Use and prices of forest chips in Finland in 1999
AFB-net V Task
Export and import possibilities and fuel prices

Pentti Hakkila, Hannu Kalaja & Ismo Nousiainen
VTT Energy
November 2000
ALTENER PROGRAMME
AFB-net V

Use and prices of forest chips in Finland in 1999

Pentti Hakkila
VTT Energy

Hannu Kalaja
Finnish Forest Research Institute

Ismo Nousiainen
VTT Energy

PUUENERGIA
Wood Energy Technology Programme
Preface

The AFB-net – European Bioenergy network carried out a special task on Export & import possibilities and fuel prices. The aim of this task was twofold. As far as the international biomass trade is concerned, the main targets were firstly to collect information about the current situation, and secondly to find possibilities to increase the trade. The main barriers were to be recognised, and ways to overcome these were to be found. A specific target was to find alternative transportation routes and organisations which are willing to participate in the international biomass trade.

The second part of the task, biomass fuel prices, is aimed at collecting information about the biomass and competitive fossil fuel prices in each country. Also the legislative, taxation and subsidy framework has impact on the price levels, so these were also taken into account. The ultimate target was to create a common framework for information collection to facilitate price comparisons and to make the price information collection a periodically repeated action.

Information on the use and prices of forest chips is scarcely available from the traditional forest statistics. In Finland, the AFB-net has worked in close co-operation with the Wood Energy Technology Programme to find out the prices of forest chips. In a survey carried out by the Programme, a questionnaire was sent to the 150 plants using forest fuels. VTT Energy and the Finnish Forest Research Institute performed the survey jointly. Because the results serve the monitoring of the Wood Energy Technology Programme, they are examined in the light of the needs and steering of the Programme.

As of the year 2000, the Finnish Forest Research Institute will start to monitor the use and market prices of forest chips and the solid process residues from the forest industry. The data from monitoring will be published annually by the sources of forest chips and by user plants of different sizes in the forest statistics bulletin of the Finnish Forest Research Institute. This bulletin is included in the official statistics on Finland.

Jyväskylä, November 2000

Pentti Hakkila
Programme manager of the Wood Energy Technology Programme

Eija Alakangas
Co-ordinator of the AFB-net
Contents

1. Introduction ..................................................................................................................5

2. The Consumption Target for Forest Chips .................................................................6

3. Monitoring the Use of Forest Chips ...........................................................................7

4. Development of the Use of Forest Chips .................................................................9
   4.1 The first appearance of forest chips .................................................................9
   4.2 Energy crisis and the use of forest chips .........................................................10
   4.3 The greenhouse phenomenon and the use of forest chips .........................11

5. Users of Forest Chips ...............................................................................................12
   5.1 Users in the early 1980s .............................................................................12
   5.2 Users at the turn of the millennium .............................................................15

6. The Raw Material of Forest Chips ..........................................................................18
   6.1 Changes in the raw material base ...............................................................18
   6.2 Small-sized trees as a raw material of forest chips ....................................20

7. The Quality of Forest Chips ....................................................................................23

8. The Market Price of Wood Fuels ..........................................................................27
   8.1 The price of forest chips ............................................................................27
   8.2 The price of sawdust and bark ...................................................................28
   8.3 The Swedish price level .............................................................................29

9. Summary ..................................................................................................................30
1. Introduction

The key objective of the Finnish Wood Energy Technology Programme of Tekes, National Technology Agency, is to quintuple the use of forest chips in five years. In Finland forest chips refer to wood chips made from tops and branches from regeneration areas and small-sized wood from thinnings which cannot be used as raw material of the forest industry. In order to monitor the development, the Programme’s steering committee commissioned a survey of the use of forest chips at time the Programme was launched in 1999. The results have been gathered in the report in hand.

The focus of the survey was on commercial forest chips including the forest chips the forest industry produced for their own use. Farms, detached houses, small-scale heating entrepreneurs and even those heating plants of a larger scale, irrespective of the size of the plant, whose use of forest chips was less than 250 m$^3$ solid or 625 loose (bulk-m$^3$) in 1999, were excluded. The questionnaire was not sent to the plants that by that time had only been considering the use of forest chips.

The biggest problem was to identify the users. The circle of users expands all the time, and no up-to-date list of users currently exists. The databases of VTT Energy and the Finnish Forest Research Institute were used as starting points. The major producers of forest chips, other than Vapo Oy, provided valuable information about the forest chip-fired plants. The user list was finally checked and completed at the local level through telephone interviews with 250 Forest Management Associations and other actors in the branch.

When the user list reflecting the situation at the end of 1999 had been composed, each forest fuelled plant was requested to answer in writing a number of confidential questions concerning the following themes:

- The amount and raw material of the forest chips used
- The proportion of forest chips in cofiring, the moisture content of forest chips, and the efficiency of combustion
- The prices paid for different types of wood fuels at plant
- The reasons for and the obstacles to extending the use of forest chips

In 1999, the users of forest chips consisted of 135 heating plants and 21 power plants. Half of the latter operated in conjunction with the forest industry. Each of the plants provided information about at least the amount of forest chips used. Some plants lacked
a clear picture of how their wood fuels were composed of forest chips and process residues from the forest industry, which may have lead to inaccuracies in the results. Not all users answered the other questions, but this did not create an obstacle to computing the average and eligible data.

2. The Consumption Target for Forest Chips

Due to the severe climate, long distances and industrial structure, the consumption of energy is high in Finland. In 1999, the total consumption corresponded to 31.3 Mtoe (1 313 PJ).

Carbon dioxide emissions from energy production amounted to 56 Mt and the total emissions of greenhouse gases to 76 Mt. According to the internal decision of the EU related to the Kyoto climate agreement, Finland is obliged to reduce her emissions to the level of 1990, i.e. to 73 Mt, by 2110. This level is currently exceeded by 4%. The task of reducing the emissions is demanding, because energy consumption is on the increase.

It is possible to reduce the amount of carbon dioxide emissions by substituting wood for fossil fuels. In 1999, 6.1 Mtoe (255 PJ) of the total energy consumption was satisfied with wood-based fuels. The proportion of wood-based energy rose from 14.7% to 19.5% during the last decade. The increase was based on by-products of the forest industry such as bark, sawdust and black liquor. The increased production of lumber, plywood and pulp increased also the production of by-products, and these by-products were utilised even more carefully than before. The production and combustion potentials of wood fuels make it possible to greatly expand the use in the future as well (Helynen 1999).

