Supply Systems of Forest Biomass in Finland

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Abstract:
The Metsäteho study investigated how logging residue chips, stump wood chips, and chips from small-diameter thinning wood and large-sized (rotten) roundwood used by heating and power plants were produced in Finland in 2010. Almost all the major forest chip suppliers in Finland were involved in the study. The total volume of forest chips supplied in 2010 by these suppliers was 9.5 TWh. Research data was collected from March-May, 2011. The majority of the logging residue chips and chips from small-diameter thinning wood were produced using the roadside chipping supply system in Finland in 2010. The chipping at plant supply system was also significant in the production of logging residue chips. More than 50% of all stump wood chips consumed were comminuted at the plant and 41% at terminals. When producing chips from large-sized (rotten) roundwood, roughly 60% of chips were comminuted at terminals and 28% at plants.

Keywords: forest residues, production, supply chains, technology, wood chip.

1 Introduction

The use of forest chips in Finland has increased very rapidly in the 21st century: In the year 2000, the total use of forest chips for energy generation was 1.8 TWh (0.9 mill. m^3), while in 2010 it was 13.8 TWh (6.9 mill. m^3) (Ylitalo 2011a). Of this amount, 12.5 TWh was used in heating and power plants, and 1.3 TWh in small-sized dwellings, i.e. private houses, farms, and recreational dwellings, in 2010 (Fig. 1) (Ylitalo 2011a).

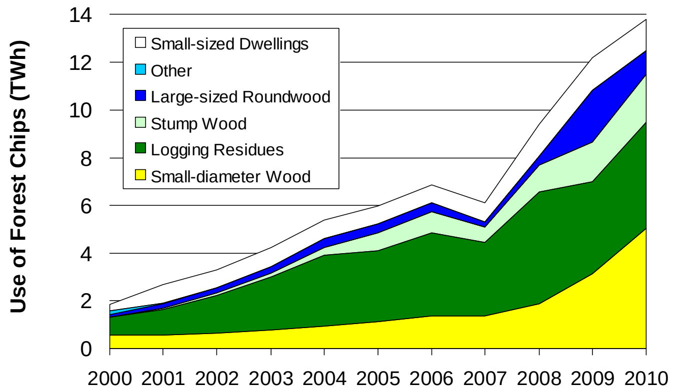

Figure 1: Total consumption of forest chips for energy generation in the 21st century in Finland (Ylitalo 2011a)

Of the forest chips used in heating and power plants (12.5 TWh), 41% came from small-diameter ($d_{1.3}$<10 cm) thinning wood produced from the tending of young stands (Ylitalo 2011a). Of the total amount of commercial forest chips used for energy generation, more than one third was produced from logging residues in final cuttings in 2010 (Fig. 1) (Ylitalo 2011a). Forest chips derived from stump and root wood totaled 16%, while 8% came from large-sized (rotten) roundwood.

In 2010, forest chips were burned by approximately 800 heating and power plants in Finland (Ylitalo 2011a). The majority of energy plants annually consume less than 10 GWh (around 5,000 m^3/a) of forest chips (Fig. 2) (Ylitalo 2011b). There are currently only eighteen large (forest chip consumption >200 GWh in 2010) power plants in Finland (Ylitalo 2011b). However, they consume more than half of the forest chips used in Finland (Fig. 2). The use of forest chips is currently the greatest in Southern and Central Finland, and relatively low in Northern Finland (Fig. 3) (Ylitalo 2011a; 2011b).

