Smart Growth on the Ground: Prince George

FOUNDATION RESEARCH BULLETIN #4

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The Potential for Local Bioenergy in Low-Carbon Community Planning

> In the future, the energy needs of Prince George may be met by renewable heat and electricity. Current hydro-electricity supply is insufficient to accommodate current demand in British Columbia, or to accommodate fuel switching away from fossil fuels. Switching to alternative low-carbon sources of heat (such as biomass, geo-exchange, and solar) will be necessary.

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Smart Growth BC

1.0 Introduction

Our carbon footprint - the amount of carbon dioxide released into the atmosphere as a result of human activity - is largely due to high consumption levels of energy derived from fossil fuels. Carbon dioxide is one of the most abundant and hence significant greenhouse gases (GHGs). Its increased concentrations resulting from human activity are accelerating the natural "greenhouse effect" of our atmosphere, leading to global climate change. In order to curb climate change, GHG emissions must be reduced significantly. Federal government studies suggest that the most cost-effective solutions for reducing GHG emissions from buildings involve minimizing energy usage, maximizing efficiency, and fuel switching to lower carbon fuels (Canmet Energy, accessed 2009).

Some studies suggest fuel switching will ultimately play a larger role than energy efficiency in reducing GHG emissions (Simpson et al, 2007). Space and water heating are among the major contributors to greenhouse gas emissions in Prince George (Sheltair, 2007). By focusing on alternative, low-carbon heat sources, Prince George can reduce its dependence on natural gas for space and water heating. Eliminating this fossil fuel as an energy source for all residential heating would reduce GHG emissions by approximately 11% in Prince George. This would take the city one third of the way towards meeting the provincial emissions reduction target for 2020 (33% below 2007 levels). All feasible renewable energy sources may need to be tapped to replace fossil fuels and meet provincial legislated targets of 80% reduction in GHG emissions by 2050. This bulletin examines biomass as an alternative low-carbon energy source that could help reduce greenhouse gas emissions in Prince George, BC, thereby fighting climate change.

photo credit: Mystic Management Ltd.

Figure 1: Site photo showing implementation of the two-pass harvesting system, which requires thin strips to be cut from the forest for removal of neighbouring overstories. Source: Mystic Management Limited, Meadow Lake, Saskatchewan.

2.0 Bioenergy

Bioenergy is energy derived from organic biomass sources, such as:

- forestry products and byproducts (wood chips, and "residues", such as waste bark or branches);
- agricultural crops (such as flax seed oil);
- food processing (including waste oils from the service industry) and domestic organic waste; and
- agricultural and aquacultural wastes (such as manure and vegetable culls).

When used for energy, biomass is considered low-carbon because it releases no more carbon dioxide into the atmosphere than it absorbed during its lifetime (not accounting for GHGs released during harvesting, transportation and processing). Replacing fossil fuels with energy derived from biomass significantly reduces the release of carbon into the atmosphere, thereby slowing climate change.

Biomass resources from forests can take a variety of forms, including residues from timber harvesting, softwood, hardwood, woodchips, and wood pellets (processed from woodchips for efficient transport). Waste wood residues from the timber/fibre industry represent about 40% of harvested tree biomass (TDB Consultants, 2005). Byproducts, such as mill waste, form the cheapest source of biomass, followed by "roadside" waste residues from harvesting. Mountain Pine Beetle salvage is the most expensive source of biomass due to salvage operation costs (Verkerk, 2008). Where forest biomass is being harvested specifically for bioenergy, trees are generally harvested at a younger age than for traditional uses (e.g., lumber) in order to maximize biomass yields over time. Several methods of harvesting biomass in various stand types are feasible, including carefully planned clear-cutting, thinning or a "two-pass" system (Figure 1), as described by Welham et al. (2002).

The conversion of biomass to energy usually begins with dry, chipped wood, or pellets if the biomass is to be transported over long distances. Chipping, re-sizing, pelletization, and drying can require significant use of energy, except for air-drying over the summer. Dry biomass can have a heat content equal to brown coal (lignite) while containing significantly less sulphur. Various energy conversion technologies are viable in Prince George, as described in Table 1.

