NEW HARVESTING TECHNOLOGY IN FOREST FUEL PROCUREMENT

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ABSTRACT: In order to increase the use of forest fuels a regional development project was launched in the fall of 2008. The coordinator of the project is Metsäkeskus Keski-Suomi (Forestry Centre of Central Finland) while VTT (Technical Research Centre of Finland) is in charge of research and technical development. The aim of this project is to enhance energy wood procurement from early thinnings, to develop the supply chains of pine stump extraction, and to decrease storage losses of energy wood at roadside and terminals.
The results of a prefeasibility study on the first generation feller-bundler (Fixteri) by Metsäteho Oy and the Finnish Forest Research Institute indicate that whole-tree bundling might enable undercutting the current costs of the separate procurement of pulpwood and energy wood from first-thinning stands. The greatest cost-saving potential lies in small-diameter ($d_{1.3}$ = 7–10 cm) first-thinning stands, which are currently relatively unprofitable sites for conventional pulpwood procurement based on single-tree harvesting.
Preliminary tests of seasoning of whole-tree bundles have been very encouraging. In some cases the moisture content of energy wood bundles has decreased from 55% to 25% after about year of seasoning at roadside (two summers).
One of the most promising devices for pine stump harvesting was developed by Karelian Puu ja Metalli Oy.

Keywords: Felling-bundling, pine stumps, storage

1 INTRODUCTION

There are very challenging goals for the use of forest fuels in Finland. So far a vast majority of these fuels have consisted of logging residues from spruce dominated logging sites. However, in the future final fellings in this kind of logging sites are going to decrease due to the planned cuts. According to forest inventories the greatest unused forest fuel potential is in young forests, particularly in unmanaged stands. Another new source for forest energy is pine stumps that are not used nowadays because of difficulties in extraction.

In order to increase the use of forest fuels, particularly in Central Finland, a regional development project was launched in the fall of 2008. The coordinator of the project is Metsäkeskus Keski-Suomi (Forestry Center of Central Finland) while VTT (Technical Research Center of Finland) is in charge of research and technical development. Important subcontractors are Metsäteho Oy and Metla (Finnish Forest Research Institute). This project is predominantly funded by EU (ERDF) while the main co-financing companies are Jyväskylän Energia Oy and Vapo Oy.

The aim of this project is to enhance energy wood procurement from early thinnings, to develop supply chains of pine stump extraction, and to decrease storage losses of energy wood at landings. In practise, the utilization of potential energy wood is not only a technological and economic challenge but it is also intertwined with the willingness of the forest owner to allow such harvesting operations in his forest. For this reason research results of the project and good practise examples of sustainable forest management are presented to all important share holders through media and harvesting demonstrations.

2 FELLING-BUNDLING

Because harvesting of energy wood from pre-commercial thinnings is very expensive, it is not always profitable and therefore such operations are often neglected. In this project a new method of bundling whole trees was chosen to be studied in detail because the results of the pre-feasibility study on the Fixteri bundle harvester, conducted by Metsäteho Oy and the Finnish Forest Research Institute, were promising. The calculations indicated that whole-tree bundling might enable undercutting the current costs of the separate procurement of pulpwood and energy wood from first-thinning stands (Fig. 1) [1].

