Bioenergy Opportunities in the Regional District of Central Kootenay
A Pathway to Development

TORCHLIGHT BIORESOURCES

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consulting engineers

Final Report

2020

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Prepared for

REGIONAL DISTRICT
CENTRAL KOOTENAY

FINAL REPORT

November 17th, 2020

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EXECUTIVE SUMMARY

The forestry sector is an important contributor to the economy of Central Kootenay, with in-forest operations, several sawmills, and the largest pulp mill in southeast British Columbia providing employment to thousands of residents. The sector also generates hundreds of thousands of tonnes of low-grade wood fibre in the form of mill and harvest residues, with the former used for heat and power generation in Canada and the United States and the latter largely left at harvest sites and burned for wildfire prevention. Central Kootenay is a large exporter of electricity to the rest of British Columbia and the United States due to the presence of numerous large hydropower facilities, but some district rural areas lack natural gas access and can be subject to power outages, resulting in poor energy security and resiliency relative to large urban areas of the province. For over a decade the Regional District of Central Kootenay (RDCK) has recognized the opportunity for wood-based bioenergy to complement local hydropower resources and reduce greenhouse gas emissions in the energy sector while simultaneously improving air quality and forestry operations by creating a market for low-grade wood fibre. However, progress on actual project development has been slow.

With a goal to accelerate bioenergy sector development, particularly in rural areas, the RDCK contracted TorchLight Bioresources and Kerr Wood Leidal to identify specific bioenergy project opportunities within Central Kootenay and to propose potential pathways to development. A review of the forestry sector indicated that while large volumes of harvest residues are not utilized and available for bioenergy production, they are a high cost fuel and it is more likely that low cost hog fuel, a bark-dominated mill residue, will be the primary feedstock for new bioenergy projects in the near term – particularly if consumer energy cost is prioritized. Economic utilization of harvest residues is likely to require financial support from a higher level of government, particularly in mountainous Central Kootenay. Given the current oversupply of low-carbon, low-cost electricity in British Columbia and pre-commercial status of wood-to-transportation fuel technologies, thermal energy (heat) was identified as the priority market for low-grade wood fibre. A comparison of communities, district energy markets, and applications identified five leading opportunities for development: 1) wood pellet boilers for rural residences and businesses; 2) small district energy systems, including centralized biomass heat plants and underground hot water piping, for rural communities such as Nakusp and Kaslo; 3) larger biomass-fuelled district energy systems to replace natural gas in Nelson and Creston; 4) a district energy system in Castlegar using waste heat from the Mercer Celgar pulp mill; and 5) replacement of natural gas in Mercer Celgar’s lime kiln with syngas from biomass gasification. For the RDCK itself, wood pellet boilers and district energy systems in rural communities and Castlegar were identified as the priority projects for further assessment and participation. Preliminary recommendations on how these projects can be financed, developed, and operated are provided in this report.

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ABBREVIATIONS

admt	Air Dried Metric Tonnes
bdt	Bone Dry Tones
CapEx	Capital Expenditure (Capital Cost)
CHP	Combined Heat and Power
CI	Carbon Intensity
C/I	Commercial/Institutional
CO$_2$e	Carbon Dioxide Equivalent
DE	District Energy
GHG	Greenhouse Gas
ICE	Internal Combustion Engine
Mt	Megatonne (Million Tonne)
MW$_e$	Megawatt Electrical
MW$_{th}$	Megawatt Thermal
ORC	Organic Rankine Cycle
RNG	Renewable Natural Gas

1 INTRODUCTION

Central Kootenay, located in southeast British Columbia, has a population of roughly 60,000 and covers an area of over 22,000 square kilometers. The Regional District of Central Kootenay (RDCK) is a local level of government that provides a large range of services. The RDCK consists of 11 electoral areas (A, B, C, D, E, F, G, H, I, J, K) and nine member municipalities: Castlegar, Creston, Kaslo, Nakusp, Nelson, New Denver, Salmo, Silverton and Slocan. Nelson is by far the largest population centre with approximately 11,000 residents. The region is highly mountainous, with most communities located in river valleys. There are approximately 25,000 employed persons in Central Kootenay, with Healthcare and Social Assistance, Retail Trade, and Construction the largest employers and collectively accounting for over one third of jobs. Agriculture, Forestry, Fishing, and Hunting, combined with Manufacturing, account for approximately 15% of the workforce.

Central Kootenay is a very large exporter of energy, in the form of hydroelectricity, to the rest of British Columbia and the United States. However, much of the district does not have access to natural gas and a few rural areas are subject to relatively common power outages. At the same time, the district's forest sector, which is concentrated in Castlegar but includes significant facilities across the southern portion of the district, has limited markets for harvest residues, the tops and branches of felled trees and damaged timber, and hog fuel, the bark-dominated residue produced by sawmills and other solid wood product facilities. Over the past decade, the RDCK has sought to address these two challenges of high energy costs and lack of markets for low-grade wood fibre by encouraging development of a regional bioenergy industry. Ideally, a strong bioenergy industry in the RDCK would utilize low-grade wood fibre, reduce slash pile burning, create local jobs, reduce greenhouse gas (GHG) emissions, lower energy costs, and improve energy resiliency. Small-scale, rural projects are considered a priority by the RDCK.

The RDCK has supported a number of bioenergy-related studies, including quantification the bioenergy resource potential in specific areas and a comparison of small-scale biomass combined heat and power (CHP) technologies. However, while there have been several successful projects, such as wood chip boilers than heat commercial and industrial buildings, growth of community-based bioenergy in the RDCK has been slow. To accelerate growth of the bioenergy industry in the Central Kootenay District, the RDCK contracted TorchLight Bioresources and project partner Kerr Wood Leidal to identify the most promising bioenergy opportunities in the district and to prepare recommendations on how specific projects could be developed successfully. This report is the outcome of that project. The report is divided into five main sections: biomass resources in Central Kootenay (forthwith referred to as RDCK), the RDCK energy market, technology options to address the energy demands using available biomass, supply chains and operations, and leading projects and initiatives.

2 FOREST RESOURCES

The RDCK boundary follows much the same path as the combined boundary of the Arrow Timber Supply Area (TSA) and the Kootenay Lake TSA (Figure 1). TSA areas extend beyond the RDCK boundary north, east, and west, with Rossland and Trail the largest population centres included in the TSA areas but not the RDCK. A small portion of the geographically-dispersed Cascadia TSA and two Tree Farm Licenses, 3 and 23, are also located in the district. The Kootenay Lake TSA has an Annual Allocable Cut (AAC) of 640,000 cubic meters (m^3) and the Arrow TSA has an AAC of 500,000 m^3. Both the Cascadia TSA portion and TFL 3 are small areas, with AACs of 9,300 m^3 and 80,000 m^3, respectively. In contrast, TFL 23 has an AAC of 450,000 m^3, although this does include a significant amount of wood volume from outside of the RDCK boundary. Combined, the AAC for timberlands within the RDCK boundaries is estimated at 1,400,000 – 1,500,000 m^3. The largest licensee in the district is Interfor, followed by BC Timber Sales and Canfor. Timber commitments across the district are presented in Figure 2. For the purposes of this report, m^3 are converted to bone dry tonnes (bdt) with an assumed density of 0.5 bdt/m^3. Harvest residue volume is assumed to be equal to 15% of harvest volume.

Most of the primary licensees own and operate sawmills or primary solid wood products processing mills in the region. The major and medium-sized wood processing facilities are identified in Figure 3. The largest mills are Interfor [210 million board feed (mmfbm)], Kalesnikoff Lumber (62 mmfbm), Canfor/Wynnwood (58 mmfbm), Porcupine Wood Products (48 mmfbm), and J.H. Huscroft (43 mmfm). Interfor's mill in Castlegar, therefore, consumes as much wood fibre as the next four largest mills combined. ATCO Wood Products, which has a significant commitment in the Arrow TSA and a smaller commitment in the Kootenay Lake TSA, operates a 142 M square foot/yr softwood veneer mill in Fruitvale just outside the district. There are also a number of small speciality mills, such as Boards by George Lumber, Hamill Creek Timber Homes, and Lardeau Forest Products (all in Meadow Creek), and Pine Profiles in Creston. Although not included in the primary licensee list, Mercer Celgar, located in Castlegar, is by far the largest wood fibre consumer in the region. With an annual capacity of 520,000 air dried metric tonnes (admt) of Kraft pulp per year, Mercer Celgar's annual wood fibre consumption is estimated at approximately 900,000 bdt per year. As noted in Figure 2, this quantity exceeds the total commitments across the district and indicates a substantial volume of wood fibre is flowing into the region to meet the fibre needs of Mercer Celgar. The mill plays a central role in the sawmill residual market in the southern interior region of BC, with the Paper Excellence Skookumchuk mill (Regional District of East Kootenay) and the Domtar Kamloops mill (Thompson-Nicola Regional District) the two other pulp mills in the region. With annual capacities of 250,000 admt and 408,000 admt respectively, both mills are smaller than Mercer Celgar. Beyond these three mills, the closest pulp mills are Quesnel (850 km to Nelson) and the BC coast (640 km to Nelson), highlighting the importance of Mercer Celgar and the Skookumchuck and Kamloops mills to southern interior wood fibre flows and sawmill residue demand.

Figure 1. Timber Supply Areas, Tree Farms Licenses, and Major Forest Product Facilities in the RDCK

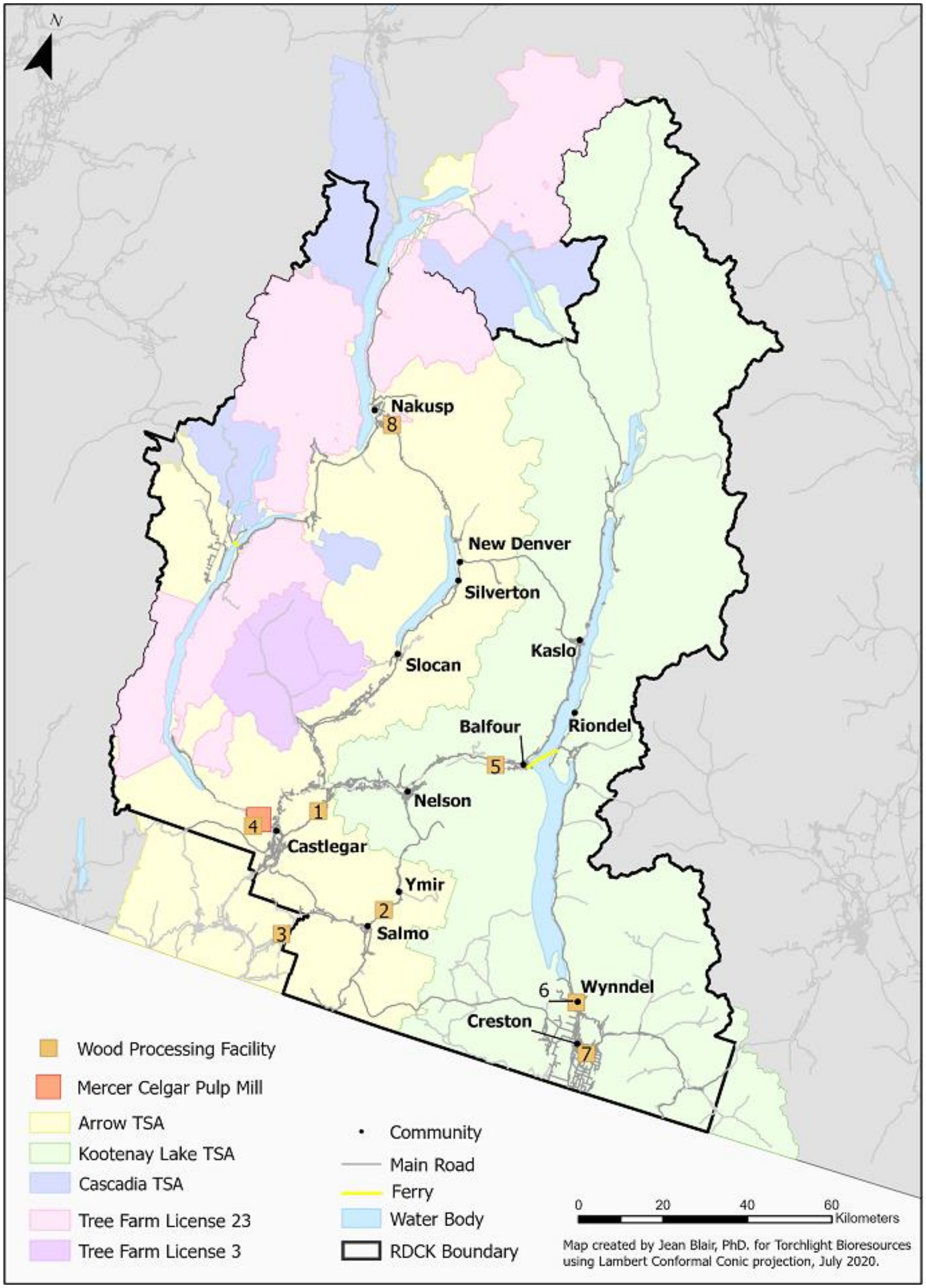


Figure 2. Timber Commitments in the Regional District of Central Kootenay

Area	Commitment (m^3)	Commitment (bdt)	Harvest Residues (bdt)	Harvest Residues (GJ)
Arrow TSA				
BC Timber Sales	157,587	78,794	11,819	224,561
ATCO Wood Products	151,627	75,814	11,372	216,068
Interfor	100,000	50,000	7,500	142,500
Tolko	47,589	23,795	3,569	67,814
Kalesnikoff Lumber	34,703	17,352	2,603	49,452
Yucwemenlucwu	17,010	8,505	1,276	24,239
Stella Jones	12,963	6,482	972	18,472
Total	**521,479**	**260,740**	**39,111**	**743,108**
Kootenay Lake TSA				
Canfor	200,842	100,421	15,063	286,200
BC Timber Sales	182,203	91,102	13,665	259,639
J.H. Huscroft	78,644	39,322	5,898	112,068
Cooper Creek Cedar[a]	69,713	34,857	5,228	99,341
Kalesnikoff Lumber	55,247	27,624	4,144	78,727
Lower Kootenay Dev't	31,043	15,522	2,328	44,236
ATCO Wood Products	20,167	10,084	1,513	28,738
Total	**637,859**	**318,930**	**47,839**	**908,949**
Cascadia TSA				
BC Timber Sales	9,310	4,655	698	13,267
Total	**9,310**	**4,655**	**698**	**13,267**
Tree Farm License 3				
Interfor	74,100	37,050	5,558	105,593
BC Timber Sales	5,900	2,950	443	8,408
Total	**80,000**	**40,000**	**6,000**	**114,000**
Tree Farm License 23				
Interfor	450,000	225,000	33,750	641,250
Total	**450,000**	**225,000**	**33,750**	**641,250**
Grand Total	**1,698,648**	**849,324**	**127,399**	**2,420,573**

[a] Timberlands division of Porcupine Wood Products

Figure 3. Primary Large-Medium Wood Processing Facilities in the RDCK

Figure 1	Facility	Location	Capacity[a]	Primary Products
1	Kalesnikoff Lumber	Thrums	62 mmfbm	Mass timber including cross-laminated timber
2	Porcupine Wood Products	Salmo	48 mmfbm	Western red cedar decking, fencing, sidings, and trim board
3	ATCO Wood Products[b]	Fruitvale	42 M sq ft	Softwood veneer
4	Interfor	Castlegar	210 mmfbm	Softwood lumber
5	Harrop-Procter Forest Products	Harrop-Procter	2 mmfbm	Fences, decking, rough sawn timber
6	Wynnwood (Canfor)	Wynndel	58 mmfbm	Wane-free specialty boards
7	J.H. Huscroft	Creston	43 mmfbm	Boards and specialty products
8	Box Lake Lumber	Nakusp	600,000 pieces	Split rail fencing
N/A	Mercer Celgar	Castlegar	520,000 admt	Kraft pulp

[a] mmfbm (million board feet); admt (air-dried metric tonnes)

[b] Located outside of RDCK but primary licensee within RDCK

While pulp chips and pulpwood flow into the district from neighbouring districts, the RDCK is a net exporter of mill residues sawdust, shavings, and hog fuel (bark and low-grade fibre). There is also little demand for hardwoods in the district. Sawdust and shavings are currently trucked to the pellet mills in Lavington (Pinnacle Renewable Energy/Tolko) and Princeton (Princeton Standard). These pellet mills have annual capacities of 300,000 t and 110,000 t, respectively. It is estimated that over 80,000 t of sawdust and shavings leave the region for the pellet mills. While these are long hauls, the economics are feasible because of the ability to share the cost of trucking with Mercer Celgar pulp chip deliveries via backhauls. This trucking cost savings, along with distance to coastal ports, is a major reason why a pellet mill has not been established in the RDCK to date. As for hog fuel, the primary destination for hog fuel from the smaller mills is the Kettle Falls power plant in Washington State. The plant, owned by publicly-traded utility company Avista, has a capacity of 53 MW_e and consumes approximately 60 tonnes per hour. Mill operators in the RDCK estimate that hog fuel exports from the district to Avista may exceed 150,000 bdt/yr. If this is the case, the district would be the majority feedstock supplier to the Avista plant. Given the plant is less than 100 km to Fruitvale and only 115 km to Castlegar or Salmo, this is not an unreasonable estimate. However, the Avista plant was constructed in 1983 and is a power-only (vs. co-generation of heat and power) plant with relatively high operating costs. It was the first utility-owned (vs pulp and paper company-owned) wood waste power plant built in the U.S. and was constructed to reduce air pollution from wood waste combustion in beehive burners. However, it is now considered the highest generating cost asset in Avista’s portfolio and can be subject to idling if market electricity prices are too low to justify wood fuel costs. Since sawmill and solid wood product facilities cannot operate without a market for hog fuel, the reliance of the forest products sector in the RDCK on the Kettle Falls plant is considered a high-risk situation. Approximately half the hog fuel from Wynnwood goes to Kettle Falls and the other half to the Skookumchuck pulp mill. A significant portion of the hog fuel produced by the Interfor Castlegar mill is used internally to fuel kilns for lumber drying.

