Woodchip Supply Options for Remote Communities

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ABSTRACT

This report on woodchip supply systems is designed to assist Aboriginal communities, particularly in remote areas, to examine the question of whether fuelling small heating systems with wood biomass (i.e. woodchips) is a viable option. To be used in conjunction with forest management planning and biomass technology information, this report provides the basis for communities to begin to design and explore woodchip supply operations which suit their individual needs, taking into account the unique circumstances and characteristics of remote Aboriginal communities. The report defines biomass energy and describes some of the benefits of biomass energy heating systems, as well as some of the challenges of supplying woodchips in remote communities. Two woodchip supply system options are examined: 1) using conventional forest machines such as skidders, dump-trucks and wood chippers; and 2) using conventional forestry-adapted agricultural machines, such as 4-wheel drive tractors, with tractor-powered forestry attachments. Information on the two options is presented with respect to planning and selecting a woodchip supply system, including advantages, limitations, and estimated costs. Chipping of wood and the operation of wood chippers are described. A suggested reading list for further information is provided. This is one of two reports with respect to Aboriginal community biomass heating systems completed with financial assistance from the federal government's ENergy from the FORest (ENFOR) program.

RÉSUMÉ

Ce rapport sur les systèmes d'approvisionnement en copeaux de bois vise à aider les collectivités autochtones, particulièrement dans les régions éloignées, à examiner si l'approvisionnement de petits systèmes de chauffage au moyen de biomasse ligneuse (c.-à-d. copeaux de bois) constitue une option viable. Destiné à être utilisé conjointement avec l'information relative à la planification de l'aménagement forestier et à la technologie relative à la biomasse, le présent rapport offre aux collectivités autochtones éloignées des éléments pour commencer à concevoir et essayer des opérations d'approvisionnement en copeaux qui répondent à leurs besoins, compte tenu de la situation et des particularités de ces collectivités. Le rapport définit ce qu'est la bioénergie, montre certains avantages des systèmes de chauffage alimentés de cette façon et expose les défis que pose l'approvisionnement en copeaux dans ces collectivités lointaines. On étudie deux sortes de systèmes : 1) le recours à la machinerie forestière conventionnelle comme des débusqueuses, des camions à benne et des découpeuses à bois; et 2) l'utilisation de machines agricoles conventionnelles adaptées à la foresterie, comme des tracteurs à quatre roues motrices avec des accessoires forestiers actionnés par le tracteur. On offre de l'information sur les deux options, en ce qui a trait à la planification et au choix d'un des deux systèmes en fonction des avantages, des limitations et des coûts estimatifs de chacun. On décrit la réduction du bois en copeaux et le fonctionnement des découpeuses à bois. On suggère une liste de lectures en vue d'un complément d'information. Ce rapport est l'un des deux documents sur les systèmes de chauffage à la biomasse destinés aux collectivités autochtones qui ont été préparés grâce à l'aide financière du programme fédéral de l'énergie forestière (ENFOR).

PREFACE

ENFOR was established in 1978 as part of a federal interdepartmental initiative to develop renewable energy sources. It is a contract research and development (R&D) program aimed at generating sufficient knowledge and technology to realize a marked increase in the contribution of forest biomass to Canada's energy supply.

Administered by the Canadian Forest Service, the ENFOR program deals with biomass supply matters such as inventory, growth, harvesting, processing, transportation, environmental impacts, and socioeconomic impacts and constraints. The program normally provides total funding for contracted studies, the results of which become the property of the federal government and are freely available to the public.

A technical committee oversees the program and develops priorities, assesses proposals, and makes recommendations. Approved projects are contracted out to the private sector. Although most project ideas are generated by Canadian Forest Service personnel, proposals from external sources are encouraged and considered. These proposals should be submitted through the appropriate regional offices or the Canadian Forest Service headquarters. Proposals are assessed in the fall of each year. The program operates on the basis of the fiscal year, from April 1 to March 31. Approximately $1 million is spent annually on ENFOR projects. The program normally provides total funding for contracted studies, while the results become the property of the federal government and are freely available to the public.

The program is coordinated by the Canadian Forest Service headquarters, but most projects are managed by one of five Canadian Forest Service centers. Scientists at these establishments initiate project proposals in response to regional and national priorities; they implement and manage approved projects; they carry out in-house R&D; and they prepare information reports. A scientific authority is assigned to each project to follow its progress and serve as the principal contact between the contractors and ENFOR program managers. The involvement of regional personnel provides the local perspective necessary to ensure the success of this national program.

Study results are either distributed as contractors' reports, or published in the Canadian Forest Service Information Report series or in technical journals. Comprehensive and detailed reports on the work are available and may be obtained on request from the addresses indicated with the individual abstracts in this publication.

For further information, write or telephone your nearest Canadian Forest research centre or the ENFOR Secretariat at the Canadian Forest Service headquarters. To have your name added to the national mailing list, write to the ENFOR Secretariat.

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Note: During the first 6 years of the ENFOR program, numerous projects were undertaken in the biomass conversion area. Efficiency and Alternative Energy Technology Branch, Natural Resources Canada, is now responsible for this topic. Information can be obtained from the Bioenergy Group, 580 Booth Street, Ottawa, Canada K1A 0E4, (613) 996-6226. For ENFOR projects initiated before 1990, please see previous volumes of the ENFOR Review.

The ENFOR program is funded by the federal Panel on Energy R&D (PERD).

PRÉFACE

ENFOR a été créé en 1978 dans le cadre d'une initiative interministérielle fédérale visant à développer les sources d'énergie renouvelable. C'est un programme contractuel de recherche développement (R-D) visant à générer un volume suffisant de connaissances et de technologies pour entraîner une augmentation marquée de la contribution de la biomasse forestière à l'approvisionnement énergétique du Canada.

Administré par le Service canadien des forêts, le programme ENFOR traite des questions d'approvisionnement en biomasse comme l'inventaire, la croissance, la récolte, le traitement, le transport, les incidences sur l'environnement de même que les répercussions et les contraintes socio-économiques.

C'est un comité technique qui surveille le déroulement du programme et établit l'ordre des priorités, évalue les propositions et formule des recommandations. Les projets approuvés sont sous-traités au secteur privé. Même si la plupart des idées de projet proviennent du personnel du Service canadien des forêts, les propositions de l'extérieur sont vivement encouragées et prises en considération. Ces propositions doivent être soumises aux bureaux régionaux compétents ou à l'administration centrale du Service canadien des forêts. Les propositions sont évaluées chaque année à l'automne. Le programme fonctionne sur la même base que l'exercice financier, soit du 1er avril au 31 mars. On consacre environ 1 million de dollars chaque année aux projets ENFOR. Le programme assure normalement le financement total des études sous-traitées, dont les résultats deviennent la propriété du gouvernement fédéral et sont mis à la disposition gratuite du public.

Le programme est coordonné par l'administration centrale du Service canadien des forêts, mais la plupart des projets sont administrés par l'un des cinq centres de foresterie du Service canadien des forêts. Les chercheurs qui travaillent dans ces établissements émettent des propositions de projet en fonction des priorités régionales et nationales; ils mettent en oeuvre et gèrent les projets approuvés; ils font certaines activités de R-D à l'interne; enfin ils préparent les rapports d'information. Un responsable scientifique est affecté à chaque projet pour suivre son avancement et servir de personne-ressource principale entre les entrepreneurs et les gestionnaires du programme ENFOR. La participation du personnel régional procure l'optique locale indispensable au succès de ce programme national.

Les résultats des études sont diffusés sous forme de rapports d'entrepreneurs ou publiés dans la série des rapports d'information du Service canadien des forêts ou dans des revues techniques. Des comptes rendus complets et détaillés des travaux sont disponibles et il suffit d'écrire à l'adresse qui accompagne chacun des résumés de cette publication pour se les procurer.

Pour d'autres précisions, veuillez écrire ou téléphoner au centre de foresterie du Service canadien des forêts le plus proche de chez-vous ou au Secrétariat ENFOR à l'administration centrale du Service canadien des forêts. Pour faire inscrire votre nom sur la liste nationale d'envoi, veuillez écrire au secrétariat ENFOR.

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Note : Au cours des six premières années d'existence du programme ENFOR, de nombreux projets ont été entrepris dans le domaine de la conversion de la biomasse. C'est aujourd'hui la Direction de la technologie de l'énergie de Ressources naturelles Canada qui est responsable de ce domaine. Pour tout renseignement, s'adresser au Groupe des technologies des énergies renouvelables, 580, rue Booth, Ottawa, Canada K1A 0E4, (613) 996-6226. Pour les projets ENFOR entrepris avant 1990, consulter les volumes antérieurs du Bulletin ENFOR.

Le programme ENFOR est financé par le Groupe interministériel de recherche et d'exploitation énergétiques (GRDE).

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INTRODUCTION

Natural Resources Canada (NRCan) is working to help remote Aboriginal communities explore options for affordable and reliable heating systems. In particular, since 1995, NRCan—Canadian Forest Service (CFS) Sault Ste. Marie, and CFS Edmonton, have been examining the option of using forest biomass, in the form of woodchips, as an option for energy (i.e., heating-fuel) in remote Aboriginal communities. Some 150 remote communities in Canada are north of the natural gas pipelines, are not connected to the electricity grids and do not have year-round road networks. These communities however, have access to significant forest resources. Several studies have indicated that there is good potential for biomass heating installations and woodchip supply operations for some of these communities.

