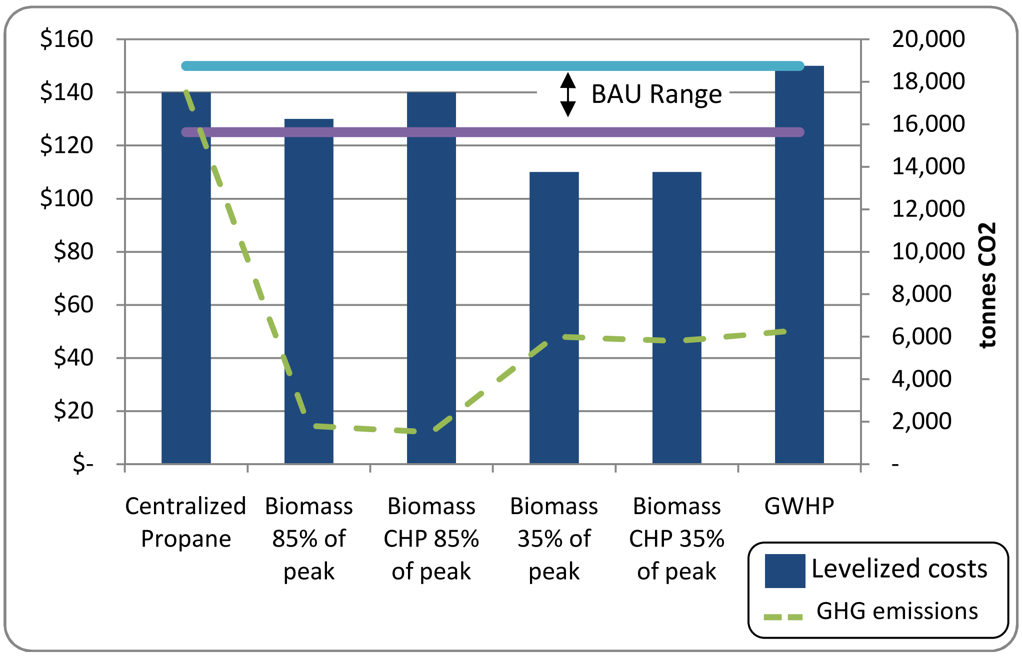
Costs for biomass and biomass CHP systems sized to 35% of peak demand are significantly lower, indicating that for the larger scenario (85% biomass baseload), the free biomass fuel does not offset the higher capital costs of the larger system. For the heating-only biomass and biomass CHP systems sized to 85% of peak demand, total biomass fuel costs are only $7 - $9 of overall levelized energy costs[25],

[21] Not including single family dwellings.
[22] The current energy centre was selected as an indicative location.
[23] Given this is a screening exercise, all levelized costs are rounded to the nearest $5. These costs include link pipes to the Highway Corridor and Resort; without these pipes, levelized costs would be $25 per MWh lower for all technologies.
[24] The cost at $120 appears equal to the cost at $150 because of rounding.
[25] Biomass fuel costs are calculated assuming 50,000 MW.h of free biomass is available, with all

so even if additional free biomass were available, these systems would still have higher life cycle costs than if they were sized to 35% of peak heating demand. The main reason is that the additional 50% of capacity only delivers an additional ~20% of annual energy.

Figure 7 shows the levelized costs for each supply scenario, as well as the GHG emissions associated with each option. For CHP options, the higher electricity purchase price of $150 is assumed, so this comparison should be considered a ‘best case’ for each CHP option.

Figure 7: Base Case Levelized Costs, Residual Value, and GHG Emissions



The dark blue bars represent the LCC of generating heating energy for space heat and DHW and providing energy transfer stations. For district heating to be viable in the absence of subsidies the alternative options need to be lower than the BAU cost of energy (to allow for DPS and other costs). The range of BAU costs, from $125/MW.h for residential space to $150/MW.h for non-residential space, is shown by the light blue and purple lines. Any difference between the BAU range and the LCC of generating heating energy is the potential margin to cover the costs of DPS, phasing, etc. which will be required for centralized energy sources.

