UBC Social Ecological Economic Development Studies (SEEDS) Student Report

Heating System Analysis:

A Comparative Investigation on the Environmental Affects of Electrical Baseboard Heating and District Natural Gas Hydronic Heating Systems

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HEATING SYSTEMS ANALYSIS

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Electrical Baseboard Heating and District Natural Gas Hydronic Heating Systems

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Report prepared at the request of Adera Development Corporation and UBC SEEDS in partial fulfillment of UBC GEOG 419: Research in Environmental Geography, for Dr. David Brownstein

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Executive Summary

Conducted for Adera Development Corporation, UBC SEEDS in partial fulfillment of UBC GEOG 419: Research in Environmental Geography, for Dr. David Brownstein, this study aims to identify the environmental costs and effects on different stakeholders involved with the implementation of electric baseboard heating and natural gas district hydronic heating solutions in buildings. In summary:

1. The difference in greenhouse gas emissions produced in electric baseboard heating and natural gas district energy heating are less than reported in an earlier study conducted by Uduman (2010) due to BC Hydro's energy imports. This report estimates that the emissions factor in electric baseboard heating is 37.78 kg/GJ while natural gas district hydronic heating is rated at 48.9 kg/GJ.

2. Despite the higher emissions associated with natural gas district hydronic heating, district energy is recommended over electric baseboard heating because it allows for the possibility to switch to lower emitting fuels. Moreover, district heating seems to better fit the future plans of BC Hydro and FortisBC.

3. It is recommended to re-study emissions generated by electricity when BC Hydro releases its 2011 greenhouse gas emissions of its energy that includes energy imports and trading activities. In addition, other fuel sources of district energy systems should be looked into.

4. Suggests that Adera Development Corporation should study alternate methods of reducing greenhouse gas emissions, specifically researching into designs that improve building efficiency, thereby reduce the demand for heating energy.

Introduction and Backgrounder

Climate change is imminent. Air pollution, acid rain, and stratospheric ozone depletion are a few of the many environmental problems urban societies face today[1]. Increases in greenhouse gas (GHG) emissions around the world have contributed to the growing environmental concerns in urban societies. Vancouver is no exception[2].

In response to emissions in Vancouver, the Government of British Columbia, in 2007, set targets to reduce GHG emissions by 33 percent by the year 2020 from 2007-levels, and a further reduction of 80 percent from 2007-levels 30 years following[3]. To compliment these reduction targets, authorities at a regional and municipal-level outlined policies to meet these Provincial targets. For instance, Metro Vancouver, formerly the Greater Vancouver Regional District, set six specific GHG emission reduction strategies that align with Provincial initiatives in its *Corporate Climate Change Action Plan* for the entire Metro Vancouver region[4].

Building operational processes, including space heating and cooling, represent a significant portion of the total GHG emissions emitted into the atmosphere. In British Columbia, buildings are responsible for 34.9 percent of all GHG emission emitted[5]. In Metro Vancouver however, building operational processes, in 2007, represent a higher portion of GHG emissions sources of 41.1 percent. Given developmental patterns and

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[1] (Rezaie and Rosen 2011).
[2] According to the *2005 Lower Fraser Valley Air Emissions Inventory & Forecast and Backcast Executive Summary* conducted by Metro Vancouver (2007), GHG emissions have steadily increased to 9 tonnes in 2005 and is projected to increase up to 7 tonnes by the year 2030 (Metro Vancouver 2007).
[3] The Government of British Columbia (2008) in the year 2007 passed the GHG Reductions Target Act (GGRTA), which committed the Province to reducing GHG emissions by 33 percent from 2007-levels by the year 2020, and a further reduction of 80 percent from 2007-levels by the year 2050 (Government of British Columbia 2008). The *British Columbia Climate Change for the 21st Century* plan drafted in 2008 set specific actions to definite is approach to reach its GHG emission goals.
[4] (Metro Vancouver 2010).
[5] (Government of British Columbia 2010).

the increasing population projections throughout Metro Vancouver, it is estimated that GHG emissions caused by space heating will continue to rise[6]. Thus, an investigation on various heating solutions that will reduce a building's impact on the environment is necessary in order to achieve the goals, targets, and strategies set by various levels of government.

District heating is a proposed potential heating solution. District heating is comprised of centralized local thermal systems, with a network of underground piping distributing heat to the consumers[7]. A variety of fuel sources can be used to power a district heating system[8]. In the City of Vancouver, for instance, the Neighbourhood Energy Utility recovers heat from untreated urban wastewater as a primary fuel for its district heating system. Meanwhile, the City of North Vancouver, through the Lonsdale Energy Corporation, uses a much more conventional district energy system powered by natural gas[9]. District heating is often marketed as an environmentally friendly heating solution[10], with many GHG emission savings and annual energy savings compared to "conventional" heating solutions[11].