The aim of the Action Plan for Renewable Energy Sources of the Ministry of Trade and Industry is to raise the use of biofuels by 2.8 Mtoe (117 PJ) per annum in the period 1995-2010. The objective is to produce 1.4 Mtoe (58 PJ) of this increase with the aid of wood-based by-products, 0.9 Mtoe (38 PJ) with the aid of forest fuels and 0.5 Mtoe (21 PJ) with the aid of recycled fuels (Action Plan for Renewable Energy 2000). Owing to the expansion and high utilisation rate of the production capacity of the forest industry, 1.1 Mtoe (46 PJ) of the growth target for the by-products has already been reached (Figure 1), whereas the share of forest and recycled fuels has remained modest so far. The growth target of 0.9 Mtoe (38 PJ) set for forest fuels corresponds to 5 million m³ (solid) of woody biomass (more than 12 million m³ chips).
With the aim of reaching the above-mentioned targets, the State promotes the introduction of renewable energy sources. The tools of the State include energy taxation, aid for investments and the production of energy wood, as well as development of technology. The focus of the five-year research and development programme is primarily on the production of forest fuels. In practice, this means forest chips, i.e. fuel chips produced of the logging residues from regeneration areas and small-sized trees from young forests. The production of forest biomass to chips takes place in the forest, at roadside storages, at terminals or on the site of use. The objective of the Wood Energy Technology Programme is to increase the use of forest chips to the level of 2.5 million m$^3$ by the end of the Programme in 2003 by technology development.

3. Monitoring the Use of Forest Chips

The Finnish Statistical Yearbook of Forestry, published by the Finnish Forest Research Institute, provides reliable and detailed data on the direct and indirect use of wood raw material by the forest industry. Wood-based energy is an exception that is excluded from the yearbook, even though approx. 45% of the unbarked timber harvested from Finnish forests (total cutting in 1999 56 million m$^3$) finally ends up in energy production, mainly as by-products of the forest industry. Only the firewood used by farms and detached houses, the amount of which was approx. 4.6 million m$^3$ (36 PJ) in 1999, is included in the statistics (Yearbook of Forest Statistics 2000).
Because a clear growth target has been set for the use of forest chips, its development must be monitored. The data from monitoring are needed by the decision-makers of the State and the municipalities, the producers and consumers of forest chips, machine and transport entrepreneurs, forestry organisations, equipment manufacturers and other actors in the branch. Monitoring serves the assessment of the effectiveness of the promotion measures, the steering of research and compilation of statistics.

In spite of its necessity, the monitoring of the energy use of wood has remained insufficient, because it is technically inconvenient. Including forest chips in the general statistics on wood consumption is problematic for several reasons:

— Forest chips contain plenty of crown mass, which accounts for 80-90% of the chips from logging residues and for 15-25% of the whole tree chips from small-sized trees. The fact that forest chips include crown mass confuses statistics, because the growth and the use of wood are traditionally restricted merely to unbarked stemwood in the present statistics.

— The proportion of stemwood in forest chips consists mainly of under-sized trees, which are included in logging residues in forest statistics. A certain amount of stemwood meeting the requirements of pulpwood as regards its dimensions and quality is included in forest chips, but it is difficult to sort out the shares for statistical purposes.

— A considerable share of the forest chips is not brought within the scope of commerce due to being used by farms and other small consumers.

— The quantitative and price data of industrial timber for statistics are gathered from the buyers, who have a statutory duty to report their timber purchases to the authorities. The duty to report is restricted to the timber meeting the dimensions of industrial wood, and it does not thus concern forest chips.

— The use of forest chips is rapidly increasing, which is why it is difficult to maintain the up-to-date lists of producers and users that are needed for monitoring purposes.

— Large-scale power and heating plants use forest chips in cofiring, and the users are not always aware of the share of forest chips in all wood fuels of the plant.

Nevertheless, the development of the use of forest chips must be monitored. The report in hand illustrates the situation in 1999. As of the year 2000, the amounts used and the raw material sources and market prices of forest chips will be included in the Finnish Statistical Yearbook of Forestry in the same manner as the industrial timber. In addition, the Finnish Forest Research Institute will annually publish a separate bulletin providing information on the use of solid wood fuels.
4. Development of the Use of Forest Chips

4.1 The first appearance of forest chips

Forest chips appeared in the Finnish fuel market in the late 1950s, when oil had begun to displace firewood and the poor demand for small-sized wood constrained the management of forests. It was considered that the best way to maintain the status of wood as a significant fuel was to automate its handling.

Most users of forest chips were farms. There were also many garrisons among the users, because a further aim was to improve the security of energy supply in view of potential emergency periods. Vapo (State Fuel Centre) was the main supplier of fuel chips.

Because the first chippers were light and manually fed, the raw material had to be carefully delimbed stemwood, from which some bark was often removed in order to promote seasoning. Also the stokers used for feeding necessitated stick-free chips. Because birch was not used by the pulp industry at that time, the bulk of the chipwood of those days would have measured up to the present dimensions of birch pulpwood.

![Use of forest chips, mill. m³ solid/a](image)

Figure 2. The use of forest chips in Finland in 1960-1999 and the target (dashed line) for 2003 of the Wood Energy Technology Programme.

Forest chips sailed with a fair wind until the early years of the 1960s, at which time approx. 400 chip-fired boilers were in use and the level of 150 000 m³ was reached. Soon after that, birchwood became a desired raw material for the pulp industry, and there was also a sharp increase in the capacity of the hardboard and chipboard
industries, which brought some relief to the small-tree problem in forestry. Because the oil price declined at the same time, the use of forest chips became unprofitable. A ten-year downturn in consumption followed (Figure 2).

4.2 Energy crisis and the use of forest chips

The Finnish Defense Forces nevertheless continued to use forest chips for heating in some garrisons. The know-how was maintained, but technological development stagnated. It was not until the two global energy crises increased the oil price manifold and the availability of oil was at stake that society woke up to the significance of domestic energy. But because energy decisions are made in the long term and require substantial investments, the shift from one fuel to another did not take place in a twinkling of an eye.