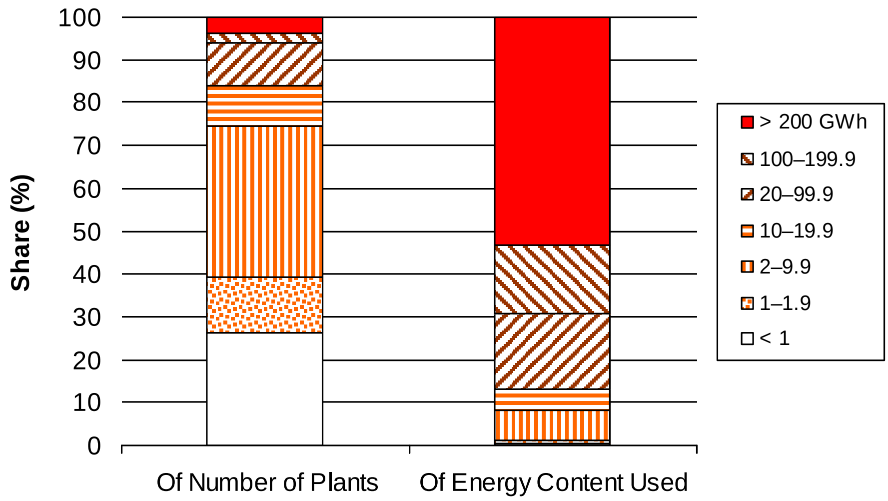

Figure 2: Use of forest chips by the class of energy content (GWh) used in heating and power plants in 2010 in Finland (Ylitalo 2011b). Figures are based on the data of the Finnish Forest Research Institute: the use of forest chips 12.2 TWh in total of 498 energy plants in 2010. The figures exclude the data of TTS Research's small heating plants (0.3 TWh & around 300 plants).

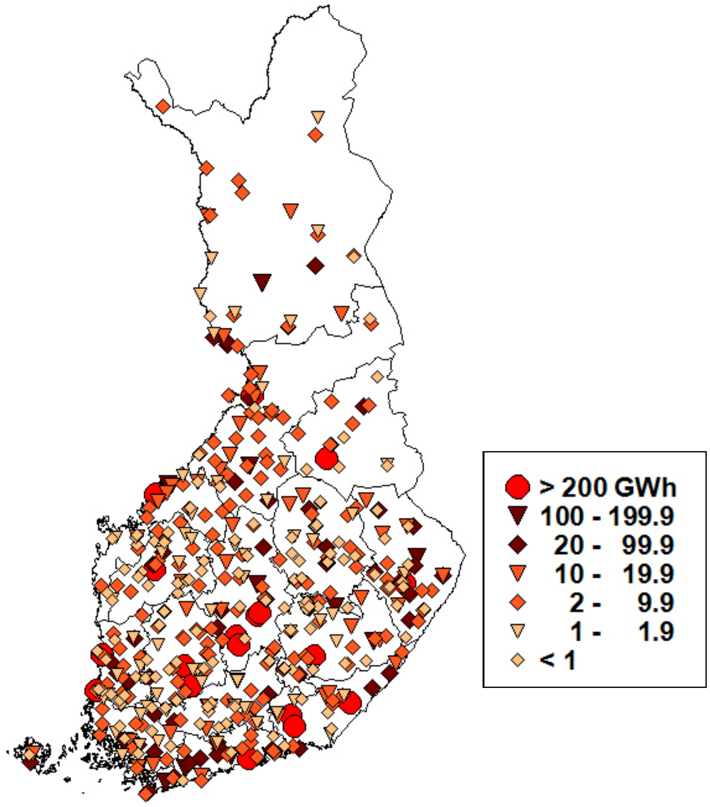

Figure 3: Use of forest chips by forestry centre in 2010 in Finland (Ylitalo, 2011b)

Metsäteho Oy has annually surveyed the supply systems used in the production of forest chips in the 21st century in Finland (Kärhä 2005a; 2005b; 2006a; 2007a; 2008; 2009; 2010). The Metsäteho study also investigated how logging residue chips, stump and root wood chips, and chips from small-diameter thinning wood and large-sized (rotten) roundwood used by heating and power plants were produced in Finland in 2010. The main results of the study are presented in this conference paper.

2 Material and methods

The supply systems of forest chips were investigated in the questionnaire of Supply Systems of Forest Biomass in 2010, which covered the production of logging residue chips, stump and root wood chips, chips from small-diameter thinning wood, and chips from large-sized (rotten) roundwood. In the survey, the supply systems were determined as follows:

- Terrain chipping: comminution at the harvesting site,
- Roadside chipping: comminution with a chipper or crusher at a roadside landing and road transportation of chips from the roadside to the plant,
- Terminal chipping: forest chip raw materials (loose or bundled) to the terminal for comminution, and then transportation of the chips by truck/train/barge from the terminal to the plant, and
- Chipping at plant: forest chip raw materials (loose or bundled) to the plant for comminution.