Concerns sometimes voiced with regard to biomass harvesting, transportation, storage, and energy conversion include:

- Loss of organic matter and woody debris at harvesting sites, with long-term damage to the ecosystem
- Visual impacts of biomass harvesting or plantations, and associated effects on recreation, properties, other land-uses, etc.
- Air quality impacts of converting biomass to heat or electricity
- Traffic impacts on communities due to bulk deliveries of biomass
- Cost effectiveness of the bioenergy production process.

Potential co-benefits often cited for the use of bioenergy, beyond the reduction in GHG emissions through switching away from fossil fuels, include:

- Reduced community energy costs
- Increased local control over energy supplies and pricing, with reduced vulnerability to fluctuations in external fuel costs
- Additional value and employment from diversified forest products, beyond timber, fibre, and pulp
- Reduced forest fire risk
- Opportunities for leadership in green energy and associated tourism
- Community pride in the industry, ownership, and self-reliance.

The following section summarizes the research carried out to date that addresses some of these issues as they pertain to Prince George.

3.0 The Potential Role of Bioenergy in Prince George

Sources of biomass in Prince George

The Prince George Community Forest (PGCF) occupies predominantly forested lands within municipal boundaries, encompassing 32,945 hectares, or almost 330 square kilometers. Approximately one third of the forested lands in the PGCF are either Crown or municipal lands. 5,000 hectares of these lands are under Crown ownership, which is historically the most viable form of land-ownership for large-scale forest production. Approximately 1,000 hectares of the forested lands in the PGCF are municipal lands, which are subject to periodic thinning to manage forest fire risk.

1) Combustion: Direct combustion of biomass can occur at residential or industrial/community scales. In this process, steam is created by burning biomass aerobically to use as a heat source, generate electricity, or do both in a cogeneration system. The efficiency of heat generation can be as high as 85% in high-efficiency stoves for individual buildings.[1] At the industrial scale, some local industry already has the infrastructure for implementing direct combustion technology.
2) Gasification: This technology converts biomass into syngas (the gas produced by a gasifier) or volatile gases that can be used as fuel, and ash as a byproduct. While both types of gasification use some biomass energy to produce the required high temperatures, they also reduce air quality problems associated with conventional biomass combustion.
3) Anaerobic digestion (biogas): A biological digester (a biogas plant where the breakdown of organic matter occurs) enables anaerobic processes (no oxygen present) to produce methane, which can be used in internal combustion engines (for electricity generation or as transportation fuel) or for heating purposes, replacing natural gas as an energy source.
4) Pyrolosis (bio-oil): In anaerobic conditions, finely chipped biomass is heated, vaporized and condensed to produce bio-oil. Bio-oil has a higher energy content by volume than raw biomass, which reduces transportation costs. It may be used in internal combustion engines or to substitute conventional fuels in boilers, furnaces, and turbines.
5) Ethanol: Ethanol derived from forest or agricultural residues may be used as a transportation or energy fuel when it is blended with gasoline. The current energy conversion efficiency is low (about 23%) but is expected to reach 32% by 2020.

Table 1: Energy conversion technologies for biomass.

As a considerable potential source of local low-carbon bioenergy, the PGCF is the focus of this assessment. Principal tree species suitable for biomass production include lodgepole pine, white spruce, and aspen. In the Prince George region, Mountain Pine Beetle (MPB) salvage and high-priority fuel-reduction activities in areas of high or very high wildfire risk represent potentially available additional sources of biomass feedstock. However, these would bring only a short-term infusion of biomass and are therefore not considered a long-term bioenergy source (Stennes and McBeath, 2006). Although MPB killed trees can be used for combustion up to seven years following mortality, current mortality rates are not expected to continue in the future (BC Ministry of Forests, accessed 2009).

Current and potential future uses of biomass in Prince George

Currently, approximately 5% of homes in Prince George use fuel wood for heat, although only 1% use it as the primary source of heat. A portion of the significant amounts of biomass presently harvested by the forest industry in the region is used as bioenergy to power certain mill operations. Various initiatives are underway to explore expanded industrial production and/or use of bioenergy.

