

## SMALL-SCALE AUTOMATED BIOMASS ENERGY HEATING SYSTEMS: A VIABLE OPTION FOR REMOTE CANADIAN COMMUNITIES?

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### INTRODUCTION

Electricity and heat energy are vital commodities in Canada's remote communities. Electricity is usually produced by diesel-fueled generators. Diesel or light heating oil is also used to heat the larger public buildings. Below the tree line, roundwood from surrounding forests is commonly used to heat private homes.

Diesel fuel and heating oil must be brought into the community by truck, barge, or in some cases, air. The associated costs are high and the supply can easily be disrupted by bad weather.

The worldwide move toward environmentally sustainable development has focused new attention on renewable energy technologies that could be appropriate to many remote communities in Canada. The term **renewable energy** refers to energy sources which, if used at sustainable rates, will not be depleted over time, but may be sustained through natural processes (i.e., wood biomass, wind, hydro, and solar). Usually, renewable energy resources can be obtained locally without high costs. Nonrenewable energy options include fuel sources which, once depleted, are lost and not replaceable (i.e., coal, oil, natural gas).

Renewable energy technologies can replace entire nonrenewable systems, or they can be used in tandem to form "hybrid systems". In many cases a combination of energy options will provide the most economic and sustainable, long term energy supply. Using heat more efficiently (i.e., reducing use, insulating, improving heat storage and distribution systems) should form a component of any

renewable energy strategy. This note focuses on the use of wood energy (forest biomass) for space heating.

### POTENTIAL BENEFITS OF BIOMASS ENERGY

Biomass energy refers to those forms of energy derived from plant or animal materials, such as wood, straw, grass, and manure. Wood is the most readily available biomass fuel in remote communities. Consequently this technical note deals with woodchips and sawmill waste, both of which can be burned in automated biomass heating systems.

For years, people have used wood-burning stoves and furnaces for space heating. These systems are usually fed manually with roundwood of various lengths. Automated systems differ by using wood that has been processed into small chips or sawdust and then automatically fed into a burner using an auger. The development of automated biomass energy heating systems began in Scandinavia in the 1970s, when oil prices skyrocketed. This technology was transferred to Canada in the early 1980s. Today, a number of automated biomass systems heat many small businesses and institutions across Canada.

Automated biomass systems can efficiently burn small-diameter wood that has no other potential use. They also provide a convenient way to use low-grade wood to heat large buildings or groups of buildings, the heating of which would not be feasible with roundwood burners. Biomass energy offers both direct and indirect (spin-off) benefits in remote communities.

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## Direct Benefits

Direct benefits include the following:

- *Substantial annual savings* After the capital costs of the system have been paid, all direct annual savings belong to the owner of the biomass system.
- *Environmental benefits* Biomass systems burn very cleanly, generate very little smoke, and are carbon dioxide (CO<sub>2</sub>) neutral. Excluding the oil used to harvest the wood, the combustion of woodchips releases only the CO<sub>2</sub> that was absorbed during the life of the trees. This CO<sub>2</sub> is, in turn, reabsorbed by the new trees that have regenerated in the harvested areas.

## Indirect Benefits

Indirect benefits include:

- *Wood vs. oil* Most of the money spent on wood chips stays in the community; most of the money spent on imported oil is lost.
- *Greater community self-reliance* There will be reduced vulnerability to fluctuations in world oil prices.
- *Enhanced economic viability of existing logging operations* Both equipment and labor can be better utilized.
- *Silvicultural benefits* It is more feasible to perform silvicultural treatments such as thinnings, and clear-cut, chipped sites are ready for planting without further site preparation.
- *Construction of biomass plants creates short-term employment in the community* Harvesting woodchips and operating woodchip burners creates long term employment during the fall and winter months when jobs in a community may be scarce.

## Reasonable Use of Biomass Energy

Biomass energy may make sense in any region of Canada where:

- heating energy costs are high (above \$0.30/liter for oil);
- there is an ample supply of low-grade biomass (most forest regions of Canada have significant biomass resources);
- there is an available source of local labor;
- there is an existing or planned commercial forest operation; and

- new buildings are being constructed, or older heating systems are being replaced.