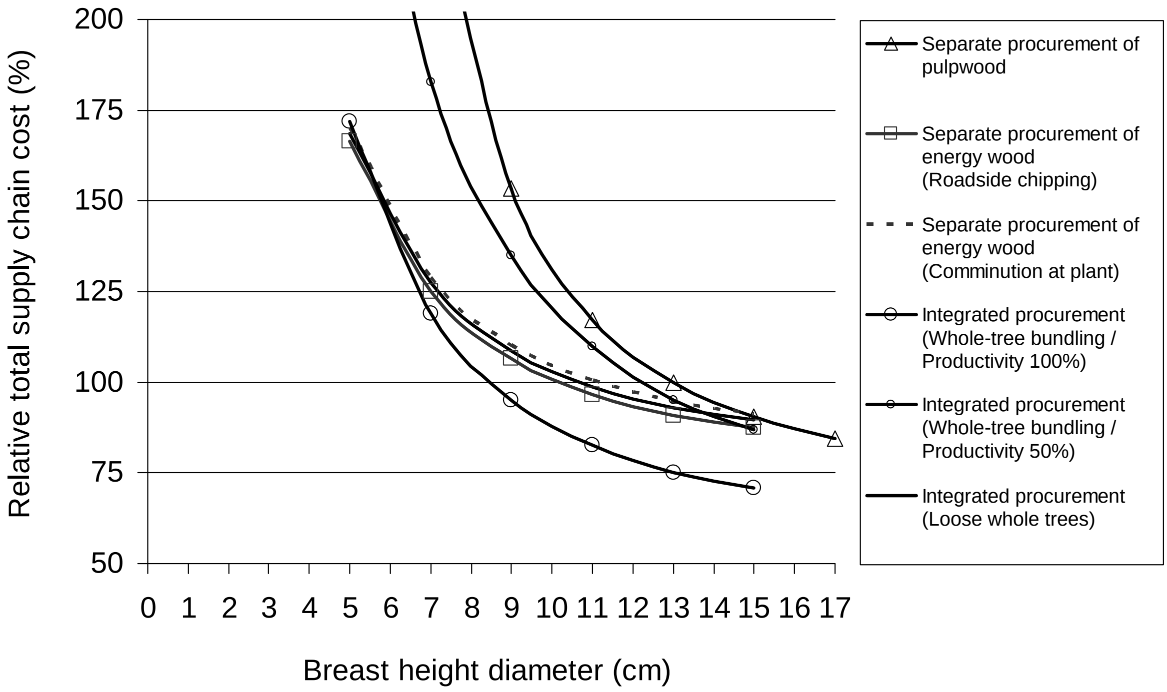

Figure 1. The pre-feasibility study on the Fixteri whole-tree bundler shows that integrated harvesting based on this concept can be the most cost-effective method when harvesting 7-14 diameter trees [1].

2.1 Felling-bundling concept explained

High harvesting costs, particularly cutting costs, is the main problem in early thinnings when harvesting both industrial roundwood (i.e. pulpwood) and energy wood. In order to increase the annual volumes of energy wood and pulpwood harvested from early thinnings, their harvesting costs will have to be significantly reduced. This can be done through in-depth integration of pulpwood and energy wood procurement using a recently developed supply system based on whole-tree bundling.

In 2007, the first prototype of the Fixteri bundle harvester capable of incorporating compaction into the cutting phase was launched by Biotukki Oy (www.biotukki.fi). Cost savings, especially in off-road and on-road transportation, can be achieved by increasing the load sizes of un-delimbed assortments by compacting them into bundles of about 0.3-0.5 m^3 in solid volume.

Figure 2. Fixteri whole-tree bundler at work. Photo: Kalle Kärhä/Metsäteho Oy.

The first prototype of the bundler was mounted on the rear end of a Valmet 801 Combi harwarder (Fig. 2). The work cycle of the Fixteri whole-tree bundler is as follows:

- The trees are felled and accumulated into bunches with an accumulating harvester head. Thereafter, the bunch of whole trees is lifted onto the feeding table of the bundler.
- The feeding rolls pull the stems into the feeding chamber of the bundling unit.
- The stems fed into the feeding chamber are cut to a length of 2.6–2.7 metres with a chain saw installed at the chamber gate.
- The stems sections are lifted from the feeding chamber into intermediate storage above.
- A sensor detects the amount of wood in the intermediate storage, in which the trees are compacted. When the storage is full, the bundle is lifted into the compressing chamber above for the final compaction and wrapping with sisal string.
- After wrapping, the bundle is dropped down along the strip road.

