SUPPLY CHAINS OF FOREST CHIP PRODUCTION IN FINLAND

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ABSTRACT: The Metsäteho study investigated how logging residue chips, stump wood chips, and chips from small-sized thinning wood and large-sized (rotten) roundwood used by heating and power plants were produced in Finland in 2008. Almost all the major forest chip suppliers in Finland were involved in the study. The total volume of forest chips supplied in 2008 by these suppliers was 6.5 TWh. The study was implemented by conducting an e-mail questionnaire survey and telephone interviews. Research data was collected in March-May 2009. The majority of the logging residue chips and chips from small-sized thinning wood were produced using the roadside chipping supply chain in Finland in 2008. The chipping at plant supply chain was also significant in the production of logging residue chips. 70% of all stump wood chips consumed were comminuted at the plant and 29% at terminals. The role of the terminal chipping supply chain was also significant in the production of chips from logging residues and small-sized wood chips. When producing chips from large-sized (rotten) roundwood, nearly a half of chips were comminuted at plants and more than 40% at terminals.
Keywords: Comminution, Energy wood, Finland.

1 INTRODUCTION

The use of forest chips in Finland has increased 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 2008 it was 9.2 TWh (4.6 mill. m^3) [1]. Of this amount, 8.1 TWh was used in heating and power plants, and 1.1 TWh in small-sized dwellings, i.e. private houses, farms, and recreational dwellings, in 2008 (Fig. 1) [1].

Of the forest chips used in heating and power plants (8.1 TWh), the majority (58%) was produced from logging residues in final cuttings in 2008 (Fig. 1) [1]. Forest chips derived from stump and root wood totalled 14% and 4% came from large-sized (rotten) roundwood. 24% of the total amount of commercial forest chips used for energy generation came from small-diameter ($d_{1.3}$<10 cm) thinning wood produced in the tending of young stands [1].

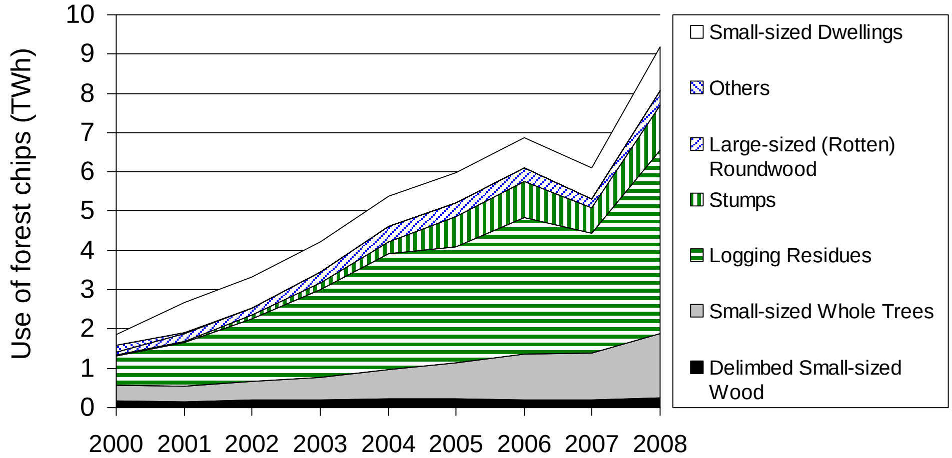

Figure 1. Total consumption of forest chips for energy generation in the 21st century in Finland [1].

In 2008, forest chips were burnt by 760 heating and power plants in Finland [1]. The majority of energy plants annually consume less than 10 GWh (around 5,000 m^3/a) of forest chips (Fig. 2) [2]. There are currently only eight large (forest chip consumption >200 GWh in 2008) power plants in Finland [2]. However, they consume approximately 40% of forest chips used in Finland (Fig. 2) [2]. The use of forest chips is currently the greatest in Central Finland, and relatively low in Northern Finland (Fig. 3) [1].