As a result of the energy crises, the production of forest chips started to increase in the late 1970s, after a delay of several years. In the course of time, new technical possibilities had matured for the rationalisation of production. The introduction of forest tractors, hydraulic loaders and heavy chippers had rendered the delimbing of chipwood unnecessary. As long as the chip feeding equipment of heating plant provided for the possibility of sticks among the chips, it was possible to change over from delimbed stems to undelimbed whole trees, whereupon a smaller labour input resulted in a larger amount of chips from the same stand. Logging residues, too, had become an eligible source of energy. At that time still, cutting was carried out by chainsaw and the logging residues remained scattered at the site. Therefore, separate bunching of residues was needed, and the recovery was not profitable.

In 1982, forest chips were used by 115 heating plants and by 4000 farms. In addition, the forest industry had started to use forest chips in energy production and as a raw material for pulp and composite boards. The commercial production of forest chips rose to an annual total of 646 000 m³. The driving force was the high oil price.

But as soon as the oil price fell sharply, the competitiveness of forest chips collapsed. Even the Defense Forces gave up the expensive heating with chips. By the end of the decade, the consumption of commercial forest chips had fallen to less than 200 000 m³. Operations were no longer profitable, which was why no more financial aid was granted for research and development. However, a lasting result of the development work done for the promotion of domestic fuels was that Finland had become the world leader with regard to peat technology.
4.3 The greenhouse phenomenon and the use of forest chips

In the early 1990s, the conditions and needs changed again. In spite of the previous disappointments, the State started to promote the use of wood-based energy even more. This time the trigger was not rise in the oil price, but the unprecedented unemployment rate, the problems caused to silviculture by the underutilisation of small-sized wood, and the global worry about the climate change. The measures adopted for promoting the use of forest chips included taxation in favour of renewable energy as well as investment aid and support for production of wood fuels. Also electricity production based on renewable energy is supported. Very important tools were the Bioenergy Research Programme in 1993-1998 and the Wood Energy Technology Programme in 1999-2003.

The long-term efforts have started to bear fruit. The use of forest chips started to rise again in the middle of the last decade. Commercial use amounted to 567 000 m³ (4.5 PJ) in 1999. On the basis of a previous survey of the TTS Institute, the amount of the forest chips used by farms, heating entrepreneurs and other small-scale users can be estimated as 180 000 m³ (1.4 PJ). The total use of forest chips thus amounted to 747 000 m³ (5.9 PJ) in 1999, which corresponds to the record level of the early 1980s.

Despite the growth of the past few years, the use of forest chips is still modest in comparison to the biomass reserve suitable for harvest in the Finnish forests and to the current production of all wood-based energy.
It is:

- 5—7% compared to the biomass reserve technically harvestable in Finland (10—15 Mm³/a, 79 – 118 PJ)
- 15% compared to the small-scale use of traditional firewood at households (4.5 Mm³/a, 35 PJ)
- 8% compared to the energy use of wood and bark residues from the forest industry (8-9 Mm³/a, 63 – 72 PJ)
- 4% compared to the energy use of the black liquor, which is a by-product of the sulphate pulp industry (3.4 Mtoe, 142 PJ)
- 0.4% of the total energy consumption

In the light of these figures, the use of forest chips may not seem to justify the efforts and funding that the public and private sectors have invested in its promotion. However, international obligations require that the use of renewable energy sources is increased in all industrial countries. In Finland forest biomass is the most important reserve of renewable energy. At least over the next ten years, forest biomass will play a key role in Finland’s Climate Change Programme and energy strategy, which are now under preparation. The expected value of forest biomass is high.

5. Users of Forest Chips

5.1 Users in the early 1980s

The use of forest chips has not been monitored very much earlier. It is probable that in 1982 more forest chips were used than in any other year before the present day. Among the users were 13 over 10 MWth heating plants, 102 heating plants of the category 0.5-10 MWth and approx. 4,000 farms and other small units of real estate. The forest industry used forest chips both as a raw material and a fuel. (Table 1).
Table 1. Use of forest chips in Finland in 1982 (Hakkila 1984).

<table>
<thead>
<tr>
<th>The forest industry:</th>
<th>m³ solid/a</th>
<th>Energy, TJ/a</th>
</tr>
</thead>
<tbody>
<tr>
<td>As a raw material for chipboard and fibreboard</td>
<td>36 000</td>
<td>-</td>
</tr>
<tr>
<td>As a raw material for sulphate pulp</td>
<td>91 000</td>
<td>-</td>
</tr>
<tr>
<td>As a fuel obtained by screening from pulp chips</td>
<td>42 000</td>
<td>333</td>
</tr>
<tr>
<td>Directly as a fuel</td>
<td>84 000</td>
<td>665</td>
</tr>
<tr>
<td>Total</td>
<td>253 000</td>
<td>998</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Heating plants:</th>
<th>m³ solid/a</th>
<th>Energy, TJ/a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delivered by Vapo</td>
<td>123 000</td>
<td>974</td>
</tr>
<tr>
<td>Delivered by Forest Management Associations</td>
<td>74 000</td>
<td>586</td>
</tr>
<tr>
<td>Delivered by the forest industry</td>
<td>72 000</td>
<td>570</td>
</tr>
<tr>
<td>Delivered by other suppliers</td>
<td>124 000</td>
<td>982</td>
</tr>
<tr>
<td>Total</td>
<td>393 000</td>
<td>3 112</td>
</tr>
<tr>
<td>Total amount of forest chips in the market</td>
<td>646 000</td>
<td></td>
</tr>
<tr>
<td>Small-scale (non-commercial use)</td>
<td>120 000</td>
<td>950</td>
</tr>
<tr>
<td>Total amount of forest chips</td>
<td>766 000</td>
<td></td>
</tr>
<tr>
<td>Total amount of forest chips used in energy production</td>
<td>639 000</td>
<td>5 060</td>
</tr>
</tbody>
</table>

In the 1980s, operations were concentrated in small-scale heating plants, half of which were municipal district heating plants. Also 14 garrisons and several educational establishments and research institutes, small-scale industrial enterprises, dairies, hospitals, gardens and other types of real estate holders were among the users. From the point of view of producers, the seasonally changing need for fuel was a problem. The need was greatest during the first quarter of the year, but minimal during the third quarter. Profitability suffered from the overdimensioning of the plants for future needs and the resulting underutilisation of capacity.