The Canadian Forest Service received funding from the ENergy from the FORest program (ENFOR) to undertake this project to examine forestry-related gaps in what is known about heating with bioenergy in remote Aboriginal communities. This involved examining management planning for small-scale operations and the harvesting, transportation and chipping of timber. Natural Resources Canada's Canadian Centre for Mineral and Energy Technology (CANMET)-Energy Diversification Research Laboratory (EDRL) in Varennes, Quebec, also contributed funding and support to this project.

This Information Report is designed to complement Information Report GLC-X-2, entitled "A forestry management planning strategy for remote communities" (Puttock et al. 1998). Together, these reports describe practical and comprehensive approaches to prepare a community for developing a forest management plan and selecting a woodchip supply option suitable to their needs and circumstances.

This study was conducted to examine timber harvesting, transportation and processing in remote community circumstances. Two woodchip supply options were developed based on data that was gathered from remote community site visits across northern Canada. In addition, many short and long-term benefits from using woodchips to fuel biomass heating facilities are described, such as employment generation and cleaner air for healthier living. Suggestions are also made about overcoming some of the challenges that may exist with regards to supplying woodchips to a biomass facility for heating public buildings. Comparative tables of the primary cost estimates for the two supply options are in the Appendices. A glossary of terms used in this report and other related terms is included. Retrofitting to displace fuel-oil and wood-stove heating (roundwood) in private dwellings is not discussed in this report.

Note: For the purpose of this report, the conversion from cords of timber to tonnes of woodchips is based on softwoods (conifers) only. However, hardwood (deciduous) conversion values are provided for information use. These values are **estimates** and based on 1 stacked cord of softwood producing **approximately** 1.6 tonnes of woodchips. Weights will vary depending on the tree species and the moisture content of the wood. The following conversions are provided as a guide:

Hardwoods: 1 stacked cord of hardwood weighs approximately 2 tonnes (i.e., green woodchips) thus, 1 tonne of hardwood chips are produced from approximately 0.5 of a stacked cord of roundwood. Furthermore, weight can increase to approximately 2.8 tonnes depending on the species of hardwood

Softwoods: 1 stacked cord of softwood weighs approximately 1.6 tonnes (i.e., green woodchips) thus, 1 tonne of softwood woodchips are produced from approximately 0.6 of a cord.

Power conversions for equipment:
1kW is approximately 1.316 hp
(Adapted from McCallum 1997b).

WHAT IS BIOMASS ENERGY?

Biomass energy refers to all forms of energy that are derived from plant or animal materials. Wood is generally the most abundant form of biomass energy available in Canada's remote communities. This report deals with woodchips and sawmill waste, both of which can be burned in biomass heating systems.

BENEFITS OF ADOPTING BIOMASS ENERGY HEATING SYSTEMS

Some of the benefits include:

1. Creation of sustainable employment in the community;
2. Lower cost heating, if all required optimum forestry and operational conditions exist;
3. Money remains in the community;

   Once the capital costs of the equipment needed for the supply system have been paid, all direct annual savings belong to the owner of the biomass heating system. Unlike fuel-oil production, wood fuel production occurs in the community, so that most, if not all, of the money spent on wood fuel remains in the community to create spin-off financial and social effects; and,
4. Reduced environmental impacts.

   Biomass systems burn very cleanly, generate very little smoke, and are considered to be carbon dioxide

(CO_2) neutral. Not including the oil used to harvest the wood, and to fuel a backup system, the combustion of woodchips releases only the CO_2 that was absorbed during the life of the trees. Practices that promote the maintenance of natural levels of CO_2 and/or decrease these levels are regarded as beneficial by many experts concerned with the earth's greenhouse effect. Tree growth through harvesting practices that promote natural regeneration, and through tree planting, will reabsorb the CO_2 that was released through burning. (L. Ciavaglia, personal communications, Nov. 1998, and McCallum 1997a)

STUDY APPROACH

Five remote communities were selected based on past research and expressions of community interest in biomass heating. Information was gathered in remote communities in northern Ontario, northern Saskatchewan and the western Arctic. Existing oil-fired heating systems in public buildings were examined to determine the level of difficulty that may be encountered if conversion to woodchip-fired boilers were to occur. As well, information was collected from each community concerning the current timber supply, geographic conditions, and available machinery that could potentially be used in a woodchip supply operation.

The study communities generally had the following conditions in common:

- clusters of public buildings, many heated with oil-fired hot air or hot water furnaces;
- many residential homes using roundwood for space heating;
- high costs for heating oil ($0.60-$1.20 per litre or more);
- located within forested areas containing many lakes and rivers; and,
- high rates of unemployment.

CHALLENGES OF SUPPLYING WOODCHIPS IN REMOTE COMMUNITIES

Despite high costs for fuel-oil ($0.60-$1.20 or more per litre) and proximity to forest resources, establishing economically viable and reliable woodchip supply operations poses many challenges in remote communities.

Some of the current challenges are:

- many communities do not have existing commercial forest industries;
- access to off-reserve harvesting opportunities is often limited;
- community residents often have very little experience operating forest-harvesting machines and lack training in careful logging techniques; and,
- communities have difficulty obtaining funds to purchase equipment necessary for harvesting and woodchip production.

WHAT IS A WOODCHIP SUPPLY SYSTEM?

For the purpose of this report, a **Supply System** Option is referred to as a **System** made up of several equipment components that work together to harvest, extract, transport (i.e., **Supply**) and process trees (i.e., from stump to biomass burner) into useful products. Woodchips for burning in a heating facility are one of the many end-products.

This report presents two **Woodchip Supply System Options**. (Table 1)

Option I:

Makes use of Conventional Forest Machines, i.e., log skidder or forwarder, log truck or dump truck and wood chipper; and

Option II:

Makes use of a Forestry-Guarded Tractor and Forestry Implements, i.e., 4 wheel-drive (4WD) farm tractor with tractor-powered (TP) forestry attachments (e.g., winch, grapple loader trailer, bulk-dump trailer and wood chipper).

HOW TO GET STARTED?

1. Ensure community interest in and acceptance for converting existing heating systems from fossil fuels to woodchip-fuel. As well, determine if there are clusters of public buildings (conversion sites) that could be converted to biomass heating. A community may wish to further explore wood biomass heating systems if they are interested in introducing an integrated approach to forest harvesting that may involve purchasing or borrowing a portable sawmill for small construction projects. Furthermore, the residue from the harvesting operation and sawmill may be chipped for fuel in the biomass heating facility.
2. Conduct a pre-feasibility study to identify and examine the factors that will affect the successful implementation of the project, by testing the conversion sites identified in #1. (above). These factors should be carefully matched to the Woodchip Supply System to ensure successful development and implementation of the project. Some of these factors include estimating the

Table 1 Supply system option guidelines

Supply System Option #I: Based on conventional forest machines (i.e., log skidder or forwarder, log or dump truck and wood chipper).	**Supply System Option # II :** Based on a forestry-guarded tractor and forestry implements (i.e., 4WD farm tractor and winch, grapple loader trailer, bulk-dump trailer and wood chipper).
May be most suitable for communities that have: • a large population (approximately 1,500) and/or a rapidly growing population coupled with substantial bioenergy needs; • community-owned forest machines or easy access to forest machines; and, • a realistic opportunity to establish a commercial forestry operation, including a market for the product (i.e., available forest to sustainably fuel a biomass heating facility). **Note:** This scenario, while not restricted to a large community, may be most suitable to communities with a population of approximately 1,500.	May be most suitable for communities that have: • a small population (approximately 500); • no access to or ownership of commercial forestry machines; • a desire to operate on a small scale basis; and, • a 4WD farm tractor for municipal-type tasks such as backhoe work, snow removal, road maintenance and fire protection. **Note:** This scenario, while not restricted to a small community, may be most suitable to communities with a population of approximately 500.

available fuel supply and the volume of woodchips that will be required for the community and investigating options for harvesting and processing the trees and transporting the woodchips.

3. Consider how a biomass-heating system fits in with other community plans. For example, if some lumber production is anticipated, logging and milling residues can be a good source of wood biomass to fuel the heating system. This is true if a sustainable fuel source is readily available and feasible for use by the community. Moreover, if additional harvesting will be required to meet the community's demand, ensure that a plan to manage the forest on a sustainable basis will be in place. Puttock et al. (1998), provides some information to consider when developing a management plan for a small-scale forestry operation. For the most part, community members with technical forestry experience can implement the framework. Certain components however, may require short-term assistance from professional forestry experts.
4. Once an appropriate Woodchip Supply System Option has been selected and a draft harvesting plan is in place, the viability of this System and other components with regards to heating with biomass can be determined. This is a key process to follow and it may be advantageous to retain the services of professional foresters, technicians, engineers and other professionals to assist with these determinations. It is important that all work be done in accordance with the wishes of the community regarding the use of forest land, and the goals identified in the community's business and/or management plan.

SELECTING A WOODCHIP SUPPLY SYSTEM

A number of factors have been identified for the selection of the two Woodchip Supply System Options. Communities should evaluate these factors and modify them according to their specific needs and circumstances.

Existing Forestry Equipment

Communities that are active in conventional forestry harvesting operations will have equipment such as a skidder or forwarder and log or dump truck and may only need to add a chipper to have all of the components for Woodchip Supply System Option I, shown in Appendix A.

Current Forest Management Plan Goals

Wood Supply

As outlined in Puttock et al. (1998), there are a number of forest factors that influence the need to develop prescriptions[1] to sustainably manage the forests:

[1] Prescriptions are usually a part of a Forest Management Plan, which is developed by a Forester or an individual with similar credentials. Prescriptions provide guidance to the forest manager on what should be done to the forest with respect to forest operations.