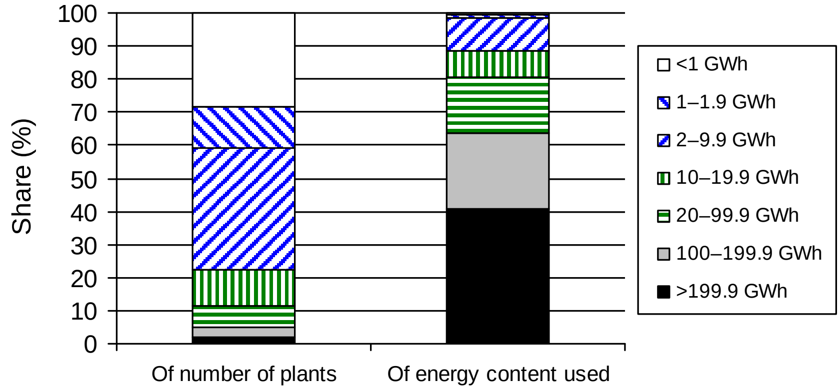

Figure 2. Use of forest chips by the class of energy content (GWh) used in heating and power plants in 2008 in Finland [2]. The figures are based on the data of the Finnish Forest Research Institute: the use of forest chips 7.8 TWh in total of 427 energy plants in 2008. The figures exclude the data of TTS Research's small heating plants (0.2 TWh & 333 plants).

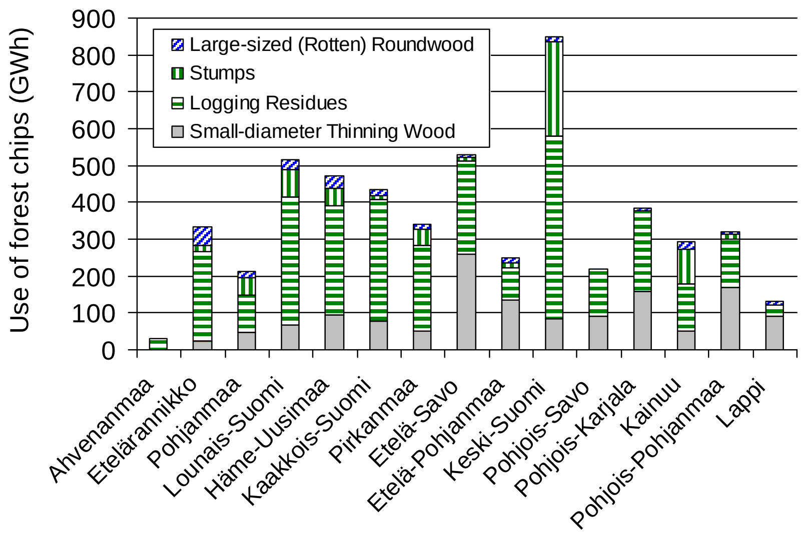

Figure 3. Use of forest chips by forestry centre in 2008 in Finland [1].

Metsäteho Oy has annually surveyed the supply chains [3] used in the production of forest chips in the 21st century in Finland [4–8]. The Metsäteho study also investigated how logging residue chips, stump wood chips, and chips from small-sized thinning wood and large-sized (rotten) roundwood used by heating and power plants were produced in Finland in 2008. The main results of the study are presented in this conference paper.

2 MATERIAL AND METHODS

The supply chains of forest chips were investigated in the questionnaire of Supply Chains of Forest Chips in 2008, which covered the production of logging residue chips, stump wood chips, chips from small-sized thinning wood, and chips from large-sized (rotten) roundwood. In the survey, the supply chains were determined as follows:

- *Terrain chipping*: comminution at the harvesting site,
- *Roadside chipping (separate chipper and chip truck)*: comminution with a chipper or crusher at a roadside landing and road transportation of chips using a separate chip truck from the roadside to the plant,
- *Roadside chipping (integrated chipper–chip truck)*: comminution and road transportation of chips with the same unit, a so-called integrated chipper–chip truck,
- *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 2008 by these (34) suppliers was 6.5 TWh (Table 1). The study was implemented by conducting an email questionnaire survey and telephone interviews. Research data was collected in March-May 2009.

Table 1. Use of different types of forest chips at heating and power plants in 2008 in Finland [1], and the total volume supplied in 2008 by the forest chip suppliers who participated in the survey.

Type of forest chips	**Total volume used in Finland [1]**	**Total volume supplied by suppliers**
	TWh	
Logging residue chips	4.7	3.5
Stump wood chips	1.2	1.2
Chips from small-sized thinning wood	1.9	1.4
Chips from large-sized roundwood	0.4	0.5
Total	**8.1**	**6.5**

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 70–100 MWh/ha. In 2008, the area where logging residues were recovered was more than 50,000 ha in Finland.

Figure 4 shows that the most common place to comminute logging residues for chips is a roadside landing. In 2008, the total proportion of roadside chipping supply chains was 58%. The share of roadside chipping with a separate chipper and chip truck was 55%, and the share of roadside chipping with an integrated chipper–chip truck was 3% (Fig. 4).