Within the RDCK, there is significant demand for sawlogs, softwood pulpwood (roundwood of insufficient grade for sawmilling), and softwood chips for pulp production. Castlegar is the dominant demand hub. Based upon the currently operating situation and cost benefit of backhauls, sawdust and shavings are generally already allocated to existing pellet plants. This is especially true in the western portion of the district, which is closer to the pellet mills in Lavington and Princeton than the area around Creston. Both ATCO Wood Products and the Lower Kootenay Band, located near Creston, assessed the feasibility of a medium or large pellet plant in the district and found one to be infeasible. While a small pellet plant (e.g., 15,000 t/yr) could be developed, this scale of mill would not be competitive for export markets and would require a strong local market. This means the primary feedstocks for bioenergy generation in the RDCK are hog fuel from primary wood products facilities (sawmills, ATCO veneer mill) and harvest residues. It is estimated that there is approximately 275,000-300,000 bdt, with an energy content of 5,300,000-5,700,000 GJ, of these materials generated annually.

The cost of hog fuel and harvest residue is very different. Currently, hog fuel is sold to Avista for $5-15/bdt (e.g., $0.25-1.00/GJ) plus trucking. In contrast, harvest residues are anticipated to be amongst the highest cost in the province due to the challenging terrain and winding road network. Interviews with primary licensees indicated a likely delivered cost for chipped residues to Castlegar or Nelson of $70-110/bdt ($4.00-6.25/GJ). This range is also consistent with modelling, including forwarding costs of $5-25/bdt, handling of $5-10/bdt, chipping costs of $40-45/bdt, and trucking of $10-25/bdt. This indicates that although harvest residue utilization is a priority for the RDCK, it is hog fuel residues from existing primary wood products facilities that will be the much lower cost fuel. It will be hard to justify a business case for energy facilities to utilize harvest residues when hog fuel could be used. Higher cost fuel results in higher energy prices for consumers. This situation could be altered if forest harvest residue collection, chipping, and transportation were financially supported by the Forest Enhancement Society of British Columbia (FESBC) or another entity.

3 RDCK ENERGY MARKET

Energy demand can be generally grouped into three primary categories: 1) thermal energy; 2) electricity; and 3) transportation fuels. In the RDCK, there is significant overlap between thermal energy demand and electricity demand due to a high percentage of homes using electricity for space heating and hot water. Although electricity and transportation markets are seeing increased integration due to the adoption of electric vehicles, electricity currently constitutes only a very small percentage of transportation energy demand at present. The reverse is also true, with transportation representing only a tiny fraction of electricity demand. Markets can also be grouped according to three primary end-uses: 1) buildings; 2) industry; and 3) transportation and machinery. On average, thermal energy constitutes 80% of residential building energy demand and two-thirds of commercial/institutional (C/I) building energy demand. Nationally, thermal energy is 80-85% of industrial energy demand, although this varies dramatically by facility type. RDCK building energy demand by fuel type is presented in Figure 4 and by community in Figure 5. Four incorporated communities in the RDCK, Nelson, Castlegar, Creston, and Salmo, have access to natural gas and natural gas represents 60% of building fossil fuel energy demand in unincorporated areas. Total natural gas consumption across the district is 1,250,000 GJ per year; the remaining communities use a combination of electricity, wood, propane and heating oil for space heating. As decarbonization efforts should focus on displacing fossil fuels, RDCK building fossil fuel demand, which currently accounts for 1/3 of building energy consumption, by community is presented in Figure 6.

Figure 4. RDCK Building Energy Demand by Fuel Type

Total: 4,900,000 GJ.[1]

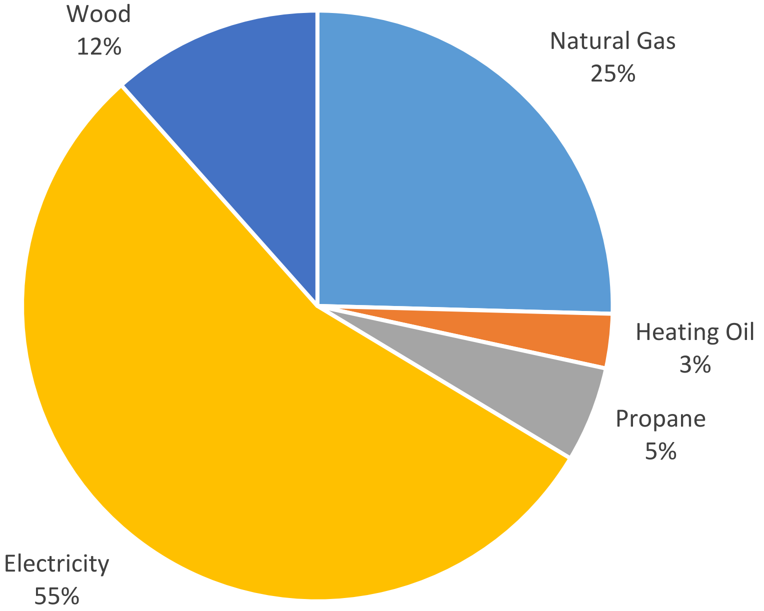
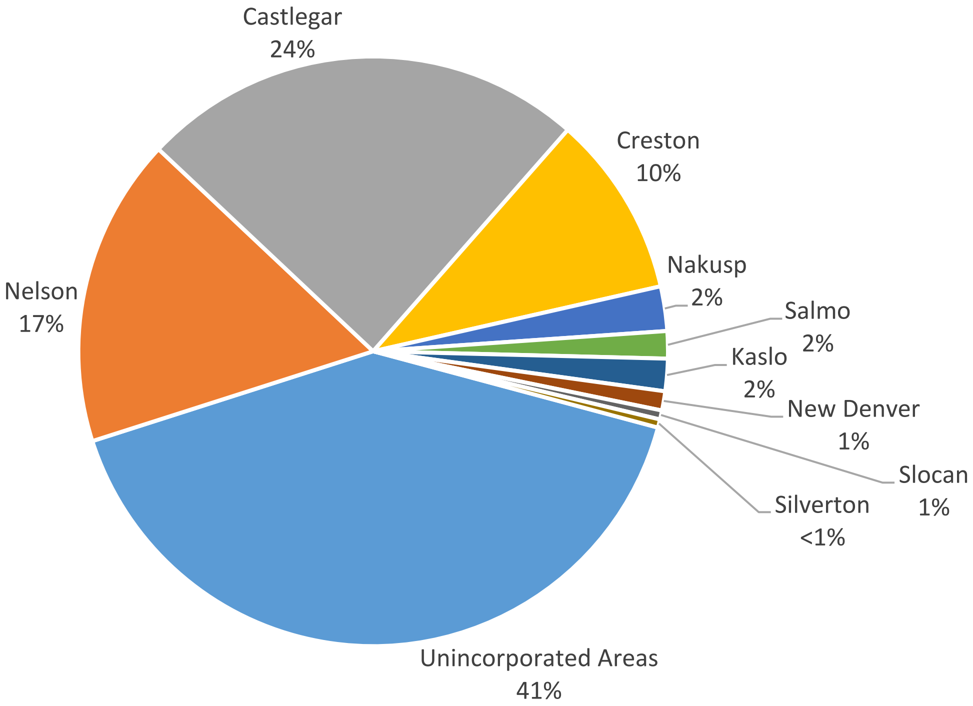


Figure 5. RDCK Building Energy Demand by Community

Total: 4,900,000 GJ.[1]



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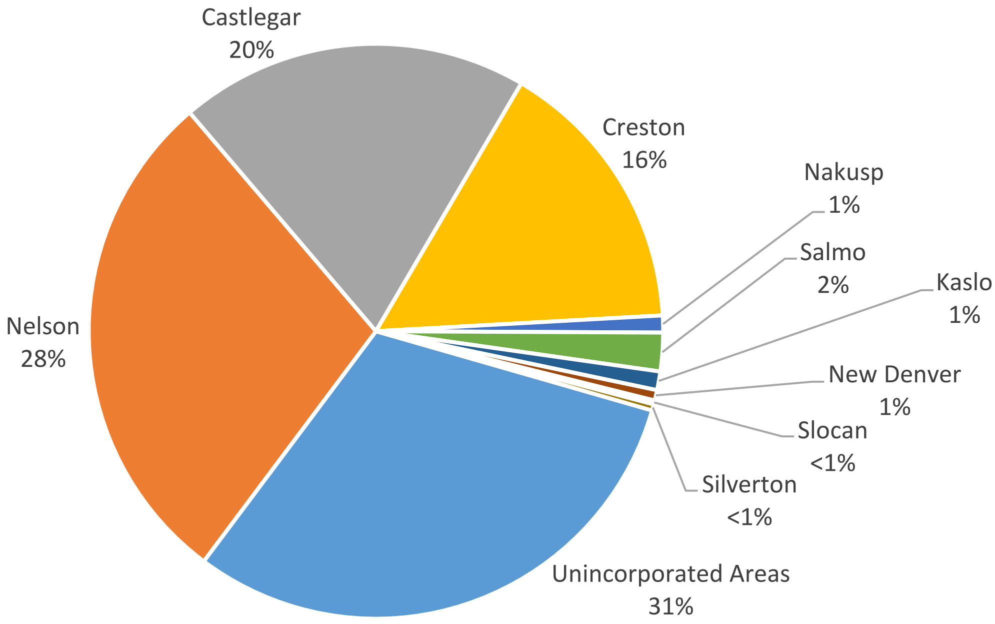
[1] Government of British Columbia, 2020. Community Energy and Emissions Inventory – 2012.

Figure 6. RDCK Building Fossil Fuel Energy Demand by Community

Total: 1,600,000 GJ.[2]



By comparing Figures 5 and 6, it can be seen Nelson and Creston have the highest percentage of fossil fuel consumption relative to total building energy consumption. This contrasts with the smaller communities, both incorporated and unincorporated, that have high rates of low carbon electricity and wood consumption. Under national and international GHG accounting directives, the CO_2 emissions from biomass (e.g., wood) combustion are not counted in energy-related emission inventories due to carbon release (and sequestration) by forests being included under the Land Use, Land Use Change, and Forestry (LULUCF) category.

There is only one facility in the RDCK listed in BC and Canada's large GHG emitters list: Mercer Celgar. The pulp mill's fossil fuel emissions were 116,500 t CO_2e in 2018. This is approximately 30% more than all building GHG emissions across the entire regional district in 2012. It also indicates that natural gas consumption by Mercer Celgar was greater than all buildings in the RDCK combined. Given the population of the RDCK increased by only 1.8% between 2011 and 2016, 2012 emissions data are sufficiently accurate for the 2018 comparison.

Light-duty vehicle fuel energy consumption has been estimated at 3,700,000-3,800,000 GJ across the district. This equates to 100-120 million litres of gasoline. As any liquid biofuels produced in the RDCK would be blended at low levels in the provincial, or broader, transportation fuel pool and not limited to use in the RDCK, the local market demand for transportation fuels will not be a primary determining factor of whether a wood-to-liquid biofuel plant would be viable in the district. This is discussed in Section 4.

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[2] Government of British Columbia, 2020. Community Energy and Emissions Inventory – 2012.

3.1 Electricity

Due to numerous large hydropower generating facilities, the RDCK is a significant net exporter of electricity to the rest of British Columbia and to Washington State. Approximately 90% of electricity consumers outside of Nelson are served by FortisBC's distribution system, with the remainder served by BC Hydro. Within the Nelson area, including Harrop-Procter, Balfour, and Queens Bay, Nelson Hydro is the local distribution company (LDC). It is one of only five LDCs in the province and is unique in its ownership of a small-scale generating asset – the 9.1 MW_e Bonnington Falls hydropower facility – and electricity distribution operations. Approximately 45% of Nelson Hydro's electricity is purchased from FortisBC.[3]

In addition to the hydropower generating facilities, the RDCK is home to a large biopower generation plant. Mercer Celgar currently generates, on average, 65 MW_e, with 45 MW_e used for internal operations. The remaining 20 MW_e is sold into the BC grid under a power purchase agreement with BC Hydro, which is set to expire in the current year (2020). Approximately 90% of current generation is derived from recovery (black liquor) boiler steam, with the remaining 10% from an older power (solid fuel) boiler. In 2010, Mercer Celgar completed a Green Energy project that added a second turbine generator that increased potential generating capacity from 48 MW_e to 100 MW_e. Mercer Celgar has indicated that the turbine generator was oversized to permit future increased generation from a new, larger capacity power boiler. This larger power boiler has not been installed to date and a power purchase agreement is required to justify the investment. It should be noted that Mercer Celgar does not have an additional need for process heat at present, meaning a new power boiler would be electricity-only and only 1/3 the efficiency of a combined heat and power plant. Adding additional boiler capacity at Mercer Celgar is likely to be the lowest cost new biopower-only generation in the district. Addition of a new power boiler to the plant is part of the company's Celgar 550 plan to increase pulp production capacity to 550,000 admt per year.

Grid electricity in British Columbia is relatively low cost compared to electricity in other Canadian provinces and the province is currently in a significant oversupply situation – estimated at 400-550 MW_e capacity on average water (3,500-5,000 GWh/yr). This situation will be compounded when the 1,100 MW_e (5,100 GWh/yr) Site C hydroelectric facility comes online. Given this position, BC Hydro is not seeking to add any new generation to the grid and has made preliminary advances to reduce generation from pulp mills in the province. There is no longer an active Standing Offer Program through which independent power producers (IPPs) could sell power to BC Hydro. Therefore, new biopower purchase agreements with BC Hydro at

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[3] City of Nelson, 2020. Electrical services (Nelson Hydro). https://www.nelson.ca/218/Electrical-Services-Nelson-Hydro

economically-feasible prices are deemed unlikely in the next 5-10 years. Interviews across the RDCK have suggested a general stakeholder opinion that Mercer Celgar is unlikely to secure a long-term power purchase agreement for the 35 MW_e of potential additional capacity. This also means that any other biopower project in the RDCK would need a power purchase agreement (PPA) with an entity other than BC Hydro – for example, Nelson Hydro – to be viable.

Co-generation of electricity is generally desirable for heating plants with a capacity greater than 10 MW_{th}. Apart from industrial projects, this heat demand would require development of a district energy (DE) system to distribute the heat. Heat is the leading product, with electricity the higher value co-product. However, the incremental cost of biopower generation is likely to be higher than the market price for electricity in BC and a power purchase agreement with BC Hydro, FortisBC, or Nelson Hydro may not be possible. In this case, an LDC that operates the DE system may also manage electricity distribution in the community.

