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The Forest Fuel Market in Finland - DRAFT

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Biomass Energy for Heating and Hot Water Supply in Belarus (BYE/03/G31)

The Forest Fuel Market in Finland

Colophon

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TABLE OF CONTENTS

Table of Figures

Table of Tables

1 INTRODUCTION

This document, prepared in the frame of the UNDP/GEF Belarus Bioenergy Projects, presents a short overview of the forest fuel market in Finland.

In Chapter 2 quantitative data on the use of wood-based fuels in Finland are given, and the use in different sectors such as the forestry industry, the district heating sector, the power production sector and the domestic sector is discussed. Forest fuels at present constitute only a small portion of the total wood use for energy generation, but its share is growing rapidly.

Chapter 3 analyses the main actors in the forest fuel market. Five large companies dominated the Finnish market, controlling three-quarters of the commercial production of forest chips. Smaller operators, that work only locally, help to keep the market competitive.

Production systems for forest chips are the focus of Chapter 4. A forest fuel production system is built around the comminution phase. Main methods used in Finland are chipping at the roadside, at the terminal and at the mill. New technology that involves in bundling of forest residues is gaining importance.

The last two chapters look at the economics of forest fuel production. Chapter 5 focuses on the costs of producing forest residue chips form final cuttings and from thinnings. The latter are higher, and the Government of Finland makes available a fuel production subsidy to whole-tree chips (but not to logging residues chips). Chapter 6 discusses the price development and competitiveness of forest chips. The price development since 1999 is looked at in more detail. Since 1999 forest chips have become more expensive as a result of increased demand, however, the prices of fossil fuels have increased more and the economics of bioenergy have continued to improve.

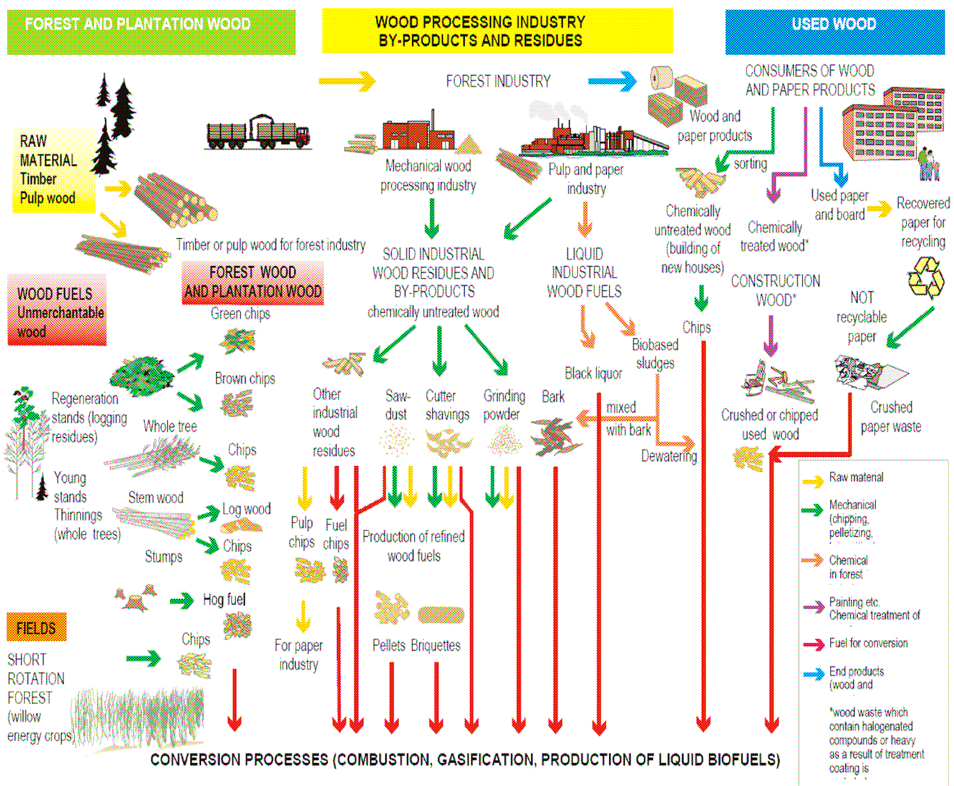
2 SUPPLY AND DEMAND OF FOREST FUELS

2.1 Wood fuels types and uses

Wood is the most important renewable energy source in Finland, accounting for 82% of renewables. The main provider and user of wood-based energy is the forest industry, which obtains wood fuels at a competitive price in connection with raw material procurement or as a by-product of wood processing.

In 2004, about 42 million m^3 of wood (306 PJ) was used for energy production, covering 20% of the total consumption of primary energy. Woody biomass is divided in the CEN classification (CEN/TS 14961) into three subgroups: forest and plantation wood, wood processing industry by-products and residues, and used wood (Figure 1).

Figure 1: Classification of the wood-based fuels according to CEN/TS 14961.



Most of the wood-based energy is recovered from liquid and solid industrial wood residues, in particular black liquor. This document focuses mainly on the use of forest fuels. So far, a modest but rapidly growing share comes from forest fuels (2.7 million m^3 in the year 2004, which compares with a total solid wood use - forest chips, bark, sawdust, industrial wood residues etc. - of 14.4 million m^3). Table 1 shows the consumption of indigenous fuels (wood fuels and fuel peat) in Finland in 2004.

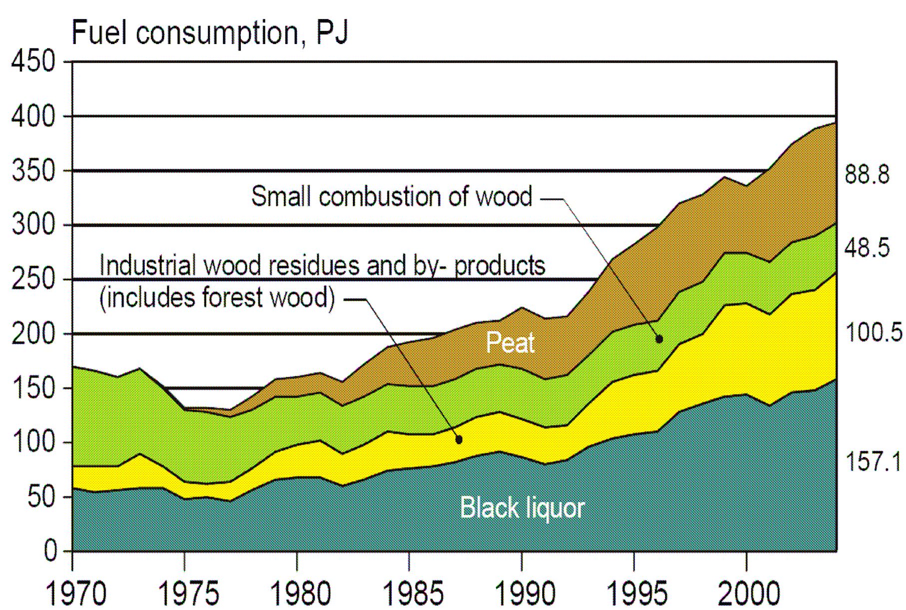
Table 1: End-use of wood by end-user groups in 2004.

Fuel/PJ	End-user group				
	Forest industry	District heating	Small-scale use[c]	Other industry & users	Total
Forest fuels[a]	6.5	5.9	2.8	3.7	18.9
Solid wood processing by-products & residues[b]	47.3	16.5	0.4	20.6	84.8
Firewood	0	0	45.3	0	45.3
Black liquor	157.1	0	0	0	157.1
Total wood	210.9	22.4	48.5	24.3	306.0

Notes: (a) Excludes firewood (b) Includes bark, sawdust, industrial chips, pellets, briquettes, recovered wood and other wood industry by-products and residues classified as wood fuels. (c) Includes the use of forest chips by farms and detached house properties

The consumption of indigenous fuels has steadily increased in Finland during the past three decades (Figure 2). The main reason for this development has been the growth in the forest industry's production, which can be seen as the increased consumption of black liquor, industrial wood residues and by-products. During the past 10 years alone, more than 100 district heating plants and 500 MW_e of new additional capacity for electricity production from wood and peat fuels were commissioned. The consumption of wood fuels by end-user sectors in 2004 is presented in Table 1.

Figure 2: The consumption of wood fuels and fuel peat in Finland in 1970-2004.



2.2 Forest fuel potential and use

The primary raw material sources of forest fuels are small diameter energy wood from young forests, and logging residues and stumps from final fellings. Forest fuels can also be produced from round wood, which has no markets as raw material for the wood processing industry due to the poor quality, quantity or location.

Only part of the total forest fuel potential is recoverable. Many technological, socio-economic and environmental factors affect the practical availability. In a recent study Lappeenranta University of Technology evaluated the techno-economic potential of forest fuel in 2010 at 86 PJ. The largest share of the potential comes from logging residues, 40 PJ (46%), whereas the share of stumps is 22 PJ (24%) and that of small diameter energy wood 25 PJ (30%) (Ranta et al., 2005). In 2004, forest fuel utilisation in energy production totalled 18.9 PJ (2.7 million m^3), which represented 6.2% of the total wood fuels use, and less than one fourth of the above-mentioned techno-economic production potential.