## Economics: Biomass Energy vs. Oil

Remote Canadian communities located below the tree line usually consist of a large number of small private homes (which are often heated by roundwood stoves or furnaces), and a small number of commercial and institutional buildings (which are usually heated with oil). In 1996, the price of heating oil in remote communities in Canada ranged from \$0.30 to \$1.20 per liter.

How does the cost of woodchip "fuel" compare to the cost of heating oil? When all production costs are considered (labor, fuel, equipment purchase and maintenance), it should be possible to produce woodchips profitably in remote communities for about \$40 to \$60 per tonne (1 tonne = 1 000 kg of green chips). Woodchips at \$40 per tonne are equivalent to heating oil at about \$0.20 per liter. If the cost of woodchips was \$60 per tonne, that would be equivalent to heating oil at about \$0.30 per liter. Thus, the direct savings from burning woodchips are substantial in those areas where oil costs are high (Fig. 1).

## Cost: Oil Fired Heating Systems vs. Biomass Fired Heating Systems

Oil-fired systems are relatively inexpensive to buy, but are generally expensive to operate in remote communities because of the high cost of delivered heating oil. Conversely, biomass systems are more costly to build, but they can have much lower operating costs when an ample supply of biomass "fuel" is available in the area.

Woodchips are a low-grade, solid fuel with a relatively low energy value per unit of volume; heating oil, on the other hand, is a liquid with a high energy value per unit of volume. To handle a low-grade, solid fuel, woodchip systems require a much larger fuel storage area as well as elaborate mechanical fuel feeding and combustion mechanisms. Hence, biomass heating systems typically cost three to four times more than do oil-fired boilers of similar output.

However, where the cost of heating oil is high (above \$0.30/liter), the savings realized from burning low-cost woodchips can justify the additional investment cost of an automated biomass system. Under these conditions, the

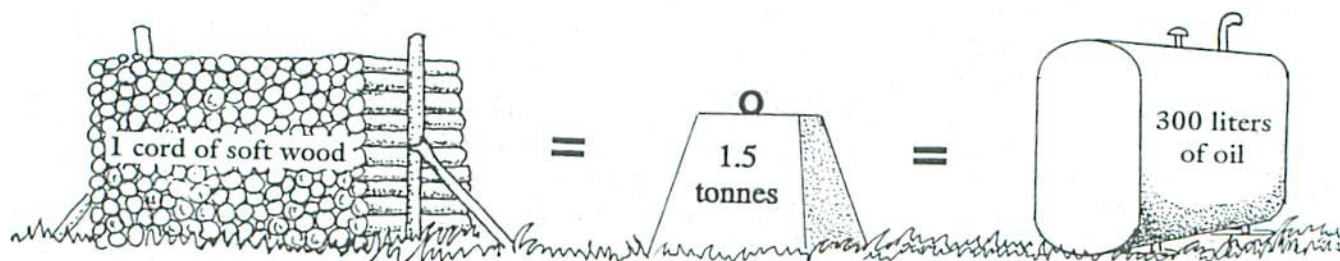


Figure 1. One cord of spruce will produce about 1.5 tonnes of woodchips. One tonne of woodchips will displace about 200 liters of heating oil. Thus, one cord of spruce will displace about 300 liters of heating oil.

annual savings will pay for the capital costs of the biomass system in a few years. Thereafter, the biomass system will provide economical and secure heat for many years to come.

## BIOMASS ENERGY HEAT DISTRIBUTION OPTIONS IN REMOTE COMMUNITIES

### Community District Heating

At the large end of the scale, a community could have a single woodchip heating plant that provides heat to all or most of the homes and buildings. A community district heating system is usually operated like a power utility, with employees on call at all times. In community district heating systems the heat distribution pipes are usually buried just below (60 cm) the surface.

District heating can be a particularly good approach when a new community is being planned because the community can be designed so as to minimize the length of the underground hot water piping. Often, the piping can be laid in the same trenches as are the water and sewer pipes, and sometimes even the electric power lines. An example of this approach is the Cree community of Ouje-Bougamou in northern Quebec. Here, a community district heating system was installed when this new town was built in 1993.