The forest industry was a significant producer of forest chips mainly for its own needs as a raw material of pulp and boards. Only a third was directly used as a fuel, and fuel was also made of the screening residues of the whole tree chips used by the pulp industry. Apart from the forest industry, forest chips were not used for the combined heat and power production (CHP).

The oil price fell sharply in the middle of the 1980s. At the same time, the pulp and board industries tightened their raw material requirements and totally gave up the use of whole tree chips. The production of forest chips was faced with a downswing, which in turn caused problems to especially machine entrepeneurs, machine manufacturers and the research in the field.
Figure 3. The location of forest-chip fired heating and power plants in Finland in 1999. Minimum use 250 m³ solid per annum (625 m³ loose, which is ~ 2000 GJ).
5.2 Users at the turn of the millennium

The use of forest chips started to increase again during the last decade. In 1999, the total number of the heating and power plants exceeding the consumption limit stated in the questionnaire was 156 (Figure 3). Most of them were located in the southern part of Finland.

At heating plants, the increase in the use of forest chips has been slow, however, and the level of the 1980s has not been reached yet. Instead, growth is now rapid in the combined heat and power production. Many power plants have made or are making changes in their fuel receiving, handling and boiler plants in order to be able to use forest chips. In 1999, altogether 40% of all forest chips were used in CHP production (Figure 4), and the share is likely to exceed 50% as soon as 2000. There is a difference between Finland and Sweden in this respect, because taxation in Sweden steers the use of wood fuels more powerfully to heat production. In Finland electricity production by wood fuels is supported by the State through a partial tax refund (8 FIM/MWh, 1.35 €/MWh).

![Figure 4. The users of forest chips in Finland in 1999.](image)

Unlike power plants, the heating plants that used forest chips in the year of the questionnaire had hardly any plans for increasing their use. A large number of new heating and power plants, to which the questionnaire had not been sent, were entering the market, however.
According to statements by the present users, the main obstacles to increasing the share of forest chips were – in the order of importance - the following:

— The high price of forest chips

— The lack of a procurement organisation or the unreliability of deliveries

— Technical limitations in the fuel receiving and handling of chips at the plant

— Insufficient boiler efficiency, especially in winter, while forest chips are used

— The unsatisfactory quality of forest chips

Apart from the price, these limiting factors are better controlled by CHP producers. More than 20 000 m$^3$ solid (150 TJ) were used among power enterprises by Pursiala in Mikkeli, Rauhalahdi in Jyväskylä and Toppila in Oulu, and among industrial plants by Kaipola in Jämsä and Tervasaari in Valkeakoski. The district heating plants in Kemijärvi, Kitee and Nivala, the power plants in Forssa and Savonlinna, and the industrial power plant in Rauma reached an annual level of more than 10 000 m$^3$ (80 PJ).

In the future the increase in the use of forest chips seems to concentrate on CHP production. The total number of the plants using forest chips is estimated to grow by 100—150 plants by 2010, and 25—35 of them will be over 20 MW$_{th}$ in size. As much as 90% of the additional use of forest chips will probably be led to the over 20 MW$_{th}$ plants and 70% to the over 100 MW$_{th}$ plants (Laurila 2000).

Forest chips are typically used in cofiring. Only small-scale heating plants can use forest chips as their main fuel, often high-quality chips from delimbed small stems. Large-scale plants are also faced with a problem of availability, because it is not profitable to procure forest chips from far away due to their low energy density. For the time being, even the longest transport distances are less than 100 km long. Table 2 presents the proportion of forest chips at the plants that have included them in the selection of their fuels. Plants that have used no forest chips at all are not included in the table.
Table 2. Selection of fuels at the heating plants that used forest chips in Finland in 1999. Plants owned by the forest industry are not included in the table.

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Size of heating plant (boiler capacity)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.5-1 MW&lt;sub&gt;th&lt;/sub&gt;</td>
</tr>
<tr>
<td>Forest chips</td>
<td>78.6</td>
</tr>
<tr>
<td>Industrial wood and bark residues</td>
<td>7.2</td>
</tr>
<tr>
<td>Peat</td>
<td>0.4</td>
</tr>
<tr>
<td>Municipal waste</td>
<td>-</td>
</tr>
<tr>
<td>Coal</td>
<td>-</td>
</tr>
<tr>
<td>Oil</td>
<td>13.8</td>
</tr>
<tr>
<td>Other fuel</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
</tr>
</tbody>
</table>

As the plant grows in size, the share of forest chips generally decreases. The following features can be observed in the dual fuels used together with forest chips:

— The additional fuel of the minor, under 1 MW<sub>th</sub> heating plants using forest chips is mainly light fuel oil. The industrial process residues used is wood, whereas no bark residues are used. The peat fuel is sod peat.

— At the heating plants in the size class 1—5 MW, relatively large amounts of wood and bark residues as well as of peat and oil are used along with forest chips. The peat is mainly sod peat and the oil – depending on the size of the plant - mainly heavy fuel oil.

— In the size class 5—10 MW, forest chips quantitatively fall behind industrial wood and bark residues, although only the plants using forest chips are included in the table. The peat is mainly milled peat and the oil is heavy fuel oil.

— For the time being, forest chips only play a minor role at the over 10 MW<sub>th</sub> plants. When the plants owned by the forest industry are not taken into account, the number of the plants of this capacity using forest chips was ten in 1999. The main fuel of these plants was milled peat, but also the amount of industrial wood and bark residues was many times the amount of forest chips. In this very group of plants, however, great growth expectations were set on forest chips.

The emphasis of the Wood Energy Technology Programme is on large-scale production and use. This is justified in the light of the great additional potential for utilisation and development. At the same time, however, the research and development work serving
the needs of the smaller, under 10 MW\textsubscript{th} plants, has remained in the background, and the real small-scale use (i.e. the under 0.5 MW\textsubscript{th} boilers) has been completely excluded from the Programme. Because the development of the small-scale use promotes the growth targets and is important from the angle of social stability and the vitality of the countryside, the aim of Tekes is to strengthen also the research on and development of the small-scale use.