In 2010, the City of North Vancouver passed bylaw 8086, which states that all new buildings of more than 1000 square-metres must connect to the Lonsdale District Energy system[12]. This bylaw required Adera Development Corporation's Seven35 development, which is located within the Lonsdale District Energy system area, to connect into the City

[6] (Metro Vancouver, 2007).
[7] (Canadian Distrct Energy Association n.d.; Rezaie and Rosen 2011).
[8] District heating systems can be powered by using a primary fuel source or by using a combination of fuel sources (Ghafghazi, et al. 2010)
[9] (City of North Vancouver 2007).
[10] (Canadian District Energy Association 2011).
[11] The City of North Vancouver district energy utility operated by the Lonsdale Energy Corporation is reported to have an annual energy savings of 49 098 gigajoules per year and an annual GHG emissions savings of 4070 tones per year than compared to "conventional methods" (City of North Vancouver 2007).
[12] (City of North Vancouver 2010).

of North Vancouver's district energy system[13]. Hoping to study the feasibility of district energy systems from an economic and environmental standpoint, Adera Development Corporation, in partnership with the University of British Columbia, proposed to conduct research on the performativity of a district natural gas hydronic system.

Because 93 percent of BC Hydro's electricity supply is considered renewable[14], using electricity as a primary fuel source for heating seems to be another sustainable heating solution. Electrical baseboard heating, where cold air is heated through a process of electrical resistance inside a wall-mounted baseboard, is a common conventional heating system in British Columbia. Thus, a life cycle comparison between a natural gas hydronic system and electrical baseboard heating was conducted.

The previous comparative study, however, is micro-level analysis, focusing on capital costs, operational costs, and environmental-economic costs on the user and the developer. There seems to be a lack of information about the environmental implications and the indirect effects with the implementation of either heating solution. This study, in partnership with Adera Development Corporation and the University of British Columbia's Social Ecological Economic Development Studies, is concerned with analyzing electrical baseboard heating and natural gas hydronic district energy utility heating solutions from a macro-level perspective, aiming to explore the short and long-term effects of the implementation of either solution.

[13] (Uduman 2010).
[14] (BC Hydro 2011).

Method

Quoting a study of future renewable energy systems, Lund, Moller, Mathiesen, and Dyrelund, researchers of the Department of Development and Planning at Aalborg University, state that "one has to include the rest of the energy system in order to evaluate how to use the available resources in the overall system in the best way…"[15] This study aims to do just this by deconstructing and mapping both heating solutions to allow for a broader understanding of all inputs, outputs, and the different stakeholders involved with the implementation of either heating solution. Much of this process will rely upon the literature reviews of government studies, scholarly articles, and engineering reports.

Heat obtained by electric baseboard heating relies on electric energy from BC Hydro, while heat from natural gas-powered district hydronic heating systems use natural gas from providers such as FortisBC[16]. This study will begin with a brief analysis of the state of energy systems of British Columbia. Upon this evaluation, recommendations will be made along with suggestions for future research on this topic.

Electric Baseboard Heating

Uduman, in the previous report comparing electric baseboard heating and natural gas hydronic heating, calculated the environmental cost of electricity based on BC Hydro's distribution of electricity sources[17]. Using 2004 statistics, Uduman claims that 92.8 percent of BC Hydro's electricity comes from hydroelectric dams. While the distribution

[15] (Lund *et al.* 2010).
[16] (Uduman 2010).
[17] (Uduman 2010)

of electricity generated by hydroelectric dams vary year-by-year depending on stream flows and conditions[18], at first glance, it seems energy generated in British Columbia is considered "clean energy." But as discovered in a report on the province's public sector emissions,

> *Under voluntary international GHG protocols, BC Hydro is not required to measure and report the emissions from purchased electricity – either domestic or imported – that is passed on to consumers. BC Hydro has chosen to voluntarily report the emissions from domestic [Independent Power Producer] purchases, but import-related emissions are not yet included in its GHG inventory*.[19]

This means that the environmental costs previously reported in Uduman's study do not factor in emissions generated from imported energy.