Most significantly, a community energy system is currently being contemplated by Prince George, and a bioenergy plant has been considered at an earlier stage. A community energy system services a network of buildings that use a shared source of heat or electricity (such as an industrial boiler) as opposed to individual buildings relying on separate sources, such as residential furnaces. Major benefits of such a network include increased efficiency (less waste heat energy); lower per capita energy consumption and cost; ability to increase system capacity or extent; relative ease of facilitating fuel switching in the future; and compatibility with mixed use urban forms and complete communities. The implementation of a community energy system requires certain enhanced infrastructure, such as insulated heat distribution pipes as well as ample consumer demand in close proximity to an energy plant. While cogeneration of heat and electricity is the most efficient method of energy generation in a community energy system, producing heat in particular will make a more significant contribution to reducing GHG emissions in British Columbia, since much of the province's electricity is hydroelectricity with a low carbon footprint.[2]

The currently planned community energy system for Prince George, to be implemented in two phases, is envisioned to service a network of over 20 downtown commercial and civic buildings that will primarily use waste heat piped from nearby industrial plants. Early projections suggest that 80% of the heating requirements of the community energy system could be satisfied from this source, while the remaining 20% could be met by natural gas.

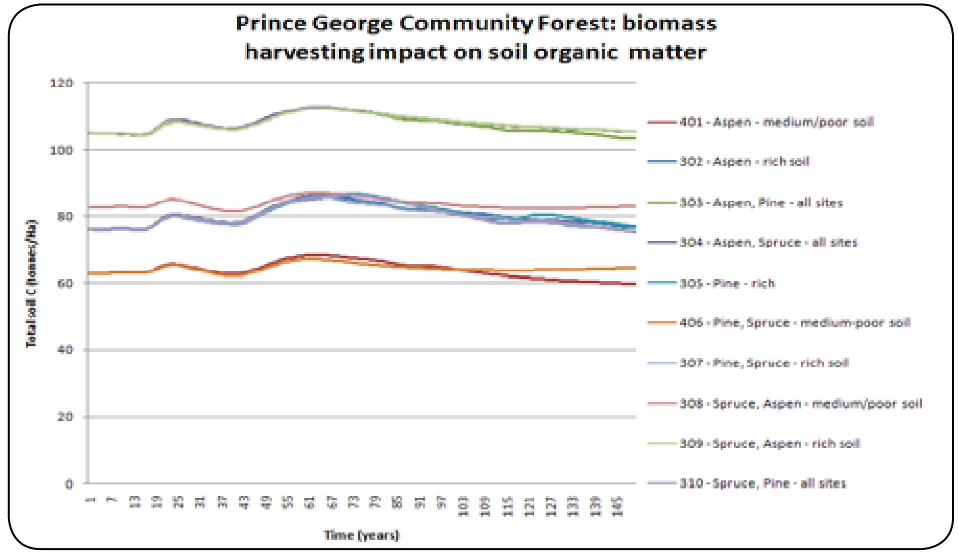
Biomass supply modeling for Prince George

As part of an effort to identify how much renewable energy might be available to the City of Prince George, a research project was undertaken by the Collaborative for Advanced Landscape Planning (CALP) with the Design Centre for Sustainability. This project estimates the capacity of the Prince George Community Forest (PGCF) to render biomass for low-carbon energy production. Sustainable management scenarios for forest biomass growth and harvesting have been modeled for a period of 150 years for the PGCF, using BC Ministry of Forests forest cover inventory, creek riparian area data, and BC biogeoclimatic zones as inputs. This ecosystem simulation model, called FORECAST, has been developed and tested over many years by Dr. J.H.P. Kimmins and his team (Kimmins, 1997) to forecast the ecological, soil and growth conditions for forest ecosystems under different management regimes over the long term. Its goal is to determine whether there is any overall decline in ecosystem productivity and health for given harvesting rates.

Recent research suggests that soil organic matter (a measure of carbon) is an effective indicator of sustainable forest management practices (Seely et al., in press). For the FORECAST simulations of the PGCF, soil organic matter and total above ground biomass were used to assess the long-term sustainability of various harvesting scenarios. In an iterative process, the FORECAST model was run with variable stand rotation lengths to achieve a management strategy that maintained a zero net change for these two variables over a management simulation period of 150 years (Figure 2). The model results suggest that sustainable rotation lengths (i.e., harvesting frequencies that do not reduce ecosystem productivity) are in the range of 15-30 years for most aspen-dominated stands and 30-50 years for most coniferous stands. However, sustainable harvesting of some other stand types with poorer site conditions would require 75-150 year rotation lengths.