6. The Raw Material of Forest Chips

6.1 Changes in the raw material base

Forest chips are produced of woody biomass that due to its composition, small diameter, rot or other defects or unfavourable logging conditions is not considered a suitable raw material for the forest industry. Compared to the producers of heat and power, the solvency of the pulp industry is so incomparable that the pulp and energy uses do not in practice compete for the same roundwood. The production of forest chips is not a threat to the sufficiency of pulpwood, but instead promotes forest management and – in the long run – the production of industrial wood.

Compared to the present use, the raw material potential of forest chips is 15—20-fold. In view of the costs and quality of forest chips, procurement can thus for the time being be directed to the most cost-effective logging sites within as short an operating span as possible. The selection criteria are based on the structure of the logging sites, the dimension and quality requirements set for pulpwood, the development of harvesting technology and the fuel receiving, handling and combustion facilities of the plants. Therefore, logging sites have changed over the years:

— At the initial stages of production in the 1950s and 1960s, forest chips were made of delimbed stemwood, because chippers were manually fed and chip feeders did not allow sticks from bits of branches. Because the pulp industry was only starting to use short-fibred pulp, the birchwood unsuitable for plywood manufacture was almost totally available for combustion. At that time, a considerable proportion of traditional firewood and forest chips was in fact made of the kind of hardwood that is nowadays led to pulping.

— As forest chip production revived in the early 1980s, the pulp industry had already started to make use of nearly all birch pulpwood available. On the other hand, the development of harvesting technology had enabled the chipping of undelimbed small trees. The emphasis shifted from delimbed trees to whole tree raw material, which significantly improved the productivity of
logging work and reduced production costs. Chip handling systems were adapted to whole tree chips, which at least at that time still were burdened by a profusion of over-sized sticks.

—— The raw material base of forest chips changed again in the 1990s. The mechanisation of logging had an epoch-making effect, as the working pattern of the single-grip harvester was adapted to the recovery of logging residues in forest regeneration areas. The expensive separate bunching was no longer necessary, which lowered the costs decisively. At the same time, a big step was taken towards integrating the production of industrial wood and energy wood. Unlike before, forest chips were introduced also at major plants, where varying particle size and the higher needle, moisture and ash contents of logging residues do not create insurmountable obstacles. As a result of these developments, in the late 1990s the increase in the use of forest fuels was strongly based on the chips from logging residues in the late 1990s.

Figure 5 shows the change that took place in the raw material base of forest chips in the late 1990s. The use of small-sized wood hardly grew at all, but there was a shift from delimbed to undelimbed trees within this category. Instead, the use of logging residues was multiplied in four years. There was also an increase in the use of forest chips from other sources, such as rot-damaged spruce wood and wood imported from Russia.

![Figure 5. The sources of forest chips in Finland in 1995 and 1999. Small-scale use excluded.](image)
6.2 Small-sized trees as a raw material of forest chips

Compared to the chips from logging residues, the chips from small-sized wood are considered to bring significant benefits to job creation and forest management. In recent years, however, the production of chips from small-sized wood has been getting nowhere owing to low cost-competitiveness. The situation has not improved in spite of the significant financial support provided by the State for the recovery of wood fuel from young forests, as specified in the Act on the Financing of Sustainable Forestry (1094/1996). There are three forms of financial support, which are not mutually excluding: for the tending of a young stand, for the harvesting of energy wood and for chipping of energy wood.

According to the Forestry Development Centre Tapio, forest owners were in 1999 paid area-based financial support for the tending of a total of 110 000 hectares of young forest. This form of support does in no way presuppose the recovery of the trees removed. Its sole objective is silvicultural. If, however, firewood is recovered from the area of tending, FIM 30/m$^3$ (2.52 €/MWh, 0.7 €/GJ) is paid for it as a harvesting support for energy wood. Only 5% of the areas receiving financial support for tending made use of this opportunity. The total harvesting support paid amounted to FIM 8 million (1.4 million €). It was allocated primarily to traditional firewood, but to a smaller degree also to wood made into forest chips:

- The area receiving support for the harvesting of energy wood, ha 5 278
- The volume of energy wood receiving support, m$^3$ 268 100
- The total amount of harvesting support, FIM (M€) 8 043 000 (1.35)

In addition to the above-mentioned forms of financial support, the State in December 1999 started to provide financial support for chipping, the amount of which was FIM 10/m$^3$ loose or approx. FIM 25/m$^3$ solid (0.7 €/GJ), when fuel chips are produced of energy wood harvested from young stands. The support is paid to the producer of chips. Because the payment of the support started at the end of the year, the total amount remained modest. For the time being, the decision concerns only the years 2000 and 2001, wherefore the producers have not considered it sensible to modify their operations yet (Alakangas & Janka 2000).

The support package for young forests is so substantial that it should create the preconditions for the production of forest chips from small-sized wood on a larger scale than at present. However, channelling this support so that the production of forest chips from small-sized wood would have increased significantly, has not been successful. It is pointed out that no such possibility to receive a subsidy like this exists in Sweden,
where the forest chips from small-sized wood is burdened also by a smaller the top diameter requirement of pulpwood.

The increase in the use of forest chips is most rapid at large-scale plants, which are expressly interested in the chips from logging residues. Logging residues constitute the most significant biomass reserves, their recovery is easy to integrate into the harvesting of industrial wood, and their production is cost-effective. For these reasons, also the research on and development of the related production and operating systems mainly concentrate on logging residues.

More attention should be given also to small-sized trees, with regard to the production technologies, procurement logistics and quality management. One-sided raw material base is not good in the long run. There are many reasons to increase research and development work:

— Production of forest chips from small-sized wood supports the tending of young forests that is threatening to become the Achilles heel of the Finnish forest management. Its significance to forest management is greater than that of the production of forest chips from logging residues from regeneration areas.

— Due to the felling work, the production of chips from small-sized tree involves more human labour, wherefore its employment-boosting effect is greater. When there is a shortage of forest workers, this advantage turns into a disadvantage.

— As to combustion properties, the chips from small-sized wood are better than the chips from logging residues. Their moisture content is easier to control, their particle size distribution is generally more even, their durability during storage is better due to their lower needle content, and for the same reason, they contain less alkali metals, chlorine and ash. Even though the significance of quality is greatest in small-scale use, it is important also in large-scale use. Well-seasoned forest chips from small-sized wood might help to maintain the quality in wintertime, when the moisture content of chips from logging residues tends to exceed the determined limits.