Through its wholly owned-subsidiary Powerex, BC Hydro participates in energy trading activities with Alberta and the western United States via the interconnected transmission network[20]. British Columbia trades to meet its own domestic demands, when BC Hydro itself does not generate enough electricity to meet the province's domestic demands, and for revenue-generation purposes[21]. This occurs when BC Hydro purchases imported electricity during off-peak periods, when prices are low, and sells excess electricity during peak periods, when prices are generally high. Alberta imports power from BC Hydro during peak periods to meet its own provincial demands. Due to Alberta's predominantly thermal-based generation system, its production capacity is relatively constant, meaning there is an excess supply of energy during off-peak periods. BC Hydro imports this energy during these periods, allowing its hydroelectric reservoirs

[18] (Clean Energy BC 2011).
[19] (Ministry of Environment 2011 p.10).
[20] (BC Hydro n.d.).
[21] (Hoeberg and Sopinka 2011).

to fill-up for use during the peak periods. It is estimated that 12 percent of the energy used in British Columbia is imported from Alberta[22].

According to the province's 2011 public sector GHG emissions report, BC Hydro's emission factor, excluding imported energy, is estimated at 6.9 kilograms of carbon dioxide equivalence for every gigajoule of energy (6.9 kg/GJ)[23]. Alberta, on the other hand, has an emissions factor of 254 kilograms per gigajoule of energy (254 kg/GJ)[24]. Given that Alberta contributes to 12 percent consumed by British Columbians, it can be estimated that 37.78 kilograms of carbon dioxide equivalence is produced for every gigajoule of energy consumed by BC Hydro customers (37.78 kg/GJ), more than 5 times BC Hydro's reported emissions factor excluding energy imports. These increases seem consistent with the increases reported by the David Suzuki Foundation[25].

In a previous study of electric heating conversion in Denmark, Lund asserts that while electric heating may not generate emissions locally, the sources of electrical generation could generate GHG emissions. And in the case of British Columbia, our sources of electricity do indeed generate GHG emissions. Given the growing energy demands in the province, especially with new industrial project proposals that will require turning natural gas into liquefied form for export to growing Asian markets[26], the supply of energy in British Columbia is continuously being strained. By 2017, according to the 2011 *Integrated Resource Plan*, BC Hydro will face a supply gap[27]. Demand-side

[22] (Bryan and Skuce 2006; Monk 2011; BC Sustainable Energy Association 2008).
[23] (Ministry of Environment 2011).
[24] (Ministry of Environment 2011).
[25] Citing the David Suzuki Foundation, Stueck of The Globe and Mail reports that British Columbia's GHG intensity jumps to 80 taking imports as opposed to 21 without imports, much of this has to do with the imported electricity from Alberta, with a rating of 891 (Stueck 2009).
[26] (Brazier 2012).
[27] (BC Hydro 2011).

management encouraging electricity conservation and efficiency is a critical component of managing this supply gap.

According to a consulting report completed for BC Hydro in 2007 by Marabek Resource Consultants, space heating is reported to consume 24 percent of British Columbia's electrical energy consumption[28]. Marabek Resource Consultants did, however, point out that at least 2090 gigawatt hours of electricity could be saved annually if natural gas and other fuels substituted electricity for space and water heating in residential and commercial applications. Given the projected supply gap in the province's energy in the next coming years, reductions in electrical demand for space heating will play a critical role of demand-side management.

Moreover, the overall ability of electricity used for space heating can be put into question. Finch, in his report *Energy Consumption in Mid and High Rise Residential Buildings in British Columbia*, completed a study on heating in multi-unit residential buildings[29]. Finch concludes that while a majority of the buildings studied were originally designed to use electricity as a primary heating source, the primary energy source for space heating is natural gas. These differences between original plans and the realities of multi-unit residential buildings must be taken into consideration.

[28] (Marabeck Resource Consultants 2007).
[29] (Finch n.d.).

Natural Gas District Hydronic Energy

Marabek Resource Consultants recommendation to switch space heating from electricity to natural gas seems to fit the plans of FortisBC, formerly Terasen Gas. Terasen Gas, in 2008, completed a resource planning assessment for it's business, exploring the social, regulatory, and market landscapes in which the company will operate in the future. The report, the *2008 Resource Plan,* recognizes the strain on the province's power grid as a result of growing domestic demand for energy. Since natural gas has only limited uses, Terasen Gas believes natural gas should be the source for space and water heating applications. Furthermore, with a manageable growth in annual demand, Terasen believes natural gas has the ability to meet the heat demands of the province. Therefore, it seems that plans for BC Hydro and FortisBC are consistent with one another.