3.1.1 Rural Communities

It is understood that addressing extended power outages (supply interruptions), which can last in excess of 24 hours, is a priority for the RDCK. The areas most prone to outages include the north end and eastern shore of Kootenay Lake, Harrop-Procter (served by Nelson Hydro), Slocan Valley between Slocan and South Slocan, and both shores of the Arrow Lakes. Most areas, apart from Harrop-Procter, are served by FortisBC. While local, small-scale biopower generation was considered as a potential approach for the communities to address outages, this will not be a viable option. The communities in question have very small electricity loads and biopower technologies at the scale required are far from economical on the BC electricity grid. The technology challenges are addressed in Section 4, but the following key points should be considered:

- None of the communities are classified as ‘remote’ (off-grid) communities. Even though they do lose power, they are still grid-connected and subject to the same grid pricing as larger centres. A power purchase agreement would be required to connect a project.
- Generation of biopower at a scale less than 500 kW_e has a generating cost of \$0.40-\$0.80/kWh, which is approximately 6 to 12 times the delivered residential electricity price in BC. It is 12 to 25 times the commodity market price for electricity, making an economically-viable PPA unavailable.
- Electricity generation efficiency greater than 15%, at the scale required, is only possible with gasification and internal combustion engine combustion of the resulting syngas. This technology approach requires very high-quality feedstock with a low moisture content, very limited bark, no contamination, and uniform chip size. This is generally not the type of material reliably available in the areas that are subject to supply interruptions.

FortisBC provided a significant amount of information about the challenges and potential supply interruption solutions for the district. Almost all power outages are due to tree strikes, which are a function of the terrain and heavily forested nature of the areas. The Kootenay Lake areas are already on a loop feed, which means that outages occur because of tree strikes on both sides of the lake at the same time. The Slocan Valley is a radial feed, which means a single tree strike will interrupt supply.

There are several actions that could be taken to improve electricity system resiliency and reduce the frequency and duration of power outages:

A. **Improved Vegetation Management:** A common cause for power outages in rural areas in the RDCK is trees and tree branches contacting or damaging power lines. An action plan for improved vegetation management, both in terms of extensivity and frequency, along the right-of-ways for power lines could reduce the frequency of power outages.

B. **Underground Transmission/Distribution Lines:** An alternative to an improved vegetation management plan is rerouting existing power lines with underground power lines. This removes the possibility for tree falls to cause power outages. However, this is a relatively high cost solution compare to managing the power line right-of-way vegetation.

C. **Additional Power Generation:** Additional power generation would reduce the likelihood of power outages not caused by tree falls onto radial lines. For example, adding electrical generation to Duncan Dam located at the southern end of Duncan Lake, north of Kootenay Lake, would increase the reliability of the power supply in the Kaslo area. However, line capacity is viewed as a major impediment to this approach and Duncan Dam supply would be seasonally intermittent.

D. **Looping Existing Radial Power Lines:** Construction of new distribution/transmission power lines to loop existing lines could reduce the frequency and duration of power outages experienced in the RDCK, particularly outages caused by trees. This is applicable to the Slocan Valley.

E. **Storage/Backup:** Battery storage of grid electricity would serve as backup in the event of an outage. This is an alternative to gasoline/diesel generators at an individual building or community level.

Based upon a preliminary assessment and discussions with FortisBC, the most viable options to avoid supply interruptions are the following:

- **Kootenay Lake, Harrop-Procter, and Arrow Lakes:** Electricity storage (batteries) at an individual building or community level. This is a low-carbon alternative to gasoline or diesel generators.

Electricity storage would be a much more viable option if electricity was not used for space or hot water heating. This is addressed in Section 3.2. This approach is projected to be lower cost than underground lines due to the distances required.

- **Slocan Valley:** Install a new line from Slocan (FortisBC) to the BC Hydro transformer in Silverton creating a loop. FortisBC doubts that the BCUC will permit this line to be included in the rate base, so another financing approach is required.

3.2 Building Heat

The dominant role for wood fuels is space, hot water, and industrial process heat. Generation of heat is 2.5 to 3 times more efficient than generation of electricity alone or production of transportation fuels. Direct combustion of wood is double the efficiency of wood conversion to biomethane (renewable natural gas) and subsequent biomethane use for heat. Wood is already a major contributor to single family detached home space heating in the RDCK, with cord wood combustion in wood stoves the dominant approach. For the purposes of this report, building heat markets are divided into single family detached homes, C/I buildings, and DE systems. The latter application uses underground hot water pipes to connect multiple buildings to a central heating plant. The potential heating fuels considered are hog fuel (industrial, DE), wood chips (industrial, C/I, DE), wood pellets (C/I, residential), and cord wood (residential). Biochar and pyrolysis oil production are not produced in the district and are not recommended; there are no small-scale commercial heating units designed to operate on these fuels. Briquettes and firelogs are options, although the large sawdust and shavings demand of the existing pellet mills in southeast BC means securing appropriate feedstocks may be challenging. They are also not fuels for primary (i.e., automated) heat source appliances.

3.2.1 Single Family Detached Houses

Cordwood use in wood stoves is typically considered a secondary heat source, since it requires refueling numerous times per day and residents cannot leave properties unattended in the winter without a primary heat source. In areas that lack natural gas, this primary heat source is usually electricity, propane, or heating oil. This report focuses on the potential role of wood as primary heating source – termed modern wood heating – that can operate automatically without daily user/building resident intervention. Although wood is widely used in the RDCK as a secondary fuel, there is still substantial use of heating oil and propane, indicating a need for a renewable, low-carbon, and reliable primary heating option.

For single family detached homeowners seeking to use wood as a primary heating source with operational requirements similar to propane or heating oil, wood pellets are the fuel of choice. Modern wood pellet boilers are highly efficient, automated, thermostat-controlled appliances that can be remotely controlled using the cloud (e.g., cellphone). Due to the flowability of pellets, they do not need to be manually fueled and most installations require only two bulk pellet deliveries per year. The only human intervention required for operations is the ash bin emptying once every 2-3 weeks. The biggest challenge with wood pellet boilers is the upfront capital cost, with a typical single-family detached home unit costing $17,000-22,000 installed. With approximately 900,000 residential pellet boilers installed in the EU, the technology is proven and reliable. Despite the high capital cost, pellet boilers are considered the leading primary (i.e., not secondary/manual) wood fuel option for residential or small C/I buildings that won't be connected to a DE system. They are most likely to be considered for buildings without natural gas access that are currently heated with propane or heating oil, or subject to extended power outages. Electricity demand by the boilers is very low and a battery storage system could supply sufficient power for multi-day operation.

3.2.2 Commercial/Institutional Buildings

Commercial and institutional buildings, such as schools and hospitals, not connected to a DE system can be heated with wood chips or wood pellets using modern wood boilers. The heat demand of larger C/I buildings necessitates larger boilers than single family detached homes, thus enabling the use of wood chip fuel. While pellets are generally a higher cost fuel than wood chips, there can be significant capital cost savings with using pellets. The larger a project is, the more likely it is to use wood chips. The boilers used at the C/I individual building scale are, like single family detached home boilers, manufactured in bulk in a factory and considered 'off-the-shelf'. There are over 60,000 C/I modern wood boilers operating in the EU at present. In Canada, there are over 450 C/I wood pellet and wood chip boiler projects in operation. In general, individual boilers less than 500 kW_{th} in capacity have very strict fuel specifications – particularly if they are consuming wood chips. Most boilers greater than 1500 kW_{th} capacity can consume bark-on wood chips but cannot operate solely on hog fuel, although there are exceptions. Within the RDCK, most C/I buildings are located in areas with natural gas access. In these locations, which are already serviced by a utility, connection to a DE system is likely a preferred approach rather than individual boilers for each building. A non-exhaustive list of potential C/I bioheat projects in the RDCK is listed below. These include very small DE systems when all buildings are owned by the same entity. Several C/I boilers are already installed in the RDCK, including a 950 kW_{th} wood chip boiler to heat the Kalesnikoff Lumber building.

Potential C/I Bioheat Projects:

- Whitewater Ski Resort
- Salmo Ski Hill

- Slocan Community Health Centre
- Arrow Lakes Hospital
- Nakusp and District Community Complex
- Nakusp Elementary and Secondary Schools
- Lucerne Elementary Secondary School
- JV Humphries Elementary-Secondary
- Redfish Elementary School
- Winlaw Elementary School
- W.E. Graham Community School
- Selkirk College

3.2.3 District Energy Systems

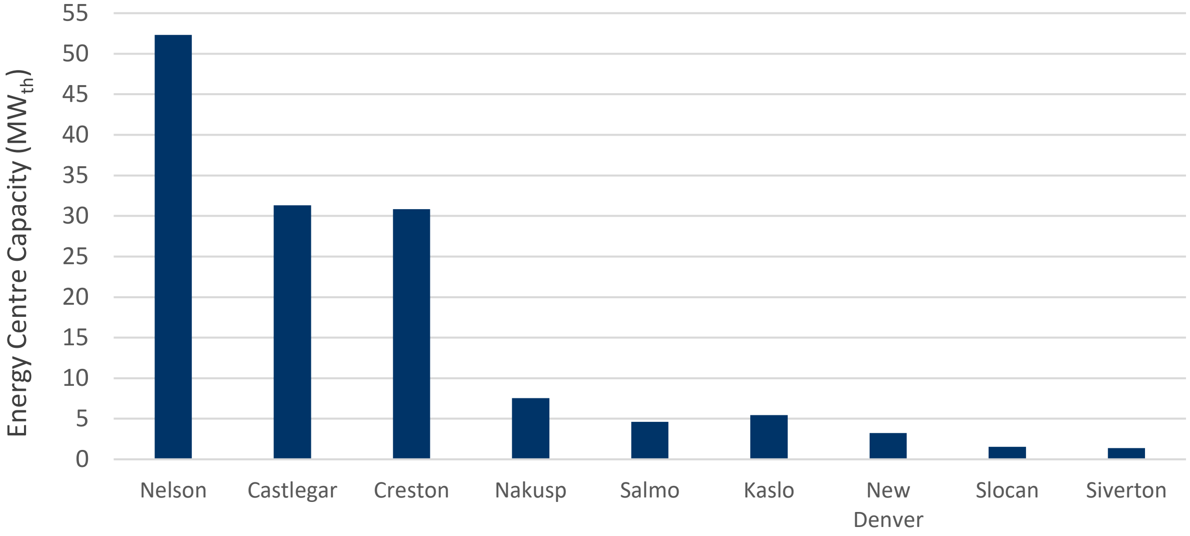
DE systems are networks of pipes, often buried, that carry heated or cooled water from a centralized plant or other energy source to connected buildings. Heating or cooling individual buildings or developments through a connection to a DE system is easier and lower cost from a logistics and operations perspective. When connected to a low carbon energy source, DE systems can potentially reduce the GHG emissions of all connected loads, depending on the heat source being displaced.

The two leading low carbon technologies for DE systems are solid biomass combustion and heat pumps. As noted above, co-generation of electricity with biomass heating is typically only viable at a scale greater than 10 MW_{th}. Figure 7 presents a rough estimate of likely biomass energy centre heat capacity by community. Based upon this estimate, the only communities where co-generation of electricity has the potential to be economically viable are Nelson, Castlegar, and Creston. If DE is feasible in the small communities, including unincorporated communities, a DE energy centre is likely to be heat-only and use off-the-shelf boiler(s).

Heat pumps operate by using electrical work to draw thermal energy from an external medium. This external medium can be ambient air, river/lake water, sewer water, industrial wastewater, or the ground. Heat pumps range in scale from servicing small single-family detached homes to large units with a capacity of 10-15 MW_{th}. Castlegar is unique amongst RDCK communities due to its proximity to the Mercer Celgar, which produces abundant waste heat at both 42 C and 80 C. While the former stream may need a heat pump or in-building hot water tank to boost the temperature for domestic hot water, the latter stream does not require any temperature boost to meet all building needs.

Figure 7. Potential Building Heat District Energy Demand by Community

Assumes 75% of building energy demand is space heat and hot water, 66% of building heat demand can be connected to the DE system, and 2200 full load equivalent hours per year.



A preliminary assessment of the DE development opportunities in communities within the RDCK was completed (Figure 8). Four DE development scenarios were conceptualized. These DES development options are:

- Phased DE system development in Castlegar, heated with waste hot water from Mercer Celgar;
- A downtown DE system in Nelson, heated with a biomass CHP plant;
- A DE system in Creston, heated by a biomass CHP plant also providing steam to the Columbia Brewery;
- Multi-site DE development including rural communities of Nakusp, Kaslo, New Denver, and Riondel.

Based upon the preliminary assessment, a DE system in Salmo will be very economically challenging due to the relatively low urban density combined with existing natural gas supply. This assessment also showed that buildings in Slocan and Silverton may be too spread out for a community-wide DE system and that individual building boilers or multiple small DE systems are likely the lower cost option. A small number of unincorporated communities, including parts of Riondel and Lardeau, may be considered for DE development, particularly if development is part of a community energy resilience strategy to reduce electricity reliance.

Community District Energy Comparison Legend

Relative Rating	Description
🟢	**Positive/Good**: Promising, no apparent key issues that would affect project development. Cost may or may not be competitive.
🟡	**Neutral**: Some residual issues exist which may be able to be resolved or mitigated upon further investigation. Cost may not be competitive.
🔴	**Negative**: Key issues exist which may be difficult or impossible to mitigate and which would impact project development. High cost.
▣	**Major Barriers**: Multiple key issues and few positive aspects indicate major barriers that would need to be overcome to establish a business case competitive to other locations. High cost.

Figure 8. Community District Energy Comparison

Community	Community Type		Criteria Rating										Conclusions
			Energy Demand		Distance to Heat Source		Building/Load Density		Bioenergy Fuel		Greenhouse Gas Displacement Opportunity		Summary Rating
Castlegar	Urban	🟡	Large community, moderate energy demand	🟢	Mercer Celgar pulp mill heat source, ~ 5 km from nearest load centre	🔴	Moderate, three load centres identified	🟡	Waste heat from pulp mill likely low cost	🟢	Existing heat source is primarily natural gas, with some heating from heating oil, wood, and propane.	🟢	🟡
Creston	Urban	🟡	Moderate, brewery has high heat demand	🟢	Biomass Boiler Plant can be centralized	🟢	Moderate	🟡	Scale permits use of hog fuel	🟡	Existing heat source is primarily natural gas, with some heating from heating oil, wood, and propane.	🟢	🟡
Kaslo	Rural	🔴	Small community. No identified high heat demand buildings	🔴	No easily identifiable central location for biomass boiler plant or other heat source	🟡	Low	🔴	Scale may permit use of hog fuel, but extensive use of electricity may reduce potential scale	🟡	Low energy demand / small community. Existing heating sources are split between heating oil, wood, and propane.	🔴	🟥
Nakusp	Rural	🔴	Small community, health care centres typically have high heat demand	🟡	Biomass Boiler Plant can be centralized	🟢	Low	🔴	Scale may permit use of hog fuel, but extensive use of electricity may reduce potential scale	🟡	Low energy demand / small community. Existing heating sources are split between heating oil, wood, and propane.	🟡	🔴
Nelson	Urban	🟡	Largest community energy demand in Central Kootenays	🟢	Biomass Boiler Plant can be centralized	🟢	Moderate	🟡	Scale permits use of hog fuel	🟡	Existing heat source is primarily natural gas, with some heating from heating oil, wood, and propane.	🟢	🟡
New Denver	Rural	🔴	Small community, health care centres typically have high heat demand	🟡	No easily identifiable central location for biomass boiler plant or other heat source	🟡	Low	🔴	Scale likely inhibits use of hog fuel; higher quality fuel required	🔴	Low energy demand / small community. Existing heating sources are split between heating oil, wood, and propane.	🔴	🟥
Salmo	Rural	🔴	Small community. No identified high heat demand buildings	🔴	No easily identifiable central location for biomass boiler plant or other heat source	🟡	Low	🔴	Scale may permit use of hog fuel, but extensive use of electricity may reduce potential scale	🟡	Low energy demand / small community. Existing heat source is primarily natural gas, with some heating from heating oil, wood, and propane.	🟡	🟥
Silverton	Rural	🔴	Small community. No identified high heat demand buildings	🔴	No easily identifiable central location for biomass boiler plant or other heat source	🟡	Low	🔴	Scale likely inhibits use of hog fuel; higher quality fuel required	🔴	Low energy demand / small community. Existing heating sources are split between heating oil, wood, and propane.	🔴	🟥
Slocan	Rural	🔴	Small community. No identified high heat demand buildings	🔴	No easily identifiable central location for biomass boiler plant or other heat source	🟡	Low	🔴	Scale likely inhibits use of hog fuel; higher quality fuel required	🔴	Low energy demand / small community. Existing heating sources are split between heating oil, wood, and propane.	🔴	🟥