Communities with access to predominantly small trees, i.e., 10-23 cm (4"-9") diameter at the butt end: A small Tractor- Powered (TP) chipper with a 56-83 kW (75-110 hp) tractor is appropriate to use. Trees are usually manually fed into this size of chipper. If a substantial volume of woodchips is required or anticipated, moving up to the next size of chipper, a small Commercial-Scale TP model, may be a logical choice. (Figure 1)

Communities with access to predominantly larger trees, i.e., 20-30 cm (8"-12") diameter at the butt end: Heavy extraction equipment (i.e., skidders and forwarders) and larger TP chippers, such as the small Commercial-Scale chipper are appropriate. These chippers are usually powered by a 75-112 kW (100-150 hp) tractor and mechanically fed using a grapple loader or similar equipment (Appendices A and B).

Land Drainage and Location of Water Bodies

Any woodchip supply system can cause damage to the harvesting site and soil if pre-harvest planning and monitoring are not done. Refer to Appendices A - D for a comparison of Options I and II and their performance in the following site conditions:

Well-drained land with good road access: Timber can be harvested over the summer when operating conditions are generally favourable. Care must be taken in the spring to monitor sites during runoff and heavy rain periods. Monitoring the harvest areas will ensure that the skidding equipment does not leave deep ruts on the site or trail system.

Wet terrain surrounded by or adjacent to water bodies: A significant portion of the annual chipping wood should be harvested during the winter and transported to a community wood yard to supply the heating plant for the following fall and winter period. Winter harvesting is preferred because the frozen ground will not only keep the logs clean from soil, but it also protects the terrain from deep ruts caused by heavy extraction equipment.

Stand Assessment

All forest operation equipment has a maximum operating capacity. Where possible, to capitalize on the best circumstances for the selected Supply System Option, an evaluation should be made against the optimum financial, on-site environmental and operating conditions to achieve a workable balance. Forestry prescriptions should be developed, based on factors such as stand age, height, species composition, desired land-use options or products and, the need to decrease the risk of fire. Furthermore, the community's goals and aspirations and proposed best "end-use" of the timber should also be part of the process.

Equipment must be evaluated and selected to match the recommendation of the timber management prescription. For example, a prescription for one stand might recommend harvesting using the **patch cut method** to encourage natural regeneration. Wildlife travel corridors could also be left in patch cut areas to provide a passage from cutting sites to natural regeneration areas. A prescription for a second stand might promote harvesting using the **strip cut method** to encourage natural regeneration or protect a fragile site. These areas can also be used as wildlife corridors. Conventional forestry equipment (e.g., log skidders and grapple loaders) can be used for applying either prescription successfully. Forestry-guarded 4WD tractors and forestry implements can also be used for these

Figure 1. Option II: 4WD Tractor and chipping at the landing. (Illustration by K. McCallum)

harvesting methods, provided the terrain is not overly rough (i.e., does not have an abundance of slash, rocks, large hills, etc.).

A prescription for a third stand might recommend **thinning** to increase tree spacing. Equipment such as a farm tractor with a grapple loader trailer could be used. This equipment combination, used in a cut-and-pile operation, is well suited to narrow extraction trails. Moreover,with experienced and careful operators, this equipment combination usually causes less damage to the site and crop trees, than if skidders or forwarders are used. To chip thinnings of 10-23 cm (4"-9") diameter at the butt end of the tree, small chippers such as TP Farm Scale are suitable (Appendix D).

Terrain

In some communities, terrain may be one of the main determining factors for selecting the most appropriate Woodchip Supply System Option.

Forest machines (e.g., skidders, forwarders, etc.) were designed to handle rugged forest sites (i.e., large hills, high slash piles, rock outcrops, etc.) (Appendix B). While farm tractors are more suitable for uniform, level site conditions, some four-wheel drive (4WD) farm tractors have been designed to operate in more difficult forest areas (Appendix D).

Remote Community Development and Woodchip Demand Considerations

Knowing the operational limitations (e.g., skidding or hauling distances, terrain, etc.) of the machines being considered will be useful in selecting the most appropriate equipment for the Supply System.

Two possible scenarios might be as follows:

1. Where construction and the desire to use local timber are major considerations; the demand for sawlogs will be high with the following implications:

   Harvesting will likely occur in the best sawlog stands; and,

   Woodchips will be produced from the tops of merchantable trees and also from trees of poorer quality and lower value trees in these stands. Sites to extract sawlogs (merchantable trees) and trees of poor quality (i.e., small size, and undesirable species, diseased, rotten, etc.) will be identified in the community's sustainable forest management and harvest operation plan.

2. Where construction is not high on the priority list, the demand for fuel-wood should continue at a constant level. In some communities there may be a desire to harvest the closest timber based solely on convenience. As harvesting fuel-wood and timber for woodchips expands farther from the community, this choice will quickly become less convenient. Areas of forest that have been identified as a fire risk in the forest management plan (i.e., overmature, dense forests) and stands of trees that need to be thinned, should be high priority areas for biomass production harvesting.

Community Demand for Woodchips

Community demand will be one of the many deciding factors with respect to identifying the machines comprising the Woodchip Supply System. The chipper selected must have the capacity to produce the woodchip volume required for the community. At the same time, a chipper should not be under-used over the long-term, as this can create unnecessary financial constraints.

Note: The total area to be harvested is highly dependent on the following factors:

- tree species, i.e., softwoods or hardwoods[2];
- tree size;
- log and/or stand quality;
- stand density, i.e., number of trees per unit area; and,
- harvesting method, i.e., thinning, patch/strip cuts, clearcut, etc.

Two scenarios are presented to demonstrate the impact community population has on the demand for woodchips. Community demand is based upon the needs identified for specific clusters of structurally sound, usually reasonably new public buildings. This could also include small clusters of residential homes in newly developed areas of the community. Buildings would have to be evaluated to determine the feasibility of installing a wood biomass heating system to replace most of the current fuel-oil heating capacity.

1. Smaller Community (i.e., population of approximately 500 people):
   - has a demand of 600-800 tonnes/year of woodchips (375-500 cords of roundwood); this volume can be produced from a harvested area of 3-5 hectares (7-12 acres) of forested land,
2. Larger Community (i.e., population of approximately 1,500 people):
   - has a demand of 1,500-2,000 tonnes/year of woodchips (938-1,250 cords of roundwood); this volume can be produced from a harvested area of approximately 10 hectares (25 acres) of forested land.

[2] See the Note, in the last section of the Introduction.

As outlined in the community's Forest Management Plan, an integrated biomass harvesting operation should make the effort to design harvesting prescriptions based on the best end-use. Targeted sources of chipping material may include tops and large branches and other non-merchantable material, and timber of low quality that may show signs of disease, rot, poor form, etc. Small branches are usually left on the site.

WOOD SUPPLY SYSTEM : SELECTION CRITERIA

The following list is a guide to help in the selection of a suitable Woodchip Supply System.

A good system should:

- address all phases of the operation, including harvesting, extraction, transportation, and processing;
- closely align community goals and aspirations with the sustainable forest management and harvest operation plan for the community;
- allow efficient and ergonomic use of equipment;
- be economical to establish and operate (e.g., purchase or rental);
- be feasible as a community-based operation;
- allow integration with the production of firewood and saw-timber.

WHICH SUPPLY SYSTEM OPTION IS BEST FOR YOU?

Supply system options

The two Woodchip Supply System Options identified in this report were based on visits to five communities. These options could also be fitted with other equipment to accommodate other community conditions that were not a part of this report. Details on costs and functions of the equipment are presented in Appendices A-D.

The Tables and supporting information in the Appendices list some extraction machines that can be used in a biomass and an integrated small-scale forest harvest operation. For both Supply System Options (Appendices A and C) the machines are listed according to the order they would be used during the field operation.

The **Forwarder** was not placed in the same table as the Skidder, but the costs are indicated to show what the cost/tonne would be if a Forwarder was used instead of a Skidder. This information has been shown below the table for comparison purposes (Appendix A). The cost of another optional chipper brand/size has also been placed in the lower part of the table for comparison purposes. **No preference has been given for either the skidder or forwarder or either of the two chippers because any or all of these could be used.** Slight variations in the processes/equipment usage described may occur to determine the best process.

(Appendix E provides a summary of Options I and II).

USING EXISTING EQUIPMENT FOR BIOMASS PRODUCTION

Purchasing dedicated Woodchip Supply System equipment may not always be feasible; this section deals with equipment already available in a community. Using existing equipment or modifying one of the two Woodchip Supply Options described in this report may be feasible as a long-term solution, or perhaps as a temporary means to build capital for future equipment purchases. Costs for Production, Per Machine Hour (PMH), Repair and Maintenance, etc., for existing equipment in a woodchip operation were not illustrated in this report.

Some examples of the use of existing equipment include the following:

1. **Backhoes and Excavators:**

   Each of these machines can be equipped with a log-grapple (crane) to load wood onto trucks or to feed a chipper.

2. **Small Bulldozers:**

   Many remote communities have small bulldozers, which can be used for skidding with a winch and pulling extraction trailers (e.g., grapple loader trailers, tandem bogie-axle forestry trailers, etc.).

   A bulldozer with a winch pulling a grapple loader trailer is a useful part of a harvest supply system, provided the hauling distance doesn't exceed 656' (200 m). An appropriate chipper must then be added , to complete this woodchip supply system.

Bulldozer Production:

- Daily production, hauling 8'(2.4m) logs, is approximately 18 cords per 9 hour day. This is equivalent to 3.2 tonnes (2 cords) Per Machine Hour (PMH); and,
- Annual production can be up to 3,200 tonnes (2,000 cords).

