BIOMASS-BASED FUELS IN CENTRAL FINLAND

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Summary
This report is done in the ALTENER-project called “FIVE EUROPEAN RES-HEAT PILOTS“ (5EURES). There is information of biofuel resources, production techniques, use, quality and employment of bioenergy in Central Finland. The report is a literature review and based on the reports and articles published in Finland.

Central Finland is a province with wide opportunities of bioenergy. Province uses active several bioenergy sources and further develops use of them. In the province there are research and training organisations, which are well known both domestic and international on the bioenergy sector. Local industry is also innovative and flourishing. In many cases results of R&D spread outside of the province and benefit so the use of biofuels.

About 39 % of the energy of Central Finland is produced by biofuels in 2000 and use of bioenergy is growing. Total energy use in 2000 was 16 450 GWh. Main bioenergy sources are forest residue chips, stumps, wood dust and bark, black liqueur and peat. Three big industrial CHP-plants and the municipal CHP-plant of Jyväskylä use about 90% of produced bioenergy. Biofuel branch has created several local working places especial in the rural areas. It is calculated that amount of workplaces could be even 2000 at the moment.
PREFACE

This report is made in the ALTENER-project called “FIVE EUROPEAN RES-HEAT PILOTS“ (5EURES) in August-September of 2005. The task was funded by EU, KTM (Ministry of Trade and Industry of Finland) and VTT. The whole project is coordinated by Jyväskylä Science Park (JSP) from Jyväskylä in Finland. Main project partners are VTT and METLA from Finland, CEBra GmbH (and Fachhochschule Eberswalde) from Germany, Enginyer tècnic del Servei de Gestió Forestal from Catalonia, Instituto Superior Technico from Portugal and Aviridis (and FOAL) from Lithuania. The target of the project is increase use of solid fuels in participating countries. The role of VTT is to submit knowledge of Finnish solid wood and combustion technology and contribute the works in different countries. This report is a part of this target. In the report it is presented the current situation of biofuels in Central Finland. There is information of biofuel resources, production techniques, use, quality and employment of bioenergy in Central Finland. The report is a literature review and based on the reports and articles published in Finland.

30.9.2005 Jyväskylä

Markku Kallio & Arvo Leinonen
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Appendix 2. Conversion factors for wood fuels.
1 OVERVIEW

1.1 DESCRIPTION OF THE CENTRAL FINLAND

Central Finland is a province of thousands lakes and large forests. Province is situated in the center of Finnish area, figure 1. Land area is 16 582 km² and total area with lakes 19 763 km². There are two large lakes in the area, Päijänne and Keitele. Average temperature in southern part of the county is 2.1 – 3.0 °C and 1.1 – 2.0 °C in northern part. Average annual precipitation is 501 - 600 mm.

![Population of Central Finland of communes and regions 31.12.2003](image)

The capital city is Jyväskylä. Most of the population of the Central Finland is concentrated at the Jyväskylä area. The population of the Jyväskylä town is 82409 (31.12.2003) and 163 390 in the Jyväskylä region (map, figure 1). Total population of the Central Finland is 266 082 inhabitants.

Population of other regions is much smaller:
- Region of Northern Central Finland 35211 inhabitants,
- Joutsa Region 6103 inhabitants,
- Keuruu Region 13296 inhabitants,
At Jämsä, Jyväskylä and Äänekoski regions there is pulp- and paper and other heavy industry.

1.2 INFRASTRUCTURE

Jyväskylä is the most important town of the region. Jyväskylä is main crosspoint of the roads to neighboring towns in the north, south, west and east. Through Central Finland goes from north to south highway A4 and the road net is well built and tight because of log trucks and domestic fuel transportation. In the figure 2 are shown the main railways and roads.

Figure 2. Main road and railways through Central Finland (Anon. 2003).

The biggest towns of Central Finland Äänekoski, Jyväskylä and Jämsä are connected with railways. Railway comes from Helsinki and goes through Jyväskylä to Eastern-Finland. East-west direction exist rails, but they are little used in industrial purposes.

