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Biomass for residential and commercial heating in a remote Canadian aboriginal community

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ABSTRACT

Most residents of Canada's 300 remote communities do not have access to natural gas and must rely upon higher cost and/or less convenient heat sources such as electric heat, heating (furnace) oil, propane, and/or cord wood. This research sought to determine the techno-economic feasibility of increasing biomass utilization for space and hot water heating in remote, off-grid communities in Canada and abroad using a two-option case study approach: 1) a district energy system (DES) connected to a centralized heat generation energy centre fuelled by wood chips; and 2) a decentralized heating option with wood pellet boilers in each individual residence and commercial building. The Nuxalk First Nation Bella Coola community was selected as a case study, with GIS, ground surveys, and climate data used to design DES routes and determine heat demand. It was determined that biomass has the potential to reduce heat costs, reduce the cost of electricity subsidization for electrical utilities, reduce greenhouse gas emissions, and increase energy independence of remote communities. Although results of the analysis are site-specific, the research methodology and general findings on heat-source economic competitiveness could be utilized to support increased bioheat production in remote, off-grid communities for improved socio-economic and environmental outcomes.

1. Introduction

1.1. Biomass heat

The low cost of natural gas, made possible by advances in extraction technologies to increase supply combined with a relatively flat demand curve over the past five years, has greatly reduced the space, hot water, and process heating costs of households and businesses across Canada [1]. However, natural gas is used by only 47% of households in Canada for space heating. Most of the remaining 53% of homes must rely upon higher cost and/or more inconvenient electric heat (e.g., baseboard for space heating; electric hot water heaters) (37%), heating (furnace) oil (9%), propane (1%), and/or biomass (6%) as their primary source of heat [2]. While a large percentage of the biomass used for space heating in Canada is in the form of cord wood (firewood), wood pellets are becoming a more mainstream option for consideration in fuel selection. Like heating oil or propane, wood pellets – which are produced from compressed sawdust – can be continuously fed to a boiler or furnace without the need for daily manual reloading. This is a significant advantage over cord wood in terms of ease of use and convenience [3].

Another highly convenient heating option that enables significant economies-of-scale in heat supply and has been widely deployed in European cities and towns is district heating. District heating systems, or district energy systems (DES), consist of one or more centralized heat generation facilities and a network of pipes to deliver hot water or steam to two or more separate buildings. Instead of each building having its own furnace, boiler, stove, or electric heaters, a heat exchange system connects the home heating

Abbreviations: bdt, bone dry tonne; DES, district energy system; DN, diamètre nominal/nominal diameter; GIS, geographic information system; GPM, gallons per minute; kWh, kilowatt hour; MWh, megawatt hour.

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system with the hot water/steam pipes of the district heating system. In Canada, the first DES was introduced in London, Ontario in 1879 and there are currently 116 systems operating across the country [4]. Many are either found in large urban centres, university campuses, or hospital complexes, but there are also examples of DES′ providing heat for smaller communities such as Oujé-Bougoumou, Québec; Drake Landing, Alberta; and Revelstoke, British Columbia (BC) [4,5]. District heating energy centres can be fueled by all the same fuels that can be used at the individual residence level, including natural gas, heating oil, propane, and biomass. However, the larger scale of centralized energy centres, as compared to distributes furnaces/boilers, also enables the use of lower grade biomass types, such as wood chips and hog fuel (residues containing bark), that are typically unacceptable for residential consumption.

1.2. Purpose and case study

The purpose of this research was to determine whether increased biomass utilization in Canada's remote communities could reduce the delivered cost of space and hot water heat for residents and commercial businesses. The Nuxalk (pronounced Noo-halk) First Nation (aboriginal peoples) community living on the Bella Coola Reserve was selected for a community case study that could be used to inform a broader assessment of bioheat and bioelectricity consumption in Canada's 300 remote, off-grid communities. Many of these communities have commonalities with Bella Coola, including heating fuel options and pricing and access to abundant biomass feedstocks. The Bella Coola Valley is a remote area on the west coast of BC, approximately 450 km north of Vancouver. The Valley, with a total population of approximately 1900, contains several communities, including the unincorporated village of Bella Coola, the Bella Coola subdivision of Four Mile, Hagensborg, and the hamlets of Saloompt, Nusatsum, Firvale, and Stuie. The Bella Coola First Nations Reserve covers half of Bella Coola village and all of Four Mile. Approximately 850 people live on the Bella Coola Reserve. The Bella Coola Valley is accessible by boat, air, or road via Highway 20 (Chilcotin-Bella Coola) from Williams Lake. However, Bella Coola is not connected to either the natural gas grid or the main BC electrical grid.