Castlegar

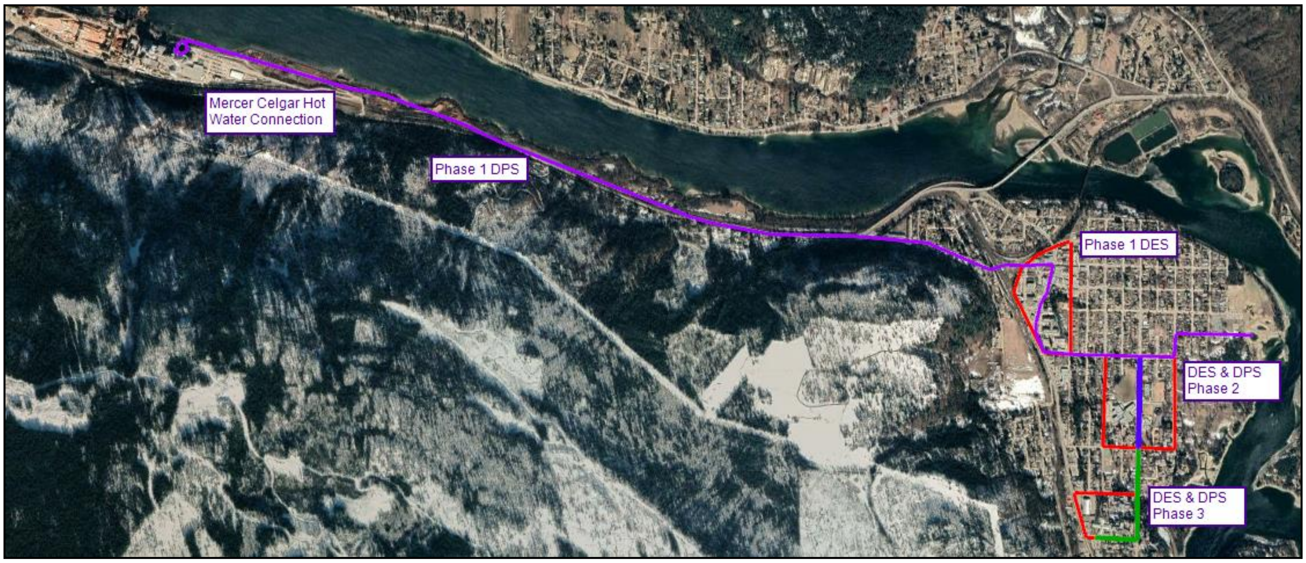
Mercer's Celgar pulp mill is an abundant source of waste heat, with a discharge of approximately 1000 L/s of 42 C hot water. Due the abundance of high temperature water currently discharged into the Columbia River at Mercer Celgar, a single high-density polyethylene for raised temperature (PE-RT) buried distribution pipe would be sufficient to serve the load centres in Castlegar. In place of a return line carrying water back to the heat source, discharging through Millennium Ponds, to create warm all-season outdoor pools, and into the Columbia River could be used to reduce the cost and bring additional benefits to the City.

A phased DE system approach for Castlegar is suggested due to separable load centres identified during screening. The Mercer Celgar mill could meet the heat needs of all these phases.

- Phase 1 – Downtown Castlegar.
- Phase 2 – Schools and surrounding residential buildings.
- Phase 3 – Health care and community centres.
- Phase 4 – Remainder of the community on the West side of the Columbia River.

Each phase of the DE system can be examined incrementally, evaluated and developed individually based on business case economics and GHG emission targets. Figure 9 below shows the load centres identified in Castlegar, in relation to Mercer's Celgar mill.

Figure 9. Mercer Celgar-Castlegar District Energy Main Lines



Each of the load centres identified for potential phases 1, 2, and 3, contain the following building types:

- Phase 1 includes a high-density area of buildings that could be heated by the DE system and is the load centre closest to the heat source at Mercer Celgar. The buildings located in the initially proposed bounds of the phase 1 DES include restaurants, cafes, public service centres (RCMP, Fire Department, and City Hall), as well as commercial/retail stores.
- Phase 2 includes two elementary schools, a high school, a church, and surrounding residential buildings.
- Phase 3 includes health care centres and adjacent residential buildings.
- Phase 4 includes the remainder of the buildings on the West side of the Columbia River.

Selkirk College and other buildings on the East side of the Columbia River could be evaluated for connection to the main city DE system following Phase 4. Figures 10 and 11 below shows the initial boundaries considered for the DE system phases for Castlegar.

Figure 10. Potential Castlegar District Energy Development Phases 1-3

Figure 11. Potential Castlegar District Energy Development Phase 4

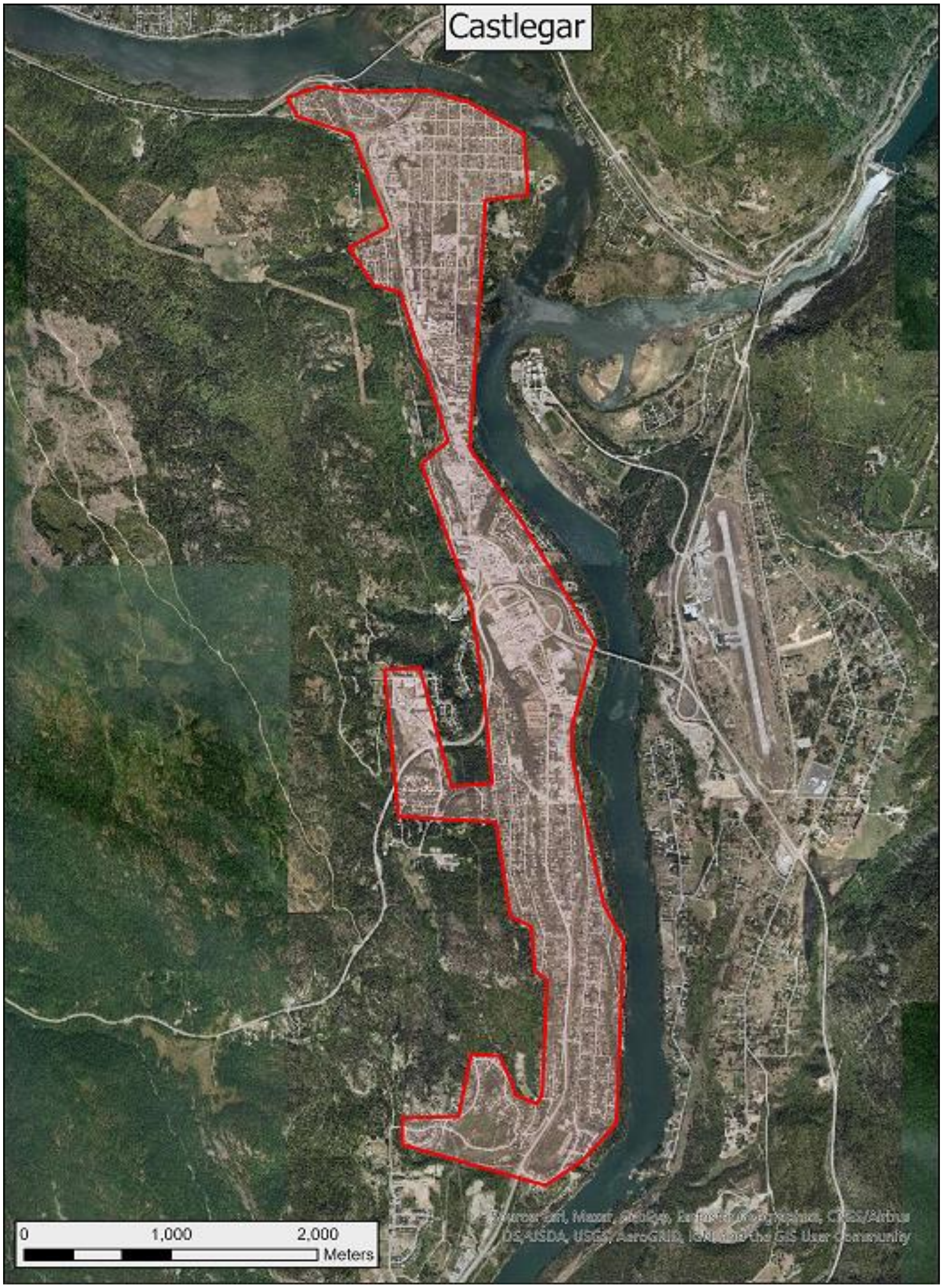


Figure 12 below shows an order of magnitude estimate for the cost to bring a distribution piping system (DPS) mainline from Mercer's Celgar pulp mill to load centres in Castlegar. The following assumptions are included:

- PE-RT pipe material is recommended for 42 C water. Due to the abundance of heat at Mercer Celgar, the insulation of PE-RT material is likely sufficient. If 80 C water were used, pre-insulated steel pipes would be required and result in a higher pipe cost;
- A cost of $1000/m for installation of a single buried PE-RT line is assumed based on KWL experience;
- All costs presented are in 2020 CAD; and
- Costs presented only allow for a mainline DPS; service branches are not included in this estimate.

Figure 12. Mercer Celgar to Castlegar – DPS Mainline Order of Magnitude Cost Estimate

Phase	Approximate Length [m]	Unit Cost [$/m]	Subtotal [$]	Contingency	Professional Fees	Total [$]
1	6,100	1000	6,100,000	50%	10%	9,760,000
2	900	1000	900,000	50%	10%	1,440,000
3	1,300	1000	1,300,000	50%	10%	2,080,000

The above cost estimates are based on KWL's previous DE system experience with projects of similar scope and are intended for planning purposes. These estimates represent civil, mechanical, traffic management, and site restoration costs on a cost per linear metre basis. Actual costs for any of the presented DPS sections will depend on such factors as market conditions, competitiveness of the tendering process, contractor workloads, existing buried utilities, geotechnical conditions, and other risks. These cost estimates do not qualify as "Class" estimates under EGBC guidelines.

Natural gas purchased from FortisBC has an all-in cost of $7.60/GJ, including the cost of delivery, carbon tax, and the gas commodity cost. The total price for purchasing renewable natural gas is $16.10/GJ. Based on an annual thermal load of 361,812 GJ/year in Castlegar, the annual cost to provide low carbon heating to all of Castlegar's thermal loads with renewable natural gas is approximately $6.3 million. The annual cost to heat all of Castlegar's thermal loads with conventional natural gas is approximately $2.7 million.

Nelson

Nelson contains a relatively high building density in its downtown area, including many restaurants and cafes which typically have high heating demands. Figure 13 shows the potential boundary for a biomass fueled DES in Nelson's downtown area.

Figure 13. Potential Downtown Nelson DE Boundary

Nelson has the largest building energy load in the RDCK. This does introduce the possibility of creating competition for fibre supply, particularly since co-generation of electricity is likely at the demand scale considered. However, the main competitor for low-cost hog fuel would likely be the Avista plant in Kettle Falls, Washington and a co-generation plant in Nelson could consume a combination of hog fuel and harvest residues. Nelson Hydro has previously examined the feasibility of developing a downtown DE system for Nelson. Both biomass and Kootenay Lake (heat pumps) were considered as energy sources in this study, with biomass selected as the lowest cost option.

Creston

Creston has the third largest annual energy demand of the RDCK communities. A DE system in Creston has the potential advantage of containing multiple buildings with typically high heating loads in relatively close proximity. These building include multiple schools, a brewery, health care centres, and restaurants. A DE system in Creston could potentially be heated by a biomass boiler plant fueled with hog fuel from J.H. Huscroft, located in Creston, and Wynnwood, approximately 10 kilometres to the north. Figure 14 below shows the proposed boundary for a DE system in Creston, serving typically high heat load buildings.

Figure 14. Potential Downtown Nelson DE Boundary

Multi-Community, Clustered Development

Rural communities can increase community resilience via development and operation of bioheat projects that can include individual building bioheat boilers, DE systems, or a combination of the two. Community-wide DE systems can be considered when building density is high (i.e., distance between buildings is small), while individual boilers for each building are preferred when building density is low. Given DE system development is likely a significant undertaking for a small municipality, it may be possible for multiple municipalities to collaborate and pursue a regional cluster development that would benefit from economies-of-scale in capital and construction costs, as well as establishment of biomass fuel supply chains. Communities that are the most likely candidates for small-scale DE development include Nakusp, Kaslo, New Denver, and Riondel, although several others, such as Silverton, could be considered. Example areas for inclusion in DE systems are presented in Figure 15.

Figure 15. Potential District Energy Service Areas in Nakusp, Kaslo, New Denver, and Riondel

Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

3.3 Industrial Heat

Wood, in the form of pulp black liquor, hog fuel, and cord wood, is the single largest contributor to energy consumption in the RDCK, with Mercer Celgar and Interfor the largest industrial consumers. In addition to its Celgar 550 initiative to increase pulp production capacity, Mercer has been assessing the potential to replace the natural gas used in the plant's lime kiln with syngas (carbon monoxide and hydrogen) generated from gasification of hog fuel. The lime kiln, which regenerates the pulping chemical lime, accounts for approximately 60% of Mercer's natural gas consumption. Fuel switching to hog fuel-based syngas would reduce natural gas consumption at the pulp mill by 1,200,000 GJ per year and is the single largest GHG reduction project possible in the district. Several pulp mills in the EU already use biomass gasification for fuelling their lime kilns, and while the approach is technically challenging, it is commercially proven. However, the economics of replacing natural gas are difficult, with the capital cost, based upon previous installations, for a hog fuel gasifier estimated at $20-25 M. As the Government of BC has permitted FortisBC to purchase biomethane (renewable natural gas) at prices up to $30/GJ, Mercer is seeking to apply this policy to the syngas produced from the gasifier and to have FortisBC spread the higher costs across the utility's rate base. This is a significantly lower risk, higher efficiency (and hence, greater GHG reductions per tonne of fuel), and more capital efficient approach than seeking to convert the hog fuel-based syngas into biomethane for pipeline injection. However, it is anticipated Mercer will face challenges securing a purchase agreement from FortisBC and the RDCK may have a role to play in making a case for this industrial heat decarbonization approach.

Additional industry wood heat opportunities include lumber drying kilns and process heat (steam) for the Columbia Brewery in Creston. A high-temperature CHP plant co-located at the latter could also serve as the source of heat for a DE system.

3.4 Transportation

As noted in Section 3, a wood-to-biofuel facility in the RDCK would provide fuel for distribution to a much larger market than the RDCK alone. Wood-to-liquid fuel technology is precommercial and is summarized in Section 4. Wood-to-liquid biofuel conversion is approximately 1/3 as efficient as thermal (heat) energy generation from wood, which means displacement of natural gas, heating oil, and propane with wood in heating applications will result in greater GHG reductions per tonne of wood than production and use of liquid biofuels. If the RDCK desires to address the RDCK transportation market with wood, a focus should be placed on CHP with the power used for electric vehicles. This approach is nine times more efficient than production and use of wood-based liquid transportation biofuels.

4 TECHNOLOGY SUMMARY

As biomass can, technically, be converted into a biological equivalent of any fossil fuel or energy resource in use today, decisions by investors and governments on strategic use of the wood resources need to focus on whether one should, rather than could, pursue any specific production pathway. The flexibility of wood as a resource for a multitude of products means companies often compete for resources and government interest. In general, it is recommended that the RDCK focus on presently commercial technology options rather than seek to be the host to first-of-kind facilities. There have been a large number of high cost biofuel and bioproduct company and facility failures and technology risk must be a key consideration of whether to pursue unique approaches. Bioenergy is a high capital cost sector and commercialization of new technologies typically takes 10 to 20 years. In order to maximize operating jobs and wood fibre consumption, reduce GHG emissions, and have a meaningful impact on the energy consumption, commercial technologies must be deployed at scale – which means either many small- or medium-scale projects or one or two very large projects.