### Minidistrict Heating

For existing communities, installing several minidistrict heating systems is usually a more practical approach. Small biomass heating plants can provide heat to clusters of public buildings that are relatively close to each other. A logical cluster might consist of a school and any other buildings heated with oil that are within 50 meters. Other suitable buildings could include the teachers' residences, band office, health clinic, daycare center, or equipment garage.

In minidistrict heating systems, long rolls of high-temperature fiberglass piping are commonly used to transport hot water to the buildings in the cluster. Piping is usually buried below the frost line. Heat distribution in the buildings is done with baseboard hot water radiators, under-floor or in-floor hot water piping, or hot air ducting.

Minidistrict heating systems can often be expanded. Additional buildings within a reasonable distance can be connected to the system until its capacity is fully utilized. If additional space is allocated in the heating plant building, a second burner can be added at a later date to increase capacity.

The minidistrict heating approach can also be used to heat a cluster of private homes. While existing homes can be modified and connected to a central heating plant, the minidistrict heating approach is best suited to groups of new homes that are designed to incorporate suitable hot-water heating and domestic hot-water systems.

It should be noted that the displacement of existing roundwood heating with woodchips does not usually save money unless the woodchips are produced more efficiently. The best opportunity will be for displacing oil-fired systems. However, a central woodchip system for a cluster of private homes can offer many other benefits. These include:

- higher combustion efficiency and lower emissions (less smoke);
- a higher level of comfort because heat is automatically controlled around-the-clock;
- the ability to incorporate a domestic hot water system with the hot water space heating system;
- increased safety—there is no danger of accidental fire in the home because the heating plant is located in a separate, remote building; woodchip systems also do not produce creosote, which causes chimney fires, because they operate at higher temperatures and levels of efficiency;
- efficient fuel production—with limited equipment, a small group of people should be able to harvest and chip in about 10 working days a year's supply of fuel for a block of homes;
- enhanced operating convenience—one person can fill the fuel hopper and de-ash the burner for a block of homes in only 15–20 minutes per day; these tasks could be rotated between different families; and
- convenience—woodchip systems can be used to heat the homes of elderly residents who may find it increasingly difficult to heat with roundwood. Communities could use biomass systems to heat the homes of elders in a convenient and cost-effective way.

If these collective benefits are important to the community, then consideration can be given to heating private homes with a small, central biomass system.

## (AUTOMATED) BIOMASS COMBUSTION PLANT OPTIONS

Automated biomass energy heating plants that may be deployed in remote communities can be categorized as *small-commercial*, *small-industrial*, and *intermediate-scale* systems. They vary in terms of size (capacity) and automation features. The appropriate choice usually depends on the size of the heat load, the money available to invest in a biomass plant, and the economic viability of the specific option.

### Small-commercial Systems

These are relatively simple, low-cost biomass plants. A tractor or skid-steer loader is commonly used to fill a 4- to 6-m<sup>3</sup> hopper. A screw auger feeds fuel from the hopper to the burner, which is a firebrick-lined chamber with a small bar grate.

The burner is connected to a hot water boiler that extracts heat from the flames. The boiler is in turn connected to the heat distribution system—a network of underground piping that transports hot water to the various buildings and brings the cooled water back to the boiler for reheating.

A relatively simple electronic control panel regulates the output of the burner. If the boiler temperature drops below a set level, the aquastat in the boiler will call for more heat and activate the burner *high-fire mode*. The combustion air fan starts and the auger delivers fuel, more or less continuously, to produce a constant jet of flame until the boiler temperature rises to a preset upper limit. The aquastat then signals the burner to go into a *hold-fire mode*. The combustion air fan stops and the auger delivers only enough fuel to maintain a fire in the burner. Larger burner types also have similar control modes, but the control panels are much more sophisticated.

The fuel hopper on small-commercial burners is usually filled twice a day—in the morning and again in the afternoon or evening. With a loader, it takes about 20 minutes to load enough fuel for 1 day. In high-use systems, hoppers are sometimes filled three times per day. The ash must also be raked off the grate once a day.