An international airport is situated in Jyväskylä. Most flights go between Helsinki – Jyväskylä. In wintertime there are 8-9 flights per day.

A canal between lakes Päijänne and Keitele exist, but it is used mostly to pleasure traffic. There has been discussion of sea canal to Finnish Gulf.

Jyväskylä, the local centre, is a town of culture, commerce, education, research, traffic and industry. Jyväskylä has a university of 15 000 students. There is a pulp using paper
mill in the centre of the town. Metso paper makes paper machines in Jyväskylä. Near by is Valtra’s tractor fabric. In the Jyväskylä region is also many kind small industry which services the province and larger areas.

Pulp- and paper towns with commerce and schools besides Jyväskylä include Jämsä, Äänekoski and Suolahti. Keuruu to the west of Jyväskylä, Viitasaari and Pihtipudas in the north, and the community of Hankasalmi to the east of Jyväskylä, are small communities with commerce, schools and small industry.

1.3 ENERGY CONSUMPTION IN DIFFERENT SECTORS AND THE SOURCES

Energy consumption grew 17% from the year 1993 to the year 2000 in Central Finland and was 16 450 GWh in 2000. About 80% of the electric power consumed in the area is imported outside the region. On the other hand, the use of wood has grown in energy production. The growth of wood consumption is based on changes done in local CPH-plants. Almost equal amounts of oil products were imported in 1993 and 2000, but the proportional share of oil diminished. Share of traffic and transportation is 50% of oil consumption.

Electric power consumption depends on the economic situation in industry, because industry consumes about 73% of electricity. Mechanical pulp production in the valley of Jämsänjoki river requires lots of electric power. Power consumption in 2002 was 6200 GWh, and the consumption of district heat 1255 GWh.

In Central Finland the long term goal of energy use is to replace oil with local fuels in heating. This means, that oil burners and boilers in heating centres are substituted with wood chip centres and oil burners in small houses and real estates with pellet burners. Another goal is increase the local power generation capacity. Pulp- and paper industry has built new power generation capacity, and there are also plans to construct a new CHP-plant in Jyväskylä.

Energy consumption and sources of energy in Central Finland in 2000 are shown in the figure 3.
2 FUEL RESOURCES IN CENTRAL FINLAND

2.1 FOREST RESIDUES

2.1.1 Present situation of forest residues

Large volumes of forest residues and other wood derived fuels are used in energy production in Central Finland. The forest area of Central Finland is 1373 km². Volume of wood in the forests is 162,908,000 m³. The amounts of pine and spruce were almost equal (44.6 vs. 37.9%) in 2002. The rest (14%) are birch predominant forests and other hard wood (3.5%). According to the estimates the share of pine will increase in the future so the volume of forest residues will diminish. Private persons own most of the forests. Other forest owners are companies and state (Nuutinen et al. 2005).

Annual harvest of logs and pulpwood in Central Finland in 2003 was about 5.9 million m³ (Anon. 2005). The share of pulpwood was 3.8 and logwood 2.1 million m³. The share of pine of logwood was 682,000 m³/a, and that of spruce 1,144,000 m³/a, rest
being hardwood. In table 1 is shown how much wood fuel it is possible to get from different wood species.

Table 1. Proportions of biomass components of different wood species (volume estimation). (Aboveground biomasses are based on equations presented by Marklund (1988) and volumes of root estimates are based on Eggers (2001) study. Stem wood loss means that share of the stem wood that does not meet the quality requirements of industrial roundwood and is thus not recovered for industrial purposes (Karjalainen et al. 2004)).