31% of the logging residues were comminuted at power plants in 2008 (Fig. 4). The share of chipping loose residues at the plant was 14%, and the share of chipping logging residue bundles at the plant was 17%. Currently, logging residues are bundled by around 15 slash bundlers in Finnish forests [cf. 9, 10]. The proportion of terminal chipping supply chain was 11% in 2008 (Fig. 4).

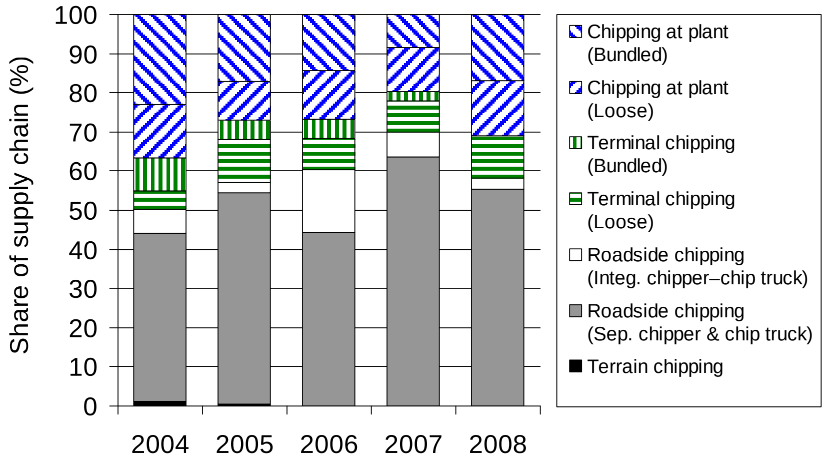

Figure 4. Proportions of different supply chains in the production of logging residue chips during 2004–2008 in Finland.

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 chain figures: 70% of all stump wood chips used for energy generation in 2008 were produced at power plants (Fig. 5). In 2008, 29% of all the stump 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. The typical stump wood removal is 150–180 MWh/ha. The period for stump lifting is limited to May–November when the ground is thawed. In 2008, stumps were removed from a total of around 7,000 hectares. Heavy-duty (working weight around 20 tonnes) tracked excavators are mainly used for the lifting of stumps [9, 10]. Approximately 150 excavators are currently used for stump lifting in Finland [cf. 9, 10].

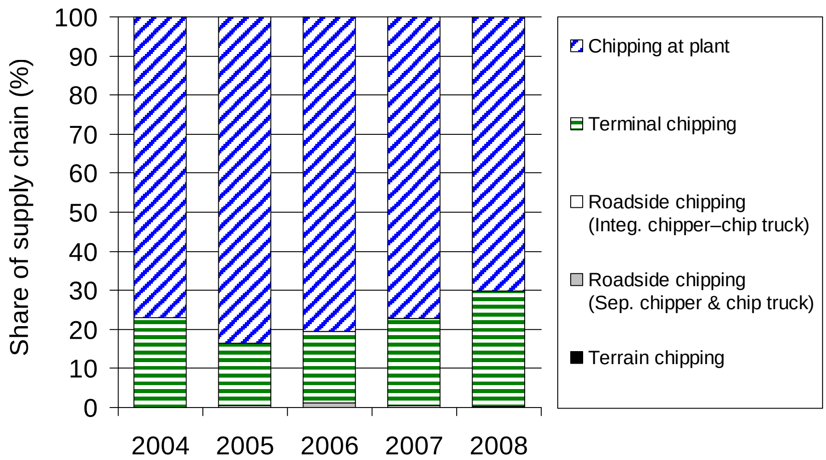

Figure 5. Proportions of different supply chains in the production of stump wood chips during 2004–2008 in Finland.

3.3 Chips from small-sized 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. In 2008, small-diameter wood for use in heating and power plants was harvested in about 20,000 hectares.

Roadside chipping still maintains an important role in the production of chips from small-sized thinning wood: 84% of all forest chips from small-sized wood were chipped at roadside landings in 2008 (Fig. 6). The share of terminal chipping was 8%. The proportion of chipping at the power plant was also 8% in 2008 (Fig. 6).

In Finland, two mechanized harvesting systems are used for small-diameter thinning wood: i) the traditional two-machine (harvester and forwarder) system, and ii) the harwarder system (i.e. the same machine performs both cutting and forest haulage to the roadside) [11]. Currently, there are more than 300 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. 9, 10]. Currently, there are also more than 50 energy wood harwarders in use in Finland.