Small-commercial biomass burners can burn woodchips or sawdust. Both are reliable and relatively inexpensive when compared to more sophisticated small-industrial systems of similar capacity. Where the heat demand is high, two small-commercial burners are often used in a twin system; only one burner is used during the spring and fall when the heat load is smaller.

Small-commercial burners built in Canada are available in sizes from 75 kW to 200 kW (680 000 BTU/hour). The installed cost of small-commercial biomass systems ranges from \$60,000 to \$130,000, depending on the number of burners and the cost of the building and heat distribution system. They are used to provide heat for a wide range of purposes: including, small factories and workshops, minidistrict heating systems on farms, greenhouses, fish hatcheries, and small stores. Figure 2 illustrates the components of a setup of a typical small-commercial biomass system.

### Intermediate-scale Biomass Systems

Intermediate-scale biomass systems have characteristics of both small-commercial and small-industrial biomass systems (described later). They are usually higher in capacity than small-commercial burners, and employ larger fuel bins and more elaborate fuel feeding mechanisms, such as pendulum screws. On the other hand, they have simple, low cost control panels; some have fixed burner grates that require manual de-ashing. Others have rudimentary moving stepgrates, with semiautomatic de-ashing systems. Usually they do not have dust collectors or induced draft fans.

Intermediate-scale biomass systems of 200- to 400-kW capacity typically cost \$150,000 to \$250,000. They are common in countries such as Sweden and Denmark, where they are used to provide heat to small sawmill kilns and other institutions.

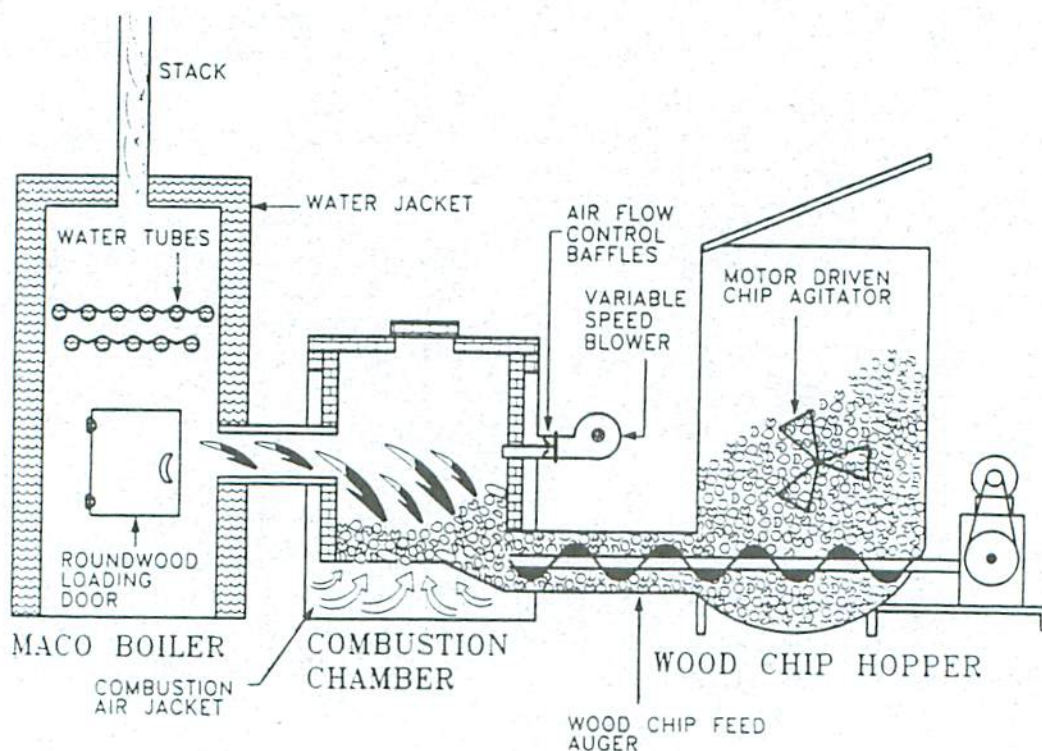


Figure 2. Small-commercial biomass system.