Advantages of Bulldozers:

- Good traction and high load capacity;
- Versatility, i.e., it can be used for other community activities such as moving snow, road building, etc.;

- Adequate hydraulic capacity to power grapple loaders, winches, etc.

Limitations of Bulldozers:

- Bulldozers can cause significant environmental damage during road building and hauling if careful planning is not done, rigidly implemented and monitored;
- Not suitable for high-speed travel or hauling distances over 200 m (656');
- Fuel consumption and undercarriage maintenance costs are high when compared to rubber-tired forestry-guarded machines.

Bulldozer Attachments: Forestry Trailers (e.g., Tandem Bogie-Axle) and Small Commercial Grapple Loader

The cost is between $5-8,000 for the trailer and $12-20, 000 for the log-grapple (crane) depending on the size and the reach of the grapple loader.

A trailer equipped with a bogie-axle maneuvers over rough terrian with less sway and lateral movement on the trailer, causing less damage to crop trees.

The following factors are applicable to most Forestry Trailers:

- Haul capacity of 3-4 tonnes (1.9-2.5 cords);
- Productivity ranges from 2-5 tonnes (1.2-3 cords) PMH to a hauling distance of 200 meters in a thinning operation. Productivity can be up to 50% higher in a clearcut or patch cut operation.

The grapple loader and trailer work together and pick up wood piled along extraction trails and transport it to a roadside landing or a community wood yard. The grapple loader trailer keeps the wood off the ground and relatively soil-free, thereby extending the life expectancy of the chipper knives. A tractor can effectivley haul these trailers up to 10 km (6.2 miles). In contrast, a bulldozer should not haul material more than 2 km (1.24 miles).

ESTIMATING THE POTENTIAL COST OF THE SUPPLY SYSTEM OPTIONS

For comparison purposes, two cost-scenarios and the estimated annual savings comparison are provided for each option in Tables 2a and 2b. These cost estimates

Table 2a Costing scenarios in a clear or patch cut operation (see Appendix A for costs in a thinning operation)

OPTION #1 Conventional forestry machines	**Est. cost per tonne of woodchips**	**OPTION # II Forestry-adapted agricultural machines**	**Est. cost per tonne of woodchips**
Chainsaw Felling Crew: 2-person moderately skilled	$12.00	Chainsaw Felling Crew: 2-person moderately skilled	$12.00
Extraction: Skidder **Note:** the cost will increase if a Forwarder is used	$13.00	Extraction: 4WD Tractor with Winch and a Grapple Loader Trailer (maintenance and labour)	$17.00
Chipping: Intermediate Commercial-Scale Chipper **Note:** this cost includes maintenance and knife costs	$13.00	Chipping: Tractor-Powered (TP) Chipper (any TP chipper could be used)	$16.00
Transportation: Log Truck with a Grapple Loader	$7.00	Transportation: Bulk Trailer **Note:** one tractor can be used in Extraction, Chipping &Transport.	$5.00
Equipment Amortization	$5.00	Equipment Amortization	$5.00
TOTAL DIRECT COSTS	**$50.00/tonne**	**TOTAL DIRECT COSTS**	**$55.00/tonne**

Table 2b Estimated annual savings comparison

Option #I	Option # II
Option #I: The example provided in Table 2a relates to the following scenario showing the cost/tonne of various components involved with woodchip production. The target annual volume of chips is 1,500-2,000 tonnes; at \$50.00/tonne this is equivalent to paying approximately \$0.24/litre for heating oil[3] with a moisture content[4] (MC) of approximately 45%. **Annual Woodchip System Savings:** A Skidder or Forwarder-based woodchip supply system producing 1,500 tonnes of woodchips per year could displace about 317,000 litres of heating oil. At \$1.00/litre, the oil would be worth \$317,000. Estimating woodchip costs at \$50.00/tonne, and the community's requirements of 1,500 tonnes per year, the total cost would be \$75,000/yr. Thus the potential direct annual savings would be about \$242,000/yr (\$317,000-\$75,000=**\$242,000**). These direct annual savings have been factored into the amortization payments. **Note: This does not include the installation costs and capital costs of the biomass heating facility.** If the annual woodchip requirement was reduced to 600-800 tonnes (may be the requirements of a community with a population of approximately 500 people) the cost of woodchips would likely increase to \$50-\$60.00/tonne. This would increase because of a higher labour cost and lower equipment utilization. (Section: Factors Affecting Biomass Volume and Chipper Utilization, p.10). A cost of \$50-60.00/tonne is equivalent to heating oil at \$0.20-0.30/litre, if the Moisture Content of the woodchips is between 40-45%.	**Option # II:** The example provided in Table 2a relates to the following scenario showing the cost/tonne of various components involved with woodchip production. The target annual volume of chips is 1,500–2,000 tonnes; \$55.00/tonne is equivalent to paying approximately \$0.26/litre for heating oil with a moisture content (MC) of approximately 45%. **Annual Woodchip System Savings:** A tractor-based woodchip supply system producing 1,500 tonnes of woodchips per year could displace approximately 317,000 litres. At \$1.00/litre, the oil would be worth \$317,000. If the cost of woodchip production were \$55.00/tonne, the total cost of the woodchips would be \$82,500 (\$55.00 x 1,500). Thus the potential direct annual savings would be about \$234,500 per year (\$317,000 - \$82,500 = **\$234,500**). These direct annual savings have been factored into the amortization payments. **Note: This does not include the installation costs and capital costs of the biomass heating facility.** If the annual woodchip requirements were reduced to 500-600 tonnes and if a semi-mechanically fed farm-scale chipper were used; the estimated woodchip cost would be \$55-65.00/tonne, which is equivalent to heating oil at \$0.22-0.26 /litre (assuming that the estimated moisture content of the woodchips is approximately 40%)

relate to harvesting using the clear or patch cut-methods, as opposed to harvesting using the thinning method (as shown in Appendices A and C).

LITRES OF HEATING OIL DISPLACED PER GREEN TONNE OF WOODCHIPS

The following table is included as an aid in the determination of the equivalent cost per litre of oil for woodchips. If the moisture content of the woodchips and the current cost per tonne of woodchips are known, the equivalent cost per litre of oil can be calculated.

An Example: Woodchips with a Moisture Content of approximately 45% displace approximately 211 litres of oil/tonne of woodchips (Table 3). If the cost of the woodchips is \$55.00/tonne, that is equivalent to buying oil at \$0.26/litre (\$55.00 ÷ 211 = \$0.26). This table and the above calculation, are also used to calculate the relative cost of woodchips compared to heating oil described in Table 2b.

[3] As mentioned in the section called "Litres of heating oil displaced per green tonne of woodchips," it is recommended to round up some of the volumes in the table provided, e.g.: Given a moisture content of 40%, 247 litres (rounded up to 250 litres) of oil are displaced/tonne of woodchips. The cost per litre is calculated: Cost/tonne (\$50.00/tonne) divided by litres displaced (from Table 3, for 40% MC) 250 litres is approximately \$0.20 - 0.30 per litre.

[4] The typical moisture content of woodchips produced from freshly cut whole trees is approximately 45% MCWB for hardwoods and 55% MCWB for softwoods. (McCallum 1997).

Table 3 Litres of oil displaced by % MC of woodchips

Moisture Content (Wet Basis)	Displaced Litres of oil/tonne of woodchips
30%	300 litres
35%	273 litres
40%	247 litres
45%	211 litres
50%	195 litres
55%	169 litres

Note: Assumes 80% system efficiency for oil burners and 70% system efficiency for woodchip combustors.

GUIDELINES FOR EFFICIENT OPERATION OF WOOD CHIPPERS

- large trees produce more chips with less handling by the people feeding the wood into the chipper;
- delimbed trees are more easily fed into the chipper;
- neatly piled logs will make handling less awkward and quicker when it comes time to extract them from the pile and feed them into the chipper;
- operators should be skilled;
- chipper size and power should be directly propotional to the butt end diameter of the dominant log size;
- regular general maintenance of the chipper is required;
- sharp chipper knives and a minimum of two backup sets of knives will keep equipment downtime to a minimum;

  Chipper knives, regardless of the chipper size and model, should be sharpened after 4-6 machine hours of operation and new blades should be purchased after approximately 20 sharpenings;

  Chipping wood with a moisture content of less than 35% for hardwoods and less than 45% for softwoods will increase knife wear (very dry wood is abrasive);
- Use a suitably sized (strength/speed) grapple loader to feed the chipper. The use of a grapple loader for feeding a chipper is more common in a Skidder or Forwarder based operation, involving a commercial-size chipper, which is able to handle larger logs or bundles of small logs.

Reducing the Moisture Content of Fuel: Field Method

A simple field method of reducing the desired % moisture content of woodchips is the **Transpiration Drying** method. Trees are cut in the summer and left with limbs on for 30-60 days before chipping. The branches, leaves and needles draw moisture out of the wood. Depending on the weather and other such variables, this will reduce the moisture content from 45-50% for green wood (freshly cut) to 35-40%, which makes excellent, high-energy fuel (Liss 1986).

FUEL SOURCE AND CHIPPING LOCATION

- The bulk of the chipping should take place in the most efficient and economical location. Generally, this is in the forest where the trees are harvested. However, in remote communities, depending on the circumstances, it could also be practical to stockpile chipping material near the heating plant and community for chipping as required (Figure 2).
- Good fuel quality and a reliable fuel supply will generate positive returns e.g., increased life of chipper, and biomass burner and decreased downtime for repairs caused by contaminated wood-fuel (i.e., debris and soil mixed in with chips).
- Fuel source (i.e., trees for chipping) should be procured from a wide enough radius from the community that the average haul-distance remains constant over time, rather than always using the wood closest to the community. Community members often harvest for convenience; harvesting the closest wood first. Once the wood nearest to the community has all been harvested, it becomes more costly and labour intensive for residents to collect from afar.