Like residents of many of the communities not connected to the natural gas grid in Canada, residents of Bella Coola face high costs for space heating – particularly when cord wood is unacceptable due to inconvenience or the inability of the homeowner to handle large logs (e.g., elderly). Most homes in the community have a combination of heating strategies for space heating and hot water. Most hot water is heated electrically, which is normally a high-cost option but is particularly high in Bella Coola because the community relies upon diesel generation for a significant portion of its electricity supply (a run-of-river hydro project also generates electricity for the microgrid). This is also a very energy inefficient means of hot water heating. Space heating for residences is typically a combination of cord wood stove and backup heating oil, propane, or electricity. Both propane and heating oil need to be transported significant distances by road to Bella Coola and are subject to large commodity price swings. Electric space heating in Bella Coola is high cost for both consumers and BC Hydro, the electricity generator which charges less than half the cost of generation to Bella Coola consumers. The rates are subsidized by other BC Hydro customers. Estimates on yearly energy consumption for heating oil, propane, and diesel are provided in Table 1. Columbia Fuels, the primary heating oil supplier in Bella Coola, estimates that, on average, 1700 L of heating oil are used by each oil-consuming Reserve residence per year, for a total of 344,000 L for all residences [6]. Commercial buildings use either propane or heating oil.

Table 1
Yearly consumption of selected energy types for reserve buildings.

Sector	Heating oil	Propane	Electricity
Residential	344,000 L	88,000 L	2,766,000 kWh
Non-residential	91,000 L	22,000 L	1,718,000 kWh
Total	435,000 L	110,000 L	4,484,000 kWh
Conversion efficiency	80%	90%	100%
Estimated cost	$1.40/L	$0.90/L	$0.13/kWh ($0.41/kWh[a])
Energy content	38.7 MJ/L	25.6 MJ/L	–
Cost of heat	$163/MWh	$141/MWh	$130/MWh ($410/MWh[a])

[a] Estimated cost of generation for BC Hydro based upon diesel efficiency of 34%, diesel cost of $1.15/L, and O&M costs (including labour) of $300,000/yr. Retail price is approximately $^1/_3$ the cost of generation.
Source [6].

Cord wood consumption, given the unregulated market and variety of cord wood sources, has not been quantified officially but is considered to have a major share of the heating market.

The Bella Coola Valley is also an economically challenged area, with average income on the reserve less than 40% of the British Columbia average (most recent statistics from 2000 Census [7]). The combination of low income and high energy costs encourages families to seek income assistance and energy subsidization. This creates a situation of government dependency and provides a disincentive to seek employment since employed persons (including even those working for minimum wage) do not qualify for the higher energy subsidies. The use of biomass for space and hot water heating is one potential option to lower energy costs and reduce reliance on energy subsidization. At the same time, utilization of local forest resources for energy production could create local jobs and keep the money spent on heating in the community rather than benefiting importers of heating oil and propane.

2. Materials and methods

The research methods utilized for the Bella Coola case study were designed to be replicable for analysis of other isolated communities in Canada and also remote/off-grid communities or industrial sites in other areas of the world. The project was generally divided into two biomass heating approaches: 1) a DES utilizing wood chips as the primary fuel for a centralized heat generation energy centre (which provides the possibility of electricity co-generation); and 2) a decentralized heating option with wood pellet boilers in each individual residence and commercial building. The potential for production of compressed particle fire logs or briquettes from mill and harvest residues was also initially considered since many homes already have wood stoves that could utilize the fire logs. However, given the abundance of cord wood in the community, the additional costs of fire log production relative to cord wood, and the lack of a significant convenience benefit compared to cord wood, an analysis was not completed. Fire log production or import to the community may be something worth considering as an incremental improvement but it would not result a fundamental, structural change to the heating system that is investigated in this research.

The study area was comprised of the village of Bella Coola including Nuxalk First Nation reserve land in Bella Coola, the reserve subdivision of Four Mile, and the township (non-reserve) lands of Bella Coola (Fig. 1). Note that areas identified in the maps in this paper were for project purposes only and are used to determine which buildings will be included in each scenario. They are not intended to represent official boundaries between reserve and non-reserve lands or to identify traditional territories of the Nuxalk First Nation. The project was largely focused on the opportunities and benefits for the Nuxalk First Nation, but given the integrated