COST FACTORS IN WOOD FUEL PROCUREMENT*

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ABSTRACT

Integrating the planning and implementation of wood-based fuel production with the procurement of industrial roundwood in conventional forestry is considered to be a feasible undertaking. When doing so, the logging sites potentially serving as sources of biomass residues to be salvaged for fuel need to be chosen on the basis of harvesting costs. It is essential to take carefully into account site-based cost factors such as the total volume of wood to be obtained from the site, site conditions, available equipment and operating technologies, off-road haulage and truck transportation distances, storage, and quality control. In addition, ecological sustainability, possibilities to concentrate operations, seasonal variation in consumption, and the wishes of land-owners also affect the choice of harvesting sites.

An important factor is the scale of operation. Harvesting machinery is expensive and thus the annual output considerably affects the costs. In addition, the greater the share of the potential fuel supply recovered, the higher the cost of procurement. This is due to longer transport distances and the need to operate on less favourable sites.

As regards deliveries of different wood fuels or fuel mixtures, the quality of the fuel and the demands of energy-generation plants should be also considered. The present situation in Finland and Sweden is such that the wood fuel delivered directly from the forest to users is recovered almost solely from final cuttings in the form of logging residues. Wood fuel obtained from thinning operations is of minor importance.

Keywords: cost factors; energy wood harvesting; forest management; bioenergy; wood fuel.

INTRODUCTION

New technologies have been developed for wood fuel harvesting, with the main focus having been on the development of machinery and less on the logistics of the supply of wood fuel. In the Nordic countries, especially in Sweden, forest energy has been recovered on a

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large scale during the past 10 years. In Finland, wood fuel has been supplied by independent wood fuel procurement enterprises. Also, large industrial wood procurement organisations such as UPM-Kymmene and StoraEnso are starting to set up wood fuel procurement systems of their own. This includes selection of harvesting technology, designing appropriate organisations and management systems for procurement, and identifying logging sites suitable for the recovery of logging residues.

Knowledge of the various cost factors is needed when assessing harvesting costs. Cost factors can be derived from work conditions defining the environment in which the operations are performed (Harstela 1993):

- Global and large-scale geographical conditions (climate, forest characteristics)
- State and local conditions (macro: plains, hilly country, mountains; public and forestry conditions, roads, communication networks, taxes)
- Work site conditions (micro: timber volume and hectares per site, assortments, harvesting season, terrain, transport distances, available methods, and machines)

The cost elements of wood procurement are utilised in assessing the profitability of enterprises, to compare harvesting methods, to estimate outputs per period of operation, and to evaluate work sites and their conditions.

Assessment of harvesting costs is needed at all stages of the decision-making hierarchy. The decision on the location of the chip plant and the decision on harvesting systems must be made **at the strategic level**. For instance, systems based on chipping before long-distance transport call for unloading and storage systems at the plant that are different from systems based on chipping at the plant. **At the tactical level**, harvesting managers must decide, for example, how much wood will be harvested annually from each district and where it should be transported. Average harvesting and transport costs per district must be known in order to optimise harvesting and transport. **At the operational level**, stands to be harvested are identified and scheduling of harvesting is decided. This calls for stand-wise cost estimations of each system available for energy wood recovery. As a result, the stands to be harvested and appropriate harvesting methods are selected.

In recent years the average cost of industrial roundwood harvesting for the Finnish forest industries has been FIM 49/m^3(over bark). Other relevant costs have been as follows: the long-distance transportation of timber has cost on average FIM 31 (US$1 = FIM 6.0), the price of industrial wood for energy has been FIM 32–44/MWh, the lowest prices paid for chips produced from logging residues have been FIM 40–47/MWh, and whole-tree chips produced from thinnings and cleanings have been priced at FIM 65–89/MWh.

Almost 90% of industrial roundwood harvesting is mechanised in Sweden and Finland, and practically all industrial roundwood is harvested using the cut-to-length method. In Finland, the machinery used in timber harvesting comprises 1200 single-grip harvesters, 1700 forwarders, and 1300 timber trucks. A truck with a drawbar trailer is the typical unit in timber and chip transport. The maximum total weight of such combination is 60 tonnes and their maximum length is 25.25 m. The average load size is 40–42 tonnes, which corresponds to 45–50 m^3 timber. In Finland, wood fuel processing involves the use of 25 or so heavy-duty mobile chippers, 100 smaller farm-tractor-mounted chippers, and about 100 chip-lorries (which are also used in peat transportation). Logging residues are usually harvested by means of forwarders equipped with expanded load spaces and a purpose-built loading grapples. Larger mills and energy plants use stationary shredders and grinders (Oijala *et al.* 1998).