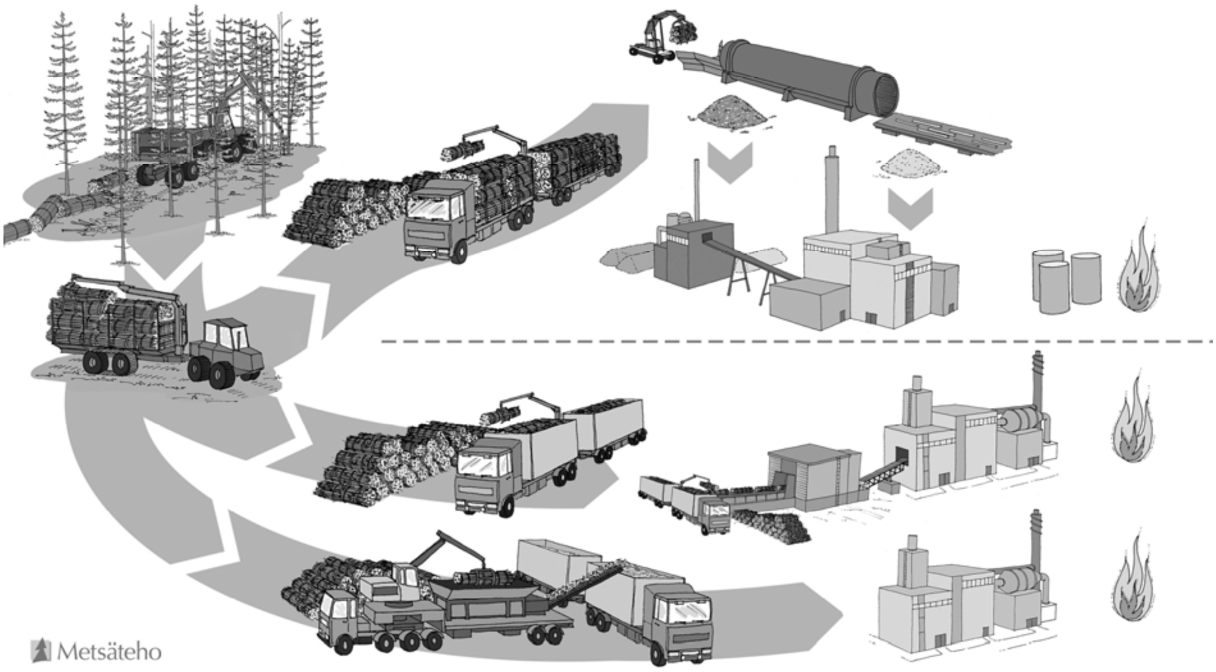

Figure 3. Supply chains of whole-tree bundles. The top figure illustrates an integrated pulpwood and energy wood supply chain and the bottom one an energy wood chain. Source: Metsäteho Oy.

Except for placing bunches onto the feeding table, the bundling process is autonomous, enabling simultaneous cutting and accumulation of subsequent bunches. In addition to bundles with pulpwood-dimensioned trees, separate energy wood bundles composing of undersized trees and undesirable tree species can be produced. The bundles are hauled by a standard forwarder to the roadside storage, from where pulpwood bundles are transported by a standard timber truck to the pulp mill and potential energy wood bundles to the end-use facility to be comminuted for energy generation.

In the case of pulpwood bundles, separation of the pulpwood and energy wood fractions takes place in the debarking drum. The pulpwood bundles are fed into the debarking process as blends with conventional delimbed pulpwood harvested from first thinnings. The method enables to increase the volumes of energy wood harvested from early thinnings without endangering the pulpwood supply for the forest industry (Fig. 3).

In a feasibility study carried out by Metsäteho Oy and the Finnish Forest Research Institute, the required productivity level of bundle harvesting (i.e. cutting and bundling) in Scots pine (*Pinus sylvestris* L.) dominated stands was assessed by comparing the total supply chain costs of the system based on whole-tree bundling with those of the other pulpwood and energy wood supply chains by means of system analysis.

The calculations indicated that whole-tree bundling enables undercutting the current costs of the separate procurement of pulpwood and energy wood from first-thinning stands. The greatest cost-saving potential lies in small-diameter ($d_{1.3}$ = 7–10 cm) first-thinning stands, which are currently relatively unprofitable sites for conventional pulpwood procurement based on single-tree harvesting.

The productivity of the bundle harvester, however, will have to be raised well above 50% of that of conventional feller-buncher. This means, for example, that the performance of bundle harvesting must exceed 4.6 m^3 (9.2 bundles) per effective hour (E_0, excluding delays) with bundle size of 0.5 m^3, when the breast height diameter (DBH) of the trees to be removed is 7 cm. In the case of trees with DBHs of 11 and 13 cm, the productivities must exceed 7.6 and 8.7 m^3/E_0-hour (15.1 and 17.4 bundles/E_0-h), respectively. [1]

Figure4 . Fixteri bundler can also be mounted on an excavator. Photo: VTT.