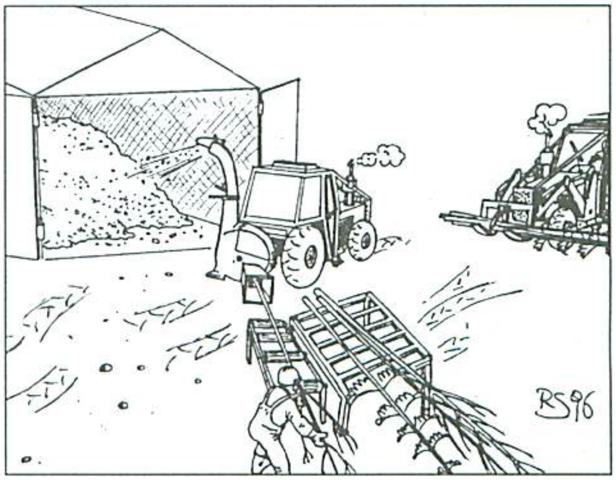

Figure 2. Option II: using a 4WD Tractor and chipping trees near the community site. (Illustrated by R. Spinelli)

AMORTIZATION PERIOD (INTEREST AND PRINCIPAL) AND MAINTENANCE COSTS

Forest machines are often amortized over five years. Maintenance costs can equal capital costs over that period if machines are heavily used, however, properly maintained, chippers can last up to 20 years. In general, machinery amortization equals about 10% of the cost of woodchip production (i.e., extraction, transportation and processing).

FACTORS AFFECTING BIOMASS VOLUME AND CHIPPER UTILIZATION

- The relatively small annual volumes of woodchips required in remote communities are constraints to the economic production of woodchips. Machine costs per tonne can be reduced significantly by increasing the annual production volume of woodchips. This may only be applicable if a community's demand for woodchips increases.
- Scientists are studying the effects of whole-tree harvesting on the biological, physical and chemical properties of forest soils. Furthermore, research is continuing as to whether whole-tree or tree-length harvesting is preferred with regards to maintaining the integrity of the soil and nutrient levels. We recommend that those involved in implementing the forest operations for a biomass operation delimb the trees at the stump to not only allow easier skidding, but to leave this material to decompose naturally. Consult federal regulations and provincial guidelines to assist with selecting the most appropriate practice for maintaining site integrity. A community-based forest management plan should also contain recommendations concerning the best practices to follow.

In summary, several components/factors should be researched before purchasing a chipper or any other forestry equipment. To assist with the decision-making process, it may be feasible to consider renting or cost-sharing required equipment on a temporary basis. This option requires that a suitable means of transportation is available.

TAKING THE NEXT STEPS TO DEVELOP A BIOENERGY OPERATION

People in remote communities who wish to start biomass operations must design a woodchip supply system and choose equipment that is suitable to their overall needs. The bioenergy Selection Criteria in the section called "Wood Supply System Options: Selection Criteria" were used to select the wood supply systems recommended in this Information Report. Those criteria, coupled with the information in the section entitled Selecting a Woodchip Supply System can be used as a starting point to assess alternative woodchip production systems.

Please contact the Canadian Forest Service representatives listed below to obtain contact information for experts in these and related areas:

- forest management aspects related to harvesting and supplying woodchips in remote communities;
- bioenergy technology and active projects;
- Canadian and international bioenergy research projects underway; and
- renewable energy technologies available for remote communities, etc.

Rick Greet, Natural Resources Canada, Canadian Forest Service, Great Lakes Forestry Centre, Communications, Operations and Client Relations Division, Sault Ste. Marie, ON (Phone: 705-949-9461);

Joe DeFranceschi, Natural Resources Canada, Canadian Forest Service, Northern Forestry Centre, Social Economics, Policy, and Liaison Division, Edmonton, AB. (Phone: 780-435-7270)

Recommended Reading

Folkema, M.P. 1989. Handbook for small-to-medium size fuelwood chipping operations. Handbook No. 7. Forest Engineering Research Institute of Canada, Pointe Claire, Quebec. 48p. Ph (514) 694-1140

Folkema, M. P. 1995. Equipment guide for wood extraction. Eastern Ontario Model Forest, Kemptville, Ont. Inf. Rep. 18. 22p. (Available from P.O. Box 2111 Kemptville, Ontario, K0G 1J0. Ph. (613) 258-8241 Fax (613) 258-8363. Cost: $8.00 including postage.)

Franklin, G. S. 1997. The business of logging: A workbook for use with the video. Forest Engineering Research Institute of Canada, Pointe Claire, Quebec. 17p.

Graham, S., Huffman, D. 1999. Biomass combustion systems (BCS); A buyers guide, Nat. Resour. Can., Energy Diversification Research Laboratory, Varennes, Quebec. 55p.

Golsse, J.M. 1997. Purchasing a used skidder or forwarder for use in small-scale operations. Forest Engineering Research Institute of Canada, Pointe Claire, Quebec. Technical Note TN-260. 12p.

Hakkila, P. 1984. Forest chips as fuel for heating plants in Finland. Finnish Forest Research Institute, Helsinki, Finland. Folia Forestalia 586. 62p. (Phone: 902-964-2297)

Harkonen, P. 1979. The chainsaw - use and maintenance. The National Board of Forestry, Jonkoping, Sweden. 67p. (Available from the New Brunswick Department of Natural Resources and Energy, Forest Extension, Box 6000, Fredericton, N.B. E3B 5H1. Ph. (506) 453-3711 Fax (506) 444-4362. (Cost: $10.20 including postage and GST.)

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Natural Resources Canada, 1995. Silvicultural terms in Canada, Second edition. Canadian Forest Service. Policy, Economics and International Affairs Directorate, Ottawa, ON. 109p.

Puttock, D.; McGregor, D.; Bevilacqua, E., 1998. A forestry management planning strategy for remote communities. Nat. Resour. Can., Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, ON. Info.Report GLC-X-2, 13p. + glossary.

GLOSSARY

AGE CLASS

A distinct group of trees or portion of growing stock recognized on the basis of age.

ANNUAL ALLOWABLE CUT (AAC)

The amount of timber that is permitted to be cut annually from a particular area. AAC is used as the basis for regulating harvest levels to ensure a sustainable supply of timber.

AVAILABLE HARVEST AREA (AHA)

The managed forest area,which may be harvested during the five-year planning term. The available harvest area is a component of the projected harvest area of the selected management alternative. (This process applies in Ontario.)

BIOMASS

The total mass of living organisms of one or more species per unit of area, or all the species in a forest community. It can be divided into above-ground biomass and below-ground biomass.

BLOCK CUTTING

Removal of the crop in block patterns in one or more operations, generally for wildlife management purposes, encouraging regeneration, or protecting fragile sites.

BUFFER STRIP

A strip of forest left relatively undisturbed to protect some element of the environment, such as a streambank, from erosion.

BUTT DIAMETER

The stem of a tree, measured at the cut end (or diameter at the stump height).

CAREFUL LOGGING AROUND REGENERATION

Harvesting operation based on shelterwood cutting principles, where advanced regeneration is protected during harvesting.

CHIPPING SITE

A predetermined location that is most suitable for chipping trees or residual areas identified for biomass production. Two possible sites include:

1. At a roadside landing, which will also require a vehicle to transport the chips. Either a truck or a tractor and bulk trailer transport are suitable.

2. At a wood yard, allowing logs to be stockpiled and chipped as required. The wood yard is usually located near the community.

CLEARCUTTING METHOD

A method of regenerating an even-aged forest stand in which new seedlings become established in fully exposed microenvironments after removal of most or all of the existing trees. Regeneration can originate naturally or artificially. Clearcutting may be done in blocks, strips, or patches.

CONIFERS

Conifers, meaning "cone-bearers," are often called "evergreens". The larches, dawn redwood and bald-cypress become leafless in winter. Conifers are also called needle-leaved trees, but most cedars, junipers, and false cypressess have small-scale-like leaves. The wood of conifers is commercially known as "softwood" even though Douglas-fir and some pines have much harder wood than "hardwoods" such as poplar.

CORD

A North American volumetric unit of wood measurement. A cord represents a pile of neatly sacked wood which measures 4 feet high x 4 feet wide x 8 feet long. The volume of this pile of wood, including air spaces, is 128 cubic feet. A cord of softwood weighs about 1.6 tonnes. A cord of softwood, when chipped, will produce 6 cubic meters ($6m^3$) of loose woodchips. A cord of green softwood (chipped) can displace approximately 340 litres of heating oil.

CROP TREE

Any tree selected to become or forming a component of the final crop.

DECIDUOUS

These trees are also referred to as "broadleaf-trees" (from the Latin "falling off") because most shed their leaves in autumn. The forest industry calls broadleaf trees hardwoods.

DIAMETER AT BREAST HEIGHT (DBH)

The stem diameter of a tree measured at breast height (1.3 m above ground level). Unless otherwise stated, applies to the outside bark dimension.

DISC CHIPPER

A type of wood processing equipment that has knives mounted on a rotating disc that most commonly sits on a vertical or near vertical axis. Generally, trees are fed into the disc at a controlled speed by hydraulically powered infeed rollers on an angle of about 45 degrees (45^0). Disc chippers are the most common type of chipper.

ERGONOMICS

An applied science concerned with designing and arranging things people use so that the people and equipment interact most efficiently and safely.