This paper discusses the cost factors involved in energy-wood procurement, and highlights the importance of the procurement organisation and the effect of scale on procurement costs.

WORK SITE CONDITIONS AS COST FACTORS

The productivity of energy-wood harvesting is affected by work site factors such as the terrain, the method of harvesting the industrial roundwood prior to recovery of the logging residues (stack size), distance to landing, and the amount of logging residues at the logging site. In addition, the total amount of logging residues to be recovered on the one site affects the the need to move machinery from site to another. Factors affecting the terrain transport of wood are illustrated in Fig. 1.

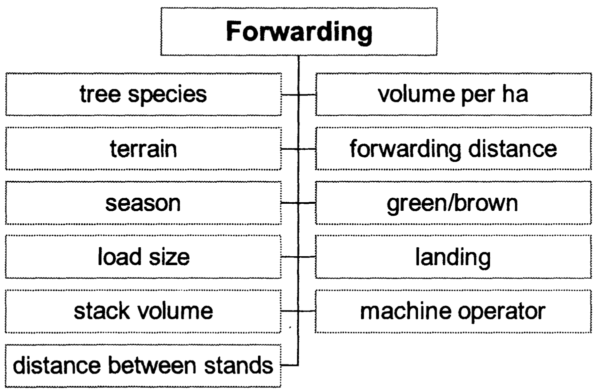

FIG. 1–Factors affecting forwarding costs.

Different harvesting methods react differently in work site factors. For instance, off-road transport performed with a forwarder is less sensitive to terrain conditions than chipping and transport of chips using a chip harvester. This must be considered when selecting machinery for a specific site.

COST STRUCTURE IN WOOD FUEL HARVESTING

Although cost assessment models differ depending on the country and type of operation, their basic structure is similar. The parameters of the cost functions often differ and depend on cost and wage levels, infrastructure, accounting practices, procurement methods, availability of slack resources, etc.

Productivity, operational factors, and capital costs are usually the foremost basics when calculating machinery costs. Administration costs and entrepreneurial risk (profit/loss) are flexible depending on the enterprise. The costs per output unit can be calculated by dividing the hourly costs by the conversion coefficient of productivity.

Normally, labour costs, including social costs and taxes, can be determined on the basis of the rates paid. Machine costs are divided into fixed and variable costs, and numerical values are determined according to the influence of each factor on the method or equipment used (Harstela 1993).

Several earlier studies emphasised the importance of observing the whole system when defining harvesting costs (Asikainen 1995, 1998; Asikainen & Nuuja 1999). A typical aspect of wood fuel harvesting lies in the interactions between operations and the systems (Asikainen 1995). These interactions always have a negative effect on system performance. For instance, the loader and the truck interact in the loading of chip trucks at the terminal. Loading productivity defines the loading time of the truck at the terminal. In unloading, the unloading terminal, weighing and unloading storage facility define the loading time at the plant. Moreover, if there are several trucks using the same loading and unloading facilities, they interact with each other when queuing. These interactions typically reduce the productivity of a harvesting system by 10–20% compared to a situation in which machinery can be operated independently.

The cost structures of different systems can differ markedly depending on system design. Systems based on chipping at the roadside consist of a forwarder, a chipper, and trucks. An in-woods chipping system uses an in-woods chipper and trucks built to take interchangeable containers. A chipper truck undertakes all stages of harvesting after the trees have been felled and delimbed. The cost structures of different systems differ from each other (Fig. 2). As a result, systems react differently to changes in harvesting conditions: a chipper truck works well in flat terrain and with short transport distances, whereas a roadside chipping system can be used in difficult terrain conditions but the landing must be on flat ground with adequate bearing capacity. A chipper truck can operate even on poor landings if roadside chipping is used. In-woods chipping can be used if the forwarding distance is short.