<table>
<thead>
<tr>
<th></th>
<th>Stem + stem bark</th>
<th>Stem wood loss</th>
<th>Branches</th>
<th>Needles</th>
<th>Tops</th>
<th>TOTAL</th>
<th>Roots estimation (Nordic and Baltic countries)</th>
<th>Roots estimation (rest of Europe)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPRUCE Group</td>
<td>55%</td>
<td>8%</td>
<td>24%</td>
<td>11%</td>
<td>2%</td>
<td>100%</td>
<td>21.9%</td>
<td>19.1%</td>
</tr>
<tr>
<td>PINE Group</td>
<td>67.7%</td>
<td>8%</td>
<td>17.7%</td>
<td>4.4%</td>
<td>2%</td>
<td>100%</td>
<td>19.8%</td>
<td>19.3%</td>
</tr>
<tr>
<td>BROADLEAVED Group</td>
<td>78.2%</td>
<td>8%</td>
<td>12.1%</td>
<td>/</td>
<td>1.7%</td>
<td>100%</td>
<td>22.4%</td>
<td>14.7%</td>
</tr>
</tbody>
</table>

Usually about 70% of spruce stumps are excavated from final cut area. In the year 2004 the amount of excavated stumps was 175 000 m³/a (Leinonen et al. 2005) in Finland. About a half of this 85 000 m³ (190 GWh) was produced in Central Finland.

Wood is usually harvested from the forest for four times before the final harvesting of the wood, table 2. Part of the harvested wood of thinning can be used as pulpwood and the yield of this is included in the table 2. In pre-commercial and 1st commercial thinning it is possible to get rather much biomass residues. Thinning might have great potential but, on the other hand, the yield is usually rather low and expenses high. There exists a state subsidy “KEMERA” for energy wood production.

Table 2. A typical management regime of a southern Finnish forest stand (Hakkila 2004).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Stand age</th>
<th>Yield of timber</th>
<th>Biomass residues</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>years</td>
<td>m³/ha</td>
<td>m³/ha</td>
</tr>
<tr>
<td>Pre-commercial thinning</td>
<td>10–20</td>
<td>—</td>
<td>15–50</td>
</tr>
<tr>
<td>1st commercial thinning</td>
<td>25–40</td>
<td>30–60</td>
<td>20–50</td>
</tr>
<tr>
<td>2nd commercial thinning</td>
<td>40–55</td>
<td>4–80</td>
<td>15–30</td>
</tr>
<tr>
<td>3rd commercial thinning</td>
<td>5–70</td>
<td>60–90</td>
<td>20–30</td>
</tr>
<tr>
<td>Final harvest</td>
<td>70–100</td>
<td>200–300</td>
<td>60–120</td>
</tr>
<tr>
<td>Total during rotation</td>
<td>330–530</td>
<td>130–280</td>
<td>25–52</td>
</tr>
</tbody>
</table>

Because the forest taxation will change in 2006 the wood markets have been in a special situation. If annual wood growth and sustainable development are taken into account, the annual harvest of wood could be 5 – 6 million cubic meters. In the future the amount of biofuels will diminish in Central Finland forests because pine will substitute for spruce. On the other hand, in the future the growth of forest will be larger. In the future small heating plants will also compete more and more of the same sources of wood residue as large CPH-plants, which might cause conflicts between them. Final
harvesting methods can change in some extent and final cuttings may be substituted partly with continuing thinning.

2.1.2 Potential of forest residuals

Potential forest residuals are forest residue chips, residues from the young forests and stumps after final cut.

In figure 4 presents the view of Metsäkeskus about the maximum potential and the maximum harvestable amounts of forest wood fuels in Central Finland. Harvestable total forest wood fuel potential is estimated in figure 4 to be about 1500 GWh/a and maximum total potential about 3400 GWh/a.

Figure 4. Harvestable forest resources of Central Finland (Pekkanen 2004)

Helynen et al. (2003) and Eletrowatt-Econo Oy (Anon. 2005) have estimated in their models the potential wood fuel production in Central Finland. Results are shown in table 3.

Table 3. Estimations of wood fuel resources in Central Finland from two studies.

<table>
<thead>
<tr>
<th></th>
<th>Stumps</th>
<th>Forest residue</th>
<th>Young forest</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helynen et al.</td>
<td>300(1)</td>
<td>815(1)</td>
<td>843(1)</td>
<td>1167(1)</td>
</tr>
<tr>
<td>2004</td>
<td>GWh/a</td>
<td>GWh/a</td>
<td>GWh/a</td>
<td>GWh/a</td>
</tr>
<tr>
<td>Electrowatt-Ekono Oy (Anon. 2005)</td>
<td>680</td>
<td>1160</td>
<td>420</td>
<td>2260</td>
</tr>
</tbody>
</table>

(1) Wood fuel resources in Central Finland after basic model.
Wood fuel resources in Central Finland after maximal model.