Biomass CHP sized to 35% of peak demand offers the lowest costs, assuming the high electricity purchase price of $150/MW.h. At $120 per MW.h, heating-only biomass and biomass CHP have comparable costs. All biomass configurations sized to 85% of peak heating demand have higher costs than when sized to 35% of peak, and the ground water heat pump option has the highest cost.

additional biomass priced at $10 / MW.h.

Base Case GHG emissions for each district energy supply scenario are also shown in the dotted green line in Figure 7, in annual tonnes of CO2 (plotted on the right axis). Biomass CHP emissions include a credit for offsetting current electricity emissions. As can be seen, there are additional environmental benefits from installing higher biomass capacity. However, these benefits come at a cost. Installing biomass equipment to meet 35% of peak demand still reduces GHG emissions by 70%. For comparison, business-as-usual GHG emissions are estimated to be 15,100 tonnes per year.

Under business-as-usual, residential buildings would consume 15,700 MW.h of electricity annually for space heating. This electricity consumption would be avoided by installing a biomass-fuelled alternative energy centre. An open-loop geoexchange system would consume 15,300 MW.h of electricity, offsetting the reduced electricity consumption by replacing electric space heaters.[26]

The density of development of new buildings in Revelstoke will affect the DPS costs of a district energy system. If growth is more dispersed, DPS costs per unit of energy sold could be too high for a new system to be viable. Given the size of the neighbourhoods included in this analysis, if growth were evenly dispersed, energy density for the base case would be only 52 MW.h per ha, which is likely far too low to support district heating. For each of the smaller scenarios – Central and South Revelstoke, the Resort, and the Highway Corridor – we will provide a more detailed analysis of energy density and DPS costs. Additional analysis will be included in Section 5.

8.2 Scenario 2: Central and South Revelstoke

Scenario 2 assesses Central and South Revelstoke combined. These neighbourhoods are both centrally located, and the area includes the existing RCEC plant (which is at capacity). This scenario has a diversified peak heating demand of 9.7 MW and annual heat energy load of 30,600 MW.h.

The life cycle costs of the alternatives for Central and South Revelstoke are summarized in Table 11. Biomass and biomass CHP levelized costs are based on equipment sized to 35% and 85% of peak heating demand.

[26] The geoexchange system has a higher efficiency than electric baseboards but is used to supply not only space heating within suites, but also DHW and ventilation loads, which would have typically been met with propane.

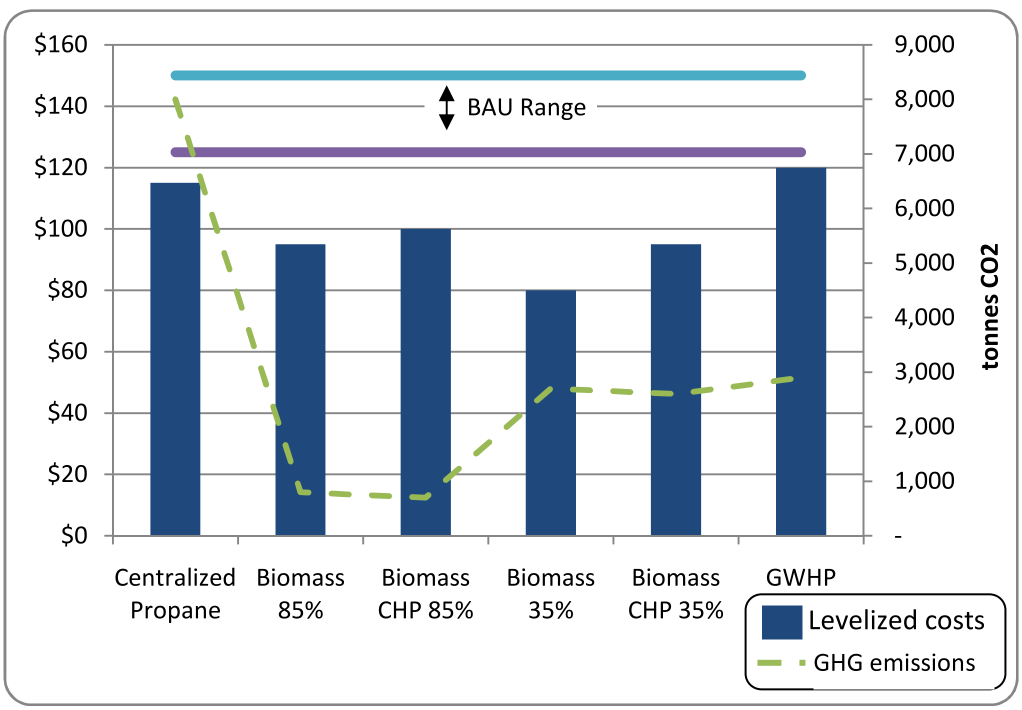
Table 11: Central and South Revelstoke Levelized Costs ($/MW.h)