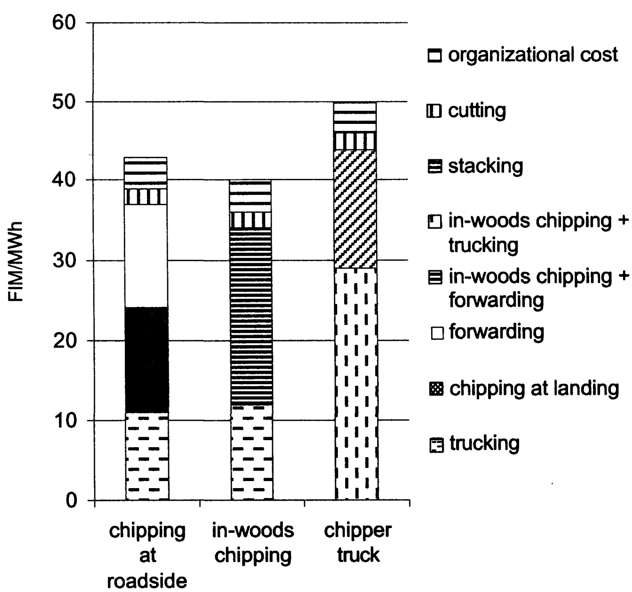

FIG. 2–Cost structures of different systems (Oijala *et al.* 1999)

SCALE OF OPERATION

The scale of operation affects procurement costs in several ways. An increase in annual production diminishes the organisational costs per unit produced. For a single procurement system the optimal situation is such that the system operates close to its annual capacity.

In a theoretical situation, a procurement organisation must hire an additional harvesting system once the maximum capacity of the existing ones has been reached. As a result, the direct harvesting costs do not diminish continuously as the volume of operation increases. The system illustrated in Fig. 3 consists of a forwarder, a chipper, and a chip truck. Their annual fixed costs are FIM 400 000, FIM 500 000, FIM 400 000, and their variable hourly costs are FIM 100, FIM 200, and FIM 100, respectively. It is assumed that average productivity of the whole system is 50 m^3(loose)/E15-h. The unit costs of harvesting decrease first, but whenever a new system is hired, they rapidly increase, because both systems must be worked below their capacity limits. Again, as both systems are worked close to their capacity limits, the unit costs reach their minimum. In practice, outsourcing machines to harvest the small extra amount, which the existing system can not harvest, often results in lower costs.

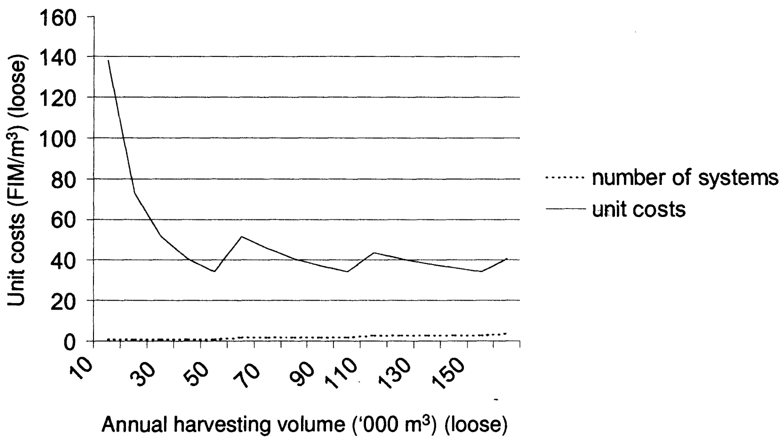

FIG. 3—Effect of annual employment of harvesting systems on unit costs.

Extensive use of forest biomass for energy generation can markedly increase harvesting costs for a number of reasons. When the share of harvested logging residues is very small compared to the potential, only the best stands are harvested. This means that the management can select stands located near the boiler plant, aiming at high yields of material per hectare and short forwarding distances. As larger and larger amounts of wood fuel are recovered, harvesting must be extended to more remote and less favourable areas. This effect of scale differs markedly in different geographical conditions. In Finland, the best resources for logging residue recovery are situated in the central parts of the country.