Almost all the major forest chip suppliers in Finland were involved in the study. The total volume of forest chips supplied in 2010 by these (14) suppliers was 9.5 TWh (Table 1). The study was implemented by conducting an email questionnaire survey. Research data was collected from March-May, 2011.

Table 1: Use of different types of forest chips at heating and power plants in 2010 in Finland (Ylitalo 2011a), and the total energy content supplied in 2010 by the forest chip suppliers who participated in the survey.

Type of forest chips	Total volume used in Finland (Ylitalo, 2011a)	Total energy content supplied by suppliers
	TWh	
Logging residue chips	4.4	3.5
Stump wood chips	2.0	1.9
Chips from small-diameter wood	5.1	3.3
Chips from large-sized (rotten) roundwood	1.0	0.7
Total	12.5	9.5

3 Results

3.1 Logging residue chips

The best sites in Finland, and therefore those mainly used for recovering logging residues, are Norway spruce (*Picea abies* L. Karst.) dominated final cuttings. The typical logging residue removal is approximately 75–100 MWh/ha.

Figure 4 shows that the most common place to comminute logging residues for chips is a roadside landing. In 2010, the total proportion of roadside chipping supply systems was 70% (Fig. 4). Comminution of logging residues at power plants comprised of 23% of the total share in 2010 (Fig. 4). The share of chipping loose residues at the plant was 13%, and the share of chipping logging residue bundles at the plant was 10%. Currently, logging residues are bundled by approximately 10 slash bundlers in Finnish forests (cf. Kärhä, 2007b; 2011). The proportion of terminal chipping supply system was 7% in 2010 (Fig. 4).

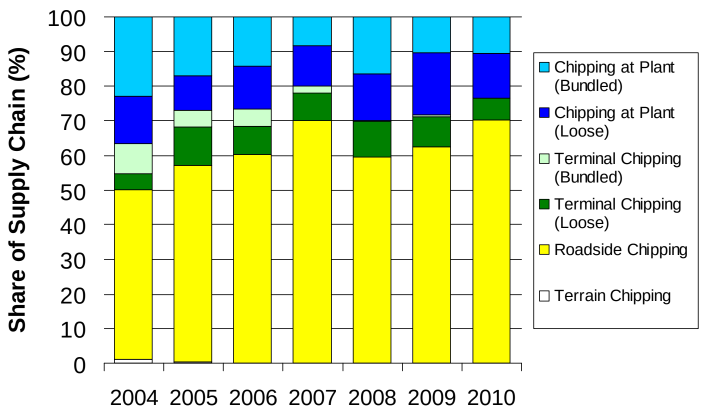

Figure 4: Proportions of different supply systems in the production of logging residue chips during 2004–2010 in Finland

3.2 Stump wood chips

Intensive development of stump and root wood harvesting began in Finland in the early 2000's. Today stump wood is a competitive wood fuel, especially for large power plants. This is clearly evident in the stump chip supply system figures: More than 50% of all stump wood chips used for energy generation in 2010 were produced at power plants (Fig. 5). In 2010, 41% of all the stump and root wood comminution was performed at terminals. Small stump wood batches were also comminuted at the roadside landings by mobile crushers.

In Finland, stumps for energy generation are extracted almost exclusively from spruce-dominated, final felling stands. Furthermore, there are currently several stump lifting tests in Scots pine (*Pinus sylvestris* L.) dominated stands (Jouhiaho & Mutikainen 2010; Erkkilä et al. 2011). The typical stump wood removal is 150–180 MWh/ha. The period for stump lifting is limited to May-November when the ground has thawed. Heavy-duty (working weight around 20 tonnes) tracked excavators are mainly used for the lifting of stumps (Kärhä 2007b; 2011). Approximately 200 excavators are currently used for stump lifting in Finland (cf. Kärhä 2007b; 2011).