All three studies agree, that maximum forest residue potential of final cut is about 1160 GWh/a. Maximum potential of stump fuel is estimated between 680 – 1000 GWh/a and the greatest difference between studies is in the potential of young forests, 420 – 1000 GWh/a.

Ylitalo (2005) has collected statistics from all the country and according to him the sources of forest residue chips are: delimbed small wood 5 (6)% in 2004 (2003), not delimbed small wood 17 (17)%, forest residue 64 (64)%, stem wood 8 (8)% and stumps 6 (5)%.

According to the Energy balance 2000 for Central Finland, about 13.3 % (2 191 GWh) of energy (total 16 452 GWh) was produced by wood fuels (forest residues and industrial by-products). According to the prognoses of Energy balance the figures of wood energy would be 23.6% (5000 GWh) in 2025. In 2025 total energy production would be 21 180 GWh.

When the Finnish energy and climate strategies were approved at the turn of the millennium, the target for the use of forest chips in 2010 was set to 5 million m$^3$ for the whole country. It has been estimated that the required amount could be extracted e.g. from following three sources: 2.5 million m$^3$ of logging residue chips, 1.5 million m$^3$ of stump wood chips and 1.0 million m$^3$ of small-tree chips from young stands.

2.2 FOREST INDUSTRY RESIDUES

2.2.1 Present situation of by-products of sawmills

A research (Ahonen et al. 2004) on the by-products, excluding the amount of bark, of sawmills shows the resources of northern Central Finland. They estimated that the annual production of wood dust is about 205 000 – 250 000 bulk-m$^3$ and that of cutter shavings about 97 000 – 109 000 bulk-m$^3$. Most of the raw material is wet. Resources are concentrated in three locations, i.e. Karstula, Pihtipudas and Viitasaari, figure 5, where the large sawmills are located.
Figure 5. Production of wet saw dust and cutter shavings in different communes (Ahonen et al. 2004).

Amount of dry material is about 110 000 – 130 000 bulk-m³, figure 6. Two main locations, Karstula and Pihtipudas have timber and wood construction industry.

Figure 6. Production of dry saw dust and cutter shavings in different communes (Ahonen et al. 2004).

During the time of research raw materials, both wet and dry, were used almost completely locally and there were rather low possibilities to make large amounts of pellets or briquettes as shown in the figure 7 (50 000 t/pellets corresponding to 240 GWh). Near the northern border of Central Finland, however outside the region, in Keitele there is a large sawmill. It is possible to do co-operation between several sawmills and to make e.g. wood pellets. Vapo Oy is constructing a large pellet mill with drying unit at Haapavesi, which is also near the area.
There are several large-scale saw mills and wood refining industries in Central Finland, table 4. Besides that several small timber-plants and sawmills work at the area as shown in figures 5 and 6. It is possible to estimate, that the amount of bioenergy, based on the wood based by-products without bark from sawmills and timber plants, is about 800 GWh. Almost all of the raw material is used for heating or as raw materials of pulp- and board industry.

Table 4. Large- and middle-scale sawmills and wood refining industry in Central Finland.

<table>
<thead>
<tr>
<th>Company</th>
<th>Place</th>
</tr>
</thead>
<tbody>
<tr>
<td>ER-Saha Oy</td>
<td>Viitasaari</td>
</tr>
<tr>
<td>FM Timber Team Oy</td>
<td>Pihtipudas</td>
</tr>
<tr>
<td>Finforest Oyj</td>
<td>Suolahti</td>
</tr>
<tr>
<td>Vapo Oy, Hankasalmen saja</td>
<td>Hankasalmi</td>
</tr>
<tr>
<td>UPM, Leivonmäen saja</td>
<td>Leivonmäki</td>
</tr>
<tr>
<td>Multian Saha Oy</td>
<td>Multia</td>
</tr>
<tr>
<td>Kyyjärven Saha Oy</td>
<td>Kyyjärvi</td>
</tr>
<tr>
<td>Mahogany UPM-Kymmene Oy</td>
<td>Keuruu</td>
</tr>
<tr>
<td>Finnforest Oyj TIWI (M-Real)</td>
<td>Keuruu</td>
</tr>
<tr>
<td>UPM Jyväskylän vaneritehdas</td>
<td>Säynätsalo</td>
</tr>
<tr>
<td>Honkarakenne Oyj, Karstulan tehdas</td>
<td>Karstula</td>
</tr>
</tbody>
</table>