2.3 Large-scale consumption of woodfuels

2.3.1 Forest industry

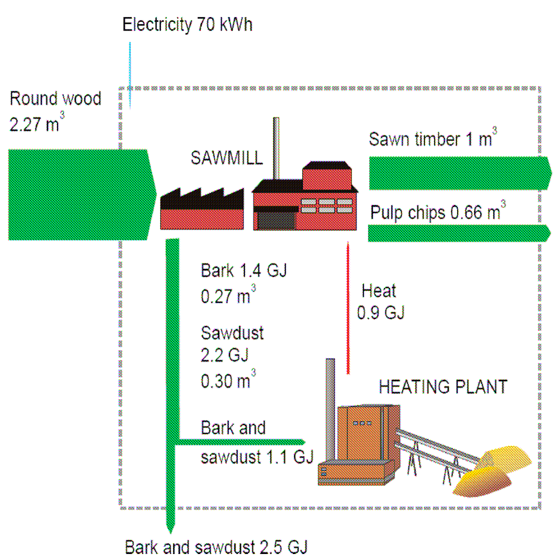
The forest industry is both the largest producer and user of wood fuels. Almost 70% of wood fuels are used in the forest industry. There are in total 28 paper mills, 14 paperboard mills, 19 pulp mills and about 90 industrial sawmills (capacity > 20,000 m^3 of sawn timber) in Finland. In many cases, paper, paperboard, pulp and sawmills are located on the same site, forming a forest industry integrate which allows efficient utilisation of raw material and energy. In many mills, a separate power production company manages the energy production. In most cases, the power producer owns, runs and maintains the power plant, and buys the fuels from the mill as well as necessary additional fuels from the market. Heat is then sold to the mill and in some cases to the district heating network, and any excess power is sold to the grid.

The round wood that the forest industry uses is acquired as unbarked, excluding a tiny volume of tropical raw wood. Only a part of the raw material used can be converted to forest products and the rest is conformed by-products. Solid by-products consist of pulp chip, bark, sawdust and industrial chips. Pulp chip and a part of the sawdust is utilised as raw material in pulp mills. Sawdust is the primary raw material for particleboard and fibreboard mills. The rest of the solid by-products are used in energy production, primarily at forest industry mills, and the surplus is sold outside.

As for the sawmills, about 20 of the 90 are co-located with pulp and paper mills and their by-product fuels are utilised inside the integrate for heat and power production. Only a few of the independent sawmills have own electricity production. Most of the sawmills produce heat for drying of sawn timber firing wood fuels in a heating plant and sell excess fuels outside to other heating and power plants. Figure 3 presents the materials and energy balances of a typical sawmill per one cubic metre of dried sawn timber (Heinimö & Jäppinen, 2005).

Wood is the most important fuel for the forest industry and wood accounted for 75% of fuels consumed in the forest industry mills in 2004. In some mills, peat is used as a complement fuel and in 2004 it covered 6% of the mill fuels. Total consumption of solid wood processing by-products (industrial chips, bark and sawdust) in energy production was 77 PJ (Statistics Finland, 2005). The total theoretical supply of the forest industry's by-products in 2002 was estimated at 97 PJ and in 2010 at 101 PJ. The theoretical potential includes sawdust, bark and industrial chips, but excludes pulp chips. A part of this supply potential is used as raw material for pulp, particleboard and pellet production. Over half of the energy use of by-products takes place on the site where they were produced and the rest constitutes the market supply of solid by-products. For the period 2002- 2010, the market supply of solid by-products from the forest industry for energy purposes is estimated at 40 PJ/yr (Ranta et al., 2005).

Figure 3: Material and energy balances of a typical sawmill for 1 m3 of dried sawn timber.



2.3.2 District heating sector

There are over 200 heat distribution utilities in Finland, and most of them produce at least part of heat by themselves. About 50 of them also produce electricity in connection with district heating. The total district heat capacity is 20.1 GWth and total connected heat load is 15.6 GWth. In 2004, the three largest district heating utilities in Finland were Helsingin Energia Oy, E.ON Finland Oyj and Tampereen Sähkölaitos. Some municipalities co-operate with power companies or local industries. CHP based heat production composed 76% of the total district heat production in 2004. Several medium-sized and small towns purchase district heat from CHP plants or industrial CHP plants owned by other companies, or produce it themselves in heat-only boilers. The share of wood and peat as fuel in the district heating sector was altogether 30% in 2004. Coal and natural gas are dominant fuels covering 63% of the total fuel use in 2004. District heating utilities have no direct access to wood fuel sources as the forest industry has. Thus district heating utilities often purchase wood fuels directly from independent sawmills and forest fuels from wood fuels supply companies. (Statistics Finland, 2005).

2.3.3 Power production sector

In 2004, the most important electricity producers in Finland were Fortum (24 TWh) and Pohjolan Voima Oy (18 TWh), which operates many power plants in the forest industry (Kara, 2005). Most of the biomass-based CHP is produced in industrial power plants, especially in the forest industry. Approximately 12 TWh of electricity was generated in forest industry mills in 2004 (Finnish Forest Industries Federation, 2006b).

2.3.4 Inventory of large-scale biomass users

In a recent publication, Lensu and Alakangas (2006) present an assessment of the number and total capacity of Finnish biomass users with capacity of more than 1 MW_{th} (See

Table 2). There are an estimated 380 biomass-fed plants, the boilers of which can generally be fuelled by several alternative fuels, most often peat and wood.

Figure 4 illustrates the locations of heating and power plants using forest fuels in 1999 and 2004. The figure illustrates the substantial growth that was achieved in just 5 years.

Figure 4 Use of forest fuels (excluding small-scale use) in 1999 and 2004.

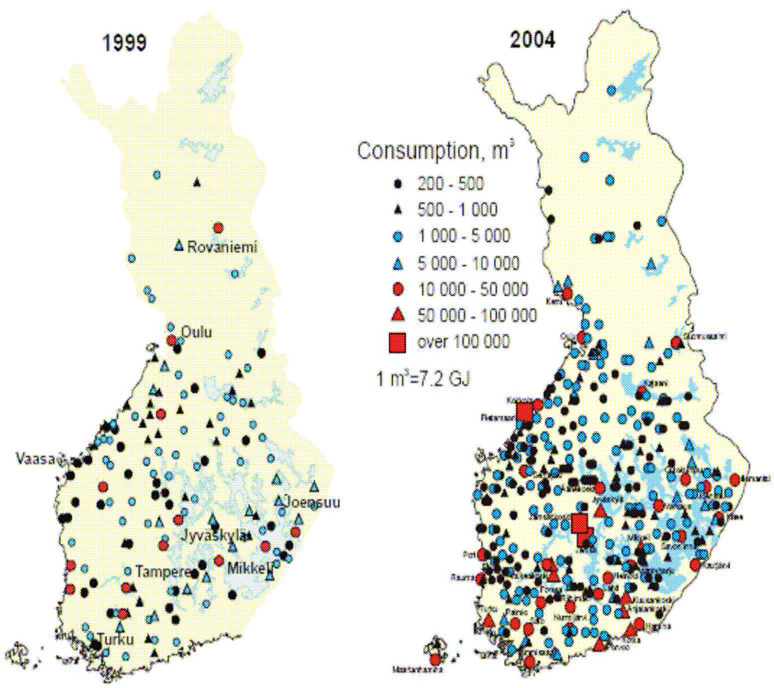


Table 2: Biomass users with capacity of more than 1 MW_{th}, 2004 (source: VTT database)

BIOMASS USERS	Amount	Unit
No. of biomass fuelled DH plants (> 1 MW)	170	pieces
Installed capacity of biomass fuelled DH boilers	900	MW_{th}
No. of biomass fuelled CHP plants	45	pieces
Installed capacity of biomass fuelled CHP boilers	3500	MW_{th}
	1380	MW_e
No. of biomass fuelled power plants	1 (peat)	pieces
Installed capacity of biomass fuelled boilers	154	MW_e
No. of biomass fuelled plants in pulp & paper industry	40	pieces
Installed capacity of solid biomass fuelled boilers in pulp & paper industry	4240	MW_{th}
	1111	MW_e
Installed capacity of recovery boilers in pulp & paper industry (*19 recovery boilers*)	4100	MW_{th}
	680	MW_e
No. of biomass fuelled plants in sawmills	57	pieces
Installed capacity of biomass fuelled boilers in sawmills (*heating plants 380MW + CHP 70MW*)	450	MW_{th}
	12	MW_e
No. of biomass fuelled plants in other industries (*62 heating plants + 33 CHP plants*)	95	pieces
Installed capacity of biomass fuelled boilers in other industries (*CHP 3600 MW)*	4200	MW_{th}
	900	MW_e

2.4 Small-scale consumption of woodfuels

Forest wood is the major source of wood-based fuels consumed in small-scale heating systems in Finland, and used by some 80% of all single-family houses, farms and summer cottages. There are 2.6 million dwelling units in Finland, of which 1.1 million are single-family houses. In 2004, the total wood fuels use in small combustion was 48.5 PJ, consisting of firewood, 45.7 PJ, forest chips, 2.8 PJ, and a modest amount of wood pellets, 0.02 PJ. The majority of wood fuels in small-scale heating systems are consumed as cut or split into a smaller size in batch-fired furnaces. The total number of stoves and fireplaces for firewood reaches almost two million; about one million of them are heat

storing models. Usually a wood stove or fireplace is used as auxiliary heat source in single–family houses. According to Rakennustutkimus RTS Oy, 60% of single-family houses in Finland use wood fuels (Statistics Finland, 2005; Statistics Finland, 2006).