EVEN-AGED

Of a forest, stand, or forest type in which relatively small age differences exist between individual trees. The differences in age permitted are usually 10-20 years; if the stand will not be harvested until it is 100-200 years old, larger differences up to 25% of the rotation age may be allowed.

FINAL CUTTING

The last of a series of progressive regeneration cuts which removes the last of the original seed trees when the regeneration is considered established.

FIRE HAZARD REDUCTION

Any treatment of fuels that reduces the threat of ignition and spread of fire (e.g., managing overmature forests, reduction and/or removal of slash).

FORWARDING

The loading of wood piled along forest extraction trails onto the load bunk of a forwarder with a grapple loader and hauling it to a roadside landing for processing and/or further transport by truck.

HARVESTING

A general term for the removal of produce (i.e., trees) from the forest for utilization; comprising cutting, sometimes further initial processing and extraction.

INTEGRATED RESOURCE MANAGEMENT (IRM)

Management of natural resources to achieve maximum benefits; integrating forest management to nontimber uses and values not only to produce timber, but also to develop the wildlife and recreational capacities of forested areas.

MATURE

In even-aged management, those trees or stands that are sufficiently developed to be harvestable and that are at or near rotation age.

MERCHANTABLE

Of a tree or stand that has attained sufficient size, quality, and/or volume to make it suitable for harvesting. Does not imply accessibility, economic or otherwise.

METRIC GREEN TONNE

A tonne (1,000 kilograms or 2,205 pounds) of woodchips, which are produced from freshly cut wood. The Moisture Content Wet Basis (MCWB) of woodchips produced from freshly cut whole trees is approximately 45% for hardwoods (deciduous) and 55% for softwoods (conifers).

MOISTURE CONTENT WET BASIS (MCWB)

Moisture content on a wet basis refers to the proportion of the total weight of a given quantity of wood that is actually water.

PER MACHINE HOUR (PMH)

This is a common abbreviation for the term "per machine hour" and usually refers to the hours the machine is actually operating. This time excludes the time the operator is maintaining the machine and refueling it.

POWER TAKE OFF (PTO)

A power drive connector found on the back of all modern farm tractors. A power take off shaft connects the PTO to a wide range of implements, such as chippers. The PTO commonly runs at either 540 or 1,000 RPM (revolutions per minute).

ROTATION AGE

The age of a tree when it has reached its maximum production of mass.

ROUNDWOOD

Round sections of tree stems with or without bark; such as logs and bolts.

SKIDDING

The dragging of whole trees from the stump to a roadside landing, where it is usually processed into sawlogs and other products that can be picked up and transported by truck.

TRANSPIRATION DRYING

A technique for reducing the moisture content in chipping material. Trees are cut in the summer and left with the branches and leaves and needles on to draw out moisture for 30-60 days before chipping. This will reduce the moisture content from 45-50% for green wood to 35-40% which makes excellent, high energy fuel.

TREE LENGTH HARVESTING

The tree is cut and delimbed (branches and crown removed) at the stump and only the log is removed from the site.

WHOLE-TREE HARVESTING

The entire length of the tree is skidded to the landing where the branches and crown are removed.

WOODCHIP MEASUREMENT

In commercial chipping operations in Canada, woodchips are generally sold by the metric tonne. This is usually done by weighing the truck when loaded and then again after it has been emptied. Woodchip buyers may also take samples and determine the average moisture content. This is often done on a spot check basis.

YARDING

This involves the use of a winch to drag whole trees to a road or extraction trail. Yarding allows wide spacing between forest extraction trails and it minimizes the area occupied by the trails. It also concentrates wood along the trails which improves the efficiency of the forwarding operations.

Terms in the glossary have been adapted from the following sources:

Forest management planning manual for Ontario's crown forests, Ontario Ministry of Natural Resources (OMNR), 1996.

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Trees in Canada, NRCan., and Fitzhenry and Whiteside Limited, 1995.

McCallum, B., Ensight Consulting, R.R. #4 Hunter River, Prince Edward Island C0A 1N0 Phone: 902-964-2297, e-mail: mccallum@isn.net

Supply System Option I

OPTION #1: CONVENTIONAL FOREST MACHINES

EQUIPMENT AND APPLICATION	CAPITAL COST	PRODUCTION IN TONNES Per Machine Hour (PMH) Note: The following values are for harvesting in a thinning operation	COSTS (Est.)		COSTS PER TONNE (Est.): Formulas for the values below are in the Calculations section				ESTIMATED DELIVERED WOODCHIP COST /TONNE
			OPERATING; Per Machine Hour	REPAIR & MAINTENANCE; Per Year	1.OPERATING COSTS (Average Estimates)		2. REPAIR & MAINTENANCE	3. ESTIMATED DELIVERED WOODCHIP COST /TONNE	4. BASED ON 800 TONNES /YEAR (could be for a small community or the volume required for a few public buildings) Calculated for 800 tonnes using the formula in # 3.)
					1. a) Per Tonne	1.b) Wage Per Tonne	2.) Cost Per Tonne, based on producing 2 000 tonnes/year	3.) Cost Per Tonne, based on producing 2 000 tonnes per year 3. = 1.a) + 1.b) + 2.)	
CHAINSAW CREW (2-moderately skilled workers, for this example)	2 @ $800 /chainsaw + $200 (safety clothing) = $2k	3-5 tonnes per person hour (for 2 cutters)	$50.00 (wages for 2 cutters and maintenance)	$400	$12.50	$9.00 ($4.50/cutter) based on $18.00/hour	$0.20	$21.70- thinning operation ($12.00 is an estimate for a patch-cut operation)	$22.00
SKIDDERS	New: $80-140k Used: $20-$50k	3-5 (midpoint=4)	$18.44 [1] (rounded to $18.45)	$6-7k (midpoint=$6.5k)	$4.60	$5.30	$3.25	$13.15	$18.05
LOG TRUCK with Grapple Loader mounted	New: $160k Used: $25-$40k	10-12 at a hauling distance of 10 km	$8-10.00	$7-10k if 150k km/year are driven	$0.85	$1.95	$4.25	$7.05	$13.40
INTERMEDIATE COMMERCIAL-SCALE CHIPPER	New: over $200k Used: $30-$60k	15-27	$20-30.00	$5-8k	$1.20	$1.00	$3.25	$5.45	$10.35
Est. Equipment Amortization for 5 years (not based on Capital Costs listed in the table. A financial or business planner should assist with determining true amortization)								$5.00	$5.00
TOTAL Estimated Option Costs (Excluding outright Capital Costs e.g., purchase, rental, etc.,)					$19.15	$17.25	$10.95	$52.35	$68.80
FORWARDERS	New: $150-220k Used: $50-75k	4-7	$25-30.00 [1]	$7-15k	$5.00	$3.85	$5.50	$14.35	$22.60
TOTAL Estimated Option Cost (Substituting the Skidder with the Forwarder) (Excluding outright Capital Costs e.g., purchase, rental, etc.)								$53.55	$73.35
SMALL COMMERCIAL-SCALE CHIPPER	New: $50-55k Used: not available	5-9	$12-15.00	$2-3k	1.95	$3.00	$1.25	$6.20	$8.10

No preference is implied for either the Intermediate Commercial-Scale or the Small Commercial-Scale Chipper. Any chipper, and its corresponding variables, can be substituted in this table.

DISCLAIMER: This table should only be used to assist with determining an estimate of the very "basic" costs of an operation. By no means is this intended to represent all the costs that are required for determining the Total Cost of an Operation per tonne including amortization and capital cost. In fact, many variables have not been included and the figures shown are only examples, as each community will have their own pay structure, available equipment and other variables. These will have an impact on the overall cost of the operation.

Note: Where ranges are presented, the midpoint has been used for calculating the Cost Per Tonne Estimates. Numbers have been rounded to the nearest 0.05 where necessary.

Calculations for COSTS PER TONNE for the following: (Skidder costs have been used as an example in the calculations below):

1. Operating costs (Average Estimates) per tonne and Wage Costs per tonne.
2. Repair and Maintenance Costs based on producing 2 000 tonnes of woodchips.
3. Estimated Delivered Woodchip Costs per tonne, based on producing 2 000 tonnes, (800 tonnes of woodchips annually, shown in column #4).

1. a) Operating Costs Per Tonne = Operating cost per machine hour ($18.45) divided by the production per machine hour (4 tonnes midpoint) = 4.60 per tonne

1. b) Operating Costs; Wage Costs Per Tonne: the following is assumed in this calculation: basic wage is $15.00 per hour; 20% benefits; one Machine Hour or Production Hour = 60 minutes. In order for a worker to produce the volume produced in one Machine Hour (60 minutes) the worker has to work 70.6 minutes. Therefore, in this Table, 1 Person Hour = 70.6 minutes (60 minutes or Machine Hour divided by 0.85 utilization factor [2] (will vary depending on the operation) = 70.6 minutes).

Example: Wage per hour (with benefits) = Basic wage per hour $15.00 + 20% benefits = $18.00 per hour

Wage per Productive Hour = $18.00 per hour (60 minutes) divided by the utilization factor of 0.85 = $21.176 rounded up to $21.18 per hour (70.6 minutes or 1 Machine hour 60 minutes)

Wage Cost per tonne: $21.18 per hour divided by 4 tonnes (midpoint) produced in 1 Machine Hour (60 minutes) = $5.30 per tonne

2. Repair and Maintenance Costs based on supplying: 2 000 tonnes per year = Repair and Maintenance Costs Per year $6-7 000 (using the midpoint of $6 500) divided by 2 000 tonnes per year = $3.25 per tonne.