Projected sustainable biomass yields vary according to stand type (Figure 3), ranging from one to three Bone Dry Tonnes (BDT) per hectare annually, with an average of 1.2 BDT per hectare annually across all stand types. This suggests that the PGCF could sustainably produce 23,300 BDT of biomass each year, of which around 7,700 BDT could be derived from Crown and municipal lands. An additional 1,750 BDT of wood could be available at sustainable rates from harvesting within high and very high fire risk areas outside of the analyzed stands, bringing the total estimated annual biomass supply to about 9,450 BDT.

These estimates should be considered as preliminary raw estimates of the capacity of the lands under consideration to generate biomass for sustainable renewable energy production. Actual bioenergy supplies would be dependent on many other factors and constraints, such as access and conditions, environmental sensitivities, costs, engineering feasibility, silvicultural needs, land use policies, and public perceptions. A feasibility study would be needed to generate actual supply forecasts.



credit: CALP

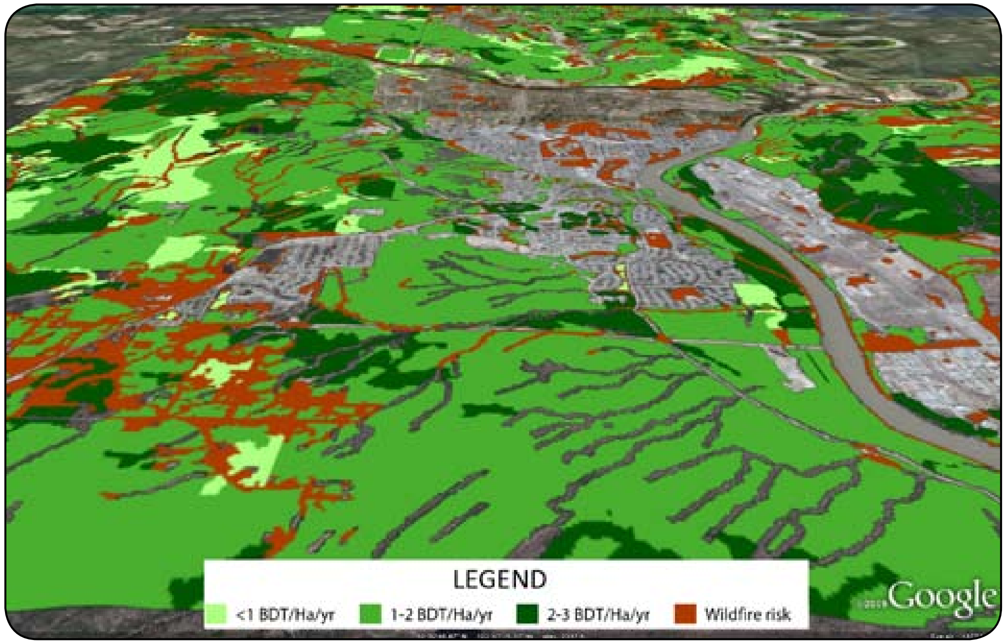
Figure 2: FORECAST modeling shows the impacts of harvesting on soil organic matter over time. This allows researchers to alter proposed harvesting regimes in order to achieve long term sustainability, as shown above with harvesting frequencies of 15 to 150 years, depending on stand type and initial soil conditions (FORECAST modeling conducted by Juan Blanco, Department of Forest Science, University of British Columbia).

4.0 Implications for Prince George

How much energy demand could potentially be met by biomass?

To put the above numbers of estimated biomass production into perspective, the equivalent energy outputs can be related to community energy demand in Prince George. In terms of the contemplated community energy systems for downtown Prince George, the 20% of the heating requirements of the system that would otherwise be met by natural gas could be met by local biomass. If potential biomass yields from sustainably managed Crown and municipal PGCF lands were used for this purpose, enough excess heat would be available to heat 1,000 attached residences in the downtown core. In other words, if all of the available biomass were converted to heat, there would be enough energy to satisfy twice the base heating load of the CES (i.e., the typical heat demand, which is about one third of the peak heat demand that occurs over very short periods of time).

If this amount of heat energy were applied exclusively to the residential sector, it would satisfy about 5% of the annual heating demand of the city. For example, in order to satisfy the total residential heating demand of Prince George in 2002 (estimated at 2,775,750 GJ)[3] with bioenergy,



credit: CALP

Figure 3: This image illustrates forest stand productivity throughout the Prince George Community Forest and additional areas that are at high and very high risk to wildfire. The resulting map was overlaid into Google Earth, allowing the viewer to see production at both small scales (such as a neighbourhood wood lot) and large scales (such as a continuous patch of forest).