Cost savings with the procurement system based on whole-tree bundling can be achieved especially in the case of relatively long forest haulage and road transportation distances. In the experiment conducted by Laitila and Jylhä, an average of 23 whole-tree bundles per load were transported by a standard medium-sized forwarder, resulting in 8–12 m3 (6100–10 700 kg) of woody biomass even without load space modification. [2] This is 30-100 % more than an average whole-tree load volume of medium-sized standard forwarders. [3] When transporting bundled whole-tree material, standard trucks with a higher load capacity of about 40 tons can be used.

When whole-tree bundling is applied to the harvesting of energy wood ($d_{1.3}$ <7 cm) only, significant cost savings are not achieved. However, in the present market situation it is well possible that more pulpwood sized trees are harvested for energy.

Figure 5. Whole-tree bundles are left at strip road to be forwarded to a landing. Photo: Ari Erkkilä/VTT.

2.2 Further studies

Metsäteho Oy and the Finnish Forest Research Institute will carry out further time studies and economic analyses on the whole-tree bundling system in 2009. The R&D project is funded by the National Technology Agency (Tekes) and the Finnish forest industries. VTT will cooperate with the above mentioned organizations in drawing conclusions on how to use the whole-tree bundling supply chain in a feasible way.

In the regional research project the following aspects are studied:

- productivity of felling-bundling and forest haulage of bundles
- interconnectedness of weight, volume, shares of pulp and energy wood, and basic characteristics of the stand
- production costs of the whole felling-bundling chain and comparison with other procurement chains
- defining of optimal use of such a machine.

In addition VTT, in cooperation with the manufacturer, will develop technical solutions for partial debarking of energy wood stems in order to hasten drying. Preliminary tests of seasoning of whole-tree bundles have been very promising. In some cases the moisture content of energy wood bundles has decreased from 55% to 25% after about a year of seasoning at roadside (two summers).

3 PINE STUMP LIFTING

One of the most common stump extraction methods is to use an excavator equipped with a simple stump rake that splits the stump and roots while pulling them off ground. Another commonly known apparatus is fitted with two counter pieces against which a cutting blade turns to split the tree stump in two. However, both devices were developed for stumps of spruce trees. Roots of spruce trees are thick and close to surface which enables splitting and pulling with a simple stump rake. The rooting system of pine trees is different. A substantial part of the woody biomass of the pine stump is in its tap root which requires much more power in pulling. If direct pulling is used, the boom and lift cylinders and other such parts of an excavator are heavily strained and are likely to wear out much faster than in usual work.

A new extraction device, developed by Karelian Puu ja Metalli Oy, splits the stump into four parts while pulling the stump off ground (Fig. 6). The whole tree stump is intended to be pulled out using the tips of the cutting blades and subsequently to be cut by the application of a compressive force with two pairs of arms applying the force to the tree stump in turns. As a result much less pulling power is needed, and therefore the device might be possible to install even to a forest machine (e.g. forwarder). The same company has also developed a special grapple for the loader of a forwarder for cleaning and handling of stumps. [4] In preliminary tests these two devices have improved the quality of chips from stump wood and made the extraction of pine stumps easier.

In summer 2009 VTT will do time and productivity studies on the new stump harvester.

Figure 6. A new stump lifting and splitting device by Karelian Puu ja Metalli Oy. Photo: Dominik Röser/Metla.

4 STORING OF ENERGY WOOD

Research on storing of energy wood and storage losses of forest fuels is divided in the following tasks:

- effect of seasoning and storage methods on the moisture content and material losses of energy wood
- state-of–the-art study of previous studies on storing logging residues and residue bundles at roadside
- developing a model with which an average moisture content of stump wood in storage can be estimated.

Four different kinds of forest fuels are included: logging residues (tops and branches), small-diameter whole trees, whole-tree bundles and stumps. One of the main aims of this study is to find out how the moisture content and quality of whole-tree bundles change during the storing at a landing and a terminal. Another focus is to develop an easy to use model for estimating the moisture content of tree stumps stored in an intermediate storage. It is particularly needed for contractor and end users of wood fuel to optimize fuels flows from storage to plant. [5]

Figure 7. Whole-tree bundles stored at landing, and ready for being transported to a pulp mill. Photo: Kari Hillebrand/VTT.

5 CONCLUSIONS

New development in small-diameter wood harvesting technology and extracting of pine stumps have shown promising results. However, with practical studies and some technical improvements the productivity and feasibility of both supply chains should be further improved. With proper management of storing of energy wood (place, technique, timing) storage losses can be reduced and the quality of chips improved.

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