According to a survey of METLA, the leading consumers for firewood in Finland are detached houses and farms composing 51% (3.8 m^3/house) and 36% (14.4 m^3/farm) of the consumption. The rest is consumed in holiday homes 11%, (1.8 m^3/house) and in other small houses 2%. About 20% of split logs (1.2 million m^3) is used in sauna stoves (Sevola et al., 2003).

There are almost 200,000 central house heating systems using wood fuels in Finland. The systems are typically used in detached houses or on farms. Wood chips and split logs are used in most of the systems, whilst wood pellets are burnt in some 5,000 boilers. However, the share of pellets is growing fast. Around 5,000 detached house, larger buildings and farms are heated with other forest fuels. Annually, about 10,000 new single-family houses are built, almost 90% of them have a fireplace or stove made of heat-retaining material (TEKES, 2004; Alakangas, 2005).

Small-scale use of wood has traditionally involved households and farms where the users themselves acquire the major part of the wood or do not pay any price for the fuel. About one fifth of the consumption of firewood was based on commercial firewood. Over 60% of commercial firewood was purchased as chopped. (Helynen & Oravainen, 2002; Sevola et al., 2003; Statistics Finland, 2005).

3 PLAYERS IN THE FOREST FUEL MARKET

Forest fuels may be delivered to the end-use facility by a forest company, separate procurement organisation for wood fuels, forestry society or by a local small-scale entrepreneur. If a forest company has own energy production, the procurement of logging residues may take place through the company's own organisation in the same manner as the merchantable wood procurement. Usually a stumpage price is not paid for logging residues. If the fuel is used in other plants, the procurement must be based on co-operation agreements between the players. Forest organisations play an important role in communication and in providing support for organised procurement, even though production and trade are in the hands of other entrepreneurs.

3.1 Large-scale forest fuel suppliers

There are three large forest industry enterprises operating in energy, wood processing and also biofuel business in Finland: UPM, Stora Enso and Metsäliitto Yhtymä. They all have an advantage over other fuel producers in the access to biomass sources of private forests in conjunction with the normal timber trade.

Box 1: Large forest industry enterprises in Finland

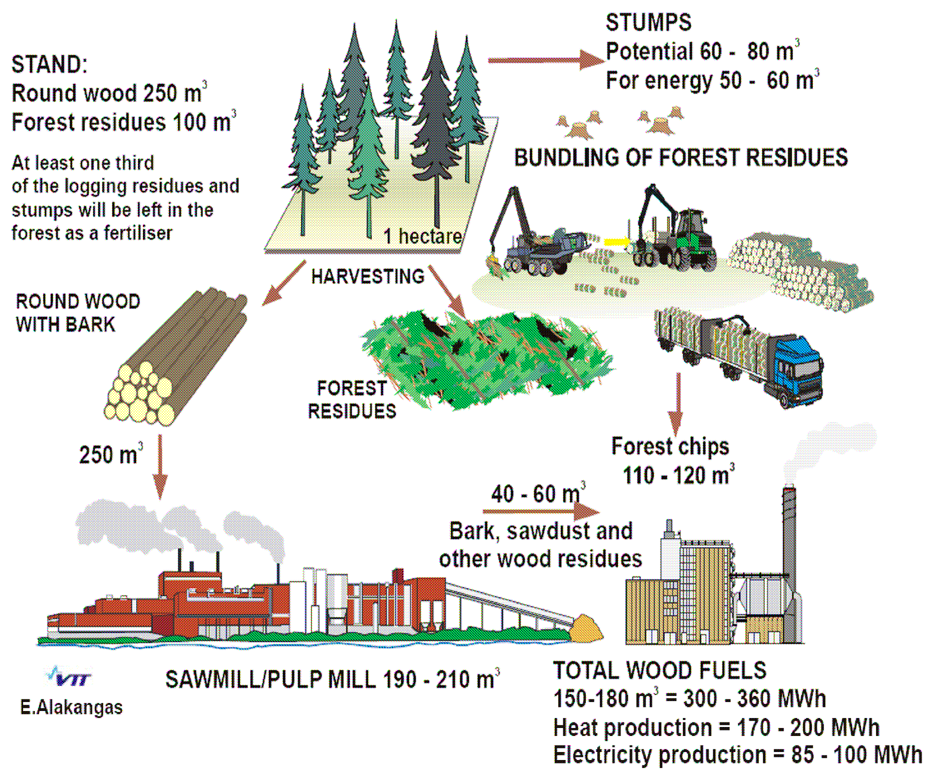
- **Metsäliitto-Yhtymä**. The forestry department of this concern is responsible for the purchase and harvesting of biomass. At the roadside, the biomass is given over to a subsidiary company.
- **UPM-Kymmene Oy**. The procurement of forest chips belongs entirely to the company's forestry department, and is integrated with the procurement of industrial raw material. In 2003, the production of forest chips was 1 TWh, most of which was delivered to CHP plants owned by Pohjolan Voima. Five of these plants are equipped with a stationary crusher for comminution of residue logs and stump and root wood.
- **StoraEnso**. Compared to the volume of timber harvesting, the scale of forest chip production is modest. The company's forestry department is responsible for production, which amounted to 0.1 TWh in 2003.

Source: Kallio & Leinonen, 2005

These big forest companies can exploit industrial wood residues from their own mills for production of wood chips or pellets, and they can integrate harvesting of logging residues into timber or pulp wood harvesting, which is illustrated in Figure 5. The three largest forest industry companies are responsible for the procurement of more than 80% of all round wood. They operate nationwide and procure their wood through special forestry departments that contract the implementation to independent entrepreneurs. Since forest residues and logs are to be recovered as a by-product of industrial timber in final fellings, the integration of the procurement of round wood and forest chips has become a common solution for forest industry companies which, in practice, dominate the raw material resource of forest residues. More than 50% of the energy wood is used at the forest

integrates inside the mill, i.e. this amount is outside the operating wood fuel market supply.

Figure 5: Example of integrated raw material and wood fuel procurement chain



In addition to the three forest companies, there are a few large companies operating on national level that are specialised in supplying wood fuels to district heating and other industrial users. Vapo Oy and Biowatti Oy are the largest actors in this field (see Box 2).

Box 2: Other nationally operating biofuel suppliers in Finland

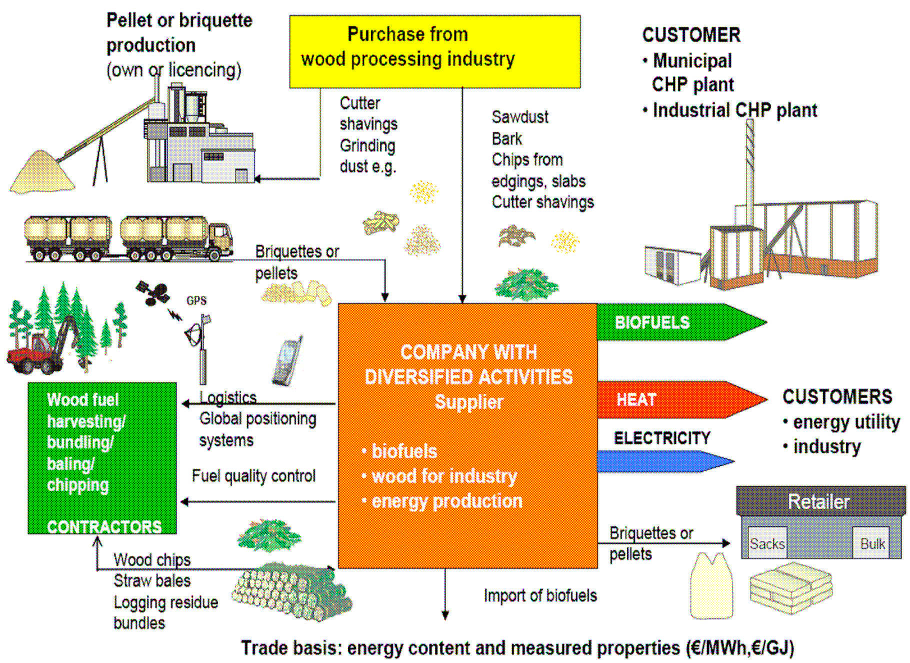
- **Vapo Energy** is the largest supplier of biofuels – energy peat, wood fuels and pellets – in Finland, Sweden and Estonia. Vapo Energy is also a leading supplier of energy crops, briquettes, potting soil and peat. Company turnover was 256.7 million euros in 2004. In autumn 2004, Vapo acquired Biowatti Oy's wood pellet business and it has currently 4 wood pellet mills and 5 contract manufactures in Finland.
- **Biowatti Oy's** main lines of business are deliveries of wood fuels to heating and power plants, raw material deliveries to the board and pulp industry and pellet factories, as well as deliveries for landscaping and composting, and for use as bedding. Biowatti's products include bark, sawdust and cutter chips, as well as logging chips, logging residue, stemwood and tree-length logs and stumps. Biowatti is responsible for comminution at the road side and delivering of the fuel to the customers. Biowatti's turnover was around 50 million euros in 2004.