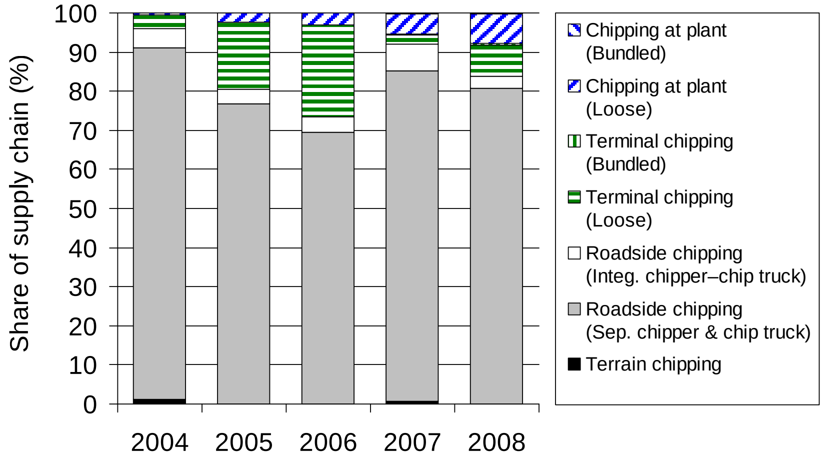

Figure 6. Proportions of different supply chains in the production of chips from small-sized thinning wood during 2004–2008 in Finland.

3.4 Chips from large-sized (rotten) roundwood

In 2008, 49% of the large-sized (rotten) roundwood for energy generation was comminuted at power plants (Fig. 7). The proportion of terminal chipping supply chain was 41% in 2008. Correspondingly, the share of roadside chipping was 10% in the production of chips from large-sized roundwood in 2008 (Fig. 7).

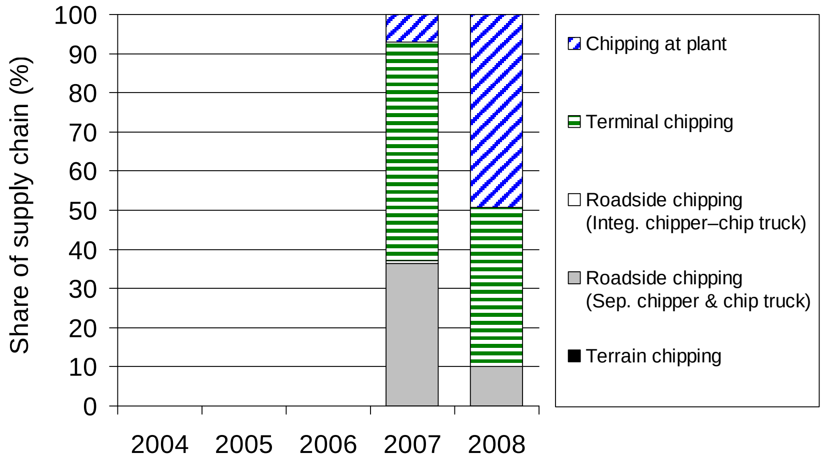

Figure 7. Proportions of different supply chains in the production of chips from large-sized (rotten) roundwood during 2007–2008 in Finland.

4 DISCUSSION AND CONCLUSIONS

Each supply chain 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-sized thinning wood and large-sized roundwood) produced and, naturally, the total supply chain costs, each determine which forest chip supply chain is used. There is, and there is never likely to be, any single universal supply chain [12].

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 10 TWh by 2010, and up to 24 TWh by 2020 [13–15]. 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 chain costs of forest chips.

In the future, the management of supply costs in all phases of the logistics chain will hold vital positions [12]. The individual parts of the supply chains 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 chains (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 [12] estimated that chipping 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 road transportation of uncomminuted raw materials for forest chips will greatly increase in the future, more efficient long-distance transportation solutions are required. The status of the terminals will also become more important.

Table 2. The main strengths and weaknesses of different supply chains in the production of forest

chips [12].

Supply chain	**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 (Separate chipper and chip truck)	• Flexibility • Considerable experience in roadside chipping • Availability of harvesting machinery.	• "Hot" chain • 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.
Roadside chipping (Integrated chipper–chip truck)	• Chipping and long-distance transportation with same unit • No hot chain • Chips to several small plants • Small harvesting sites.	• Small payload • Long transportation distances • Long-distance transportation costs • Large roadside storage space for forest chip raw materials • Untidy roadside storage areas after harvesting operations.
Terminal chipping	• No hot chain • 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 chain costs.
Chipping at plant (Loose)	• No hot chain • Large-scale production • Powerful comminution • Most cost-efficient total supply chain 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 chain • 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.

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