The amount of fuel a power plant is able to get (logging residues from final-felling operations) at a given average cost of wood delivered at the mill, is indicated in Fig. 4. Plants located near the coast have to procure their wood from within a semicircular area, whereas

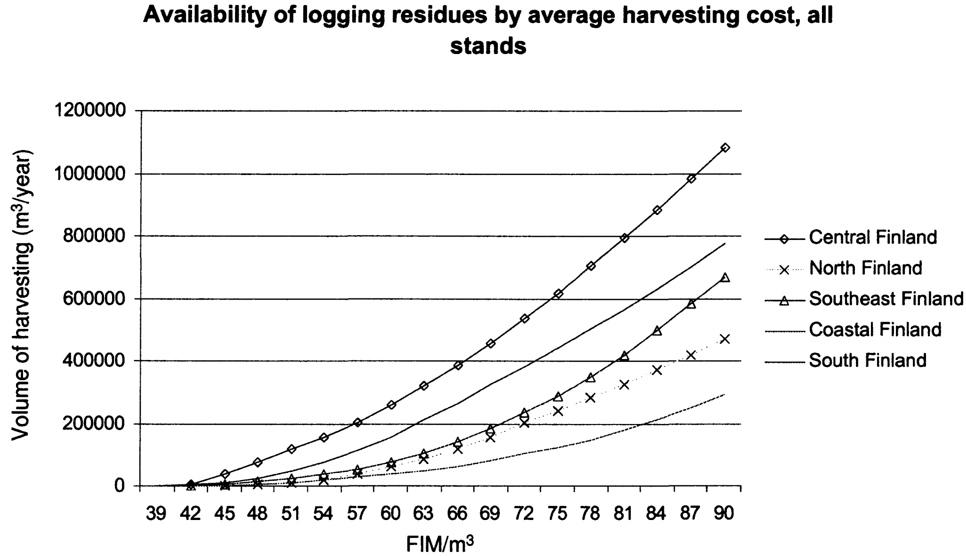

FIG. 4—Effect of scale of wood fuel procurement and plant location on harvesting and transportation costs.

plants in the interior can procure wood from all around the mill. This has a considerable effect, especially on transport costs. In Finland, forests located near the coast are typically pine-dominated and thus the density of energy wood is markedly lower than in spruce-dominated stands in central and eastern Finland.

ORGANISATION OF WOOD FUEL PROCUREMENT

When large forest-industry companies start recovering wood fuel, fairly simple management tools can be used. Even a spreadsheet application with links to the company's logging site database and map software is sufficient. A manager can run the system as long as there are only a limited number of sites and logging systems operating, and only a few boiler plants to be supplied. But as the scale of operation grows, more sophisticated management and control systems are needed. Because energy wood recovery should be a part of every forest-industry company's operations, its integration with larger management systems becomes a necessity.

Integration in a complex roundwood procurement management system is very difficult if the nature of a new harvesting and transport system differs markedly from what the existing system was built to cope with. GIS systems can usually be easily integrated: the locations of landings and volumes of timber assortments are basically similar in wood fuel and industrial roundwood harvesting systems. The difficulties begin with the chipping and transport phases. If chipping at the landing is used, a chip truck must be utilised in long-distance transport. The operation principle and truck type are such that transport optimisation routines must be appropriate for a different operation principle. This is often a very demanding and costly task and can cause operational instability throughout the wood-flow management system.

The simplest solutions can be achieved if the transportation means and operation principles of the wood fuel procurement system are similar to those of roundwood procurement. In this sense, the prototype Swedish technology producing cylindrical residue bundles, "residue logs" as it were, is ideal. Residue logs can be handled in a manner similar to that of roundwood. The same machines can be used in off-road transport and truck transport. Existing transport optimisation tools can be directly applied. No specific machinery is needed in material handling once the aforementioned residue logs have been formed. Timber trucks are used mainly for roundwood transportation and thus logging residue bundles are just one wood assortment among others.

Considerable savings can be achieved in organisational costs. These costs in energy wood harvesting (running the operation, searching of suitable harvesting site, etc.) have been high. A typical figure is FIM 8/m^3, whereas the figure for roundwood procurement is a mere FIM 3/m^3. The effect of organisational costs is demonstrated in Fig. 5. In the chip transport alternative, chipping is done at the roadside, while in systems based on transporting residues and residue logs chipping is done at the plant. For loose residue and chip transport systems, the organisational costs are generally FIM 8/m^3. What may be called the "cigar bundling" system is not a competitive one if the organisational costs are the same as in energy wood harvesting (FIM 8/m^3). However, if the costs are lowered to the level typical for roundwood harvesting (FIM 3/m^3), bundling-based harvesting becomes competitive.