### Small-industrial Biomass Systems

These systems are fully automated and more sophisticated. They have much larger fuel bins, computerized control systems, burners with automated de-ashing augers, and smoke venting systems that are normally equipped with dust collectors and induced draft fans. Figure 3 illustrates a larger, industrial-class biomass system. Small-industrial biomass systems are typically used to heat large schools or businesses and small community district heating systems such as the one in Ouje-Bougamou.

Small-industrial biomass systems are normally constructed in sizes of 1 MW or greater for large heat loads. Where large volumes of oil can be displaced, small-industrial biomass systems can be quite economic. Small-industrial biomass systems can be constructed in the smaller sizes (e.g., 300- to 500-kW) but they are expensive relative to their capacity, costing \$350,000 to \$500,000. Thus, the pay-back on them may be longer.

### BIOMASS SYSTEM OPERATORS

Biomass systems represent a significant investment, and are not as fully automatic as oil-fired heating systems. They require people who are committed to operate the system throughout the entire heating season. Woodchips must be

produced and loaded into feed hoppers, ash must be removed daily from the burner, and system functions must be closely monitored. Failure to dedicate reliable people to biomass system operation can result in a shutdown and a need to switch to more expensive, oil-fired back-up systems.

### WOODCHIP FUEL SUPPLY OPTIONS

The goal of any forest operation should be to maximize the utilization of harvested trees and to ensure that the harvest operation provides for the establishment of a new crop of productive trees. With regard to utilization, harvested trees should be sorted so that a range of products reflecting the quality of the trees can be produced (i.e., sawlogs from the bole, firewood or woodchips from small diameter and dead or diseased trees).

If a remote community has a logging operation, it could be reasonable to integrate it with woodchip fuel production. The small-diameter stems and tops from softwood sawlogs can be chipped. Poplar (*Populus*, spp.), white birch (*Betula papyrifera* Marsh.), and dead or diseased trees can be processed to fuelwood or chipped, depending on the market demand.