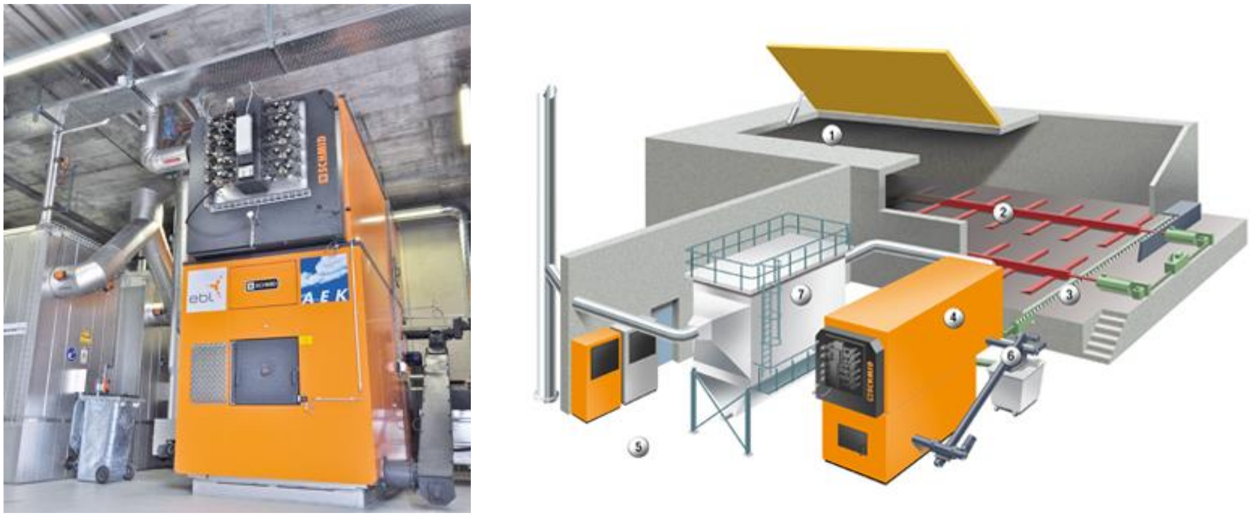
4.1 Heat Only

As noted in Section 3.2.1, modern wood heating consists of boilers for primary building space and hot water heat. Wood pellets are the preferred fuel for residential homes or small C/I buildings while wood chips often have an economic advantage for larger C/I buildings and DE systems. Some off-the-shelf boilers larger than 1 MW_{th} can consume hog fuel. Residential wood pellet boilers are automated and require little human intervention beyond emptying the ash bin once every 2-3 weeks. The largest biomass boiler manufacturer in the world, Austrian company Fröling, produces over 35,000 units per year. These are available in Canada, as are boilers from ÖkoFen, another Austrian manufacturer with sales of 8,000 to 10,000 units per year. An example of a residential pellet boiler is presented in Figure 16.

Figure 16. Fröling PE1 Wood Pellet Boiler (20 kW_{th})

Off-the-shelf wood fuel boilers are generally available at capacities up to 1.5 MW_{th}. These boilers all produce hot water at <100 C. Multiple boilers can be installed at a single energy centre in a cascading manner, with maximum energy centre capacity typically 6 MW_{th} (4 x 1.5 MW_{th} boilers). Beyond this scale, on-site custom boiler fabrication is the norm. An example of a C/I boiler is presented in Figure 17.

Figure 17. Schmid UTSR-1200 (1.2 MW_{th})

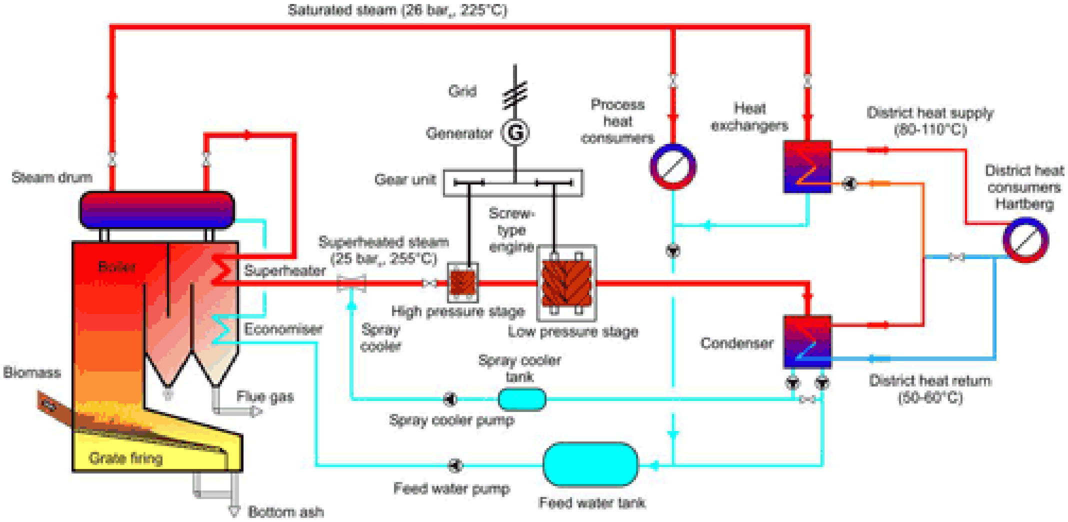


4.2 Combined Heat and Power

4.2.1 Steam-based Generation

Conventional CHP generation involves the combustion of biomass in a grate or fluidized bed boiler that generates steam. Steam is used to turn a turbine generator for electricity generation and thermal energy (heat) is recovered as steam or hot water. A simple diagram is provided in Figure 18.

Figure 18. Steam-based Combined Heat and Power Generation

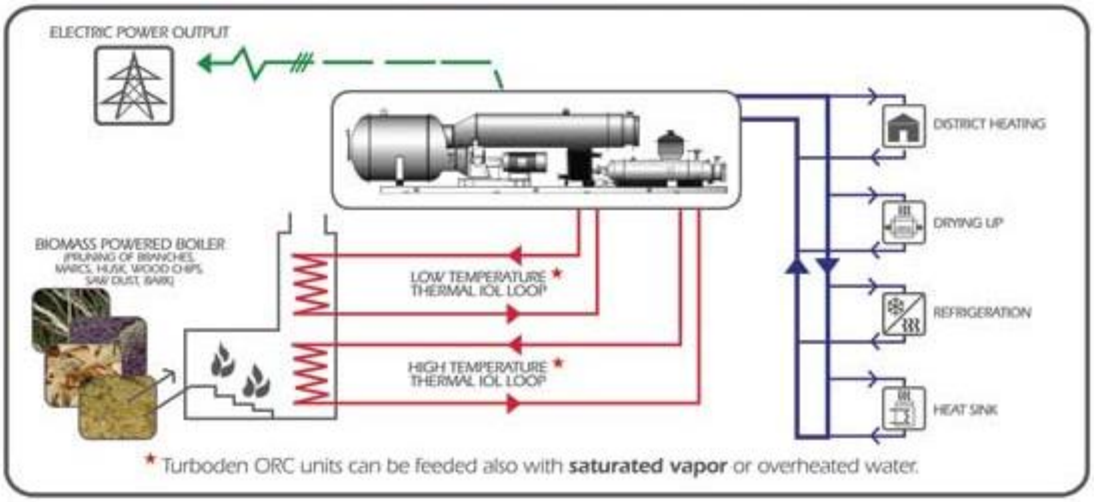


Steam-based generation is by far the most common CHP design worldwide and is the approach used by Mercer Celgar. It is also the most likely technology approach for a biomass CHP in Creston, given the process steam requirements of the Columbia Brewery. However, Canadian provinces, including British Columbia, have amongst the strictest operating requirements globally and require virtually all steam plants to be supervised 24/7 by power engineers. This places a high operating cost burden on smaller CHP plants connected to community DE systems, which are continuously monitored but often unmanned in the EU.

4.2.2 Organic Rankine Cycle and Gasification/Internal Combustion

There are two leading alternative biomass CHP technologies, both of which have already been implemented in British Columbia. The first is the combination of a thermal oil heater combustor, which heats a thermal oil to 300-340 C without vaporizing, and an organic Rankine cycle (ORC) generator. Thermal oil heat is transferred to the ORC, a heat engine which contains an organic fluid that is evaporated to drive a turbine. The organic fluid is condensed using a heat sink – typically a DE system – and completes the cycle (Figure 19). Hence, the ORC is a closed system and not subject to the same supervision operating requirements as steam. Since the ORC is a closed system, low quality fuel (e.g., hog fuel) can be used in the combustor. There are approximately 500 of these installations in the EU and West Fraser has installed ORC units at two sawmills in BC. The combination of a thermal oil heater and ORC is the most likely combination for a CHP in Nelson.

Figure 19. Turboden Organic Rankine Cycle Flow Diagram



The second CHP technology combination, which is only relevant for applications <500 kWe, is gasification followed by combustion of the resulting syngas (CO and H_2) in an internal combustion engine (ICE). Since the syngas must be combusted inside of the engine, it must have a very high purity and not contain tars: longer-chain organic molecules. Purifying the syngas is always the most challenging technology component and a large number of projects have failed due to impure syngas. Syngas purity is strongly impacted by feedstock quality and therefore this technology combination has very strict feedstock requirements. In general, fuel must either be wood pellets or whitewood chips with a moisture content <20%, both of which require active drying of material. There are approximately 1,000 of these installations in the EU, but almost all are 150 kW_e or less units. In order to be economically viable, they receive substantial above-market prices (e.g., C$0.50/kWh) for the generated electricity. A gasifier and ICE was installed in the remote BC village of Kwadacha, but is not recommended for any communities in the RDCK due to the lack of economic competitiveness. The cost of generation is approximately 10x the market price for electricity in British Columbia and BC Hydro/Fortis BC will be unable to provide a PPA anywhere near the required rate to economically develop a small-scale grid-connected biopower project in the RDCK.

4.3 Wood to Liquid Fuels and Biomethane

All wood-to-liquid biofuel and biomethane (renewable natural gas) technologies are precommercial. Despite billions of dollars invested in these technologies to date, there are no commercial-scale facilities operating at capacity on a continuous basis. The Government of Canada and provincial governments have provided significant grant funding since 2003 to commercialize cellulosic ethanol and other advanced biofuels. The most substantial fund was the $500 M NextGen Biofuels Fund, which was administered by Sustainable Development Technology Canada. Advanced biofuel technology companies that received grant funding from the Government of Canada include Enerkem, Ensyn, Iogen, Dynamotive, Lignol, Woodland Biofuels, Greenfield Global, Comet, Pond Biofuels, and Licella/Canfor. Of the Canadian grant recipients, only Enerkem and Ensyn have pioneer, first-of-kind semi-commercial plants in Canada that are currently operating. The small 10 ML/yr Ensyn wood pyrolysis plant in Renfrew, ON produces Renewable Fuel Oil (pyrolysis liquids) for the institutional U.S. space heating market but processing into transportation fuel has only been conducted in small-volume trials by its joint venture, Envergent, with oil refinery technology company UOP. Construction began on Ensyn's 40 ML Coté Nord project in Port-Cartier, QC in 2016 but the plant has not been commissioned to date. The Governments of Canada and Quebec contributed approximately 75% of the $104 M capital cost. Companies in other countries have faced similar advanced biofuel technology scale-up and commercialization challenges, including high feedstock cost, inconsistent feedstock properties, equipment non-performance, lower-than-anticipated yields, low fuel pricing, and the very large capital investments and facility required for fuels production commercial viability. Significant cost and fuel carbon intensity reductions in the conventional ethanol sector have also reduced the impetus for development of novel wood biofuels. None of the integrated cellulosic ethanol plants in the U.S. are operating successfully and numerous advanced biofuel technology company insolvencies, including Range Fuels, KiOR, and Abengoa in the U.S. and Choren in Germany, have reduced investor appetite.

Policy created an opportunity for advanced biofuels, but, to date, technology commercialization and scale-up has proven more difficult than anticipated. As an example, the U.S. Energy Security Act of 2005 specified a blending requirement of over 60,000 ML/yr of cellulosic biofuel by 2022, with cellulosic ethanol anticipated to supply the vast majority of this volume. As of 2019, annual cellulosic ethanol production is below 25 ML/yr. Since all wood-to-liquid biofuels technologies are precommercial, they are not recommended for the RDCK.

REN Energy International has announced plans to develop a wood-to-biomethane plant in Fruitvale and has signed an offtake agreement with FortisBC. However, this offtake agreement should not be viewed as an indicator that FortisBC believes the project will be successful; it is simply an offer to purchase the biomethane if it is produced. The largest wood-to-biomethane facility completed to date is the C$225 M 20 MW$_{th}$ GoBiGas project in Gothenburg, Sweden. The plant, which has been mothballed, involved the most experienced biomass gasification and engineering teams in the world but faced numerous challenges and was only able to operate continuously on wood pellets for less than 2,000 hours. The project report indicates a facility would need to consume 450,000 bdt/yr of whitewood chips to have a chance of being economically viable.[4] Even if a plant could operate commercially, the energy efficiency would be approximately half that of using wood directly in a boiler for heating and it would have a capital cost 10x that of a wood boiler. RDCK support of wood-to-biomethane is not recommended.

4.4 Heat Pumps

Heat pumps use electricity and temperature differentials to create heating or cooling. Heat pumps can be service individual buildings or used in a centralized heating plant to increase water temperature from a main source (e.g., sewer, pulp mill discharge) for use in a DE system. Use of biopower to operate heat pumps is an indirect form of bioenergy.

This summary covers three heat pump technologies which may be suitable for low carbon heating in the relatively dense cities of Castlegar and Nelson, and in the RDCK's other more remote communities:

- Air Source Heat Pumps
- Ground Source Heat Pumps

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[4] Larsson A, Gunnasrsson I, Tengberg F. 2018. The GoBiGas project – demonstration of the production of biomethane from biomass via gasification. Göteborg Energi.

- Water Source Heat Pumps

Heat pumps can be owned by building owners or they can be operated by as a city utility with the heat pumps owned by a municipality. Large-scale (>5 MW_{th}) heat pumps are generally used for DE systems.

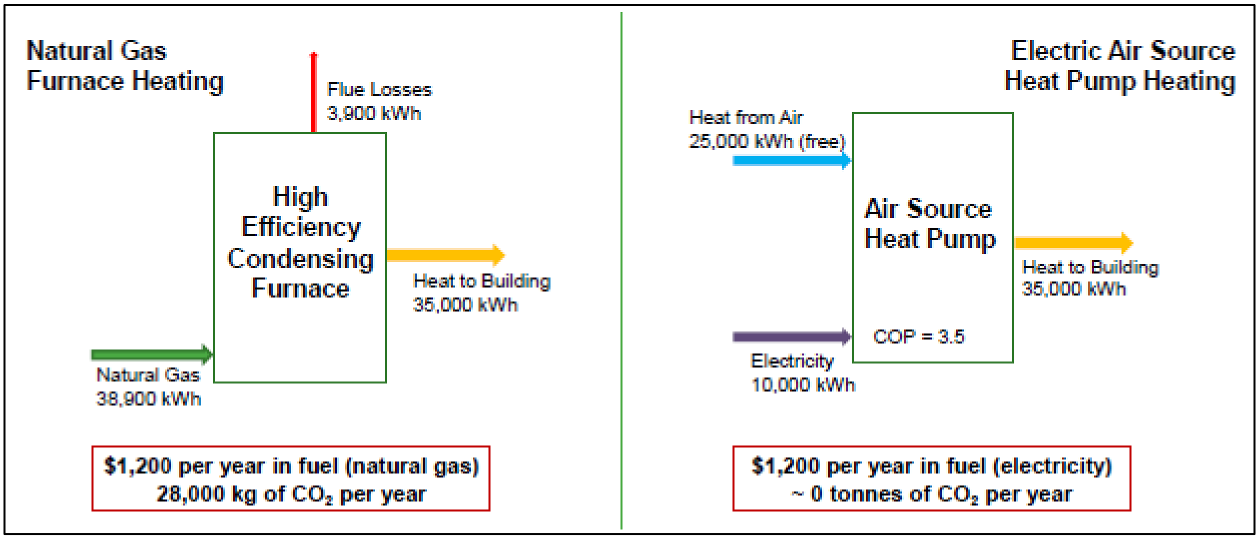
The Mercer Celgar “Celgar 550” investment presents an opportunity to lower the RDCK greenhouse gas emissions and produce electricity. This additional electrical generation could be utilized by heat pumps to further offset greenhouse gas emissions in the RDCK by offsetting fossil fuel use for heating in Castlegar.