In 2003 the annual harvest of logs and pulpwood was about 5.9 million m$^3$ in Central Finland (Anon. 2004a). Part of log wood is sawn in sawmills, located outside of the region of Central Finland. In the statistic, collected by Ylitalo (2005), the use of wood residues in industry of Central Finland was 274 GWh, corresponding to 404 GWh of sawdust and 1475 GWh of bark in 2004. The total use of by-products was 2153 GWh.
2.2.2 Potential of by-products from sawmills

Eletrowatt-Econo Oy (Anon. 2005) estimated that in Central Finland in 2002 the total amount of by-products was 2340 GWh, and the estimate for 2010 would be about 2500 GWh. The real market potential is, however, less, 890 GWh in 2002 and 980 GWh in 2010. In 2002 52% of by-products were bark, 33% sawdust and 15% chips for industry. In 2010 the share of sawdust will be 63%, chips for industry 20% and bark 17%. In the future bark is used almost completely by companies.

Helynen et al. (2003) estimated that according to the basic model, the amount of wood by-products in industry, is 2264 GWh/a and according to the maximum model 2604 GWh/a in 2010.

2.2.3 Pulp and paper industry

In Äänekoski there is chemical pulping industry, so black liquor is formed as by-products of the process. Production of this biofuel in 2004 was 1981 GWh (Anon 2004b). Black liquor is burned in the recovery boiler of the mill. Besides black liquor pulp mill produces also bark fuel, which is sold.

All organic sludges of pulp- and paper industry, except pasta sludges, can be combusted. Several sludges include both organic and inorganic materials and burning of them must be evaluated case by case. If the ratio of organic vs. inorganic substances, and the mass of these on dry basis is known, it is possible to calculate the heating value. Many times the sludges are so wet, so that burning of them actually decomposes the sludge. At present all the sludges which are suitable are burned in order to produce energy and for decomposition of the sludge.

2.3 PEAT

Peat has an important role in Finnish energy production. During the last years the annual energy use of peat has been 17 - 27 TWh. Technically usable fuel peat potential of Finland is 13 000 TWh (1100 million toe).

Peat production area at Central Finland is about 6000 ha. Most of the area is used by Vapo Oy, 5500 ha. Total mire area of Central Finland is 136 978 ha. According to the researches, the suitable area for peat production is 43 800 ha after GTK (Virtanen et al. 2003). Estimated peat potential suitable for production in Central Finland is 559 TWh.

Main production method is milled peat production. Depending on the summer and used production methods, the amount of harvest can vary greatly. It is possible to use the values 380 - 500 m³/ha for amount of harvesting and heat value of 0.9 MWh/m³ for milled peat (sod peat 1.27 MWh/m³) in the calculations. In 2002 peat production was 2117 GWh/a and the production area was 4700 ha. Of that milled peat production was 1983 GWh and sod peat production 134 GWh. At the moment peat production and
consumption are in balance in Central Finland. When new CHP-plant of Jyväskylä is built more peat fuel is needed.

If there is demand for peat fuel it is possible to increase peat production. Production areas near the consumption places, as well as the best and cheapest logistic systems are studied all the time. Highest production potential is at Saarijärvi area. The share of the area of the peat resources of Central Finland is over 50% of the total.