3. Estimated Delivered woodchip costs per tonne based on producing 2 000 tonnes per year: Example: 1 a) $4.60 + 1.b) $5.30 + 2.) $3.25 = 3.) $13.15 Use the same formula for determining the values shown in column 4, except calculate it based on 800 tonnes per year.

[1] Golsse, J.M. 1997. Purchasing a used skidder or forwarder for use in small-scale operations. Forest Engineering Research Institute of Canada, Pointe Claire, Quebec. Technical Note TN-260.

[2] Adapted from Forest Engineering Research Institute of Canada (FERIC) publication, The Business of Logging: A Workbook for Use With the Video April, 1997.

SUPPLY SYSTEM OPTION # I: CONVENTIONAL FOREST MACHINES:

SKIDDER OR FORWARDERS, LOG TRUCK, CHIPPERS

SKIDDERS

Function and Limitations:

To transport, by winch or grapple loader, whole-trees or delimbed logs from the harvesting site to roadside or another location for chipping/processing. While suited to work in clearcut or strip cut operations, this will vary according to site conditions, operator experience, tree size, ground moisture content and skidding distance. Skidders are designed to skid logs up to a distance of **200 metres** to a roadside landing. Productivity will be higher in a clearcut skidding operation and lower in a thinning operation where only selected trees are harvested. A highly skilled 3-person crew (i.e., 2 cutters and 1 machine operator) being paid using the piecework method, can fell, delimb, top trees up to 9-12 metres (30'-39') in length, and skid to a landing 72-80 tonnes (45-50 cords). In a remote community with moderately skilled people, approximately 600 tonnes of woodchips could be produced in 12-14 working days.

Annual maintenance costs are lower for skidders than for forwarders. Skidders require careful operator handling to avoid damaging residual crop trees and to work effectively on soft ground or wet areas where tires can leave deep ruts. Skidding in the summer can cover logs with soil, making them unsuitable for chipping, however, this can be greatly reduced or eliminated if skidding is done over snow, as skidders operate very well in the winter.

FORWARDERS

Function and Limitations:

Similar to skidders in design, but with a grapple loader and log-carrying load-bunk, forwarders allow efficient pick up and transportation of delimbed logs or whole trees, up to 9 metres (30') in length. Hauling distances should not exceed **400 metres (1,312 feet or one quarter of a mile)**. Suited to work in clearcut or strip cut operations. Can be used in thinning operations, however the machine width requires trails that are at least 30 metres (98') wide. Effective during winter months, on frozen ground and in summer on firm ground.

See variables listed in Appendix A under Forwarder. A highly skilled 3-person cut and skid crew (i.e., 2 cutters and 1 machine operator) can fell, delimb and transport 80-90 tonnes (50-56 cords) of delimbed trees per day in a strip cut or clearcut operation when cutting trees of 20-30cm (8"-12") diameter at the butt -end. Using this method, an annual supply of 600 tonnes of woodchips could be produced in 10-12 working days by a moderately skilled crew.

Annual maintenance costs are higher than for skidders, and they also require careful operator handling to avoid damaging residual crop trees. On wet areas, tires can leave deep ruts. Timber is less likely to become covered with soil as timber is raised above the ground for transporting to landings. Not suitable for transportation of timber on highways or well-traveled roads.

LOG TRUCK

Function and Limitations:

To haul logs to a sawmill, firewood for residential heating, or chipping material to a community-chipping yard to process into woodchips. Modifications can also be made to the truck to accommodate the transportation of woodchips that may have been chipped near the harvesting area. Having a log truck would be beneficial if there are enough sawlogs and low quality chipping material to keep it fully loaded during its runs. Estimated Delivered Cost: $7.00 per tonne.

In the event that a log truck is not available, other equipment such as a Grapple Loader Trailer hauled by a skidder, could transport the logs back to the community, if the distance was within 10km (6.21 miles). Delivery Cost per tonne is not available for this method of transportation.

DUMP TRUCK

Should the community decide to chip at a landing near the harvesting site, and if a Dump Truck is available, it could be adapted to haul woodchips (the sides would have to be extended to carry woodchips). Estimated Delivered Cost: $7.00 per tonne. A dump truck equipped with a grapple loader, could also haul logs and be useful in other municipal operations.

CHIPPERS

Two types of typical commercial disc-chippers are: 1. Small Commercial-Scale and 2. Intermediate Commercial-Scale. Both types have been identified for comparison and information purposes only; there are other brands and models that should be investigated. Disc chippers consist of a large vertical disc with 2 or 3 knives mounted on it. Logs are pulled into a chipper automatically by hydraulically powered infeed rollers. Logs are fed to commercial chippers by a grapple loader and the chipper is usually mounted on a trailer chassis. It is good practise to have extra fuel available near the working area to refuel equipment as needed.

1. Small Commercial-Scale, e.g., Mobark 2400, 135-150 kW (180-200 hp) or **Bandit 1250/54,** 150 kW (200 hp):

Function and Limitations:

These types of commercial-scale chippers are the smallest that could supply woodchips for a remote community with a population of approximately 1,500-2,000. Having between 134-149 kW (180-200 hp) of power, they can chip trees up to 30-36 cm (12"-14") diameter at the butt end. Given highly skilled operators, these chippers could produce between 8-10,000 tonnes of woodchips per year.

2. Intermediate Commercial-Scale chippers: e.g., Trelan D60, 190-228 kW (250-300 hp)

Function and Limitations:

To purchase a new chipper of this model can cost over $200,000, which would not likely be feasible for a remote community beginning to explore woodchip production. Chippers of 190-228 kW (250-300 hp) can handle logs up to 46 cm (18") diameter at the butt end, which are mechanically fed into the chipper. The cost of diesel fuel for this size of chipper (using 2.5-4.0 litres/tonne of woodchips) is very small (proportional to about 1%) compared to the heat energy value provided by the chips.

OPTION # II: FORESTRY GUARDED TRACTOR AND FORESTRY IMPLEMENTS

EQUIPMENT AND APPLICATION	CAPITAL COST	PRODUCTION IN TONNES Per Machine Hour (PMH) Note: The following values are for harvesting in a thinning operation.	COSTS (Est.) OPERATING; Per Machine Hour	COSTS (Est.) REPAIR & MAINTENANCE; Per Year	COSTS PER TONNE (Est.): Formulas for values below are in the Calculations section — 1. OPERATING COSTS (Average Estimates) 1. a) Per Tonne	1. OPERATING COSTS (Average Estimates) 1.b) Wage Per Tonne	2. REPAIR & MAINTENANCE 2.) Cost Per Tonne, based on producing 2 000 tonnes/year	3. ESTIMATED DELIVERED WOODCHIP COST /TONNE 3.) Cost Per Tonne, based on producing 2 000 tonnes per year 3.) = 1.a) + 1.b) + 2.)	ESTIMATED DELIVERED WOODCHIP COST/TONNE 4. BASED ON PRODUCING 800 TONNES PER YEAR (could be for a small community or the volume required for a few public buildings) Calculated for 800 tonnes using the formula in # 3.
CHAINSAW CREW (2-moderately skilled workers)	2 @ $800/chainsaw + $200 (safety clothing) = $2k	3-5 tonnes per person hour (for 2 cutters)	$50.00 (wages for 2 cutters and maintenance)	$400	$12.50	$9.00 based on $18.00/hr	$0.20	$21.70 - thinning operation ($12.00 is an estimate for a patch-cut operation)	$22.00
4 WHEEL DRIVE 75 kW (100 hp) TRACTOR with Winch mounted (cost for a new tractor includes forestry guarding @ $5-6k + tires @ $3k each need either 2 or 4 tires)	New: $80-110k + $3-5k for a new winch Used: $30-40k+$6k-11k for guarding & a winch (new or used)	1-3 (midpoint =2)	$19.12 [1] rounded up to $19.15	$700-1.5k (midpoint= $1.1k)	$9.60	$10.60	$0.55	$20.75	$22.95
FARM-SCALE; TRACTOR POWERED (TP) CHIPPER	New: $14-17k Used: Not available	3-5	$4-6.00	$400-600	$1.25	$5.30	$0.25	$6.80	$7.20
BULK TRAILER TRANSPORT	New: $30-60k	2	$1	$100	$0.50	$10.60 (cost/tonne will decrease in a patch-cut operation)	$0.05	$11.15	$11.25
Estimated Equipment Amortization for 5 years (not based on Capital Costs listed in the table. A Financial planner or business planner should determine true amortization)								$5.00	$5.00
TOTAL Estimated Option Costs (Excluding outright Capital Costs e.g., purchase, rental, etc.,)					$23.85	$35.50	$1.05	$65.40	$68.40
4 WHEEL DRIVE 75 kW (100hp) TRACTOR (includes forestry guarding) with Grapple Loader (GL) & Trailer	New: $70-110k + $14-28k for a GL and trailer (new or used GL & trailer)	3-5	$19.12 [1]	$700-1.5k (midpoint= $1.1k)	$4.80	$5.30	$0.55	$10.65	$11.50
TOTAL Estimated Option Cost (Substituting the Winch with the Grapple Loader & Trailer) (Excluding outright Capital Costs e.g., purchase, rental, etc.,)								$55.30	$56.95
SMALL COMMERCIAL-SCALE TRACTOR-POWERED CHIPPER	New: $30-60k Used: Not available in Canada	5-8	$6 - 8.00	$600-1k	$1.10	$3.25	$0.40	$4.75	$5.35

DISCLAIMER: This table should only be used to assist with determining an estimate of the very "basic" costs of an operation. By no means is this intended to represent all the costs that are required for determining the Total Cost of an Operation per tonne including amortization and capital cost. In fact, many variables have not been included and the figures shown, only examples, as each community will have their own pay structure, available equipment and other variables. These will have an impact on the overall cost of the operation.