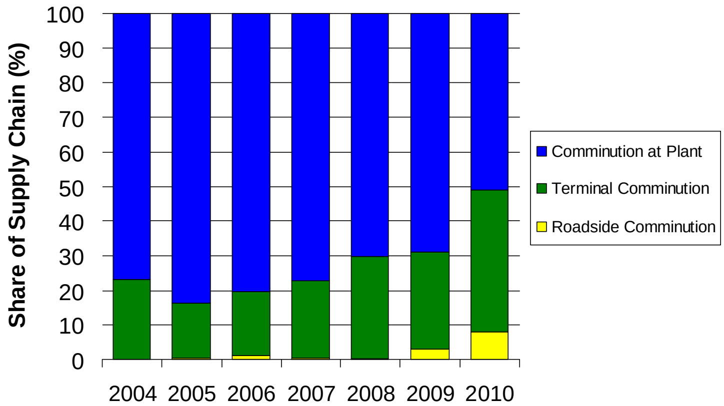

Figure 5: Proportions of different supply systems in the production of stump wood chips during 2004–2010 in Finland

3.3 Chips from small-diameter thinning wood

Chips from small-sized thinning wood are produced in Finland from small-diameter (mainly $d_{1.3}$<10 cm) whole trees and delimbed stemwood harvested in young stands. The typical whole-tree removal is 80–120 MWh/ha. When harvesting energy wood as delimbed stemwood, the removals are lower than with whole trees. Roadside chipping still maintains an important role in the production of chips from small-diameter thinning wood: In 2010, 83% of all forest chips from small-sized wood were chipped at roadside landings (Fig. 6). The share of terminal chipping was 10%. The proportion of chipping at the power plant was 7% in 2010 (Fig. 6).

In Finland, two mechanized harvesting systems are used for small-diameter thinning wood:

- the traditional two-machine (harvester and forwarder) system, and
- the harwarder system (i.e. the same machine performs both cutting and forest haulage to the roadside) (Kärhä, 2006b).

Currently, there are some 300–350 harvesters equipped with either a felling head or energy wood harvester head with accumulating and feeding properties for cutting small-sized thinning wood in young stands (cf. Kärhä 2007b; 2011). There are also more than 50 energy wood harwarders in use in Finland.

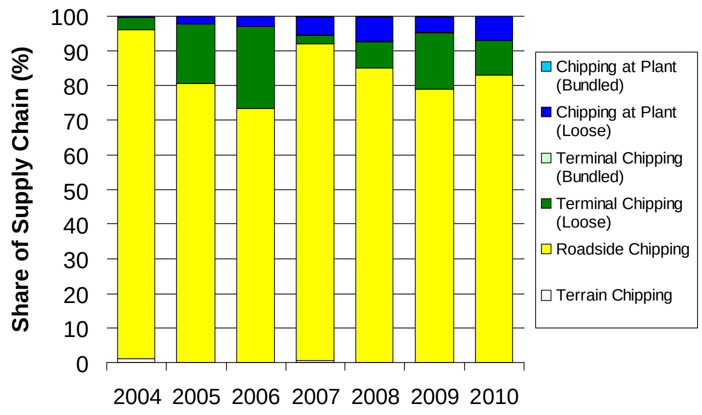

Figure 6: Proportions of different supply systems in the production of chips from small-diameter thinning wood during 2004–2010 in Finland

3.4 Chips from large-sized (rotten) roundwood

In 2010, the proportion of the terminal chipping supply system was 59%. Nearly 30% of the large-sized roundwood for energy generation was comminuted at power plants (Fig. 7). Correspondingly, the share of roadside chipping was 13% in the production of chips from large-sized roundwood in 2010 (Fig. 7).

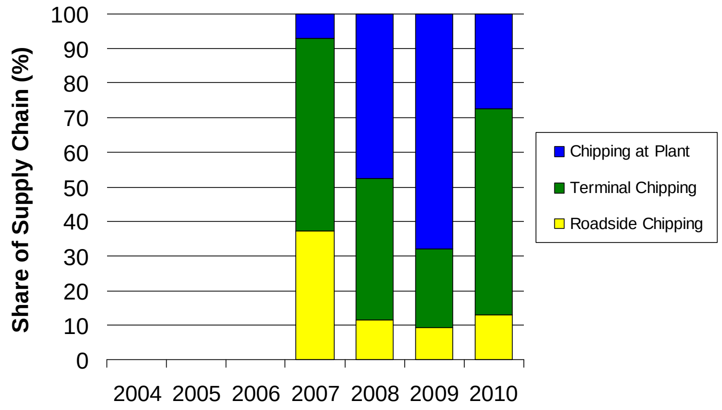

Figure 7: Proportions of different supply systems in the production of chips from large-sized (rotten) roundwood during 2007–2010 in Finland.