Energy Source	Centralized Propane	Biomass Heat Only	Biomass CHP $120/MW.h electricity price	Biomass CHP $150/MW.h electricity price	Open GX
Biomass Sized at 35% of Peak Demand	$115	$80	$100	$95	$120
Biomass Sized at 85% of Peak Demand	n/a	$95	$105	$100	n/a

As in the base case, heating-only biomass offers the lowest life cycle cost, and all larger biomass systems are more expensive. For this scenario, loads are small enough that even a biomass CHP system sized to 85% of peak heating demand consumes approximately 50,000 MW.h of biomass per year, so by the assumptions of this analysis the fuel is all free.

Levelized costs for Central and South Revelstoke are shown in the blue columns in Figure 8. The range of BAU costs is represented by the light blue and purple lines.

Figure 8: Central and South Revelstoke Levelized Costs, Residual Value, and GHG Emissions



For a viable district heating system, DPS costs would typically be 5 – 12% of total levelized costs. Given the BAU range of $125 – $150 per MW.h, this would be equivalent to $6 – $18 per MW.h. As the lowest-cost option, heating-only biomass sized to 35% of peak demand, has an available residual of $45 compared to the low end of the BAU range, it appears as though there is sufficient residual to cover DPS costs, with excess funds available for phasing costs and other system costs.

However, this is only if energy density is high enough. At low energy densities, DPS costs increase. If new development were dispersed evenly throughout the Central and South Revelstoke areas, energy density would be only 74 MW.h per ha, far too low to be a node for a successful system. For energy density to be 500 MW.h per ha, roughly equivalent to RCEC's current energy density, new development would have to be concentrated in a 61 ha area with an average overall floor area ratio of 0.7. To meet the target energy density of 800 MW.h per ha, new development would have to be concentrated in a 38 ha area with an average FAR of 1.1[27]. Energy densities, phasing costs, and other system costs would need to be explored more in-depth in a detailed screening.

GHG emissions for each heating source are also shown in Figure 8. GHG emissions are represented by the dashed green line, and are in tonnes of CO2 per year (plotted on the right axis). For comparison, business-as-usual GHG emissions are estimated at 6,300 tonnes per year.

Under business-as-usual, residential buildings would consume 9,500 MW.h of electricity annually for space heating assuming 50% of the residential space heating load is met with baseboard heating. This electricity use could be offset by developing a district energy system, though an open-loop geoexchange system would consume 6,900 MW.h of electricity annually.

The Central Revelstoke area also includes several existing buildings which are candidates for connection to the RCEC system. These loads are relatively small compared to the long-term growth projections for the Central and South Revelstoke areas, and are not included in this analysis. Over the near-term, individual existing buildings may be connected to RCEC's existing system where economical and capacity exists in the RCEC system.