4.4.1 Air Source Heat Pumps

Air source heat pumps (ASHP) operate by drawing energy from outside air. Heating efficiency is heavily dependant on the ambient outdoor air temperature and as outdoor air temperature declines in winter months, ASHP lose efficiency/capacity. ASHPs are typically well suited for connection to individual buildings. In the summer months, ASHPs can be run in a reverse operation to provide cooling/air conditioning.

Figure 20 below outlines an example comparison between the emissions of a typical ASHP and conventional natural gas furnace when used to heat a single building.

Figure 20. Natural Gas Furnace and Air Source Heat Pump Comparison



4.4.2 Ground-Source Heat Pumps/Geoexchange

An alternative to ASHP, ground source heat pumps (GSHP), also know as geoexchange, can be used to provide seasonal heating and cooling that is largely independent of outdoor ambient air temperature. Geoexchange operates on the principal of drawing/rejecting heat to and from the ground to through a fluid medium, typically water or a glycol/water mixture. This water/mixture is pumped through vertical or horizontal buried loops of piping to provide heating or cooling to the secondary side of the heat pump. Groups of buried geoexchange loops are referred to as "Geoexchange Fields".

Geoexchange fields have the benefit of being seasonally independent, as beyond a certain depth, ground temperatures are relative stable all year round regardless of the surface air temperature. Geoexchange fields typically have large footprints compared to other heat pump solutions, requiring more buried piping loops as heating/cooling loads increase. Additionally, the cost to install geoexchange fields is highly variable between different locations, as the geotechnical structure of the subsurface strongly impacts the complexity of laying the buried pipe loops. Land value of proposed field locations also strongly affects the cost of geoexchange heating/cooling solutions.

4.4.3 Water-Source Heat Pumps

While ASHP and GSHP can be theoretically installed anywhere with varying degrees of efficiency, water source heat pumps (WSHP) requires a significant water reservoir/source to draw heat from. This source heat can come from:

- Sewer main heat recovery, requiring specialized equipment in conjunction with WSHP to extract heat from sewer flows with temperatures on the order of 10 C.
- River/Lake water, such as the Columbia River that flows through Castlegar, or Kootenay Lake for shoreline communities such as Nelson.
- Waste industrial heat, such as the heat Mercer's Celgar pulp mill cooling water that is currently discharged into the Columbia River.

Each of the above WSHP heat sources could be utilized by RDCK's communities, depending on the water sources available to each community. In Castlegar for example, each technology could be implemented. River/Lake WSHP could draw heat from the very large flows in the Columbia River to heat individual residences that are situated near the river. Sewer heat recovery WSHP could be used to draw waste heat from the effluent in Castlegar's sewer mains/interceptors to heat buildings adjacent or near to the sewer mains.

WSHPs could also play a part in a distribution piping system such as the one previously mentioned between Mercer's Celgar mill and Castlegar's load centres. WSHPs could be used to upgrade the 42 °C wastewater temperature to higher temperatures as needed before being distributed to the load centres.

5 SUPPLY CHAIN AND OPERATIONS

As identified in Sections 3 and 4, industrial heating, individual building heat, and DE systems, heated with centralized bioheat or CHP plants, are the most viable approaches for bioenergy generation in the RDCK. Each of these three primary applications requires a unique biomass fuel supply chain that is appropriate for the properties of the fuel(s) and technology utilized. The primary industrial heat opportunity is fuel switching from natural gas to hog fuel-based syngas in the lime kiln at Mercer Celgar. This would involve a redirection of hog fuel from Avista Kettle Falls to Mercer Celgar and result in a near three-fold increase in energy efficiency per tonne of feedstock.

5.1 Wood Pellet Production and Distribution Hubs

There is currently no wood pellet production in the RDCK, although a significant volume – likely more than 80,000 t/yr – of sawdust and shavings from mills in the RDCK is used to make wood pellets at plants in Lavington and Princeton. Although a long trucking distance, the cost is manageable as transportation is a backhaul of the primary wood chip delivery to Mercer Celgar. Multiple organizations and leaders in the RDCK have expressed an interest in establishing wood pellet production in the district, which could supply local consumers. While this is a possibility, the current lack of local demand makes financing and constructing a new pellet plant difficult. Currently, over 98% of British Columbia's wood pellet production is exported and almost all the plants were financed based upon overseas offtake agreements. The current backhaul situation with sawdust and shavings from Interfor, Kalesnikoff, and Mercer Celgar makes construction of a large pellet plant in the western part of the district supplying overseas markets quite unlikely. In the Creston area, small-scale pellet production could be considered if sufficient local demand was already present. For example, a 15,000 t/yr plant would need to have a market of 1,800 to 2,000 homes using pellets as the primary (boiler) fuel. This presents a 'chicken and egg' pellet supply-demand challenge, with establishment of demand (e.g., pellet boilers) likely required before a pellet plant could be financed. A small-scale plant is unlikely to supply overseas markets and, in general, production costs will be higher per tonne than large plants due to poor economies-of-scale on capital and operations. However, targeting the residential pellet market, as compared to the industrial pellet market served by most pellet producers in BC, could make a pellet plant modestly viable. J.H. Huscroft and Wynnwood would be the primary feedstock suppliers. Taking into consideration the small volume of sawdust and shavings generated in the Creston area and the modest local wood pellet demand at present, a more likely scenario would be combining these feedstocks with feedstock from other mills in the Kootenay River valley for a large-scale plant near Cranbrook.

Most consumers know of bagged wood pellets, but for primary heating appliances, which meet all the space and hot water heat needs of a house or other type of building, the volume of pellet consumption makes bagged pellets physically demanding and, in many cases, impractical. Bulk residential delivery of wood pellets, which mirrors delivery of propane or heating oil, is very common in Europe and the Northeast U.S. Pellets are blown from a delivery truck into a bulk pellet storage hopper, which is usually located in the basement or garage (Figure 21). Storage can also be located underground or outside in durable bins. The combination of wood pellet boilers and bulk delivery is the primary proven approach for replacing propane, heating oil, and electricity in homes not connected to DE systems.

Figure 21. Bulk Pellet Delivery

Although forest product producers in the RDCK do not foresee development of a pellet plant within the district in the near- to medium-term, the pellet plants in Lavington and Princeton have a combined capacity of over 410,000 t/yr. Given the distance from these plants to many buildings in the RDCK, direct delivery from the plant to homes is not likely to be economically viable. Instead, pellets could be trucked using high capacity (40 t) b-trains to strategically-located pellet storage hubs in the RDCK. Smaller local distribution bulk delivery trucks, carrying 12-18 t, could deliver pellets from these bulk hubs to homes and C/I buildings. Based upon a preliminary analysis, a three-hub network of New Denver, Castlegar, and Creston could supply almost all buildings in the RDCK with a maximum 100 km service area (Figure 22).

5.2 Hog Fuel Delivery for District Energy Systems

Bark-dominated hog fuel, produced by sawmills and the ATCO veneer mill, is the lowest cost wood fuel in the RDCK. Hog fuel can serve as a feedstock for bioheat and CHP plants larger than 500 kW_{th}, although it is typically used for projects 1 MW_{th} and up. In the RDCK, this will be predominantly DE systems rather than individual C/I buildings. Based upon the energy demand analysis, the most likely locations for DE systems that could use hog fuel are Nelson, Creston, Nakusp, Kaslo, and New Denver. The smaller centres of Silverton, Slocan, and unincorporated communities are more likely to use wood chips from harvest residues or wood pellets due to the fuel property requirements of smaller boilers. The closest sawmill to Nelson, Nakusp, Kaslo, and New Denver is the Kalesnikoff Lumber mill. A map showing transportation distances is presented in Figure 23. The identification of Kalesnikoff as a potential supplier is not intended to indicate a mill preference; the map simply shows the shortest hog fuel transportation distance for these communities. Hog fuel could be combined with chipped harvest residues to supply the same DE system energy centre. Some of the smaller sawmill, such as Boards by George, Hamill Cree Timber, and Pine Profiles, could potentially supply whitewood chips to small bioheat projects in close proximity to the mills. However, any wood chip-fuelled bioheat development will require a secure fuel supply and guaranteeing supply from small sawmill owners may be more challenging than from larger owners.

Figure 22. Potential Pellet Hubs and Supply Areas

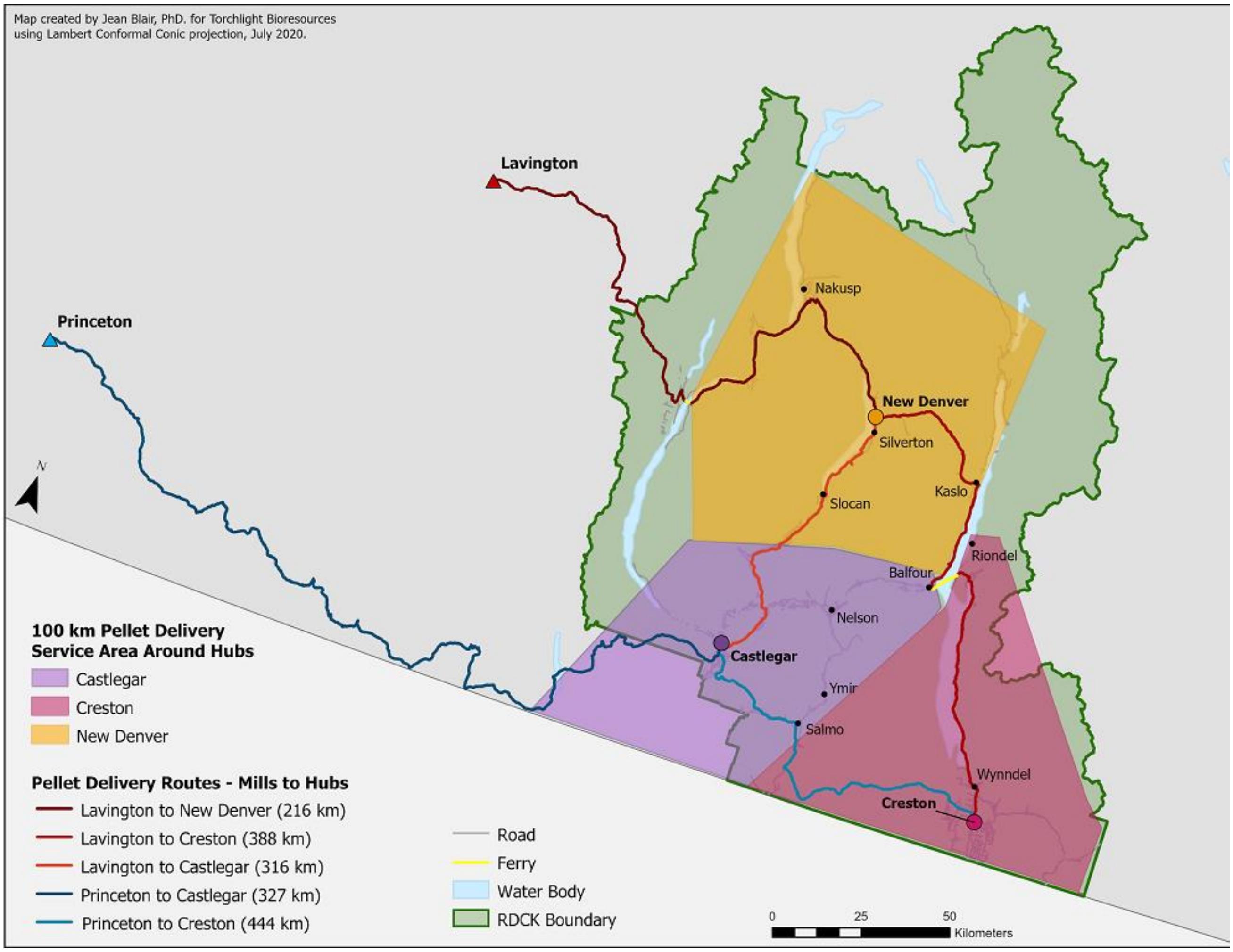
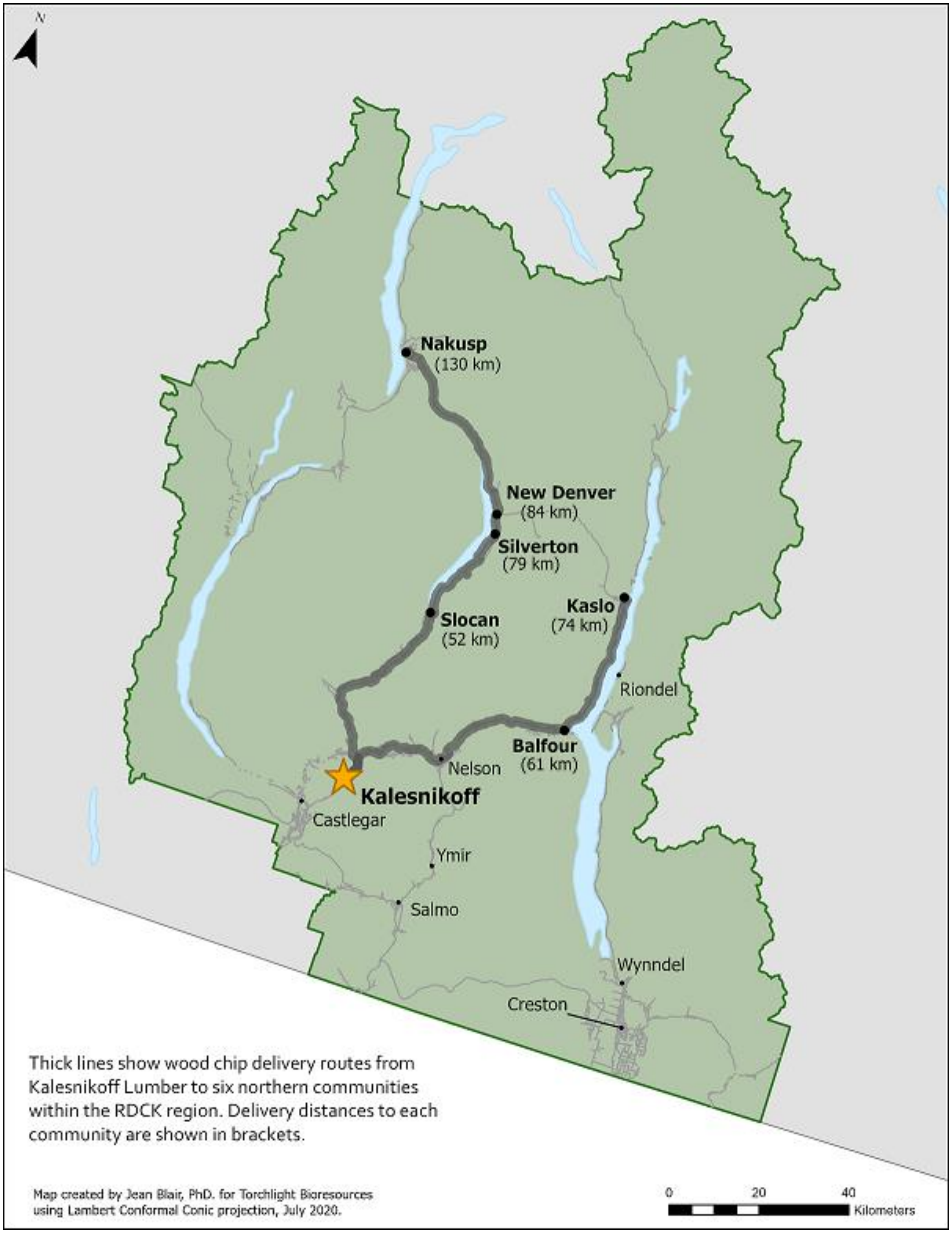


Figure 23. Hog Fuel Delivery Distances from Kalesnikoff Lumber



Thick lines show wood chip delivery routes from Kalesnikoff Lumber to six northern communities within the RDCK region. Delivery distances to each community are shown in brackets.

Map created by Jean Blair, PhD. for Torchlight Bioresources using Lambert Conformal Conic projection, July 2020.