4 Discussion and conclusions

Each supply system has its own strengths and weaknesses (Table 2). The harvesting conditions, roadside landing capacities, road transportation distances, operating volumes and storage capacities of heating and power plants, availability of production machinery, the type of forest chips (i.e. logging residue chips, stump chips, and chips from small-diameter thinning wood and large-sized roundwood) produced, and naturally, the total supply system costs, each determine which forest chip supply system is used. Due to the unique characteristics of the supply chain at any given time, no single universal supply system exists (Kärhä 2007c).

Table 2: The main strengths and weaknesses of different supply systems in the production of forest chips (Kärhä 2007c).

Supply system	Strength	Weakness
Terrain chipping	• Chipping and forest haulage with same unit • Small harvesting sites • Small roadside storage space • Cleanliness of storage areas after harvesting operations.	• Ineffective chipping • Uneven harvesting sites • Size of terrain chipper's container • Long forwarding distances • Uneven and muddy storage areas • Breakdowns • Winter conditions.
Roadside chipping	• Flexibility • Considerable experience in roadside chipping • Availability of harvesting machinery.	• "Hot" system • Utilization rate of chipper • Large roadside storage space for forest chip raw materials • Small and muddy storage areas for machines • Untidy roadside storage areas after harvesting operations.
Terminal chipping	• No hot system • Good quality management of chips • Security of chip deliveries • Chips to several small plants • Plants with small storage fields or stocks • Small harvesting sites • Effective comminution • Winter conditions.	• Establishment expenses of new terminal • Identifying appropriate terminal areas • Extra handling times • Relatively high total supply system costs.
Chipping at plant (Loose)	• No hot system • Large-scale production • Powerful comminution • Most cost-efficient total supply system with relatively short transportation distances.	• Energy content of loose material loads • Long transportation distances • Long-distance transportation costs • Large roadside storage space and large storage fields at the plants are required • Untidy roadside storage areas after harvesting operations.
Chipping at plant (Bundled)	• No hot system • Large-scale production • Effective forest haulage • Low forest haulage costs • Small roadside storage space • Long transportation distances • (Timber truck in long-distance transportation) • Powerful comminution • Low comminution costs.	• High bundling costs • Bundling strings when using slow-speed crushers.

There are very challenging targets for the future usage of forest chips in Finland. The aim is to increase the annual consumption of forest chips for energy generation up to 25 TWh by 2020 (Pekkarinen 2010). As the supply volumes of forest chips increase, intensified procurement is necessary, meaning harvesting operations must expand to include smaller and poorer quality sites (i.e. less removals, more difficult terrain, and longer forwarding distances). It is also likely that road transportation distances will be somewhat longer in the future than today. All these factors mean increased cost pressures on the total supply system costs of forest chips.

In the future, the management of supply costs in all phases of the logistics system will hold vital positions (Kärhä 2007c; 2011). The individual parts of the supply systems should work more efficiently (e.g. utilize the most efficient working methods, adoption of the most suitable production technology, maximization of loads in forest haulage and road transportation) and especially, increase integration between supply systems (e.g. minimization of waiting and terminal times). Moreover, quality management of chips (i.e. moisture content in the case of logging residues, and impurities with stumps) has to be increased to a suitable level than it is presently.

Kärhä (2007a; 2007c; 2011) estimated that comminution will move from roadside locations closer to the heating and power plants, partly to terminals, and partly directly to the plants. This will undoubtedly prove to be the case as, in approximate terms, the closer to the plant chipping is performed, the more cost-efficient it is. Differences will, nevertheless, remain between forest chip suppliers regarding the volumes of forest chips produced in terminals and at the plant. As the volumes of uncomminuted raw materials in road transportation used for forest chips increases in the future, more efficient long-distance transportation solutions (e.g. railway, waterway, precomminution, bundling) are required, and also the status of the terminals will become more important.

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