From an environmental standpoint, however, natural gas heating applications do have associated environmental costs[30]. The City of North Vancouver's district energy utility is estimated to produce 2200 tones of carbon dioxide equivalence for its 45 000 gigajoules of energy it will produce[31], or approximately 48.9 kilograms of carbon dioxide equivalence for every gigajoule of energy (48.9 kg/GJ). These estimates are relatively close to the emissions factor for natural gas, rating at 49.9 kilograms of carbon dioxide equivalence per gigajoule of energy (49.9 kg/GJ), found in Ministry of Environment's 2011 report on *BC Public Sector Gas Emissions*[32]. Looking at emissions, natural gas district energy utilities, with an emissions factor of 48.9 kilograms per gigajoule consumed (48.9 kg/GJ), still produce more carbon dioxide equivalence than electric

[30] (Uduman 2010).
[31] (City of North Vancouver 2007).
[32] (Ministry of Environment 2011).

baseboard heating, which is estimated at 37.78 in this report (37.78 kg/GJ). But this difference is much less than previously reported in Uduman's study.

With growing demand for natural gas in Asia[33], the availability of natural gas, as reported earlier by Terasen Gas, may be in question. However, district energy utilities do not necessarily need to rely on natural gas as a primary fuel source. Indeed, as Rosen, Le, and Dincer point out in their study presenting the efficiency energy and exergy of cogeneration-based district heating systems, a combination of primary fuel sources can be used[34]. In the case of Lonsdale Energy Corporation, the City of North Vancouver has been working to implement alternative fuel sources, ranging form solar applications to biofuel applications, and even geothermal applications, which thereby offset emissions generated by burning natural gas[35]. Meanwhile, the City of Surrey is moving forward with its Surrey Central district energy utility powered by geothermal exchange[36]. Sewer heat recovery and biomass, among many other sources, offers much lower GHG emissions[37].

Recommendations and Future Research

While natural gas district hydronic energy systems have higher emissions than compared to electric heating solutions, these systems have the ability to switch to lower-emission fuels, such as biomass[38]. Another important consideration that district energy systems can contribute to the reduction of emissions of existing buildings in a service area and is not only limited to new developments. It is possible to retrofit existing

[33] (Brazier 2012).
[34] (Rosen *et al.* 2005).
[35] (City of North Vancouver 2007).
[36] (City of Surrey 2010).
[37] (Ghafghazi *et al.* 2010).
[38] (Ghafghazi *et al.* 2010).

individual hydronic buildings by connecting to the district energy network, thereby reducing its emissions.

However, this paper aims not only to analyze environmental costs associated with the implementation of electric baseboard heating and natural gas district hydronic heating, but also, to indicate how these technologies fit within the interconnected energy systems of British Columbia. The analysis of state of British Columbia's energy systems and the future plans of stakeholders, such as BC Hydro and FortisBC, are important in order to see how electric baseboard heating and natural gas district hydronic heating systems may play a role in the future of British Columbia. Finding ways to complement the plans and goals of all stakeholders are important. District heating as discussed in this study, seems to fit better in the plans of the different stakeholders than electric baseboard heating.

Still, the study of energy, especially in the context of energy systems and heating in the context of British Columbia, is complex. Calculating the true emissions of electricity, for instance, requires an in-depth analysis. This report gives only a rough estimation of the emissions factor of British Columbia based on preliminary energy trading practices with Alberta. It does not include energy trading practices with other partners, such as the United States. Until clearer information with regards to energy trading is made available for scholarly review, the true emissions generated by the consumption of electricity in British Columbia will not be known. Thankfully, "starting in 2011, importers of electricity are required to report GHG emissions associated of this electricity."[39] When this data becomes available, it is recommended to review and conduct another comparative analysis between electric baseboard heating and natural gas district hydronic heating,

[39] (Ministry of Environment 2011)

specifically comparing the GHG emissions generated by both heating technologies. It may also be worth studying other fuel sources of district hydronic heating to find lower emitting alternatives.

Given that private developers must follow city bylaws, such as City of North Vancouver's bylaw 8086[40], it seems that private developers have restricted agency over the debate on heating technologies for the future. But private developers can play a role in a green and more sustainable future. The reduction of demand for energy is a reoccurring theme in this study; this should be addressed in future research. Moving forward, it is recommended that Adera Development Corporation study methods for the reduction of demand for heating, such as finding methods for designing buildings to improve on its operational efficiency[41].

Concluding Words

This paper comparatively analyzes electric baseboard heating and natural gas district hydronic heating by studying the energy systems through the stakeholders of BC Hydro and FortisBC. The complexity of these energy systems are indicated in this study, showing that there really is no clear answer. Electric baseboard heating has the potential of being green, but this is based on the sources of electrical generation. Meanwhile, natural gas district hydronic heating may generate more emissions than electric baseboard heating, but its benefits may be important for consideration. Still, additional research on the topics of energy systems must be conducted in order to gain

[40] (Ctiy of North Vancouver 2010)
[41] See *PassivHaus* projects of Europe (Centre for Alternate Energy, n.d.)

a better understanding of energy. Only then can there be specific recommendations on heating technologies for the future.

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