2.4 AGRICULTURAL ENERGY

Energy production from agricultural sources is still small. There are several possibilities: straw, corn (oats for heating, barley for ethanol production), oleifera turnip rape (light heating oil and diesel) and reed canary grass for heating (Olsson et al 2004) purposes. At the moment reed canary grass is the most important and economically (subsidiaries) attractive of these plants. In the year 2000 in the Central Finland the amount of fallow fields was 35 000 ha (equal for 880 GWh of RCG).

Finland is aiming to utilize reed canary grass (RCG, Phalaris arundinacea) and straw for energy production (Lindh 2005) together with peat and wood fuels. Reed canary grass is cultivated by farmers, and Vapo Oy and Pohjolan Voima Oy. Of the RCG-cultivated area in Central Finland the share of fields is about 618 ha, which equals to 15.4 GWh. In Finland there are currently about 10 000 hectares of reed canary grass cultivated for energy purposes. A typical amount of harvested crop is 5 500 kg DS/ha, which equals to 25 MWh/hectare.

About 2 200 – 2 800 hectares of peatlands, used for commercial peat production, are annually withdrawn from peat production because of gradual exhaustion of the fields. Most of these fields are suitable for cultivation of RCG. RCG plantations are a method for purifying the runoff waters of peat production areas and landscape restoration sites.

2.5 PELLETS AND BRIQUETTES

In Central Finland briquette plant of Pihtipudas makes 1500 t/a briquettes and a pellet plant of Keuruu 3000 kg/a pellets. In energy unit pellet and briquette production is 21.6 GWh.

Dry wood dust and shavings come from wood processing (timber) industry. Demand of raw material is high in pellet, briquette, board- and pulping industries. A problem is that several raw material sources are relatively small, so it is logistically expensive to exploit these sources, and there are not enough raw materials for a local mill. Good example of the difficulties is shown in the research of Ahonen et al. (2003) on pellet raw material resources in northern Central Finland. The potential pellet production capacity with dry raw material in Central Finland is calculated in the table 5.

<table>
<thead>
<tr>
<th>Raw material</th>
<th>Pelttets</th>
<th>Pellets</th>
</tr>
</thead>
</table>

Table 5. Production capacity of pellets in Central Finland (Määttä & Paananen 2005).
<table>
<thead>
<tr>
<th></th>
<th>bulk-m³</th>
<th>t/a</th>
<th>GWh/a</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min</td>
<td>Max</td>
<td>Min</td>
</tr>
<tr>
<td>Southern Central Finland</td>
<td>33 000</td>
<td>44 000</td>
<td>3 300</td>
</tr>
<tr>
<td>Northern Central Finland</td>
<td>76 000</td>
<td>84 000</td>
<td>8 000</td>
</tr>
<tr>
<td>Total</td>
<td>109 000</td>
<td>128 000</td>
<td>11 300</td>
</tr>
</tbody>
</table>

It is possible to build small 1 – 2 pellets plants for local markets. If wet raw material will be used the potential is much bigger. There has been interest to produce pellets for ex. from forest residue in small scale.

Five rather large pellet factories have artificial drying units for wet raw materials. All pellet factories are located outside the Central Finland, but three of them are so near, that it is possible to transport dry or wet raw material for pellets from Central Finland. Vapo Oy has the saw mill of Hankasalmi which could be even a potential place for pellet mill.

### 2.6 BIOGAS

Use of biogas is still low in Central Finland. Biogas production and use is studied in the University of Jyväskylä.

Biogas is produced locally at the sewage treatment plant of Nenänniemi and dumping place of Mustankorkea both located in Jyväskylä. The production of biogas is 3 499 000 m³ corresponding to the heating value 15.5 GWh. 11.9 GWh of biogas was used for heat generation. The rest is used at plants, for production of mechanical energy. Small amount of electric power is also produced.

The farmer Erkki Kalmari who uses biogas as a fuel of his car, lives in the municipality of Laukaa. The fuel methane is made by biomethanization of cattle sewage. In Finland (Mainio 2005) has built eight farm biomethanization stations and four is under construction. Interest for methane generation is high. About 600 guests visited one of farms, generating methane in Riihimäki. Methane is used at farms for heating and small scale production of electricity. Interest to use methane as a fuel of vehicles, tractors, private cars, trucks and busses, is also growing.