- **Turveruukki Oy** produces and supplies wood fuels, agrobiomasses and energy peat for heating and power plants as well as households. Turveruukki's turnover was 15 million euros in 2004.

Source: Lensu & Alakangas, 2006

These biomass fuel traders trade most of marketable wood fuel. They make purchase contracts with sawmills and other wood suppliers and sale agreements with energy companies (Figure 6). Typically, energy companies have also direct contacts to smaller wood suppliers, which act only locally. The energy company Pohjolan Voima Oy also buys large amounts of chips from the large forest industry UPM-Kymmene Oy.

Figure 6 Wood fuel trade on a large scale



The five largest companies (Metsäliitto-Yhtymä, UPM, StoraEnso, Biowatti & Vapo) control three-quarters of the commercial production of forest chips. They can benefit from the large scale and the logistics systems available. However, as a large part of the chips is actually used by these producers themselves, competition is reduced (Hakkila 2004).

There are different ways to organise the large-scale wood residue delivery and trade (Kallio and Leinonen, 2005):

1) One organisation purchases, harvests, delivers and sells both round wood and forest residue. Example: UPM.
2) In an organisation two (affiliated) companies, one for harvest log wood and forest residue, one for chipping and selling the forest residue. Example: former cooperation between Metsäliitto and Biowatti Oy.

3) Contract between two separate companies, one for harvest log wood and forest residue, one for chipping and selling the forest residue. Example: contracts between StoraEnso and Vapo Oy.
4) Contract between two separate companies, one for harvesting, chipping forest residue and the other for trade. Example: Vapo Oy and private entrepreneurs.

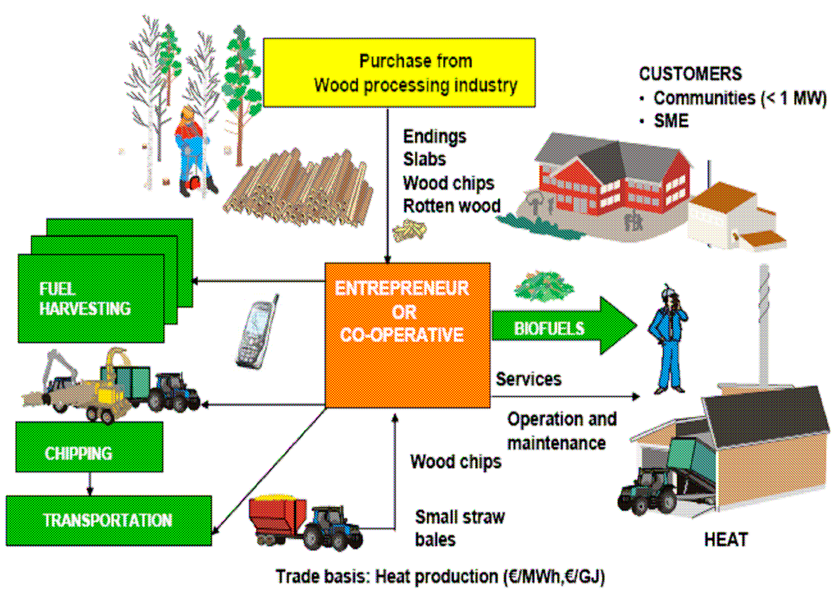
Boundary line between two enterprises is usually at roadside stock, one looks after the harvesting and forest haulage to stock, the other will chip or crush the forest residue and transport it to customer.

3.2 Smaller-scale forest fuel producers and traders

Forest fuel producers and suppliers operating on a much smaller scale include forest machine and truck entrepreneurs, heating entrepreneurs, and part-time firewood suppliers.

Instead of working as contractors for the large companies, some forest machine and truck entrepreneurs act as independent fuel producers, either alone or through a network. Because of the small size of the enterprises, they operate only locally. Nevertheless, they have a positive effect on competition in the field. The Trade Association of Finnish Forestry and Earth Moving Contractors encourage its members to sign independent chip delivery contracts by promoting networking.

Figure 7: Small-scale heat entrepreneurship



In the heating of small district heating (DH) plants and large separate municipal buildings such as schools, a heating entrepreneurship model has been used in fuel procurement and also in the operation and maintenance of boiler plants. Usually, heating plants are invested by municipalities or industry and often the boilers are renovated from light fuel oil (LFO) use to wood fuels. The heating entrepreneur is a single entrepreneur, co-operative, limited company or entrepreneur consortium selling heat. Usually, these

entrepreneurs are farmers and harvest small-sized wood on their own woodlots or purchase industrial wood residues or cutter shavings from the local wood processing industry. In 2005, the number of these entrepreneurs in Finland has increased to 250 using wood chips annually about 420 000 m^3 loose (1.2 PJ) . The previous number does not include district heating companies or nationwide fuel suppliers, which offer the total service of heat supply. Average size of the boiler is less than 500 kW_{th}.

Typical firewood suppliers are local entrepreneurs whose production volume and marketing efforts are low. There are 2 000 log wood traders, which sell typically about 150 m^3 annually. The total amount of annually traded firewood is 1.1 million m^3. The share of commercial firewood is anticipated to increase in the future. Firewood is produced mainly from pulpwood (54%) and 67% of the total volume of firewood is made by birch. The information about firewood suppliers is often spread by word of mouth. The prices, quality of products and standard of service vary a great deal. The MottiNetti e-marketing service was launched to eliminate the above-mentioned bottlenecks of the growing business. In recent years, also firewood can be bought on the Internet from several traders (www.halkoliiteri.com, www.klapikeskus.fi). Most of the firewood producers are small companies, but now there are also some larger nationwide firewood producers, such as Klapikeskus and Tulipuu Oy. Some firewood producers in Northern Finland also sell firewood to Norway. The value of the domestic firewood trade is € 60 million according to VTT (Tuomi & Peltola, 2002; Seppänen & Kärhä, 2003; Tahvanainen et al., 2003; Jouhiaho, 2004; Erkkilä et al., 2006).

4 FOREST CHIP PRODUCTION SYSTEMS USED

A forest chip production system consists of a sequence of individual operations performed to process biomass into commercial fuel and to transport it from source to plant. The main phases of chip procurement are purchase, cutting, off-road transport from stump to roadside, comminution, measurement, secondary transport from roadside to mill, and receiving and handling at the plant. The system offers the organisation, logistics and tools to control the process (Hakkila 2004).

A forest fuel production system is built around the comminution phase. The position of the chipper or crusher in the procurement chain largely determines the state of biomass during transportation and, consequently, whether subsequent machines are dependent on each other, i.e. whether the system is hot or cool. Comminution may take place at the roadside or landing site, at the source, at a terminal, or at the plant where the chips are to be used (Hakkila 2004).

The main methods used in Finland for production of forest chips made of logging residues are chipping at the roadside, at the terminal and at the mill. In minor scale is used chipping at the terrain. There is also a new harvesting technology based on bundling of forest residues. For the production of forest fuel from thinnings and from stumps and roots additional production systems are in place.

The next paragraphs briefly describe the forest chip production methods used in Finland. A recent and detailed overview can be found in the VTT report "*Production Technology of Forest Chips in Finland*", prepared in 2005 in the frame of the European Commission supported BIOSOUTH project.

4.1 Chipping at the roadside landing-method

Logging residues are hauled to the roadside landing all year round from the surroundings of the terminal, Figure 8. Residues are stored at the terminal and dried there over the next summer, so it is possible to improve the quality of the fuel. Chipping of residues is carried out all-year round, and chips are delivered by common solid fuel transportation vehicles. The objective is that logging residues are chipped directly to the long distance transport trailers without any storage of forest residue chips at the landing (Leinonen 2004).

4.2 Chipping at the terminal-method

The production phases of the forest residues harvesting chain of forest residues for fuel based on the chipping at fuel terminal, Figure 9, are terrain haulage, storage and drying, chipping or crushing of forest residues and road transport of forest residue chips to power plant. The working phases are the same as in the harvesting chain as in the chipping at the roadside (Leinonen 2004).