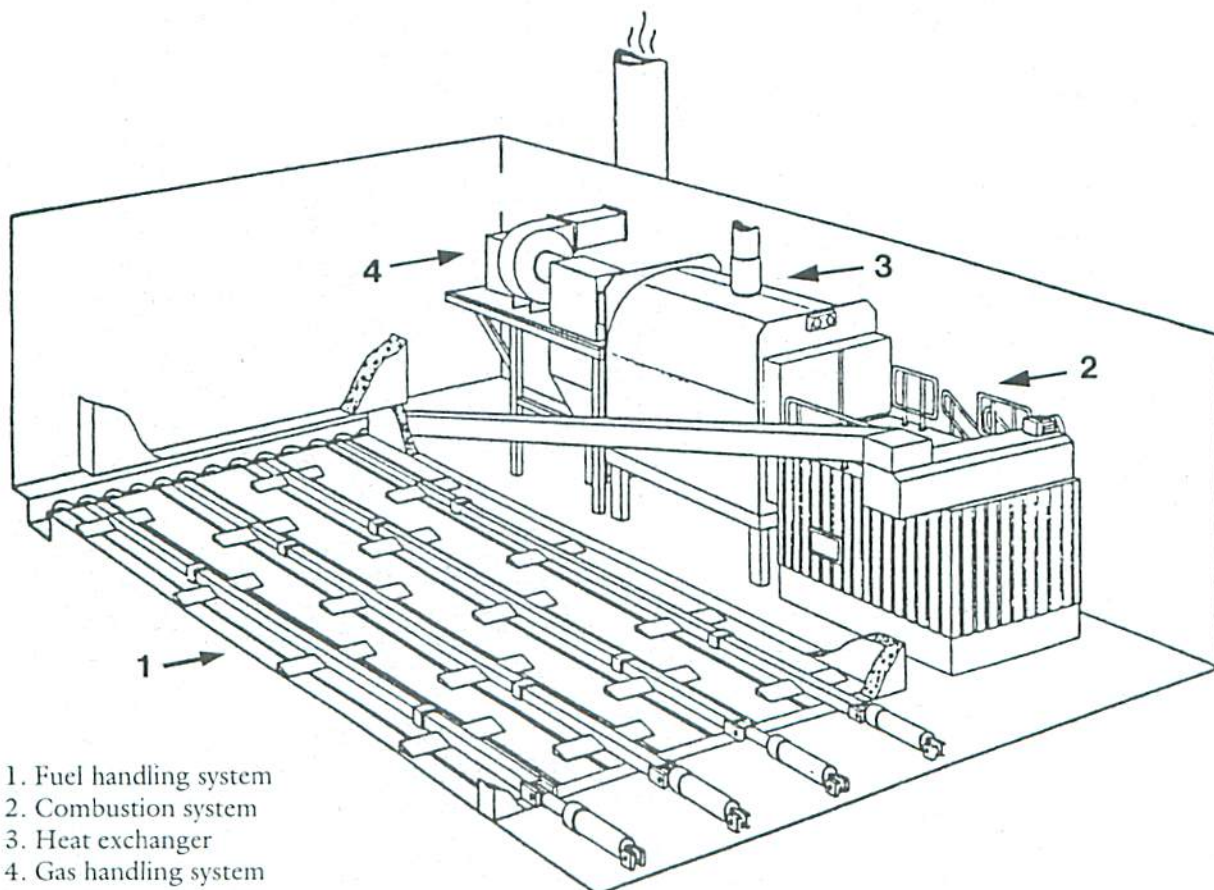


Figure 3. A small-industrial biomass system consists of four separate components, categorized by function.

The size of wood that can be chipped is limited by the size of the chipper selected. Large-diameter trees require a large chipper with a powerful engine. Because of the high cost of large chippers, most small scale chipping operations employ small-scale chippers that can chip trees up to about 23 cm in diameter. These are often powered by farm tractors. However, larger, used industrial chippers are often available at a reasonable cost.

Chipping can take place at a logging landing site. However, in remote communities where winter roads may be used for transport, the most logical approach is probably to stockpile chipping material near the heating plant and chip it as it is required.

If there is no logging operation in the community, a *stand-alone operation* to supply wood and produce chips will have to be established. A common option in eastern Canada is to employ a farm tractor and a tractor-powered winch and trailer equipped with a grapple loader to extract wood and transport it to the heating plant for chipping. In this case, the chipper would also be powered by the tractor. If the tractor has a front-end loader, it can be used to fill the fuel bin of the biomass system. Moreover, a tractor can perform other functions in a community, such as clearing snow and powering a backhoe attachment for digging trenches.

Whoever produces the chips must ensure a steady supply to the heating plant. Chips must be of good quality, and free of dirt and oversized sticks (sticks are produced when chipping knives get too dull). Sticks can cause jamming and shutdowns of the fuel-feed system; dirt will cause excessive wear.

## CONCLUSIONS

Replacing existing systems or meeting new demands for heat energy with biomass as a fuel in remote communities can contribute to the development of a more sustainable way of life and increased community self-reliance. Energy is critical to a community's survival, and decreasing the amount of external influence over energy can help communities to stabilize and plan for their future.

Benefits of biomass systems can include:

- direct savings compared to high-cost oil heat;
- increased circulation of energy dollars inside the community (for imported oil, 90 percent of the cost leaves the community; with locally produced wood chips, approximately 75 percent of the revenue remains to be spent on other commodities);
- long-term employment opportunities in harvesting, processing, and operating biomass systems; heat is usually needed and annual fluctuations are usually minimal; and
- enhanced opportunities to develop other wood processing operations (i.e., sawmills) to utilize the higher quality portions of the harvested trees.

Automated biomass systems are best suited to communities that have:

- a need for jobs and a commitment to create them;
- relatively high energy costs;
- an ample supply of forest biomass;
- an existing or planned commercial forest operation;
- a firm goal, not only to reduce energy costs, but also to improve the sustainability of energy systems and to reduce environmental impacts; and
- the ability to arrange financing for the capital costs of biomass systems.