131,500 hectares of forest would be required (assuming the average sustainable extraction rate of 1.2 BDT per hectare annually). This equals approximately four times the area of the entire PGCF or the approximate extent of a 20 km "buffer zone" around the city (Figure 4). In reality, much of this heat demand might be obtainable renewably from ground-source heat-pumps and certain types of solar energy, in combination with bioenergy and other renewable sources.

What about air quality and particulate emissions?

In 2001, 30,580 tonnes of dust (PM10) were emitted in the Prince George airshed (PGATMC, 1996). These are pollutant particles of dust, soot, ash or smoke that measure up to 10 micrometers in diameter, and can lead to health problems if they build up to unsafe levels in the air. Wildfires are the highest particulate emitters, followed by slash pile, beehive and silo burning. The technologies for biomass combustion or energy production (described in Table 1) differ significantly in the amount of particulate emissions each produces. Industrial combustion reduces emissions, with numerous technologies such as complete burning, carbon burnout, flue gas cleaning and electrostatic precipitators making this reduction significant. Smaller combustion systems may rely on electrostatic precipitators (removing particles from emissions by means of an electrostatic charge); scrubbers (including a variety of technologies which use fibrous filters, liquids or solvents); and baghouses (filtering out an airstream like a vacuum cleaner—the most effective technology if volumes and temperatures are moderate). Gasification is most effective at reducing particulate emissions, as it produces less than 0.01 grams of dust(PM10) per Kilowatt hour (ENVINT, 2008). This would result in a total of 0.1076 tonnes of dust (PM10) per year if the total of sustainably harvested biomass from Crown and municipal lands in the PGCF were processed using this technology. The same amount of particulates would be emitted by one average low-sulphur diesel bus over a travel distance of 31,647 kilometers.[4]

How would bioenergy help reduce our carbon footprint?

GHG emissions resulting from space and hot water heating can be reduced by up to 92% by switching the heat source of a building from natural gas to biomass wood chips or pellets. Modern biomass gasification technology can achieve these reductions while keeping particulate emissions at levels comparable to natural gas. If all of the energy that could be generated by the projected sustainable biomass yield from PGCF Crown and municipal lands (138,500 Gigajoules per year) were to be used for fuel switching from natural gas to gasified biomass, almost 3,800 tonnes of carbon dioxide emissions could be avoided annually. This is equivalent to 75% of emissions from corporate buildings in Prince George forecasted for 2012.

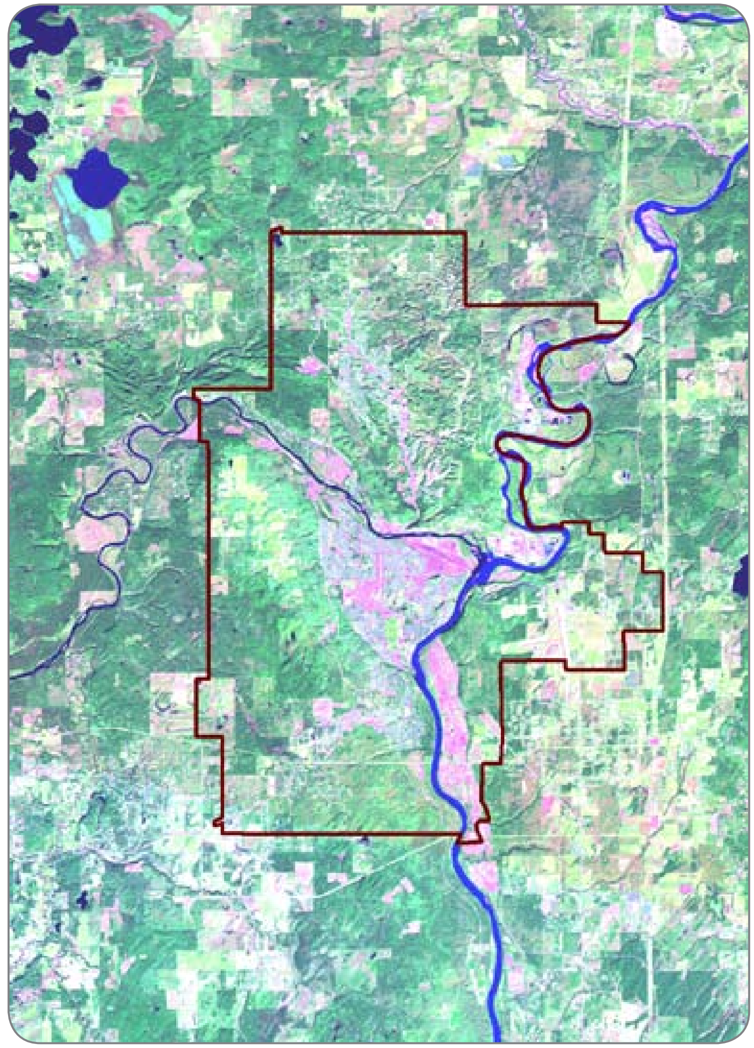
5.0 Setting Indicators and Targets for Low Carbon Energy Use in Prince George