Figure 8 Chipping of forest residue at the roadside

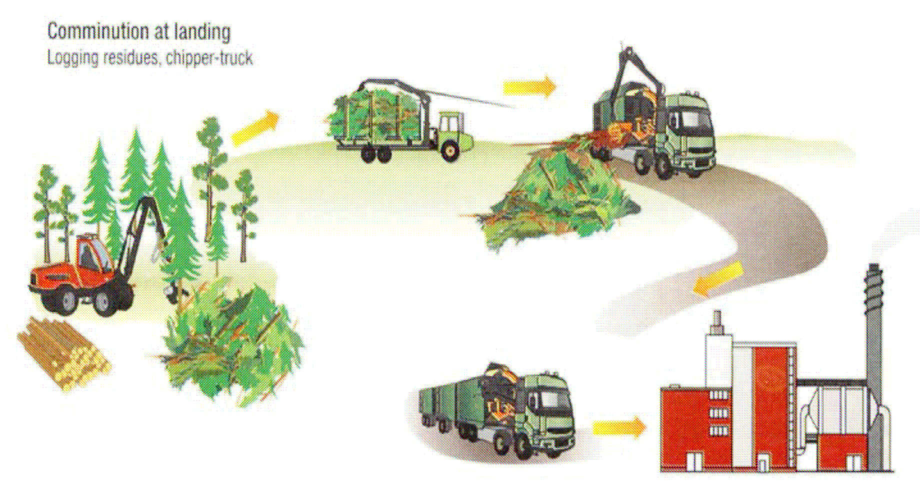
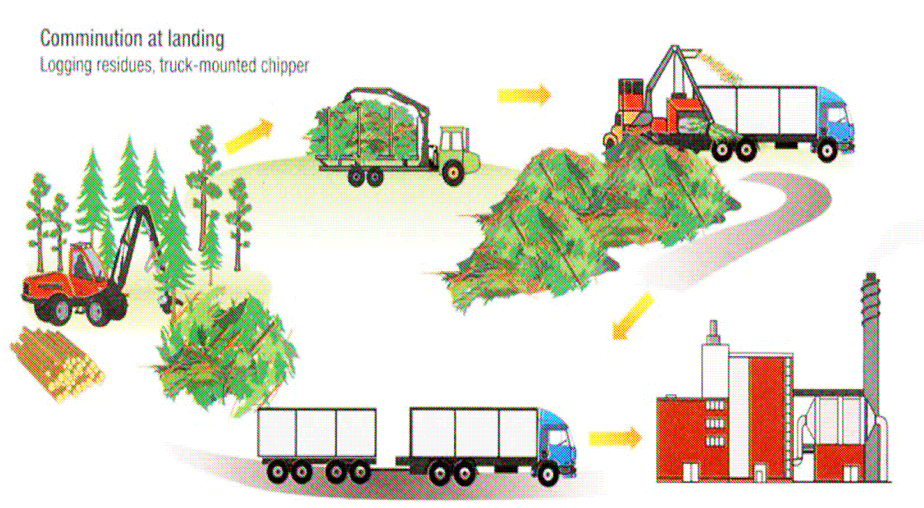


Figure 9 Chipping of forest residue at the terminal



4.3 Chipping at the stand-method

Terrain chipping is based on a single machine so called terrain chipper, which chips forest residues into a container at the stand and haul the chips in a container to the landing or to the roadside, Figure 10. The container is emptied by tipping the chips into and transports them to the power plant and returns the emptied containers to the landing (Leinonen 2004).

4.4 Chipping or crushing at the power plant-method

The fourth major chain of processing logging residues for fuel is chipping or crushing them at the end use facility, which normally can be implemented more economically than in terrain or at the roadside. Also processing at the plant avoids the problems of the hot chain, and chipping/crushing can be implemented more economically than at the stand,

landing or roadside (Savolainen & Bergren 2000). A promising alternative for transporting whole logging residues is bundling before long distance transport and chipping at power plant.

Figure 10 Chipping at stand with terrain chipper

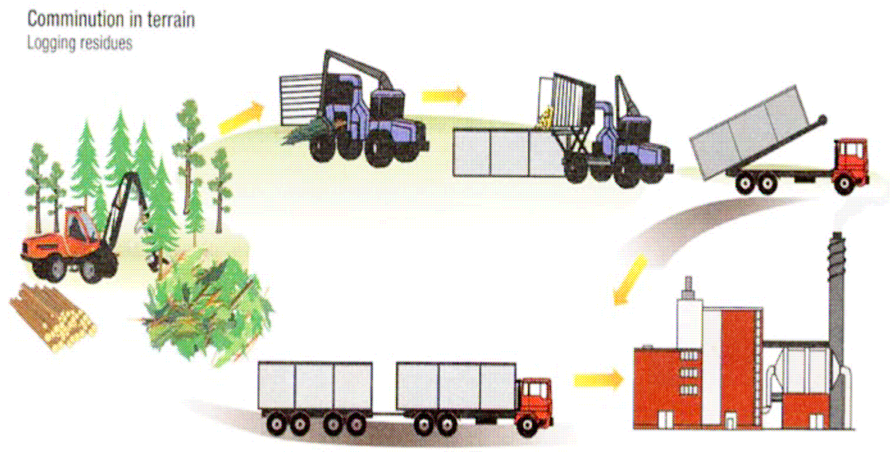
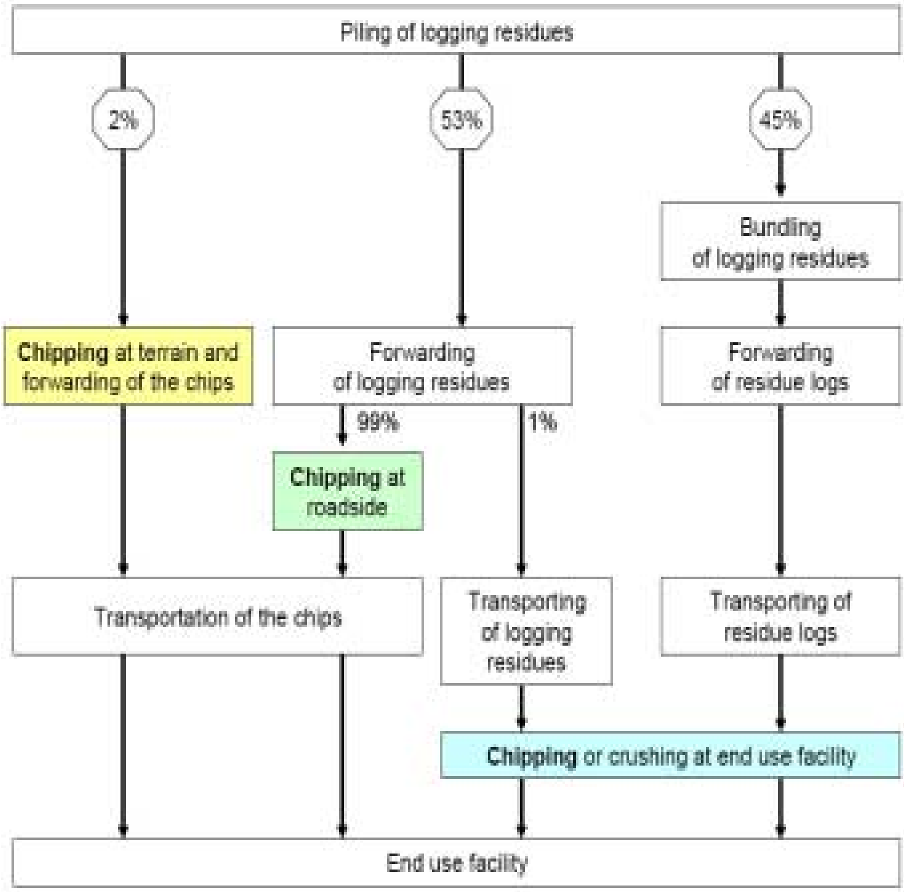


Figure 11 Bundled forest residue chipped or crushed at power plant

4.5 Comparing comminution options

In Finland, is has become more common lately to use centralised crushing due to easier process control. In this case the transported material is loose or compacted into bundles. However, the majority of chipping still occurs at the roadside. Terrain & terminal chipping are the minority chipping systems in Finland. The share of production systems of forest fuel supply is presented in Figure 12.

Figure 12 Share of forest fuel production systems (estimates by Electrowatt-Ekono)



Laitila (2005) briefly compares a few aspects of the comminution systems:

- **Hot chain versus cold chain.** In roadside chipping the chipper and truck are dependent on each other (”hot chain”). As a consequence, the operating time of chipper or chip truck may be wasted by waiting, resulting in a low degree of capacity utilisation and high chipping costs. Chipping at an end use facility makes the chipper & chip truck independent of each other (”cold chain”) and makes it easier to assure a high degree of capacity utilisation and thus to achieve low chipping costs.
- **Load volume.** The low bulk density /load volume of unprosessed material is the weak link in the end-use facility chipping system. New technology (e.g. the bundling of slash or the delimbing of small trees) helps to improve the bulk density and reduces transport costs.
- **Investment costs.** The costs of centralised comminution equipment is high, and an end use facility chipping system is suitable only for large plants. For small plants the roadside landing chipping system is suitable also for the small plants.

5 PRODUCTION COSTS OF FOREST FUELS

5.1 Production costs of forest residue chips from final cutting

While fossil fuels occur in large deposits and can be produced at a constant cost, forest fuels are scattered and must be collected from a large number of locations. Technical logging conditions vary widely, and the variations are reflected in the productivity and cost of work (Hakkila 2004).