8.3 Scenario 3: Highway Corridor

Scenario 3 assesses the Highway Corridor, a small area bordering the Trans-Canada Highway. This is the smallest service area, with a diversified peak heating demand of 4.5 MW and annual heat energy load of 11,700 MW.h. However, the Highway Corridor is also the smallest neighbourhood by area, and it could have the highest energy density depending on development patterns. Assessing the Highway Corridor tests the effect of avoiding the cost of a link pipe from the existing RCEC plant. The life cycle costs of the candidate heat sources for the Base Case are summarized in

[27] All FAR estimates are assuming that 40% of total land area is used by public rights-of-way.

Table 12. Biomass heat only and CHP levelized costs are based on equipment sized to 35% and 85% of peak heating demand (two scenarios).

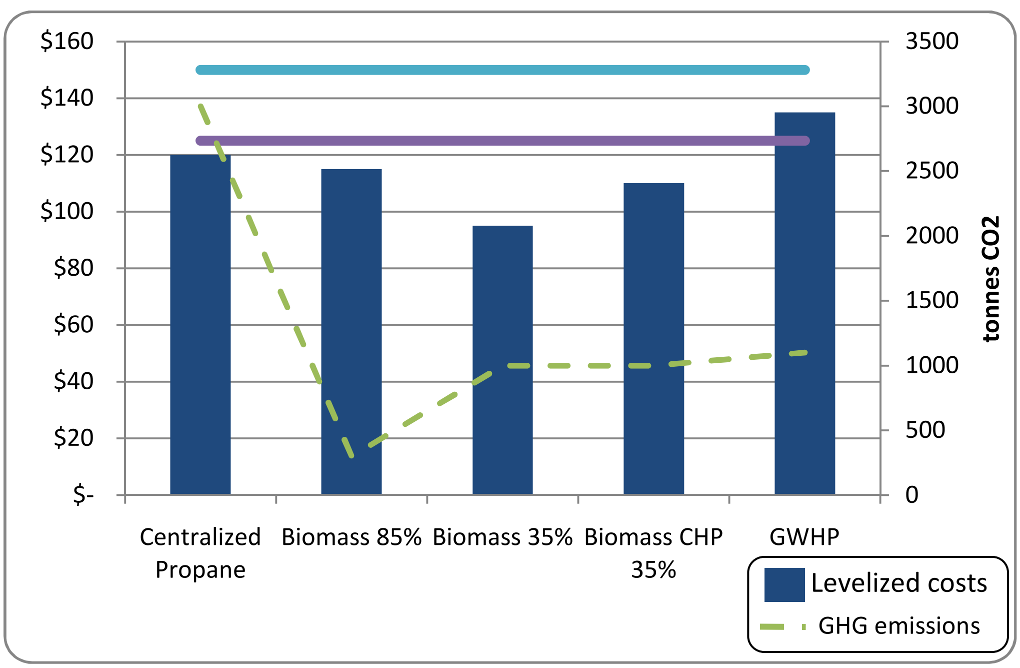
Table 12: Highway Corridor Levelized Costs

Energy Source	Centralized Propane	Biomass Heat Only	Biomass CHP $120/MW.h Electricity Price	Biomass CHP $150/MW.h Electricity Price	Open GX
Biomass Sized at 35% of Peak Demand	$120	$95	$115	$110	$135
Biomass Sized at 85% of Peak Demand	N/A	$115	$185	$180	N/A

The levelized costs for biomass CHP increase as capacity decreases, so it can be very challenging to make these systems economical at a smaller scale. When sized to 85% of peak heating demand, biomass costs are considerably higher. Biomass CHP costs are higher than BAU even at higher electricity purchase prices, leaving no residual value for DPS and other costs. The larger CHP alternative is not considered further.

Figure 9 shows the levelized costs for the remaining supply scenarios, as well as the range of BAU costs.

Figure 9: Highway Corridor Levelized Cost, Residual Value, and GHG Emissions



Biomass sized to 35% of peak heating demand has the lowest levelized cost. For biomass CHP sized to 35% of peak demand to be competitive with heating-only biomass sized to 35% of peak demand, the electricity purchase price would have to be over $300 per MW.h. All of these costs are based on free biomass fuel.