— Chips from small-sized wood are especially suitable for small-scale procurement and use, for which a growth target of 0.6 Mtoe (25 PJ) or 3 Mm³ has been set in the Action Plan for Renewable Energy Sources. The production of chips from small-sized wood can be integrated in the tending of young forests by Forest Management Associations.

— The preparedness to produce alternatively forest chips from small-sized wood would also allow more latitude to the large-scale producers and users of the chips from logging residues, because expanded procurement activity will make it impossible to skim chips only from the most favourable stands and
restricted zones of supply. When the harvesting conditions become more difficult, when the transport distances get longer and stumpage expectations revive, the stand-specific cost factors will change. Chips from small-sized wood from in favourable stand conditions may then become less expensive than the chips from logging residues harvested in unfavourable conditions. If the financial support pertaining to the forest chips from small-sized wood is exploited in an appropriate manner, the gap can be narrow in some cases even now.

— When there is an economic downswing in the sawmill industry, the availability of sawdust, bark and logging residues is tightened. Under such circumstances, the preparedness to produce chips from small-sized wood would improve the reliability of deliveries.

![Diagram of forest chips at plants of different sizes in Finland in 1999.](image)

**Figure 6. The sources of forest chips at plants of different sizes in Finland in 1999. Forest chips from delimbed stems include also chips from rot-defected spruce and low-quality wood imported from Russia.**

The selection of raw material is affected by the importance of quality factors, the resources of the procurement organisation and its linkages with the forest industry, the structure of forests, the fuel receiving and handling systems as well as the ownership of the plant. Figure 6 presents the sources of forest chips at plants of different sizes in 1999. The smallest plants set the highest quality requirements for forest chips, which is why they primarily use delimbed stemwood. As the plant grows in size, undelimbed whole trees and, before long, logging residues tend to replace delimbed stems for cost reasons.
7. The Quality of Forest Chips

The fact that wood fuels are renewable and environmentally friendly is an incomparable advantage. Their quality properties do not always meet the requirements for modern fuels, however. Especially erratic variations in quality are injurious.

The essential quality factors of forest chips are the following (Impola 1998):

— The moisture content (%) affects the haulage, caloric heating value, efficiency of combustion and durability during storage.
— The energy density (MWh/m³ loose) affects the haulage, need for storing space and the maximum efficiency of the boiler.
— The particle size distribution affects the handling of the chips and chip density.
— The needle content affects the durability and the nitrogen, chlorine, alkali and ash contents of chips.
— Purity affects the wear and tear of surfaces, the amount and fusibility of ash and the need to change the material of the fluidised bed.
— The ash content affects the caloric heating value, the need to clean the boiler as well as the costs of handling the ashes.

The significance of quality factors is greatest at small plants. It may have been considered previously that the quality of forest chips was of secondary importance to large-scale plants, because it is possible to combust even wet chips in a big boiler by mixing the chips with other fuels. Experience has shown, however, that quality must be attended to in every case. In spite of improvements, sharp variations occur in the quality of forest chips between different plants as well as annually, seasonally and truckload-wise.

The only quality factor included in the survey was the moisture content of chips, which in practice is probably the most important of the above criteria. Because the moisture content affects the caloric heating value of wood, it also affects the costs of the forest chips, calculated per energy content. The average monthly moisture contents of the forest chips received by plants of different sizes in 1999 are presented in Figure 7.

The figure shows that:

— The moisture content is lowest in midsummer, when the use of forest chips is smallest. It is highest in midwinter during the peak heating season.
— The moisture content is lowest in the chips of small plants and highest in those of large plants. The differences between the size classes are partly due to differences
in the sources of the forest chips. Small-scale plants use more small-sized wood, the moisture content of which is easier to control. Large-scale plants use logging residues, the harvesting logistics of which are smoothest when fresh chips are produced. Small-scale plants must pay more attention to the moisture content of chips simply because the share of forest chips is largest on their entire fuel palette.

The summer of 1999 was exceptionally favourable with regard to seasoning, which was visible as the low moisture content of forest chips during the rest of the year. For example, the moisture content of the chips from logging residues delivered to the Kaipola mills fell on average by 5-10 percentage points in the summer of 1999, compared to the summer of 1998 (Kalliola 2000).

Figure 7. The seasonal variation of the moisture content (green weight basis) of forest chips as delivered to heating plants of different sizes in 1999.

The moisture content of freshly-felled small-sized wood and logging residues is approx. 55% for softwood and 45% for birchwood most of the year. If the moisture content falls from 55% to 45%, the net calorific heating value of biomass increases by 6%. If the moisture content falls further to 35%, the total increase is as much as 11%. At the same time, the efficiency of combustion increases, which further increases the significance of seasoning.

Figure 8 shows the seasonal variation in use of forest chips. Forest chips are not used in summertime when the moisture content is at the lowest and the net calorific heating value is at the highest. In other hand many plants have to restrict the use of forest chips during wintertime, because moist forest chips are not able to produce the required peak load. Forest chips may be then be replaced by dryer fuels such as peat.
Seasonal fluctuation in the use of forest chips during the year creates problems in the fuel logistics system and employment resulting in an increase in the production costs. In the wintertime more forest chips could be used when the quality improve, but in the summertime the problem remains.

Figure 10 shows the annual efficiency of the heating plants that combusted forest chips in 1995 and 1999. The figure illustrates the efficiency of cofiring, not the average efficiency of the mere combustion of forest chips. The rate of efficiency increases according to the size of the plant. The difference is explained by the improved efficiency of boiler technology and an increase in the proportion of peat at the expense of wood containing more moisture as the plant grows in size. The figure also shows that the rate of efficiency was higher in 1999 than in 1995. Increased efficiency may partly be due to more advanced technology, but the moisture content of the fuel, which at least for forest chips was lower than average in 1999, is probably even more important.

Figure 8. The monthly variation forest chips use in different size of plants in 1999, excluding the use by forest industry.
Figure 9. The monthly variation of total use of forest chips in 1999, excluding the use by forest industry.

Figure 10. The annual efficiency of forest chip-fired heating plants in Finland in 1995 and 1999.