Knowledge of the cost factors of forest chip production has been vague. This is a shortcoming from the viewpoint of technology development. The effect of factors such as stand conditions and hauling distances should be known in order to (Hakkila 2004):

- Identify the most advantageous stands for chip production,
- Estimate the change in the cost when the demand for chips increases or when the quality requirements of the fuel are tightened,
- Focus on the key problems in machine and method development,
- Collect basic knowledge needed by decision makers who direct subsidies to the production of forest chips.

Korpilahti (2000, 2001) has calculated the harvesting costs of forest residue chips for four main methods used in Finland (Table 3). The calculations are based on research data.

The most economical harvesting chain of forest residue chips was **chipping at the power plant**. The production costs of the chips at the power plant using this method was 8.19 €/MWh, when the road transport distance was 80 km. This method is used in a few plants in Finland. The road transport costs in this method can be decreased by increasing the net load of the trucks. This is possible by compressing the forest residues in the truck (Korpilahti 2000, 2001).

Production costs of forest residue chips using **chipping at the roadside chain** was 8.44 €/MWh. This is only 3% more expensive than using chipping at the power plant chain. This chain is the primary production chain in Finland. Much depends on affiance of the chipping machine and other delays at the loading place (Korpilahti 2000, 2001).

Production costs using **bundling technology chain** was 9.09 €/MWh. This is 10 % more than when chipping at the power plant. The bundling technology has just recently been developed and it has been in use in Finland for only some years. Therefore there are lots of possibilities to develop it further, especially associated with the bundler efficiency and truck transport (Korpilahti 2000). The economy of bundling becomes better, when transport distance grows (Korpilahti 2001).

The most expensive harvesting chain of forest residues was **chipping at the terrain**. The harvesting costs using this method were 37% more than using the chipping at the power plant chain, being 11.25 €/MWh (Korpilahti 2000, 2001). This method is used in some extent in Finland.

Table 3 Costs of the four harvesting chains of forest residues (€/MWh; Korpilahti 2001)

	Production Method A Haulage 150 m, transport 40 km				Production Method B Haulage 300 m, transport 80 km			
Work phase	Bundle	Terrain chip	Road chip	Plant chip	Bundle	Terrain chip	Road chip	Plant chip
Bundling	3.31	-	-	-	3.31	-	-	-
Forest haulage	1.22	-	2.18	2.18	1.62	-	2.58	2.58
Chipping at stand or roadside	-	6.03	2.54	-	-	7.08	2.54	-
Road transport	2.26	2.64	2.28	3.19	3.46	4.17	3.32	4.79
Chipping at power plant	0.71	-	-	0.82	0.71	-	-	0.82
Total	**7.50**	**8.67**	**7.00**	**6.19**	**9.09**	**11.25**	**8.44**	**8.19**

Notes: Bundle means bundling harvesting chain, Terrain chip means chipping at terrain chain, Road chipping at roadside chain and Plant chip is chipping at the plant harvesting chain. The 1st value for terrain chipping includes both forest residue chipping and terrain haulage of chips. The 2nd value for terrain chipping is based on road transport using exchangeable containers.

5.2 Production costs of forest residues from thinnings

Chips from energy wood thinning and first thinning are made from whole trees (whole tree chips) or from delimbed stems (stem chips). Farms and small-houses excluded, the use of small tree chips is tiny in Finland because of the higher price of the chips compared to the forest residue chips. The reason for the higher price of small tree chips is the small tree volume and the small total yield of wood biomass that is possible to be collected from the stands.

The costs of the harvesting chains of thinning are dependent on harvesting machinery, harvesting method and harvesting conditions in different stands. The harvesting costs are furthermore affected by total amount of merchantable and energy wood, haulage distance, terrain accessibility and other factors. The mechanical harvesting devices are most applicable to logging sites, which produce both energy wood and merchantable round wood (Savolainen & Bergren 2000).

Integrated production of round wood and energy wood is cheaper than production of energy wood alone. The smaller the harvested trees are, the more profitable it is to harvest them manually (using chain saw). Thus logging sites with only energy wood should be harvested manually. It is difficult to compare the different harvesting methods because working conditions differ a lot.

5.3 Comparing production costs; production subsidies

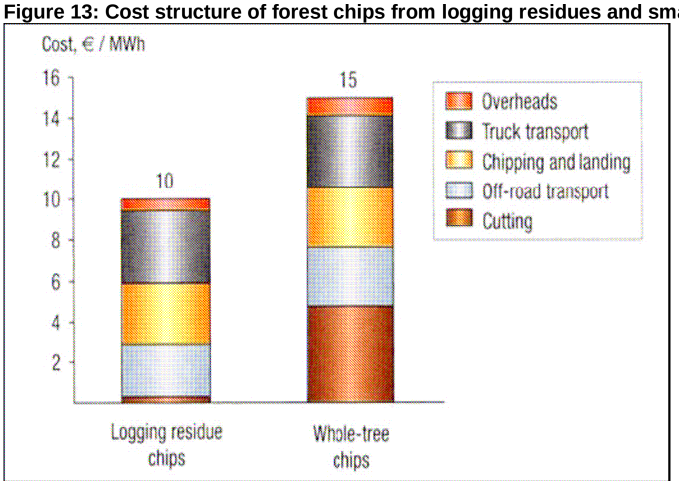
A significant gap exists between cost of fuel from the early thinnings and that from final cuttings[1]. The gap is caused by the high cost of cutting and bunching of small-sized trees from thinnings, whereas in the other phases of the procurement chain cost differences are

[1] Average costs may be misleading, since costs vary considerably. For example a single productivity factor, the stem volume, affects the cost of cutting and, consequently, the cost of the entire procurement chain. The effect is stronger in mechanised than in manual cutting.

modest. If no stumpage is paid, the cost level is 10 €/MWh for logging residue chips and 15 €/MWh for whole-tree chips (Figure 13, sourced from Hakkila 2004). The former meets the solvency of the users, but the latter exceeds it by some 5 €/MWh.

Small sized tree chips are mainly used by heating plants. They are able to pay more for the fuel than power plants (Leinonen 2004).

Figure 13: Cost structure of forest chips from logging residues and small whole trees.



Because of the higher production costs, whole-tree chips are subsidised but logging residue chips are not. When small-diameter wood is harvested from young thinning stands, a subsidy of about 5.5 €/MWh is paid to chip producers. The stands must meet specific silvicultural criteria. When stump and root-wood is harvested from regeneration areas which have been logged in summer time, a subsidy of about 0.9 €/MWh is paid because the treatment helps to protect the next tree generation from root rot fungus. No direct support is awarded for the production of fuel chips from logging residues from late thinnings or final harvest.

Other government support measures employed to make renewable energy economically competitive on the open markets include (Hakkila 2004):

- **Energy taxation of fossil fuels used for heat production**. A carbon-based fuel tax was imposed on heat production in 1990. Wood-based fuels are free of tax because of their carbon neutrality. The energy tax changes the price ratios of fuels, greatly enhancing the competitiveness of wood in heat production. See also Chapter 6
- **Support for electricity production**. Since 1997, no carbon-based fuel tax is imposed on fuel that is used for the production of electricity. Instead, electricity consumers are charged a tax of 6.9 €/MWh_e, independently of the source of energy. In case forest chips are used to generated the electricity, the tax is refunded to the producer.
- **Grant for investments**. Financial support can be granted to promote the introduction of new technology in the production of forest chips. For special equipment, such as chippers, crushers, bundlers, accumulating felling heads and biomass vehicles, the subsidy is typically 10-25%. Projects involving innovative technology are given priority.

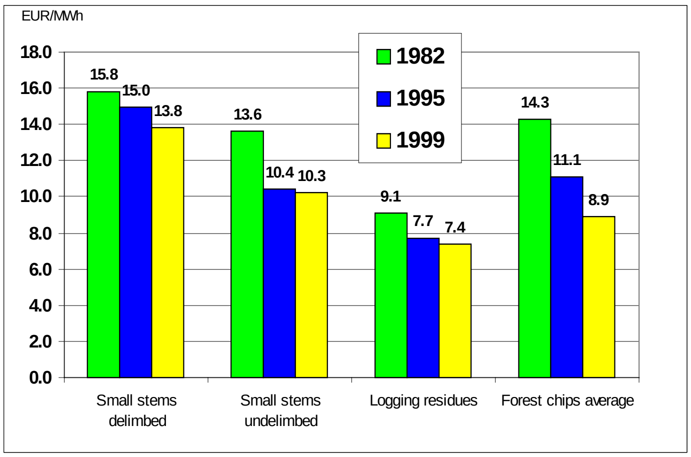
- **Financial support for the development and commercialisation of technology**. The primary channel for funding applied R & D is the National Technology Agency Tekes, which gives a high priority to the use of renewable sources of energy. Annual funding is about 10 M€, of which more than 50% is allocated to bioenergy.