Metener Oy (www.metener.fi/) is a commercial company which plans and contributes in use of methane gas. It is specialised to farm-scale solutions. Other biogas companies are e.g. MK-Protech Oy (http://www.mk-protech.fi/) and Stemco Oy (http://www.stemco.fi/).

In next years it is possible to make bioethanol from grain or from cellulose of wood. In Sweden lignin of wood, by-product of production of bioethanol, is pelletised.
2.7 SUMMARY OF BIOFUELS

From the domestic fuels peat has the biggest energy sources in Central Finland. Peat potential suitable for production in Central Finland is estimated 559 TWh. Annual peat production is about 2200 GWh/a at the moment.

From the forest wood based fuels the maximum potential of forest residue from final cut is about 1180 GWh/a, but harvestable potential is about 700 – 800 GWh/a. Maximum potentials of stumps and young forest are alike, about 1000 GWh/a. Harvestable potential for stumps is about 600 – 700 GWh/a and for young forest 300 – 400 GWh/a. Total potential for forest wood fuels is about 3000 GWh/a and harvestable potential about 1500 – 2000 GWh. At present use of solid forest wood fuels in Central Finland is about 800 GWh/a.

Production and use of black liquor has been several years about 2000 GWh/a.

Potential use of residues from wood industry will be in 2010 about 2500 – 2600 GWh/a. Now it is about 2200 GWh/a. The most important of residues from wood industry is bark fuel.

There are also small sources of energy; pellets, briquettes, biogas, bio-oils and reed canary grass. At the moment the total share of these energy sources is under 100 GWh/a, but it will grow in the future.

In table 6 is shown present and in 2010 estimated bioenergy sources of Central Finland.

Table 6. Present and in 2010 estimated bioenergy sources of Central Finland.

<table>
<thead>
<tr>
<th>Biofuel</th>
<th>2004 GWh</th>
<th>2010 GWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black liquor</td>
<td>2000</td>
<td>2000</td>
</tr>
<tr>
<td>Peat(^7)</td>
<td>2200</td>
<td>3000</td>
</tr>
<tr>
<td>Ind. by-products</td>
<td>680</td>
<td>800</td>
</tr>
<tr>
<td>Bark</td>
<td>1480</td>
<td>1500</td>
</tr>
<tr>
<td>Forest residue chips</td>
<td>600</td>
<td>1160</td>
</tr>
<tr>
<td>Yong forest</td>
<td>180</td>
<td>500</td>
</tr>
<tr>
<td>Stumps</td>
<td>85</td>
<td>700</td>
</tr>
<tr>
<td>Pellets &amp; briquettes</td>
<td>22</td>
<td>30</td>
</tr>
<tr>
<td>Reed canary grass</td>
<td>15</td>
<td>100</td>
</tr>
<tr>
<td>Biogas etc.</td>
<td>16</td>
<td>50</td>
</tr>
</tbody>
</table>

\(^7\) Peat potential 559 TWh. It might be a new partly peat using CHP in Jyväskylä.
3 CONSUMPTION OF BIOMASS FUEL

3.1 PLANTS USING BIOFUELS

3.1.1 Municipal CHP-plants

In Central Finland there is one large municipal CHP-plant in Jyväskylä. It generates district heat (180 MWth) for the city of Jyväskylä, generates electric power (82 MWe) and process steam for a paper mill located in town. Heat and power is generated by milled peat, chipped or crushed forest residues, wood dust, bark and stumps with a fluidized bed boiler. The plant is described in details in the section 3.3.1.

There are also two smaller plants in the province, generating district heat and small amount electric power (Kumpuniemen Voima Oy, Suolahti, 45/3.7 MW and Puulaakson Energia Oy, Karstula 10/0.95MW).

3.1.2 Industrial CHP-plants

Local industry has three large CHP-plants located in Jämsänkoski, Jämsä and Äänekoski. Their total capacity is 130 – 230 MW and type of boilers is fluidized bed. In appendix 1 there is a table 1_1, in which these plants and their fuels are described. Jämsä is one of the example plants described in the chapter 3.3.2.