Moisture control is closely related to storage and procurement logistics, and the aim is to find optimum solutions for both. Material is also lost during storage due to the shedding of needles or the decomposition of biomass. There are several ongoing projects in the Wood Energy Technology Programme, the aim of which is to lower the moisture content of both forest chips and industrial process residues, while only little attention has been given to small-sized wood and sawdust in this respect so far.
8. The Market Price of Wood Fuels

8.1 The price of forest chips

Even though the production costs of forest chips are still high, the market prices fell radically over the last decade. The fall was partly apparent, but largely also real. Statistical errors have resulted from the fact that the price of the energy statistics in the early 1990s exclusively referred to the finest forest chips produced from delimbed wood, and when this price was later replaced with the average price of all forest chips, an erroneous picture of a sudden 50 per cent drop in the price appeared.

But the price of forest chips has declined also in reality. The nominal prices are now considerably lower than two decades ago, and the drop has been even sharper in the real prices (Figure 11).

![Figure 11. The development of the average nominal prices of forest chips by source at heating plants, VAT excluded.](image)

The price range of forest chips is wide. Chips from small-sized wood are expensive, because also the costs of felling must be included in the price and because the harvesting takes place in thinning stands. The price is particularly high, when the chips are made from delimbed stems. For this reason, the amount of chips from delimbed stems is decreasing in the market. Many small-scale heating plants, however, still require chips from delimbed stems because they are free from over-long particles from branches.
Chips from logging residues are most cost-effective, because felling is no cost burden. In addition, the recovery of logging residues takes place on regeneration sites and can easily be integrated into traditional logging. The weakness of the chips from logging residues is a higher moisture and needle content and an irregular particle size. Small-scale heating plants therefore prefer chips from small-sized wood despite the higher price, especially if the alternative is light fuel oil. As the know-how and quality consciousness increase, also the quality of forest chips from logging residues improves, which means that they may become a suitable fuel also for minor heating plants.

The reduction in the price of the forest chips from logging residues is partly due to the development of general logging technology. The mechanisation of cutting created an opportunity to low-cost bunching of logging residues, and the vigorous tendering of machine and transport services lowered the general cost level of industrial wood procurement by 20-30% in ten years. When an integrated procurement system is used, the development of the harvesting costs of industrial wood is naturally reflected also in the costs of the by-product, i.e. the forest chips. The average price of forest chips has fallen also because the proportion of logging residues in total production is increasing. The favourable cost trend has additionally been strengthened by increased production volumes, by increased annual operation rate of machines, by smoother production logistics as well as by new technical solutions. It follows that forest chips from logging residues have become an interesting fuel also for large-scale power plants.

8.2 The price of sawdust and bark

Forest chips are combusted side by side with bark and wood residues from the forest industry. Industrial wood residues are by far the most economical to produce, which is why their market price is lower than that of forest chips. The use of forest chips is thus considered only when industrial residues of a suitable quality are no longer sufficiently available at local level.

The production volumes of industrial bark and wood residues are much larger than those of forest chips. Even though the producers combust the bulk of their processing residues themselves, a large amount of fuel is available for the market from the mechanical forest industry. In fact, the major suppliers of wood fuels sell more industrial bark and wood residues than forest chips.

Even though the production of sawdust and bark is now record-breaking due to an upswing in the sawmill industry, there seems to have been a slight increase in the prices of these products. It can be expected that the prices will continue to rise as the demand increases, especially if there is a depression in the sawmill industry resulting in a
decreased availability of by-products. The following figures show the price levels (excl. VAT) of wood and bark residues in Finland, Sweden and 20 European countries in 1999.

Table 3. Prices of wood fuels in Finland, Sweden and in 20 European countries.

<table>
<thead>
<tr>
<th>Plant type and fuel</th>
<th>FIM/MWh</th>
<th>€/GJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price at a heating plant in Finland</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Bark</td>
<td>38</td>
<td>1.78</td>
</tr>
<tr>
<td>- Sawdust</td>
<td>36</td>
<td>1.68</td>
</tr>
<tr>
<td>- Fuel chips from industrial wood residues</td>
<td>43</td>
<td>2.00</td>
</tr>
<tr>
<td>Price at a heating plant in Sweden</td>
<td>67</td>
<td>3.13</td>
</tr>
<tr>
<td>- Bark and wood residues on average</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Price at an industrial plant in Sweden</td>
<td>56</td>
<td>2.62</td>
</tr>
<tr>
<td>- Bark and wood residues on average</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average of 20 European countries, AFB-net survey 1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Forest residues</td>
<td>22–178</td>
<td>1.02–8.33</td>
</tr>
<tr>
<td>average 71</td>
<td></td>
<td>average 3.42</td>
</tr>
<tr>
<td>- Industrial by-products (solid)</td>
<td>17–194</td>
<td>0.58–9.07</td>
</tr>
<tr>
<td>average 51</td>
<td></td>
<td>average 2.38</td>
</tr>
</tbody>
</table>


8.3 The Swedish price level

With some minor exceptions, the prices (excl. VAT) of forest chips vary in Finland between FIM 40/MWh (1.9 €/GJ) and FIM 80/MWh (3.7 €/GJ). The average price of forest chips was FIM 53/MWh (2.5 €/GJ) in 1999.

In Sweden, the average price was much higher, FIM 80/MWh (3.7 €/GJ) for heating plants and FIM 75/MWh (3.5 €/GJ) for industry (Prisblad för biobränslen, torv m m. 2000), although the proportion of forest chips from logging residues was clearly larger in Sweden than in Finland. The Swedish harvesting conditions are not more difficult than the Finnish ones, rather on the contrary. Exceptions from this are better quality control and longer transport distances in Sweden. Due to the larger consumption, the average trucking distance is 60 km in Sweden, while it still appears to be less than 40
km in Finland. Transport distances are becoming longer in Finland, too, which creates cost pressures.

The reason for the approx. 50% higher Swedish price level is the heavier taxation of the fossil fuels in heat production. High prices of alternative fuels has led to a rise in the price of forest chips. It has been possible to allow higher production costs, which also include the stumpage paid to the forest owner and the costs arising from longer seasoning.