5.3 Harvest Residues

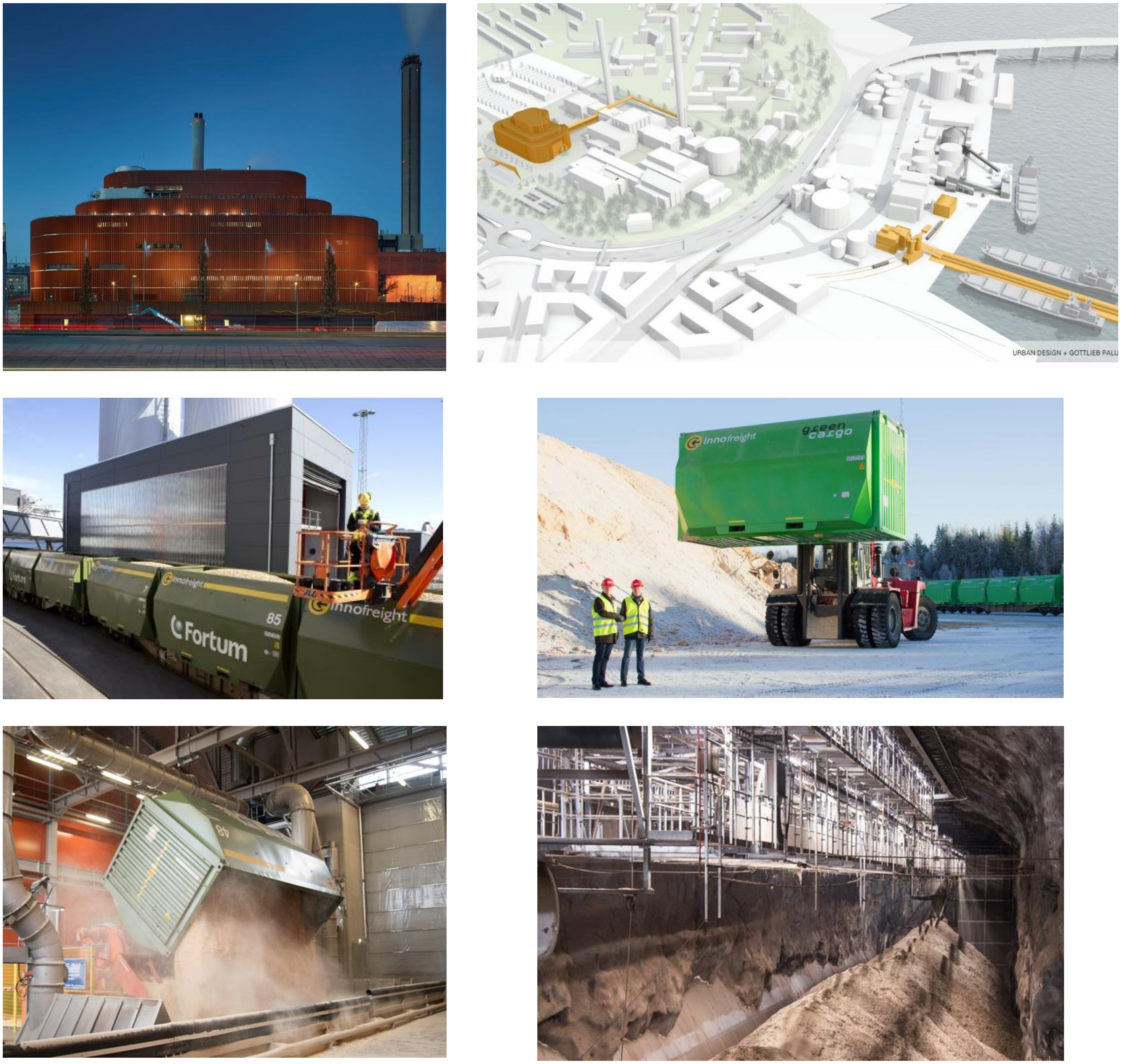
Collection and processing of harvest residues in the RDCK is likely to be higher cost that many other regions of BC due to the challenging terrain. In discussions with mill operators, a delivered cost of $70-110/bdt was deemed reasonable. This is approximately $4.00-6.25/GJ, which means harvest residues, unlike hog fuel, do not provide a significant fuel cost savings relative to natural gas at current carbon price levels. Combined with a significantly higher capital cost, particularly for new DE systems, the business case for use of harvest residues to displace natural gas will be difficult. The primary caveat to this statement is if harvest residue collection is financially supported by other activities or a third party. The most promising source of funding to support harvest residue collection operations is the Forest Enhancement Society of British Columbia (FESBC), which has allocated $235 M for 250 fire risk reduction and forest improvement projects to date. Mercer's Celgar 550 initiative is the other major potential contributor to biomass residue collection support. Under Mercer's plan, 75% of the wood fibre collected from current harvest residues would be used for pulp production and the remaining 25%, which would be the bark-dominated stream, would be used for energy. This approach essentially uses the higher value pulp fibre to financially support collection of low-grade harvest residues and could create a notable number of forest operations jobs in rural areas.

Following discussions with forest operations managers in the region, the most likely operational approach to increase low-grade fibre removal from harvest sites is reducing the topping diameter to >2 inches and forwarding these 'rat tail' stems to a central chipping site. With the RDCK terrain and use of cable yarding, forwarding branches to a landing is likely infeasible at a significant number of cut blocks. Reducing the topping diameter is anticipated to permit the collection of the majority of currently discarded/burned material.

5.4 Large Urban Decarbonization

Copenhagen and Stockholm will be the first cities in the world to reach 'Net Zero' emissions and are both doing so using large, city-wide DE systems connected to central wood and waste-fuelled CHP plants. The 410 MW_{th} Värtaverket plant in downtown Stockholm consumes 1 million tonnes per year of wood residues, heats 190,000 residences, generates enough electricity for 150,000 electric vehicles, and reduces GHG emissions by 650,000 t CO_2e/yr. Approximately 40% of wood residues consumed by Värtaverket are delivered by rail and 60% are delivered by ship (Figure 23). Should Vancouver, Calgary, Surrey, or another large urban centre take the action required to significantly decarbonize, a large urban market for wood residues could be created. Rail transportation is the most likely method of delivery of RDCK wood fibre to downtown CHP plants. However, Canadian cities have not, to date, taken the actions required for significant decarbonization and a large urban market for wood residues is not likely to be established in the near-term.

Figure 24. Stockholm Värtaverket Wood-Fuelled CHP Plant and Supply Chain



6 LEADING PROJECTS AND INITIATIVES

6.1 Overview

Based upon the assessment of wood fibre resources, RDCK energy market, energy demand by community, and provincial energy policy, five potential bioenergy projects/initiatives are considered worthy of further investigation. An initiative is defined as multiple small- or medium-scale energy projects of similar scope and technology approach (e.g., wood pellet boilers in multiple homes) and an emphasis was placed on projects where the RDCK could play a role. For this reason, individual wood chip boilers at commercial buildings developed as B2B projects, are excluded. These five projects/initiatives were presented to the RDCK Community Sustainable Living Advisory Committee (CSLAC) on August 18th, 2020.

1. **Wood Pellet Boiler Network**

   This initiative would seek to install 200 or more wood pellet boilers in homes and commercial/institutional buildings outside of towns and villages considered viable for DE. One or more bulk pellet supply hubs would be created within the RDCK, with New Denver proposed as the first potential site. Pellets would be delivered to storage depots from Lavington and/or Princeton in high capacity b-train trucks. Smaller bulk delivery trucks would deliver pellets to customers throughout the service area. The pellet boilers can be viewed as ‘decentralized infrastructure’ that is more applicable to rural areas than DE systems. Wood pellet boilers would significantly decrease the electricity demand in areas subject to power outages. The pellet boiler network could be combined with an initiative to install electricity storage (battery) infrastructure, resulting in a resilient heating system.

2. **District Energy in Castlegar**

   The large amount of waste heat released by Mercer Celgar into the Columbia River presents the most attractive DE opportunity in the RDCK. A DE system in Castlegar would require installation of a 5 km mainline hot water pipe from the pulp mill. While installation of the DE system would undoubtedly have a high capital cost, the fuel and operational costs of the system are likely to be significantly lower than natural gas. This would also lead to a large decrease in GHG emissions and make Castlegar a national leader in decarbonization. Numerous towns and cities in the EU are heated with pulp mill waste heat.

3. **Rural Community District Energy Systems**

   Developing DE systems in a number of small communities under the umbrella of a single project will provide economies-of-scale and make development more attractive to investors. Based upon a preliminary analysis, the most attractive small communities for DE development are Nakusp, Kaslo, New Denver, and Riondel. The first three of these have sufficient heat demand that a community-wide DE system could be fuelled with low cost hog fuel. Riondel is likely to require wood pellets or high-quality wood chips. In all cases, it should be recognized that DE systems are generally higher cost in communities with a low population density but that wood fuel is generally more competitive with propane and heating oil than natural gas.

4. **Urban District Energy in Creston and Nelson**

   Creston and Nelson have the highest building density of communities in the RDCK, which makes them potential candidates for downtown DE systems fuelled by hog fuel. Given their scale, co-generation of electricity for local demand is likely to improve the economics of development. While Nelson has the significantly larger number of large heat loads (buildings), Creston is home to the Columbia Brewery. The brewery needs process heat (steam) for brewing and other facility operations, which suggests a steam-based CHP plant could be an option. Condensed steam would provide the heat required for the hot water DE system. Both sites will be challenged economically due to the availability of low-cost natural gas but use of local wood fuel would create local jobs and keep energy expenditures in the community.

5. **Mercer Celgar 550 and Gasifier**

   Mercer's plan to increase pulp production capacity would rely heavily on increased harvest residue utilization. In addition to economic benefits to the region and decreased slash pile burning, it would also result in a new stream of fuel-quality wood fibre being removed from harvest sites. Of the two potential bioenergy projects considered by Mercer, increased electricity production and displacement of lime kiln natural gas, it is the latter that will have much great GHG benefits and higher efficiency. Fueling the lime kiln with syngas generated from a hog fuel gasifier would be the equivalent of eliminating 100% of natural gas presently consumed by buildings in the RDCK. In contrast, additional electricity generation would add more electricity to an oversupplied market and would not result in any GHG reductions within the RDCK. The RDCK could have an important role to play by influencing provincial renewable gas policy.

Following a discussion and deliberation, CSLAC recommended projects/initiatives 1, 2, and 3 – wood pellet boilers, Castlegar DE, and rural community DE systems – be investigated further and described in greater detail. These are presented in Sections 6.3 – 6.5.

6.2 Potential RDCK Role in Nelson, Creston, and Mercer Celgar Projects

Development of DE systems in Creston and Nelson were not chosen to be in the top three due to the presence of low-cost natural gas in these larger centres and the difficulty for wood-fuelled DE systems to compete economically with natural gas under current energy and carbon price markets/policies. Of the three larger urban centres in the RDCK with natural gas, Castlegar is considered the priority opportunity for DE development due to the waste bioheat generated by Mercer Celgar. Despite the economic challenges, Nelson Hydro is pursuing development of a small wood-fuelled DE system connecting several city-owned buildings in Nelson. This project has received some grant funding from the Government of Canada but may also require provincial support to be economically viable. The RDCK may want to support a City of Nelson and/or Nelson Hydro application for additional grant support (e.g., Investing in Canada Infrastructure Program/CleanBC). A DE system in Creston is likely to benefit from participation of the Labatt-owned Columbia Brewery, which requires steam for beer production. The brewery should be engaged from the start if Creston is interested in developing a DE system. However, like Nelson, substantial grant support is likely required to make a project economically viable.

The exclusion of Mercer Celgar 550 and lime kiln gasifier from the top three is not an indication of the merits of the projects but of the limited role for the RDCK in development. However, the RDCK could contribute to a positive investment decision by Mercer by engaging the provincial government on two fronts. The first is on grading (classification) of wood fibre and the stumpage associated with that fibre. An impediment to Mercer implementing full forest fibre utilization, which would increase the amount of wood, including harvest residues, delivered to Mercer Celgar, is the risk of low value wood being graded as sawlogs. This grading results in a much higher stumpage than pulpwood or biomass and can lead to uneconomical pulp production. The RDCK, working with Mercer, could consider advocating for changes to BC's stumpage system that would enable greater fibre removal from harvest blocks and a reduction in slash pile burning. This could be justified on the basis of both health and economic benefits to RDCK residents. The second role for RDCK is in advocating for equivalent policy treatment of syngas (H_2 & CO) and renewable natural gas/biomethane (CH_4). The Greenhouse Gas Reduction (Clean Energy) Regulation of the British Columbia Clean Energy Act permits FortisBC to purchase biomethane at prices of up to $30/GJ. However, this regulation does not permit FortisBC to purchase syngas or provide a financial incentive for syngas production/use. As discussed in Section 4.3, conversion of wood-based syngas to biomethane is precommercial, high capital cost, high technology risk, and results in a significant decrease in efficiency. Therefore, it is preferable, both economically and environmentally, for Mercer to consume wood-based syngas directly to replace natural gas rather than try to convert it into biomethane. If this syngas could flow through a dedicated pipeline owned by FortisBC, FortisBC signed renewable gas supply purchase and supply agreements with Mercer, and BC treated syngas and biomethane equivalently, fuel switching from natural gas to hog fuel would be economically attractive for Mercer. This project should be considered a priority for GHG reduction within the RDCK.

6.3 Wood Pellet Boiler Network

6.3.1 Purpose and Success

The wood pellet network would establish a local bulk wood pellet storage and delivery logistics system. This would be coupled with rapid adoption of wood pellet boilers in residential, commercial, and institutional buildings that could be operated collectively as a 'distributed utility'. Small DE networks of a few buildings, heated with small (<500 kW_{th}) central boilers, could also be wood pellet consumers. The focus would be on areas that lack natural gas access, are at risk of electricity supply disruptions, and have high rates of propane and heating oil consumption. This implies predominantly unincorporated areas in the RDCK. As an example, an initial distributed utility network of 200 boilers, with a capital cost of $5-6 M, could support broader adoption across the region and prove the business model.

Pellets would be delivered by large bulk trucks (b-train) from existing pellet mills in Lavington and Princeton to distribution hubs in the RDCK, with New Denver proposed as the first hub, followed by Castlegar and Creston. From these distribution hubs, small (e.g., 13-18 t) bulk pellet delivery trucks would deliver pellets to boilers in the pellet network. This bulk delivery approach is widespread in Europe and has been adopted in the U.S. northeast as well. Pellets delivered at a cost of $250/t is the equivalent of $14/GJ ($0.35/L) for propane or $60/MWh for electricity on a useful heat fuel cost basis.

6.3.2 Proposed Development Approach

Pellet boilers have a high capital cost relative to air-source heat pumps and propane and heating oil furnaces. The capital cost is generally lower than ground-source heat pumps. Over the 20- to 30-year life of a residential pellet boiler, the levelized cost of energy is usually lower than heating oil and electricity due to the lower fuel price of wood pellets. The need for a government-coordinated pellet network exists because building owners do not typically have a 20- to 30-year time horizon for ownership their building or boiler capital cost recovery. Government-owned DE system utilities are generally well understood, but DE systems will not be viable for rural, widely distributed buildings. The proposed wood pellet network has many similarities to DE system heat utilities, but without the pipes connecting each building. In this regard, the wood pellet network of many individual boilers at separated buildings could be considered a decentralized or distributed utility.

For wood pellet boilers to be widely adopted over a short time period, a development approach that requires little or no building owner investment is required. The proposed approach is to source infrastructure funding from the Governments of British Columbia and Canada, likely via the Investing in Canada Infrastructure Program, to cover 73.3% of the capital cost of the boilers, wood pellet storage, and bulk delivery truck(s). The remaining 26.7% of the capital cost could be financed by debt from the Municipal Finance Authority of BC or a private sector partner. The rate of return of the private sector financing partner could be fixed under the terms of a partnership or concession agreement.

It is recommended that boiler installations and network operation be carried out by a publicly-owned utility company managed by a contracted party or by the private sector financing partner. The RDCK could be the sole shareholder of the distributed utility company or ownership could be shared with municipalities in the region. Given the costs of operating and managing a utility company, it may be preferrable for small rural municipalities collaborate with the RDCK and each other, rather than seek to establish a separate utility corporation for each municipality.

6.3.3 Role of the RDCK

As most of the buildings that are not candidates for connection to DE systems are in unincorporated areas, the RDCK is the local representative government. Even for wood pellet-heated buildings within small, rural incorporated municipalities, it is logical for the RDCK to play a leadership role in utility creation and oversight due to the pellet network spanning multiple municipalities. The RDCK could seek to bring together multiple municipalities to become shareholders in a single, region-wide ‘Central Kootenay Bioheat Utility’ (CKBU). The RDCK could be a shareholder of the CKBU, with a specific focus on representation of unincorporated areas. Incorporated municipalities could also be shareholders in the CKBU. The board of directors of the CKBU would be composed of representatives from the public shareholders, along with potential independent directors. Achieving scale with the CKBU would permit professional energy managers and staff to be hired to operate the utility. If each municipality sought to establish its own heat utility, they would be unlikely to have sufficient revenue to justify dedicated utility staff and would therefore have to rely upon existing municipal staff.