Compared to the Base Case, a standalone plant to serve the Highway Corridor area can deliver heat at a lower levelized cost. A link pipe from the Central Revelstoke Area near the existing Downie plant to the Highway Corridor is a significant additional cost that is avoided by building a smaller neighbourhood-scale plant.

Generally, for viable district energy systems, DPS costs make up about 5 – 12% of total levelized costs, if energy density is sufficiently high to make the system viable, equivalent to $6 – $18 if costs are equal to the BAU range. As the thermal-only biomass option has a residual value of $30 when compared to the low-end of the BAU range, it may be a viable heat source for a district energy system if energy density is sufficiently high.

The Highway Corridor is only 32 ha, and is the smallest neighbourhood assessed in this report. If the projected future growth were evenly dispersed, energy density would be roughly 400 MW.h per ha, which is lower than RCEC's current energy density. To achieve 500 MW.h per ha, new development would have to be concentrated in a 23 ha node with an average FAR of 0.7. For an energy density of 800 MW.h per ha, energy density would have to be concentrated in a 15 ha node with an average FAR of 1.1.

GHG Emissions for all screened heat sources for the Highway Corridor are also shown in Figure 9 (see dashed green line). As in the other scenarios examined, there are higher GHG reductions associated with the larger biomass system. Under business-as-usual, GHG emissions would be 3,100 tonnes per year.

Under business-as-usual, 1,000 MW.h of electricity would be consumed annually for residential space heating in the Highway Corridor. The open-loop geoexchange option's heat pump would consume 2,700 MW.h of electricity annually.

8.4 Scenario 4: Resort

Scenario 4 is the Resort area. Much of the land in the Resort area is owned by Revelstoke Mountain Resort, the developer of a major ski resort and related properties. This scenario has a diversified peak heating demand of 8.0 MW and 25,000 MW.h of annual heat energy load by 2030. The life cycle costs of the candidate heat sources for the Resort area are summarized in Table 13. Biomass heat only and CHP levelized costs are based on equipment sized to 35% and 85% of peak heating demand (two scenarios).

Table 13: Resort Area Levelized Energy Costs

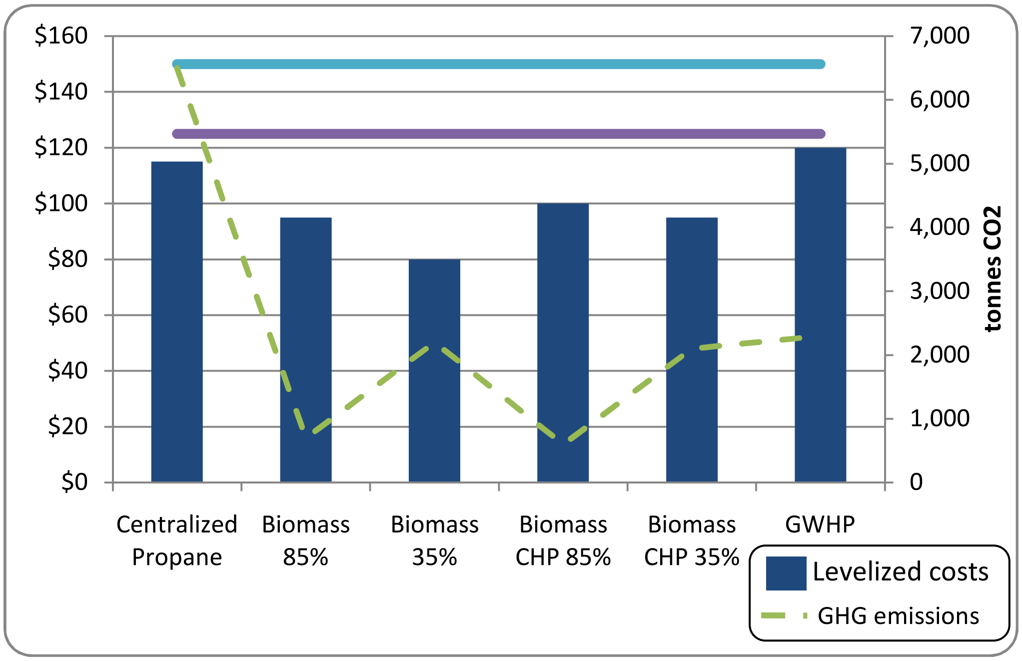
Energy Source	Centralized Propane	Biomass Heat Only	Biomass CHP $120/MW.h Electricity price	Biomass CHP $150/MW.h Electricity price	Open GX
Biomass at 35% of Peak	$115	$80	$100	$95	$120
Biomass at 85% of Peak	N/A	$95	$105	$100	N/A