The annual production and use of forest chips amounts to over 3 million m$^3$ (23 PJ) in Sweden. Of this amount, 2.2 million m$^3$ (17.4 PJ) are made of logging residues, 0.4 million m$^3$ (3 PJ) of small-sized wood and 0.5 million m$^3$ (4 PJ) of rot-damaged wood (Andersson 2000, Björheden 2000). In recent years, however, the volume has not grown as expected, but has remained on the same level as before. Behind this are the present prosperity of the sawmill industry and the resulting abundant availability of by-products, and on the other hand, a rapid increase in the use of pellets, briquets and wood powder produce. Another constraint to increasing the use of forest chips in Sweden is the import of wood fuels. Especially the import of recycled wood fuels has grown rapidly. The recycled wood from Central Europe is very cost-competitive, because as far as the producer is concerned, the alternative of combustion is normally a landfill, which involves considerable waste charges.

In Sweden, the heavy environmental taxation has made it possible for heating plants to use forest chips on a larger scale than anywhere else in the world. The price of forest fuels has rised, which has resulted in large-scale import of wood fuels. In fact, 30-40% of the wood fuel used in district heating (20 – 30 PJ) is imported (Vesterinen & Alakangas 2001). Thus, the highest price level in the world of wood fuels has started to slow down the growth of the domestic production of forest chips. When a tax system in favour of wood was created, the aim was of course not to import wood from abroad.

9. Summary

The forest chips made of logging residues and small-sized wood unsuitable for industrial raw material will play a key role in Finland’s efforts to substitute renewable energy sources for fossil fuels over the next ten years. Clear growth targets have been set for the use of forest chips.

Because forest chips were neither included in the general monitoring of wood use nor in forest statistics, the Wood Energy Technology Programme commissioned a survey of
the use of forest chips in the first year of the Programme, i.e. in 1999. The results of the mapping are presented in this report.

In 1999, forest chips were used by 135 heating plants and by 21 power plants. The total use of forest chips amounted to 747,000 m$^3$ (5.9 PJ), which figure includes the non-commercial small-scale use, 180,000 m$^3$ (1.4 PJ). After a lengthy recession, the record level of the early 1980s was finally reached. Plenty of modifications that will make it possible for plants to use forest chips in cofiring are currently under way, and also completely new plants are under construction.

Of the total production of commercial forest chips, 60% were used by heating plants and 40% by power plants. Growth is now mainly concentrated in large-scale power plants, whose share of the total consumption of forest chips is increasing all the time. Forest chips are generally used as a mixed fuel, together with wood and bark residues from the forest industry, as well as with peat. As the plant grows in size, the proportion of forest chips in the fuel decreases due to limited availability.

Due to tighter requirements for quality, the forest chips aimed at small-scale use are made exclusively of small-sized trees. Nevertheless, already more than half of the commercial forest chips are made from logging residues. Growth is now limited to the forest chips from logging residues, but it would be quite in order to balance procurement activity between all types of logging sites. Therefore, also the research on and development of the chips from small-sized wood should be intensified.

The producers and users of forest chips have started to give increasing attention to the qualitative characteristics of forest chips, the most important of which is the moisture content. Small heating plants use forest chips with lower moisture content than large power plants. More attention than at present should be given to the moisture content. If it is possible - in one way or another - to lower it from the 55% of the freshly-felled woody biomass to 45%, the net calorific heating value will grow by 6%. The need to lower the moisture content is not limited to forest chips, but applies to bark and sawdust as well.

The nominal price of forest chips has declined by 35% over the past two decades. This has been possible due to a general decline in the procurement costs of timber, technological advances in both the production of forest chips and the related procurement logistics, an increase in production volumes, and the fact that the emphasis has shifted from the expensive chips from delimbed stems to whole tree chips and further to those from logging residues. In spite of this, the most serious barrier to increasing the use of forest chips is the market price, which is considered too high by the users. In 1999, heating plants paid on average FIM 61/MWh (2.9 €/GJ) for the
whole tree chips, FIM 44/MWh (2.1 €/GJ) for the chips from logging residues and FIM 53/MWh (2.5 €/GJ) for all forest chips. At the same time, the price level of sawdust and bark was under FIM 40/MWh (1.9 €/GJ). In Finland, the prices were clearly lower than in Sweden, where the heating plants paid as much as FIM 80/MWh (3.7 €/GJ) for forest chips and FIM 67/MWh (3.1 €/GJ) for industrial wood and bark residues. In comparison of 20 European countries, average price for forest residues was in 1999, FIM 73/MWh (3.4 €/GJ) and for industrial wood residues 51 FIM/MWh (2.4 €/GJ) (Vesterinen & Alakangas 2001).

Attitudes towards the use of forest chips are favorable. A large number of new heating and power plants technically suitable for wood fuels are being designed and constructed. The total fuel output of the new plants built during 1997 and 2010 is estimated to be 3450 MW_{th} (Electrowatt-Ekono 2000). At the same time, cost pressures will arise due to longer transport distances, less favorable logging sites and stumpage price expectations. To counterbalance this, the development of the machines and production systems must be continued, and also the quality of forest chips must be improved taking account of both small-scale and large-scale use.

As of the year 2000, the Finnish Forest Research Institute will start to monitor the use and market prices of forest chips and the solid processing residues from the forest industry. The data from monitoring will be published annually by the sources of forest chips and plant sizes in a forest statistics bulletin of the Finnish Forest Research Institute. The results will be available in Internet in the METINFO (www.metla.fi/metinfo). Results will also be published in the Finnish Statistical Yearbook of Forestry. This will facilitate the monitoring and steering of the programmes on the use of wood energy, as well as assessing the effectiveness of the promotion measures taken.
References


www.tekes.fi/english/programm/woodenergy
The European Agriculture and Forestry Biomass Network

Eija Alakangas, Network Co-ordinator, VTT Energy
P.O. Box 1603, FIN-40101 Jyväskylä, Finland
Tel. +358-14-672 550, Fax. +358-14-672 598
e-mail: eija.alakangas@vtt.fi

http://afbnet.vtt.fi

Prof. Pentti Hakkila, Programme Manager
VTT Energy
P.O. Box 1604, FIN-02044 VTT, Finland
Tel. +358 9 456 6672, Fax. +358 9 456 5000
e-mail: pentti.hakkila@vtt.fi

www.tekes.fi/english/programm/woodenergy