6 MARKET PRICES AND COMPETETIVENESS OF FOREST FUELS

6.1 Woody biomass fuel prices

Comprehensive studies of forest chips prices have been performed in 1982, 1995, and 1999. The nominal price of forest chips decreased by 35% over the 1982-1999 period (Figure 14). The average price of forest chips at heating plants (forest industries and large CHP plants excluded) dropped from 14.3 €/MWh in 1982 to only 11.1 €/MWh in 1995 and 8.4 €/MWh in 1999. Although the price decrease was less dramatic other wood fuels also became cheaper during this period.

Figure 14: Development of prices of forest chips at heating plants, 1982, 1995 & 1999, VAT excluded.



This price decrease was the a result of the following factors:

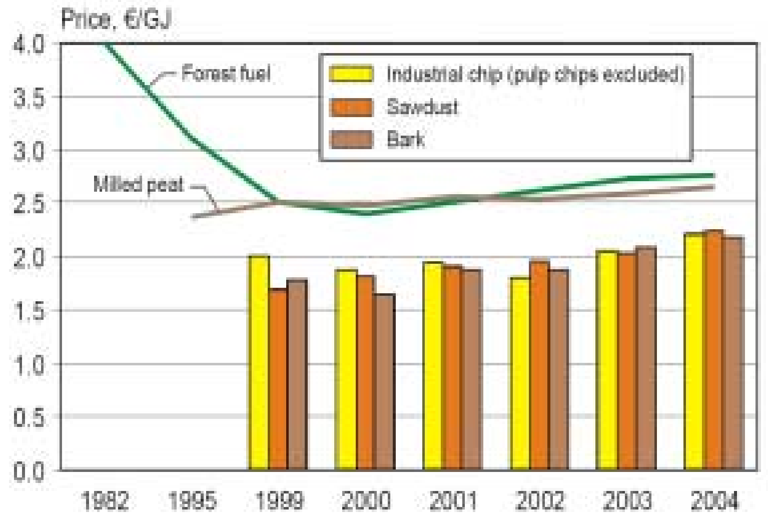
- Development of logging and transport equipment and procurement systems
- Development of procurement logistics through education and experience
- Growth of the scale of operations
- Shift to cheaper resources (whole trees and logging residues instead of delimbed stems)

Finnish experiences indicate that the prices of biomass fuels can be reduced by taking the following measures:

- Competition and operating fuel market are needed: more than one fuel supplier operating nationally and hundreds of local contractors
- Presently short-term contracts (<1 year) and contracts with several suppliers are preferred by energy producers
- Boilers and plants are designed for several fuels: biomass is used only if it is the most competitive alternative
- Harvesting and logistics of biomass-based fuels is integrated to wood procurement for pulp and saw mills
- Harvesting methods are developed systematically

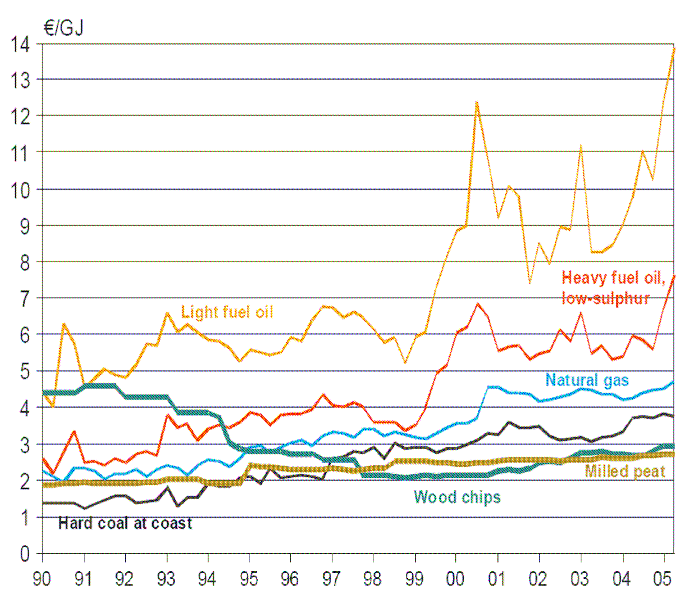
Since 1999, prices and volumes of solid biofuels are monitored on a regular basis by Statistics Finland, Electrowatt-Ekono and METLA. The prices of wood fuels and milled peat delivered at plant sites in the period 1999-2004 are presented in Figure 15. As predicted in the 1999 Survey, the nominal price of woodfuels did not decrease further, but as a result o increased demand raised instead. However, the economic feasibility of using woodfuels in both power and heat production continued to increase between 2000 and 2004, due to fossil fuels becoming much more expensive in this period (Figure 16).

Figure 15: Wood fuels and milled peat prices delivered at plants in 2000–2004.



Note: The price of wood chips is an average price of solid wood fuels combined from different sources, and therefore differs from the prices in METLA' s statistics.

Figure 16 Consumer prices of fuels in heat production (incl. energy taxes, excl. 22% VAT).



Note: The fossil fuels tax levels have been quite stable without substantial changes.

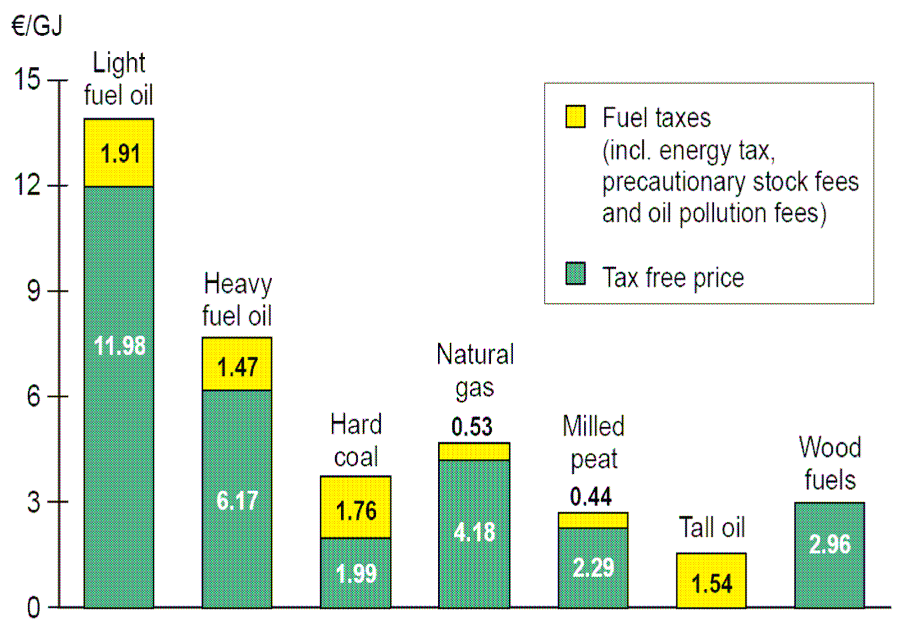
6.2 Energy taxation and woody biomass competitiveness

Fuels used in the production of electricity are exempted from energy taxes, whereas in heat production some fuels are taxed, including fossil fuels and tall oil. The total price of a fuel is composed of market prices and taxes. Table 4 presents an overview of selected energy taxes whereas Figure 17 shows total fuel prices in heat production.

Table 4 Selected energy taxes in Finland as of July 2005

Product	Unit	Excise tax	Security of supply fee
Light fuel oil	EUR c/l	6.71	0.35
Heavy fuel oil	EUR c/kg	5.68	0.28
Coal EUR/t	EUR/t	43.52	1.18
Natural gas	EUR c/m^3	1.82	0.084
Fuel peat	EUR/MWh	0	-
Tall oil	EUR c/kg	5.68	-

Figure 17 Fuel prices in heat production in June 2005 (price of tall oil not available).



Energy taxation of fossil fuels changes the mutual competitiveness of the fuels based on market prices. The energy taxation has rendered consumer prices of heating oils and coal more expensive compared to wood fuels.

6.3 Impact of emission trading on woodfuel competitiveness

Since the introduction of the European Union Emission Trading Scheme (ETS) in January 2005, large power plants and energy-intensive industries in the EU are required to gradually reduce their greenhouse gas emissions in two successive compliance periods (2005-2007 and 2008-2012 respectively). As a result of introducing the ETS, the emission

reductions of a participating company represent an economic value. Under ETS biomass co-firing is considered carbon neutral, and an industry that combusts or co-fires biomass instead of fossil fuels generates emission reductions, which can be sold at the carbon market (or be kept in case a company is short of credits).

Emissions trading increases the energy plants ability to pay for wood fuel as the high price of emission allowances (EUAs) decreases the competitiveness of fossil fuels like peat and coal (see Table 5). If the price of emission allowances is 20 €/tCO_2, the ability of a peat burning installation to pay for solid biofuels will increase theoretically by 7.6 €/MWh (under the assumption that the plant can handle fuel substitution). The effect is linear with respect to the price of emission allowances. For plants not included in the ETS scheme, the ability to pay is of course not affected.