The larger capacity CHP plant can take advantage of some economies of scale relative to the smaller plant, so the larger and smaller CHP systems may have comparable costs. For the larger biomass options, biomass consumption is sufficiently low that all biomass is assumed to be free. Heating-only biomass sized to 35% of peak heating demand is still the lowest-priced option.

Figure 10 shows the levelized costs for the screened heat sources for the Resort area. Levelized costs are represented by the blue columns, and the range of BAU costs is shown by the light blue and purple lines. Biomass sized to 35% of peak heating demand has the lowest levelized costs. Costs for this option at the Resort are lower than for other areas included in this analysis because the relatively high proportion of residential space at the Resort area means that any district heating system there would have less 'peaky' loads and higher utilization[28]. GHG emissions for each screened heat source are also shown in the dashed green line in Figure 10, plotted on the right axis in tonnes of CO2 per year.

[28] We assume that residential space is electrically heated and hotel space is heated with propane. However, development patterns at the Resort may vary. Residential space at the Resort may have different usage patterns from non-Resort residential space, and would need to be investigated further in a detailed business analysis.

Figure 10: Resort Area Levelized Costs, Residual Value, and GHG Emissions



For the lowest-cost option – heating-only biomass at 35% of peak heating demand – the available residual when compared with the lower end of the BAU range is $45. Given the expected DPS system costs of $6 – $18 for a viable system, there is likely sufficient residual available for DPS costs, with residual value remaining for phasing costs and other system costs, assuming energy density is sufficiently high.

Given the size of RMR's development area – nearly 850 ha, the largest neighbourhood included in this analysis – future development of MURBs, hotels and commercial space would have to be concentrated in a smaller area for a district energy system to be viable. Clustering this type of development within a 50 ha area with an average FAR of 0.7 would yield an energy density of 500 MW.h per ha, comparable to RCEC's existing system. Concentrating development within a smaller 31 ha node with an average FAR of 1.1 would lead to the target energy density of 800 MW.h per ha.

Under business-as-usual, 5,200 MW.h of electricity would be consumed for residential space heating in the Resort area. The open-loop geoexchange system's heat pump would consume 5,700 MW.h annually.

Table 14: Summary Table – All Scenarios

Description	Units	All Neighbourhoods Combined	South and Central	Highway Corridor	Resort
BAU Cost of Heat	$/MW.h	$125 – $150 for all scenarios			
BAU GHG Emissions	t/yr	15,100	6,300	3,100	5,800
Lowest Cost Heat Source	n/a	Biomass CHP Sized to 35%	Biomass Heat Only Sized to 35%	Biomass Heat Only Sized to 35%	Biomass Heat Only Sized to 35%
Levelized cost of heat (excluding DPS, phasing, finance, etc.)	$/MW.h	$110	$80	$95	$80
Absolute GHG Emissions	t/yr	5,800	2,700	1,000	2,200
GHG Emission reductions (compared to BAU)[29]	t/y	9,300	3,600	2,100	3,600
Electricity savings[30]	MW.h	15,700	9,500	1,000	5,200
Max node size to meet target energy density of 800 MW.h	ha	n/a	38	15	31
FAR Target	n/a	1.1	1.1	1.1	1.1

9.0 Strategic Directions and Policy Recommendations

District heating has the potential to help Revelstoke accomplish the goals set out in the 2009 Official Community Plan by increasing energy self-reliance, keeping energy dollars in the community, reducing GHG emissions, promoting Smart Growth principles, and directing development towards existing neighbourhoods. There are several findings from this analysis that can guide implementation.