The questionnaire (*see* Appendix A) included in this note can help planners, economic development officers, and Aboriginal organizations evaluate the potential for biomass systems in their communities.

## REFERENCES

Ouje-Bougoumou Community. 1993. On the road to self-reliance: The impact of alternative energy technology on community development. An Ouje-Bougoumou Community report. Ouje-Bougoumou, QC. 24 p.

## GLOSSARY OF TERMS

**Biomass energy:** Energy derived from plant or animal materials, including wood.

**Biomass combustion system:** System designed to burn biomass fuels, such as woodchips and sawdust.

**Backup system:** Existing oil-fired systems in buildings.

**Heat distribution system:** Insulated pipes buried beneath the ground to connect various buildings and baseboard hot water radiators within buildings.

**Simple payback:** The time it takes for the savings from a biomass system to pay off the extra investment costs and then start to generate ongoing savings as compared to oil heating systems.

**Cord:** A North American volumetric unit of wood measurement. A cord represents a pile of neatly stacked wood that measures 4 feet high x 4 feet wide x 8 feet long. One cord of softwood weighs 1.5 tonnes; one cord of hardwood weighs 2 tonnes.

**Disc chipper:** The most common type of chipper available. A disc chipper has knives that are mounted on a large, rotating disc that usually sits on a vertical axis. Trees are fed into the disc at an approximate 45° angle.

**Oil displacement:** One tonne of freshly cut, chipped wood (burned in an efficient combustor) will displace about 200 liters of heating oil.

## APPENDIX A

### Biomass Energy and Your Community Preliminary Questionnaire for Remote Communities

Community: \_\_\_\_\_ Compiled by: \_\_\_\_\_

#### *Current Energy Supply*

- |   | Yes                      | No                       |
|---|--------------------------|--------------------------|
| 1. What is the primary heating method for your public buildings (i.e., band office, health station, school, hotel)? |                          |                          |
| Oil   | <input type="checkbox"/> | <input type="checkbox"/> |
| Electricity   | <input type="checkbox"/> | <input type="checkbox"/> |
| Both  | <input type="checkbox"/> | <input type="checkbox"/> |
| Other (please specify) _____  | <input type="checkbox"/> | <input type="checkbox"/> |
| 2. What is the cost of energy to public buildings?  |                          |                          |
| Oil—greater than \$0.40/liter   | <input type="checkbox"/> | <input type="checkbox"/> |
| Electricity—greater than \$0.20/kWh   | <input type="checkbox"/> | <input type="checkbox"/> |
| 3. Does heating oil ever have to be flown into your community?  | <input type="checkbox"/> | <input type="checkbox"/> |

#### *Potential Supply of Forest Biomass*

- |   |                          |                          |
|---|--------------------------|--------------------------|
| 4. Is your community surrounded by forest and would it be available for harvesting in a sustainable fashion?  | <input type="checkbox"/> | <input type="checkbox"/> |
| 5. Is there a supply of sawmill or logging residues near your community?  | <input type="checkbox"/> | <input type="checkbox"/> |
| 6. Is there an existing or planned logging and/or sawmill operating in your community?  | <input type="checkbox"/> | <input type="checkbox"/> |
| 7. Are there people in your community who would be willing and able to be employed in a biomass harvesting operation and in the operation of a heating plant? | <input type="checkbox"/> | <input type="checkbox"/> |

#### *Energy Demand*

- |   |                          |                          |
|---|--------------------------|--------------------------|
| 8. Are there plans to build any new public buildings and/or replace existing heating systems in your community?   | <input type="checkbox"/> | <input type="checkbox"/> |
| 9. Have you ever experienced energy shortages in your community?  | <input type="checkbox"/> | <input type="checkbox"/> |
| 10. Do community members have any health, spiritual, cultural or environmental concerns with the current heating system (i.e., pollution, fuel spills, etc.)? | <input type="checkbox"/> | <input type="checkbox"/> |

If you have answered "yes" to seven of the above questions, you may wish to further investigate biomass opportunities.

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