Both the Smart Growth on the Ground process for downtown Prince George and the new provincial standards for Official Community Plans set out in Bill 27 call for target setting related to greenhouse gas emission reductions.

Currently, natural gas for space and water heating is the primary source of building-based greenhouse gas emissions in Prince George. Approximately 87% of residences use natural gas as a primary heat source, with approximately one-third of residential heat being used for generating hot water and two-thirds for space heating. Only approximately 13% of Prince George residences are presently using heat energy sources other than natural gas (Winfield-Lesk, 2004), which may include local, low-carbon sources.

In the future, the energy needs of Prince George may be met by renewable heat and electricity. Current hydro-electricity supply is insufficient to accommodate current demand in British Columbia, or to accommodate fuel switching away from fossil fuels. Switching to alternative low-carbon sources of heat (such as biomass, geo-exchange, and solar) will be necessary. Significant reductions in the carbon footprint of communities can be achieved through various combinations of expanded community energy systems using biomass and waste heat; more individual residential and commercial buildings switching from natural gas to high-efficiency wood stoves and boilers (using local logs, chips or pellets); and the use of ground-source heat pumps, solar thermal hot water as well as other renewable sources.

A suggested indicator for making Prince George a sustainable low-carbon community is: the percent of heating demand in Prince George that is supplied by local, low-carbon energy (such as biomass, geo-exchange, or solar).



credit: CALP

Figure 4: The Prince George Community Forest and potential biomass resources within the municipality (boundary shown in red). Additional land base outside of the Prince George Community Forest would be needed to heat all homes using biomass energy. A more likely energy mix, however, would be to use biomass in the downtown Community Energy System, complemented by other heat sources (such as solar thermal and geoexchange) in lower density areas.

photo credit: Marches Energy Agency

Figure 5: Biomass-powered cogeneration plant that produces heat and electricity for the town of Gussing, Austria (population 4,000). Local forests provide wood chips, which fuel a gasification process that generates eight Megawatts.

For the purposes of the Smart Growth on the Ground process, a possible target would be 46% of downtown Prince George buildings using local, low-carbon heat energy sources by 2020. This is 33% better than the current 13%, therefore matching the provincial GHG emission reduction target of 33% below 2007 levels by 2020.

Another, longer-term target would be 93% of downtown Prince George buildings using local, low-carbon heat energy sources by 2050. This is 80% better than the current 13%, therefore matching the provincial GHG emission reduction target of 80% below 2007 levels by 2050.

Precedents or other benchmarks for reaching or moving towards such targets can be found in many other communities internationally that have begun to aggressively switch to renewable energy sources under local control. For example, the small town of Gussing, Austria has replaced essentially 100% of fossil fuels used for heat and power in the community, primarily with locally sourced biomass (Figure 5). As a result, the town has gained international fame as a centre for renewable energy, attracting industry, scientific and training facilities, and large numbers of green energy tourists.

6.0 Conclusions

Research findings to date suggest that the PGCF has the capacity to sustainably produce 23,300 BDT of biomass each year, of which around 7,700 BDT could be derived from Crown and municipal lands. This could generate around 138,500 Gigajoules of heat energy. Additional supply may be derived from harvesting in high and very high fire risk areas. Biomass from these sources could be converted to bioenergy to replace natural gas in the planned community energy system for downtown Prince George (and possibly in an expanded system), as well as in individual homes and businesses. This is with the caveat that high air quality standards can be met and other feasibility issues are carefully considered.