General findings

- **Neighbourhood scale versus city scale**. Neighbourhood-scale plants will likely deliver lower costs than a single city-scale district energy plant. The costs to provide link pipes from Central Revelstoke to the Highway Corridor

[29] Not including GHG emission reductions from RCEC's existing system.
[30] Assuming the alternative energy source is not an open-loop geoexchange system. Also, the hotels at the Resort and Highway corridor opted for electric space heating, electricity reductions would be an additional 2,000 and 800 MW.h/year respectively (assuming biomass DE is the supply option).

and Resort areas appear to be higher than any benefits from economies of scale in a larger sized plant. Additionally, the implementation issues and risks associated with district energy may be easier to manage at a neighbourhood scale. If building development can be directed along connection corridors there is the long-term potential for an interconnected system throughout Revelstoke, similar to district energy development in Sweden and other parts of Europe.

- **Biomass plant type and sizing**. Biomass is an attractive supply option in Revelstoke, so larger biomass plants and CHP systems have been considered for expanding RCEC. In every scenario included in this screening, biomass equipment sized to 35% of heating demand offers the lowest levelized energy cost. Even if all biomass fuel is assumed to be available at no cost, biomass plants sized to 85% of peak heating demand have a higher levelized energy cost because the reduced propane costs are outweighed by the higher capital costs with biomass boilers. Additionally, even when electricity sales prices are assumed to be $150 per MW.h, CHP systems have higher levelized costs than heating-only systems in all scenarios except the base case of 22 MW of diversified demand. As there are other significant costs and challenges associated with developing the base case, including the link pipe costs mentioned above, the heating-only biomass systems sized to 35% of peak heating demand are the lowest cost option. As this is only a screening-level analysis, biomass CHP should also be considered in any subsequent assessment, as costs for biomass CHP are less well understood and have greater uncertainty. Heating-only biomass is a much better understood technology and has been implemented in many systems across a wide range of capacities.

- **Electricity use reductions**. District energy systems can potentially reduce electricity consumption for space heating in Revelstoke by replacing electric space heaters with hydronic systems and an alternative energy source. Hydronic conversion is an incremental cost to developers; however, BC Hydro is offering a capital incentive program to offset some of those costs to developers. If the alternative energy source is an open-loop geoexchange system, reductions in electricity use will likely be offset by additional consumption by an energy centre heat pump.

- **Energy density**. The future of district heating systems in Revelstoke is dependent on energy density levels. High levels of new construction may not be enough to ensure the viability of district heating systems if new development is dispersed. District heating systems require ‘nodes’ of density, particularly for initial system development. Promoting future district heating expansion in Revelstoke will likely require significant coordination with land use policies to ensure sufficient energy density. Once a system is established, it may be able to expand into less dense areas depending on loads and DPS costs.

- **Biomass supply.** There is adequate biomass supply at Downie to supply district energy expansion. Strategies to use cedar hog fuel in biomass combustion will greatly increase the biomass fuel supply. Other sources are available.

Neighbouhood findings

- **Highway Corridor** - Of the three scenarios included in this analysis, the Highway Corridor area has the most rapid projected growth, with much of it taking place by 2020. Diversified peak heating demand for new construction is expected to be 1.3 MW by 2015, 2.6 MW by 2020 and 4.5 MW by 2030. A 1 MW biomass boiler would meet roughly 35% of expected peak heating demand in 2020.

  The Highway Corridor area is also compact, so it is relatively less challenging to achieve higher levels of energy density. The nearby Trans-Canada Highway means that the area already has significant truck traffic, so additional trucks to deliver biomass are not likely to be a nuisance. These factors combined with the significant available margin for DPS and other costs for a heating-only biomass system make the Highway Corridor an attractive area to develop an additional district heating node in Revelstoke.