Note: Where ranges are presented, the midpoint has been used for calculating the Cost Per Tonne Estimates. Numbers have been rounded to the nearest 0.05 where necessary.

Calculations for COSTS PER TONNE for the following: (4-WD Tractor with a Winch costs have been used as an example in the calculations below):

1. Operating costs (Average Estimates) per tonne and Wage Costs per tonne.
2. Repair and Maintenance Costs based on producing 2 000 tonnes of woodchips.
3. Estimated Delivered Woodchip Costs per tonne, based on producing 2 000 tonnes, (800 tonnes of woodchips annually, shown in column #4).
1. a) Operating Costs Per Tonne = Operating cost per machine hour ($19.15) divided by the production per machine hour (2 tonnes = midpoint) = $9.58 rounded up to $9.60 per tonne.
1. b) Operating Costs; Wage Costs Per Tonne: the following is assumed in this calculation: $15.00 per hour basic wage; 20% benefits; a Machine Hour or Production Hour = 60 minute. In order for a worker to produce the volume produced in a Machine Hour (60 minutes) the worker has to work 70.6 minutes therefore, in this Table 1 Person Hour = 70.6 minutes (60 minutes or Machine Hour divided by 0.85 utilization factor [2] (will vary depending on the operation = 70.6 minutes).
Example: Wage per hour (with benefits) = Basic wage per hour $15.00 + 20% benefits = $18.00 per hour
Wage per Productive Hour = $18.00 per hour (60 minutes) divided by the utilization factor of 0.85 = $21.176 rounded up to $21.18 per hour (70.6 minutes or 1 Machine hour being 60 minutes)
Wage Cost per tonne: $21.18 per hour divided by 2.0 tonnes (midpoint) produced in 1 Machine Hour (60 minutes) = $10.59 rounded to $10.60 per tonne.

2. Repair and Maintenance Costs based on supplying: 2 000 tonnes per year = Repair and Maintenance Costs Per year $700-$1 500 (using the midpoint of $1,100) divided by 2 000 tonnes per year = $0.55 per tonne.
3. Estimated Delivered Woodchip Costs per tonne: Example: 1.a) $9.60 + 1b.) $10.60 + 2.) $0.55 = 3.) $20.75. Use the same formula for determining the values shown in column 4. except calculate it based on 800 tonnes per year.

[1] Golsse, J.M. 1997. Purchasing a used skidder or forwarder for use in small-scale operations. Forest Engineering Research Institute of Canada, Pointe Claire, Quebec. Technical Note TN-260.

[2] Adapted from Forest Engineering Research Institute of Canada (FERIC) publication, The Business of Logging: A Workbook for Use With the Video, April, 1997.

SUPPLY SYSTEM OPTION # II: FORESTRY GUARDED TRACTORS AND FORESTRY IMPLEMENTS

4 WHEEL DRIVE (4WD) TRACTORS with required implements (i.e., Winches, Grapple Loader, LOG TRUCK and Tractor Powered (TP) Chippers

4WD TRACTOR of 75 kW (100 hp)

Function and Limitations:

To skid/transport delimbed trees to the roadside landing. Tractors can travel at higher speeds and longer distances, on suitable roads, than either a skidder or forwarder. Given that the cost of a new 4WD forestry guarded tractor with forestry graded tires can range in price from $80,000-$110,000, it should be used 1,200-1,500 hours per year to make it an economically viable operation. In general, 4WD tractors are readily available and less expensive than most log skidders and/or forwarders, depending on the condition.

The cost of an average used 75 kW (100 hp), 4WD tractor is approximately $30-40,000.

Upgrading a new or used 4WD tractor for forestry use can cost an additional $8-23,000 depending on the modifications required and the attachments included with the purchase, e.g., guarding at $5-6,000; winch (new) at $3-5,000; forestry graded tires at $3,000/tire (purchase in pairs), etc.

Other applications for a 4WD tractor include winter snow removal using a plough or snow blower. The tractor has a front-end loader, it can also be used to load the truck or hopper with woodchips to supply the biomass boiler. The tractor's power take-off (PTO) can power a chipper, a sawmill and/or a firewood processor.

Required attachments:

Winch: TP winches have a line pull of 3-8 tonnes which is comparable to hauling 2-4 logs with a 38 cm (15") diameter at the butt end and a length of 12-15 m (40-50'). For a biomass operation, harvesting with a winch should be done in the winter, to keep trees free from soil, which could quickly dull chipper knives. In patch or strip cuts, productivity could be as much as 50% higher than productivity in a thinning operation, (i.e., the machine has to maneuver more when harvesting in a thinning operation), (Appendix C). Logs should not be skidded more than **2km** (1.2 miles) by winch **(similar to winching with a Skidder)**.

Cost range for a new winch: $3-5,000 and a used one is half the price.

Grapple Loader Trailers: A trailer equipped with a hydraulic Grapple Loader (crane) for loading and unloading logs. A grapple loader trailer can be used effectively for transporting wood distances up to **10 km** (6.2 miles).

Cost range for a Grapple Loader : $12-20,000 new and a used one is $9-13,000.

Cost range for a Grapple Loader Trailer : $17-28,000 (new).

Tandem Bogie-axle Bulk Dump Trailer: in the event that a Dump Truck is not available, this trailer together with a 4WD tractor, can transport woodchips, sawdust, and gravel on relatively smooth road surfaces. A trailer equiped with a bogie-axle will be able to maneuver better over rough terrian with less sway and force on the trailer.

Cost range for a Bogie-axle Bulk Dump Trailer: $5-8,000.

TRACTOR POWERED (TP) CHIPPERS

1. TP-Farm Scale

Function and Limitations:

A 56-83 kW (75-110 hp) tractor powers these chippers. Chips logs up to 23 cm (9") diameter at the butt end. Delimbed trees are preferred. Logs are usually fed into the chipper by hand. A second tractor equipped with a grapple loader can be used to feed logs into the chipper, to speed up the chipping production. At full capacity, and with skilled workers, these chippers have the ability to chip 500-600 tonnes/yr.

An annual supply for a public building (the size of a typical home) will be approximately 16 green tonnes of woodchips (10 cords). This volume could be chipped in 4-5 hours.

2. TP-Small Commercial-Scale:

Function and Limitations:

A 75-112 kW (100-150 hp) tractor powers these chippers. Unlike the Farm-scale size, these chippers are mechanically fed with a grapple loader and can chip logs up to 33 cm (13") diameter at the butt end. Suitable to produce annual volumes of woodchips exceeding 600 tonnes. In some commercial operations in Finland and Denmark these chippers can produce 3-5,000 tonnes annually. (This example is provided for information only. Productivity ranges achieved in Finland and Denmark may not be attainable in remote communities, because site conditions and many other variables are not the same.)

Other Models of Tractors Available

Other models of tractors that were not part of the table include the Canadian-built New Holland (Versatile) TV 140 and the Finnish Valtra 115. These articulated tractors have special features that enhance maneuvering in the forest, and allow very slow speed control necessary for some sites, i.e., in a thinning operation. Cost range for 83-87 kW (110-115 hp): $90-130,000 (new).

Several companies also sell 75 kW (100 hp) 4WD Tractors with a rotating seat for easier operation of the Grapple Loader. Cost range: $70-80,000 (new).

Summary Table

SUMMARY OF SYSTEM SUPPLY OPTIONS # I AND # II

As stated in Appendices A and C, these estimates are based on harvesting for a thinning operation. In a patch or clear-cut harvesting operation, productivity, depending on the level of experience the crew has, can be up to 50% higher than in a thinning operation. This increase in productivity will also reduce the estimated cost/tonne and thus should have an overall positive impact on the cost/tonne of the total operation. For both System Supply Options, it is assumed that no new roads have been or are planned to be constructed, as this will increase the cost estimates provided below.

Please Note: The cost figures are estimates based on information derived from a variety of sources. A detailed approach can be completed through professional assistance or by implementing the procedures in publications such as The Business of Logging*.

TOTAL ESTIMATED DELIVERED WOODCHIP COST/TONNE (THINNING OPERATION)

	Based on producing 2 000 tonnes of woodchips per year	Based on producing 800 tonnes of woodchips per year
OPTION I **Conventional Forest Machines:** using the following: 2 person Chainsaw Crew; **Skidder**; Log Truck with Grapple Loader mounted; and, Intermediate Commercial-Scale chipper	$52.35	$68.80
OPTION I **Conventional Forest Machines:** using the following: 2 person Chainsaw Crew; **Forwarder**; Log Truck with Grapple Loader mounted (or the GL could be on the Forwarder instead); and, Intermediate Commercial-Scale chipper	$53.55	$73.35
OPTION II: **Forestry Guarded Tractor and Forestry Implements:** using the following: 2 person Chainsaw Crew; **4WD 75 kW Tractor with Winch**; and, Farm-Scale Tractor Powered (TP) chipper and Bulk Trailer Transport	$65.40	$68.40
OPTION II: Forestry Guarded Tractor and Forestry Implements: using the following: 2 person Chainsaw Crew; **4WD 75 kW Tractor with Grapple Loader Trailer;** and, Farm-Scale TP chipper and Bulk Trailer Transport	$55.30	$56.95
Note: For Option II, depending on the situation, it may be practical for a community to include both a Winch and Grapple Loader trailer with a 4WD farm tractor to complete the Supply System Option.		

* A Workbook for Use With the Video, Gordon S. Franklin, by Forest Engineering Research Institute of Canada (FERIC), 1997.