Table 5 Effect of excise taxes in 2005 and price of emission allowances on the competitiveness of different fuels (in (€/MWh)

Fuel	Fuel price (€/MWh)	Excise tax & security of supply fee		Effect of the price of emission rights	
		Heat production	CHP	10 €/t CO_2	20 €/t CO_2
Wood: forest chips	12.0	0.0	-/- 2 *	0.0	0.0
Wood: side products	9.0	0.0	-/- 1.2 *	0.0	0.0
Wood: agro-energy	12.0	0.0	-/- 1.2 **	0.0	0.0
Peat	8.5	0.0	0.0	3.8	7.6
Natural gas	15.5	1.9	0.8	2/0	4/0
Coal – coast	7.6	6.3	3.3	3.4	6.7
Coal – inland	8.6	6.3	3.3	3.4	6.7
Heavy fuel oil	22.5	5.3		2.8	5.5
Light fuel oil	4.9	7.1		2.7	5.3

Notes: *) In power production, a support of 6.9 €/MWh is paid for forest chips and 4.2 €/MWh for other wood fuels **) Power produced from willow is supported with 4.2 €/MWh.

In the second half of the first year of trading, the price of emission allowances exceeded 20 €/t CO_2. As a result, ETS had a remarkable effect on the biomass market in Finland. Wood fuel suppliers were encouraged to bring more wood chips to the market as wood chips could be collected from stands that were earlier unprofitable. The increased ability to pay for wood fuel and increased production costs of wood chips drove the price up, while the increased supply decreased the price. All in all the price increased at a moderate rate. Thus emissions trading can increase both the amount of wood fuel supply as well as the price for wood fuels.

Emissions trading also affect the wood fuel markets by tightening the competition between energy plants and raw material users. The demand for wood fuels has been estimated to be higher at the energy plants within the emissions trading system than those outside the system. Large forest industry companies can also secure their own wood fuel procurement, which will decrease the amount of marketable wood fuel. This will, especially, affect small municipal plants which may face difficulties in their energy wood procurement.

In 2005, the first year of the emissions trading period, the average price of wood fuel increased by 9 %. According to the Finnish Forest Research Institute (METLA) the end-user average price of forest chips increased by 12% (to 11.1 €/MWh) and by 8% (to 8.0 €/MWh) for forest industry by-products in 2005. The forest chips use increased by 13 % and totalled 5.2 TWh in 2005, while the use of forest industry by-products dropped by 10% and totalled 19.6 TWh due to the two month strike in the pulp and paper industry.

If the price of emission allowances remains high the price of wood fuels is likely to continue to increase steadily due to emissions trading and increased demand. The supply of forest industry by-products is not estimated to increase and the growth potential for solid biofuel markets is in forest chips.

LITERATURE

Documents consulted to prepare this fact sheet

Jussi Heinimö & Eija Alakangas, Solid and Liquid Biofuels Markets in Finland – a study on international biofuels trade. Prepared for IEA Bioenergy Task 40 and EUBIONET II - Country Report of Finland. ISBN 952-214-199-2, April 2006. Available at www.bioenergytrade.org/downloads/finlandcountryreport260406.pdf

Electrowatt-Ekono Oy, ET Bioenergy, WP1, Country Report: Finland, 17 November 2005, available at www.eubionet.net

Pöyry Energy Oy, ET Bioenergy, WP2, Country Report: Finland, 14 July 2006, available at www.eubionet.net

Terhi Lensu & Eija Alakangas, Current situation and future trends in biomass fuel trade in Europe - Country report of Finland, VTT, June 2006. Prepared for EUBIONET II - Efficient trading of biomass fuels and analysis of fuel supply chains and business models for market actors by networking. Available at www.eubionet.net

Markku Kallio & Arvo Leinonen, Production Technology of Forest Chips in Finland. VTT Processes, Project report PRO2/P2032/05 dated 12.09.2005
Available at www.bio-south.com/pdf/ForestRes_Prod.pdf

Satu Helynen, Success factors of bioenergy for CHG mitigation in Scandinavia. Presented at the IEA Bioenergy Task 38 workshop 12-13 November 2001 in Edinburgh, Scotland. VTT Energy, Jyväskylä, 2001

Additional data sources

Alakangas, E. (ed). 2005. Puupolttoaineiden pientuotannon ja -käytön panostusalue-Vuosikatsaus 2005 (Small-scale production and use of wood fuels research area - Annual Review 2005).Tekes. Teknologiakatsaus/Technology Review 185/2005. 158 p.

Erkkilä, A., Kaipainen, H., Paappanen, T., Alakangas, E., Lindblad, J., Sikanen, L., Tahvanainen, T., Kähkönen, T. & Airaksinen, U. 2006. Uusi pilkkeen käsittelykonsepti valmistuksesta asiakkaalle (The study of the basic for the new method of chopped firewood). VTT Project report PRO2/P2066/05.

Finnish Forest Industries Federation. 2006b. "Facts and Figures". http://english.forestindustries.fi/figures

Hakkila, P. 2004. Developing technology for large-scale production of forest chips. Wood Energy Technology Programme 1999 - 2003. Final report. Technology Report 5/2004. Tekes. 44 p. Available: http://www.tekes.fi/english/programm/woodenergy.

Heinimö, J. & Jäppinen, E. 2005. ORC-teknologia hajautetussa sähköntuotannossa. (ORC-technology in distributed electricity generation). Lappeenranta University of Technology. Department of Energy and environmental technology. Research report EN B-160. ISBN 952-214-014-7. 84 p. Available: https://www.lut.fi/fi/yliopisto_lyhyesti/alueyksikot/mikkelin_yksikko/bioenergiatekniikka/ORCteknologia%20hajautetussa%20s%E4hk%F6ntuotannossa%20EN-B%20160.pdf.

Helynen, S. & Oravainen, H. 2002. Polttopuun pientuotannon ja käytön kehitystarpeet. Teknologiakatsaus 124/2002. TEKES (National Technology agency). 27 p.

Jouhiaho, A. (ed). 2004. Pilkkeen kaupallinen tuotanto (Commercial production of chopped firewood). Työtehoseuran julkaisuja 392. 139 p.

Korpilahti, A. 2000. Käyttöpaikalla haketukseen perustuva puupolttoaineen tuotanto. (Forest residues harvesting chain based on chipping at the end use) Espoo. Technical Rescarch Centre of Finland. In: Alakangas, E. (toim./ed.) Puuenergian 92 teknologiaohjelman vuosikirja 2000 (Yearbook 2000 of Wood Energy Technology Programme). VTT Symposium 205. p 137-143. In Finnish.

Korpilahti, A. 2001. Käyttöpaikkahaketukseen perustuva puupolttoaineen tuotanto. Forest residues harvesting chain based on chipping at the end use) Espoo. Technical Rescarch Centre of Finland. In: Alakangas, E. (toim./ed.) Puuenergian teknologiaohjelman vuosikirja 2001 (Yearbook 2001 of Wood Energy Technology Programme). VTT Symposium 216. p 137-152. In Finnish.

Laitila, M. 2005. Mäntyöljystyä taistellaan. Talouselämä 35/2005. ISSN 0356-5106. 28.10.2005. p. 18.

Leinonen, A., 2004. Harvesting technology of forest residues for fuel on the USA and Finland. Espoo. VTT. VTT Tiedotteita – Research Notes 2229. 132 p. + app. 10 p.

Ranta, T., Lahtinen, P., Elo, J. & Laitila, J. 2005. The regional balance of wood fuel demand and supply in Finland. Bioenergy 2005. International Bioenergy in Wood Industry Conference and Exhibition. Jyväskylä.12-15 September 2005. FINBIO - The Bioenergy Association of Finland. pp. 39-45.

Savolainen, V. & Bergren, H. 2000. Jyväskylä. Wood fuels basic information pack. Benet, Energi Dalen & Jyväskylä Polytechnic. 191 p.

Seppänen, A. & Kärhä, K. 2003. The chopped firewood trade in Finland. Työtehoseuran Metsätiedote 4/2003 (662) (in Finnish). 4 p.

Sevola, Y., Peltola, A. & Moilanen, J. 2003. Polttopuun käyttö pientaloissa 2000/2001. Metsäntutkimuslaitoksen tiedonantoja 894. Vantaa. 30 p.

Statistics Finland. 2005. Energy Statistics 2004. Official statistics of Finland. Energy 2005:2. Helsinki. 149 p.

Statistics Finland. 2006. "Asuntokanta (Dwelling stock). Dated 31.10.2005". URL http://www.stat.fi/til/asu/index.html.

Tahvanainen, T., Sikanen, L., Karppinen, H. & Tolvanen, K. 2003 MOTTINETTI - marketing chopped firewood and services via the Internet. BIOENERGY 2003. International Nordic Bioenergy Conference. 2.-5. September 2003. Jyväskylä. Finland. pp. 514-516.

Tekes. 2004. Growing Power. Renewable solutions by bioenergy technology from Finland. 2nd edition. National Technology Agency. Available: http://www.tekes.fi/julkaisut/GrowingPower_Brochure.pdf.

Tuomi, S. & Peltola, A. 2002. Polttopuun käytön nykytila pientaloissa (The present state of fuelwood use in detached houses in Finland), Työtehoseuran metsätiedote 15/2002 (658) . (In Finnish). 4 p.