  However, developing a district heating node in this area will likely require policy direction from the City of Revelstoke. While the Highway Corridor is compact, energy density could still be too low for a district heating system to be viable. Moreover, if no policy tools are used to incentivize district heating connection, a district heating system may be a challenge to implement. New buildings are excellent candidates for district heating systems, as developers can monetize potentially large savings in equipment and associated space. However, newly built buildings with stand-alone heating equipment are typically difficult to connect cost-effectively because of new heating systems already in place.

  The most effective policy tool the City of Revelstoke could use to promote a Highway Corridor district heating system would be to establish a district heating system service area bylaw. Under such a policy, new buildings built in this area would need to be configured for district heating connection, with hydronic in-building systems and a small area set aside for ETS equipment. Slow load growth can be a challenge for implementation; however, initial new development can be serviced with small temporary propane boiler plants, with an alternative energy source introduced once loads have grown sufficiently large.

  Service area bylaws are effective methods for promoting district heating development, particularly for systems which rely on alternative energy sources with relatively higher capital costs. However, establishing a mandatory connection area would require buy-in from the community that district heating is not only an effective means of achieving any energy and emissions goals, but also a competitive source of heat and an effective use of City resources.

For a service area bylaw to be enforced, there must be an existing district energy system available to provide service. One option is to focus on a small node within the highway corridor (e.g., 2 or 3 new buildings). RCEC or a third party could install the DPS and temporary propane boilers until loads reach a level that would support an alternative energy module. The temporary propane boilers then become the peak/backup capacity at the nodal plant, or used elsewhere in the RCEC system. The service area bylaw and other policy instruments are discussed in greater detail in the CEEP.

The buildings in the target node must be hydronically heated to be compatible with district energy. To defray some of the incremental capital costs to developers for hydronic heating systems, BC Hydro is developing a capital incentive program. The City is in discussions with BC Hydro about the applicability of the incentive program to new developments in Revelstoke. The hydronic incentive program is a useful bridging mechanism until such time as the City can develop and enforce a service area bylaw to capture new buildings as customers.

BC Hydro capital incentives and a service area bylaw policy would be equally applicable to the Resort lands and South/Central Revelstoke.

Land use policies which promote densification in the Highway Corridor area will also help promote a future district heating system. In the absence of further efforts to promote density, the Highway Corridor may not have sufficient energy density for a district heating system to be viable. Some municipalities have found that densification promotes multiple goals simultaneously – for example, not only does it increase energy density, but it also may help create more pedestrian-oriented downtown areas. In other studies, we’ve found district energy target densities to be similar to target densities that support affordable housing and other community amenities. District heating can be a supporting element of a broader approach to achieving community goals.

- **Revelstoke Mountain Resort** - As the Resort area is largely owned by a single private landowner, Revelstoke Mountain Resort, any future district heating development in the area will require significant coordination between the City and RMR. However, there are potentially significant benefits from this collaboration. Coordinating multiple property owners can be a significant challenge for district heating system development, so the area’s consolidated land ownership could be an advantage. Loads at the Resort are large enough to establish a heating-only biomass plant with significant GHG reductions versus BAUl, which may be an attractive option for this high-profile ski resort. If promoting district energy development is a key priority for the City, there may be “win-win” opportunities when dealing with RMR. Recognizing RCEC already had talks with the resort about district energy expansion but did not reach agreement, stronger City policy support may help.

- **Central and South Revelstoke** - For Central and South Revelstoke, the key question is the density and pace of future development. As the area is large and includes a wide variety of landowners, getting a more detailed picture of likely future development patterns could be challenging. However, in the absence of this information, it will be difficult to do a more detailed screening of district heating opportunities in the area. Again, any active policy direction to encourage densification in specific areas, or direct new development to defined sub-areas of these neighbourhoods, will affect opportunities for district energy development.

Appendix A – Screening Assumptions

Appendix B – Screening-Geoexchange Assessment