Community energy systems operate best at medium and higher density settlements, particularly with mixed-use areas that allow cycling of heat between generation sources and users. Strategies that involve adapting existing facilities with lower capital investment and shorter pay-back periods seem to offer the most immediate opportunities for Prince George. Planning policy that encourages these integrated community designs and land-use mixes would greatly improve the feasibility and efficiency of a Prince George community energy system fueled by sustainably harvested biomass.

Further studies of a range of renewable energy sources and their feasibility are required, with initial studies already underway on solar thermal energy. This would contribute to an integrated study of low-carbon strategies for all of Prince George, building on the downtown planning exercise. It would also inform a wider visioning process to engage broader public dialogue and awareness (Sheppard, 2008), review policies, set formal targets, and promote action on climate change—thereby fostering a sustainable community.

References

Flanders et al. 2009. A Preliminary Assessment of Renewable Energy Capacity in Prince George, BC. Report Prepared for Natural Resources Canada.

Kimmins, J.P. 1997. Predicting sustainability of forest bioenergy production in the face of changing paradigms. Biomass and Bioenergy 13: 201-212.

Lowell D., W. Parsley, C. Bush, and D. Zupo. 2003. Comparison of Clean Diesel Buses to CNG Buses. 9th Diesel Engine Emissions Reduction (DEER) Workshop 2003, Newport, RI.

Prince George Airshed Technical Management Committee (PGATMC). 1996. Prince George Air Quality Management Background Report. Prince George, BC.

Seely, B. C. Welham, and J.A. Blanco. In press. Towards the application of soil organic matter as an indicator of ecosystem productivity: Deriving thresholds, developing monitoring systems, and evaluating practices. Submitted to Ecological Indicators in 2009.

Sheltair. 2007. City of Prince George Energy and Greenhouse Gas Management Plan.

Sheppard, S.R.J. 2008. Local climate change visioning: A new process for community planning and outreach using visualization tools. Plan Canada 48 (1): 36-40.

Simpson, J., M. Jaccard, N. Rivers. 2007. Hot Air: Meeting Canada's Climate Change Challenge. McClelland & Stewart, Toronto.

Stennes, B., and A. McBeath. 2006. Bioenergy options for woody feedstock: Are trees killed by mountain pine beetle in British Columbia a viable bioenergy resource? Canadian Forest Service, Pacific Forestry Centre.

TDB Consultants Inc. 2005. Biomass Estimation for Forested Lands in the City and Surrounding Area. Report prepared for City of Prince George.

Verkerk, B. 2008. Current and Future Trade Opportunities for Woody Biomass End-products from British Columbia, Canada. Unpublished Masters of Science thesis, Faculty of Forestry, University of British Columbia.

Welham, C., B. Seely, and H. Kimmins. 2002. The utility of the two-pass harvesting system: an analysis using the ecosystem simulation model FORECAST. Canadian Journal of Forest Research 32: 1071-1079.

Winfield-Lesk, 2004. Wood Stove Exchange Program for the Prince George Airshed – Year 2. Submitted to Wood Stove Exchange Steering Committee, Ministry of Environment.

Resources

BC Ministry of Forests: http://www.for.gov.bc.ca/hfp/mountain_pine_beetle/faq.htm, accessed 2009

Canmet Energy, Natural Resources Canada: www.canmetenergy-canmetenergie.nrcan-rncan.gc.ca, accessed 2009

Gussing, Austria: www.mea.org.uk/news/mea-visits-impressive-eco-town-gussing-austria

Endnotes

1. See Winfield-Lesk, 2004, for a discussion of the Prince George wood stove exchange program.
2. The carbon footprint of our electricity consumption will continue to increase while we continue to import more electricity from neighbouring generators such as Alberta. This is a trend that can be reversed by decreasing our demand or by generating more low-carbon energy within British Columbia.
3. The residential energy consumption in Prince George was 3,701,000 Gigajoules in 2002 (this figure is projected to increase with population growth). Approx. 75% of the energy consumed was used for space heating and hot water (Sheltair, 2007).
4. An average low sulphur diesel bus emits 5.5 grams of dust($_{PM}$10) per mile (0.0000034 tonnes per kilometer) (Source: Lowell et al., 2003).

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