For the pellet heat network to succeed, the RDCK needs to lead efforts to secure bioheat infrastructure grant funding from federal and provincial governments. The high upfront cost of pellet boilers will inhibit adoption in the absence of grant funding. Project planning and grant applications can be done using internal resources or selecting a preferred private sector development partner to secure the grants. As a precedence example, TorchLight Bioresources secured $2.8 M from the Government of Ontario for the Municipality of Dysart et al in Ontario to develop a bioheat utility. This funding flowed to the municipality and TorchLight was able to prepare the grant funding application and required prefeasibility study without a cash cost to the Municipality of Dysart et al due to agreement between the municipality and TorchLight on selection of TorchLight as the private sector development partner in the event of a successful grant application.

6.4 District Energy in Castlegar

6.4.1 Purpose and Success

Castlegar has a unique opportunity to utilize, via a DE system, the waste heat of the Mercer Celgar pulp mill to displace natural gas in building heat supply. As the cost of waste heat is anticipated to be low, the primary hurdle to DE development is the high capital cost – particularly given the 3.5 km distance between Mercer Celgar and Castlegar. The system would use a heat pump to boost the temperature of the mill waste heat prior to distribution to buildings in the City of Castlegar if the 42 C discharge water from Mercer Celgar was used as the primary heat source. With an infrastructure grant from the federal and provincial governments, waste heat DE in Castlegar is anticipated to have a lower levelized cost of energy than natural gas.

A DE system in Castlegar is likely to be developed in stages, with the first stage consisting of the main supply line from Mercer Celgar to Castlegar and connection of major commercial and institutional buildings near City Hall. The potential supply of waste heat from Mercer Celgar is dramatically higher than all the building energy demands of Castlegar, making access to capital for infrastructure expansion the key determinant of system development, expansion to other large buildings, and, ultimately, single family detached homes. A Castlegar DE system would generate income for the City and make it a national leader in decarbonization.

6.4.2 Proposed Development Approach

A full feasibility study is required to determine the capital and operating costs of a multi-stage DE development in Castlegar. Currently, the Federation of Canadian Municipalities (FCM) offers grant funding to cover 50% of the costs of DE feasibility studies. For the remaining 50%, Natural Resources Canada offers grant funding via the Investments in Forest Industry Transformation (IFIT) fund for forest industry participants to complete feasibility studies on bioenergy and bioproduct developments. Mercer Celgar would be eligible for this fund. While these together total 100% of study costs, FCM requires municipalities to contribute 10% of the cash costs of feasibility study completion. Given the potential large income and decarbonization potential, it is recommended the City of Castlegar contribute this 10%, which is likely to be between $35,000 and $40,000. If FCM grant applications are prepared by the City of Castlegar and Mercer Celgar, a competitive process could be held to select a feasibility study team. Alternatively, a consulting team could prepare the grant funding applications, with the understanding they would be awarded the work upon acceptance of the proposals by

FCM and Natural Resources Canada. Mercer Celgar may have a preferred consultant, in which case the City of Castlegar may wish to follow Mercer Celgar's recommendation.

Upon completion of the DE feasibility study and a positive business case outcome, the consulting team, in collaboration with the City of Castlegar, Mercer Celgar, and potentially, the RDCK, could prepare an application for infrastructure grant funding. The most likely source of a public infrastructure grant for a waste heat DE system is the CleanBC/Investing in Canada Infrastructure Program. This program provides 73.3% of infrastructure capital costs as a grant if funds flow to municipalities or regional districts. More federal infrastructure funding may be available as part of a COVID-19 economic recovery plan. It is recommended that a competitive process for a private sector development partner occur prior to application for grant funding.

The recommended business structure is a 100% municipal and/or regional district-owned heat utility. A private sector partner, which could lead development, construction, operation, and/or maintenance, could be selected via a competitive process. The private sector partner could also be responsible for financing 26.7% of the project capital cost if the City of Castlegar did not want to take on debt financing. Full public sector ownership of the DE assets is possible via a multi-decade concession agreement with the private sector partner. This concession agreement would detail the permitted rate of return on capital deployed and terms for recovering operation and maintenance expenses from the customer base. The concession agreement could include a clause to permit the City of Castlegar to take over operation and maintenance of the DE system in the future. Potential DE finance, development, operation, and maintenance partners include:

- CreativEnergy – owner of Vancouver DE system and backed by investment fund InstarAGF
- Corix – BC Investment Management Corporation entity and active DE developer/operator in BC
- Enwave – Brookfield Infrastructure company; owner of Toronto, Seattle, and London, ON DE systems
- Anbaric – DE investment vehicle for Ontario Teachers Pension Plan
- Engie – French utility company with concession to develop and operate Ottawa DE system

6.4.3 Role of the RDCK

Development of a DE system in Castlegar will require an active leadership role by the City. However, the RDCK could ensure a development in Castlegar benefits smaller, rural communities in the district by linking the financing, development, and operation of a Castlegar DE system with that of smaller DE systems in the district. This inclusion of multiple systems under a single development and ownership umbrella could be accomplished by requiring a private sector partner to participate in the development multiple systems and/or include the Castlegar DE system as an asset of the Central Kootenay Bioheat Utility. As with the Alectra Utilities, which is an electrical utility in Ontario owned by multiple cities and municipalities, the City of Castlegar would likely have a larger shareholding than smaller municipalities due to the higher value of the assets in the City than smaller centres.

6.5 Rural Community District Bioenergy Systems

6.5.1 Purpose and Success

Numerous rural communities in Central Kootenay lack access to natural gas, resulting in use of high cost propane, heating oil, and electricity for building heat. Several small population centres, including Nakusp, Kaslo, New Denver, Riondel, and Silverton, could establish wood-fuelled DE systems to lower energy costs, reduce GHG emissions, and improve air quality for residents, businesses, and institutions. To keep delivered energy cost low, the dominant fuel is likely to be hog fuel from sawmills, although harvest residues may be feasible – particularly if FESBC financial support is secured. While the RDCK has prioritized use of harvest residues as a bioenergy feedstock, the preferred choice will ultimately depend upon the delivered cost of energy for consumers. It will be hard to justify use of harvest residues if hog fuel is available at 1/10th the cost. Community DE systems fueled by low-grade wood fibre would also reduce community reliance on electricity and could be operated during power outages with modest electricity backup for pumps. The small number of commercial/institutional buildings in most rural communities means single family detached homes are likely to be connected to the system from the start.

Successful rural community bioheat DE systems would improve the energy security of communities while ensuring energy expenditures stay in the community. Establishing an alternative market for sawmill hog fuel would also support the forest industry in the district and reduce the industry's reliance on the Kettle Falls, WA power plant. The rural community DE systems would be complementary to the wood pellet boiler network and the preferable bioheat approach – DE system or individual building boiler – would be determined on a building-by-building basis. In many communities, a combination of individual boilers and DE systems connecting multiple buildings is likely. A few C/I buildings, such as hospitals and schools, may be able to support the operation of individual building wood chip boilers if a DE systems is deemed unfeasible for the community. As an order-of-magnitude example, the capital cost of a bioheat energy centre and DE system connecting 50 buildings may be in the order of $4-5 M. The capital cost will likely be higher per building than individual boiler installation, but the scale of a multi-building DE system permits the use of much lower cost fuel (hog fuel) than wood pellets. Hog fuel at $15/t has a useful heat cost of $1.50/GJ or $5.50/MWh.

6.5.2 Proposed Development Approach

As with a Castlegar DE system, DE systems in rural communities will also need full feasibility studies to secure infrastructure grant funding. Given the small scale of these systems, it is recommended that systems in multiple communities be included within the scope of a single feasibility study. While other sources of funding, such as Natural Resources Canada's Clean Energy for Rural and Remote Communities fund, are available to cover the costs of a full feasibility study, the most likely sources are the same as the proposed Castlegar DE feasibility study: FCM Green Municipal Fund DE study stream and Natural Resources Canada's Investments in Forest Industry Transformation fund. In the case of IFIT funding, the most likely forest industry lead is not Mercer Celgar but the solid wood product mills: Interfor, Kalesnikoff Lumber, Porcupine Wood Products, Wynnwood (Canfor), J.H. Huscroft, and ATCO Wood Products. Based upon the scale of operation and mill proximity to potential rural DE communities, Interfor and Kalesnikoff are recommended as the two primary industry partner options.

Following completion of a feasibility study and upon identifying an attractive business case for one or more DE systems, infrastructure funding can be sought from the Investing in Canada Infrastructure Program. In addition to the 'Green Stream', which is an option for all bioheat projects, rural community DE projects would also be eligible for the 'Rural and Northern Communities Stream'. While an application to the Green Stream could include multiple DE systems under a single proposal, the funding limit cap for the Rural and Northern Communities Stream makes individual DE system applications more likely.

The administrative, management, and personnel costs of a single small rural community DE system will be high compared to larger systems on a per unit energy basis. To benefit from economies-of-scale and ensure energy prices are as low as possible for consumers, it is recommended multiple systems be managed by a single utility company. As identified, a Central Kootenay Bioheat Utility corporation could own multiple bioheat DE systems in addition to distributed utility individual building boilers. Municipalities hosting a DE system would be shareholders in the utility, with RDCK acting as shareholder for unincorporated areas.

Similar to the Castlegar DE system, rural community DE systems could be co-financed, developed, constructed, operated, and maintained by a private sector entity. This could include First Nations-owned companies. To attract large DE operators to small communities in Central Kootenay, it is likely necessary to utilize a single concession agreement for multiple systems to achieve sufficient scale, lower specific transactions costs, and make investment feasible.

6.5.3 Role of the RDCK

The RDCK is the entity that can make economies-of-scale in rural DE system development possible by bringing together multiple communities, incorporated and unincorporated, under a single umbrella. This should result in lower heating costs for all residents and businesses connected to the systems/bioheat boilers than would be the case if each system operated as its own utility corporation. The RDCK's involvement is also essential for residents and businesses in unincorporated communities to participate in DE development, since the RDCK is the most local/lowest level of government for these communities. The human resources and management capacity of the RDCK is also likely to exceed that of many small communities.

6.6 Summary Recommendations

Based upon this analysis of the Central Kootenay forest sector, energy systems and markets, and potential projects, the following five actions by the RDCK are recommended:

1. **Seek infrastructure funding for a distributed wood pellet bioheat utility**

   The CleanBC/Investing in Canada Infrastructure Program is the most likely source of grants, although new funds may be made available in support of COVID-19 economic recovery. Selecting a private sector preferred distributed utility development partner early in the process is recommended. The private sector partner should lead completion of a prefeasibility study on the wood pellet network prior to grant application.

2. **Support feasibility studies for rural district energy and bioheat systems**

   Similar to recommendation #1, infrastructure funding is required to economically develop small district energy systems in rural communities such as Nakusp and Kaslo. However, a full feasibility study, including DE system layout and engineering, is necessary to apply for infrastructure funding. The RDCK should select a preferred partner to secure grant funding, which would cover 90% of project costs, from FCM and Natural Resources Canada to complete these feasibility studies. The RDCK would need to provide the remaining 10%, as per FCM rules. Ultimately, the partner could also work with the RDCK to secure infrastructure funding. The DE systems, along with individual building wood pellet and wood chip boilers, can be included as assets of the Central Kootenay Bioheat Utility.

3. **Support a feasibility study for a Castlegar district energy system**

   Working with Mercer Celgar and the City of Castlegar, the RDCK can support the completion of a feasibility study on a pulp mill waste heat-fuelled DE system in Castlegar. A DE development partner, likely with access to institutional capital, should be selected via a competitive process after engineering feasibility study completion. The most likely feasibility study funding approach is similar to the rural DE systems, with 90% of costs covered by FCM and Natural Resources Canada, although it is the City of Castlegar that would be the preferred 10% study cost contributor instead of the RDCK.

4. **Engage with Mercer Celgar on Celgar 550 and lime kiln gasifier advocacy**

   While Mercer Celgar will be the owner and operator of developments at the pulp mill, the RDCK can play an important role in moving these projects forward. Both are challenged by provincial policy design and the RDCK could advocate for changes based upon the potential benefits of the projects to residents of the RDCK. The place to start is a conversation with Mercer on the provincial policy changes the company wishes to see enacted.

5. **Create a publicly-owned Central Kootenay Bioheat Utility corporation**

   Involvement of the RDCK in bioheat sector development in the district will be best handled by an arm's length utility corporation tasked with developing, owning, and operating (potentially by private partners) assets. These include both DE systems and individual building boilers (wood pellets for residences and small C/I buildings, wood chips for a few larger C/I buildings). The CKBU Corporation could initially be 100% owned by the RDCK, but municipalities could become shareholders as DE systems were developed and added to the inventory of assets.

APPENDIX A: SUMMARY OF RECOMMENDED PROJECTS

Project	Proposed Development Approach	Role of the RDCK	Funding Requirements & Actions
Pellet Boiler Network	• Complete feasibility study and business plan for installation and operation, including bulk fueling, of 200 boilers • Apply for infrastructure funding from CleanBC/Investing in Canada Infrastructure Program (Green or Rural and Remote Streams)	• RDCK would establish a Central Kootenay Bioheat Utility (CKBU) company, with RDCK and municipalities as shareholders • Develop business plan internally, by contracting consultants, or by selecting preferred utility company partner via RFP – with selected partner completing business plan	• If RDCK wants to contract a consultant for the business plan, likely ~$100,000 • If RDCK wants to develop CKBU with partner, launch RFP to select preferred partner • CleanBC application for 200 boilers, bulk storage, and truck likely $3.7-4.4 M (73.3% of total project cost)
District Energy in Castlegar	• Complete feasibility study for multiple zone, staged DE build-out using waste heat from Mercer Celgar • DE system to be 100% publicly owned, but potential private partner co-financing, developing, operating, maintaining • Apply for infrastructure funding from CleanBC/ICIP (Green Stream)	• Engage with Mercer Celgar on heat supply and support City of Castlegar in selection of consultants • Encourage City of Castlegar to be major shareholder of CKBU and include the Castlegar DE system as an asset of the utility company • Assist in selection of private partner (if desired)	• Establish MOU with Mercer on heat supply and feasibility study • Mercer to submit IFIT study funding application to NRCan (50% of study cost) • City of Castlegar to submit DE feasibility study funding application to FCM (40% of study cost) • 10% ($35,000 – 40,000) of costs must be covered by City of Castlegar and/or RDCK • CleanBC application likely >$15 M
Rural Community District Bioenergy	• Complete biomass heat (wood chip) DE/bioheat feasibility studies for multiple rural communities • Apply for infrastructure funding (e.g., $15 M) from CleanBC/ICIP (Green or Rural and Remote) • Municipalities to be shareholders in CKBU	• RDCK to lead process to complete multiple DE/bioheat utility feasibility studies • Establish relationship with preferred feedstock supplier(s) • Incorporate CKBU and represent unincorporated communities as shareholder	• Establish MOU with wood chip fuel supplier(s), with Interfor and Kalesnikoff most likely • Fuel supplier to submit IFIT application • RDCK to submit FCM application • 10% ($35,000 – 40,000) of costs for four systems must be covered by RDCK
District Energy in Nelson & Creston	• Development of downtown (high building density) wood-fuelled biomass CHP & DE systems in Nelson and Creston	• Support Nelson and Creston as required • Consider inclusion of DE systems as asset of CKBU; Nelson and Creston as shareholders	• Feasibility studies can be funded using a combination of IFIT and FCM grants (90%), combined with 10% from municipalities
Mercer Celgar 550 and Gasifier	• Mercer desires to increase pulp capacity and fuel switch lime kiln from natural gas to hog fuel and harvest residues • The lime kiln gasifier would be the largest GHG reduction project in Central Kootenay, while Celgar 550 would reduce slash pile burning	• Engage with Mercer to determine provincial policy change requirements: 1) Greenhouse Gas Reduction (Clean Energy) Regulation of the British Columbia Clean Energy Act for equal treatment of syngas and biomethane; 2) harvest residue grading and stumpage	• No funding from RDCK required • Advocate for provincial policy change on behalf of Central Kootenay residents that would benefit environmentally and economically from reduce slash pile burning and fuel switching away from natural gas