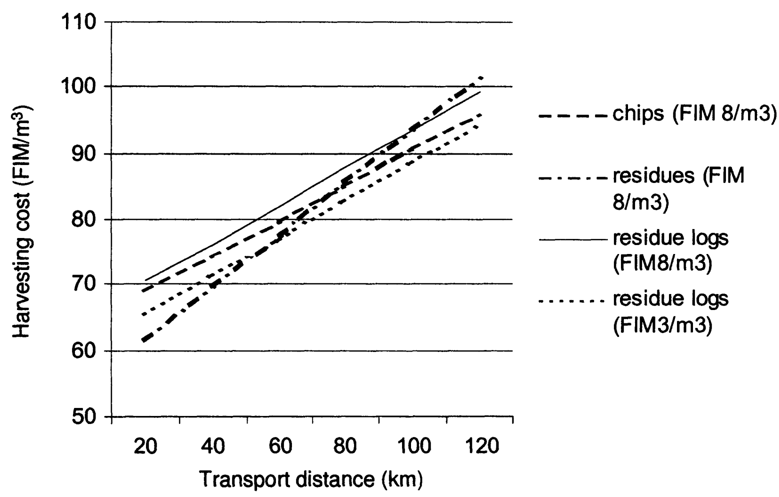

FIG. 5–Effect of organisational costs on procurement costs.

WOOD QUALITY AS A COST FACTOR

The quality of energy wood affects fuel costs in several ways. Impurities such as stones, metals, and sand can damage chippers provided with cutting blades, necessitating more frequent replacements or sharpening. Chipper productivity is impaired due to dullness of the blades and the same applies to the particle size distribution of the chips produced. Blade costs are FIM 1–2/m^3 loose for green logging residues without impurities. The normal figure for blade costs is FIM 2–3/m^3 loose. Dry residues cause 10–20% higher blade costs and impurities among the material can raise the blade cost up to FIM 5/m^3 loose.

The moisture content of wood also affects the transport cost of the material. Freight costs are based on the weight of the loads. Thus, the more water there is in the material, the less fuel is transported. Furthermore, high water content, and especially its variation, causes problems for combustion process control.

Reducing the moisture content calls for storage of the material either on the site, at landings, or at the terminal/plant. Storing promotes the effective energy content of the material, especially when the storage involves providing protection from rain (Brunberg *et al.* 1998). In the case of tree sections the value of the wood material increased by 12% during storage. This could have been more but storage can also cause considerable raw material losses (Brunberg *et al.* 1998). For instance, the storage of spruce material can lead to 20–30% losses due to defoliation. As a result, recovery rate at the site diminishes. The number of potential recovery sites becomes too small in volume, and thus the radius for procurement area increases. This raises trucking costs. In addition, the loading times for forwarders or in-woods chippers can increase due to lower material density (Kärhä 1994).

Infrastructures, handling techniques, boilers, and volume and quality requirements for raw material differ according to the size and combustion principle of energy plants. Moisture content, net caloric value, energy density, and particle size are the foremost factors in practical wood energy trade. Quality manuals for solid wood fuels, for firewood, and for recovered biofuels have been produced in Finland—Quality Assurance for Solid Wood Fuels (FINBIO 1998a), Quality Assurance for Firewood FINBIO 1998b), Quality Assurance for Recovered Fuels (FINBIO 1998c). These manuals, made for commercial purposes, are based on wood fuel quality classification in accordance with the foremost wood fuel characteristics from the point of view of energy plant operation.

CONCLUSIONS AND DISCUSSION

The profitability of wood fuel procurement can be increased by efficient targeting of harvesting operations to stands where the conditions are favourable for energy wood recovery. Running of operations in an optimal way calls for knowledge of the factors influencing procurement costs. Furthermore, information on how each system works under different conditions is required when selecting machinery for different conditions.

The scale of operations has a major impact on procurement costs. Full employment of the acquired machinery is important from the wood fuel entrepreneur's point of view. Expensive machines involve high capital costs and thus they must be used close to their capacity to be economical. Large boiler plants units must purchase wood over a wide geographical area. The areal availability of wood fuels varies according to forest structure and the shape of the procurement area. Therefore, a careful examination of availability and price of wood should precede a decision to build a plant in a certain place.

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