Most of the biofuels from Central Finland are used in these four CPH-plants, table 7. During the last years the use of wood based fuels have increased compared to peat. Consumption of forest residue chips has increased significantly in last years, figure 8.
Table 7. Use of biofuels and peat in 2003 at four big CPH-plants (data M. Flyktman, VTT).

<table>
<thead>
<tr>
<th>Plant</th>
<th>Forest residue</th>
<th>Bark, saw dust</th>
<th>Peat</th>
<th>Other, oil, coal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GWh</td>
<td>GWh</td>
<td>GWh</td>
<td>GWh</td>
</tr>
<tr>
<td>Jyväskylä CHP</td>
<td>186</td>
<td>466</td>
<td>1414</td>
<td>262</td>
</tr>
<tr>
<td>3 industrial CHP</td>
<td>470</td>
<td>1197</td>
<td>812</td>
<td>73</td>
</tr>
<tr>
<td>CHP total</td>
<td>656</td>
<td>1663</td>
<td>2226</td>
<td>335</td>
</tr>
<tr>
<td>Total use in Central Finland</td>
<td>684</td>
<td>2331*)</td>
<td>2276</td>
<td></td>
</tr>
</tbody>
</table>

*) part of industrial by-products is used other purposes as fuel and exported outside the district.

Figure 8. Consumption of forest residue chips in Central Finland in the years 1996 – 2004 (Pekkanen 2004).

3.1.3 Municipal heating plants

In Central Finland there are four municipal heating plants, the capacities of which are between 10 – 25 MW. Besides that, there are 20 smaller heating plants with output between 1 – 10 MW. The smaller plants have usually grate boilers and they use chipped forest residues, peat or bark as a biofuel. More data of the plants is in the table 1_1 of appendix 1.

There is a regional plan to construct or reconstruct 14 municipal heating plants by the year 2010. 5 – 10 plants might also be constructed or reconstructed to CHP-plants.
3.2 PRIVATE HOUSES AND SCHOOLS, GREENHOUSES

In Central Finland there are about 70,000 inhabited real estates. Most of them are located towns. Most private houses are heated by electricity, oil or district heat. Farmhouses and small houses in rural areas are usually heated with wood chips, pellets or chopped and splitted log wood fuels. The figure 9 shows the structures of heating choices in northern Central Finland. Farmers get wood fuels from their own forests for their own use (about 70%), but they can also sell a part of the produced wood fuel. Stoker-burners smaller than 50 kW are popular burners for wood chips, and even for pellets. For pellets there are several special burners and boilers on the market.

Log wood is used for heating of saunas, fireplaces and free time cottages (over 30,000 in Central Finland). Consumption is occasional, but there are potential markets also for chopped and splitted log woods.

Green houses and some municipal houses, schools use wood pellets, wood chips or sod peat in their local heating centers. The capacities of boilers are usually 100 – 200 kW. Combustion unit depends on the chosen fuel. Stokers are usually used for wood chips, and a pellet burner for fuel pellets.

Figure 9. Heating of small houses in northern part of Central Finland. (Ahonen et al. 2004).

Forest Research Institute (Metsätutkimuslaitos) has estimated that use of small wood in 2003 in Central Finland was 835 GWh. According to the statistical year book “Finish statistical Yearbook of Forestry 2004” (Anon. 2004a), the small wood consumption was as fuel in real estates was 398 000 m³ (830 GWh). The use of wood rejects for heating was 84 000 m³ (175 GWh).
3.3 SUMMARY OF USE OF LOCAL BIOFUELS

The use of solid wood fuels in Central Finland is presented in the table 8. Total amount of use of solid wood fuels was estimated to be 3017 GWh in 2004. The by-product of the process of chemical pulping industry is black liqueur. Production of it in 2004 was 1981 GWh. The third very important fuel in Central Finland is peat. The consumption of it in 2003 was estimated to be 2276 GWh.

Table 8. Use of solid fuels in heat- and CHP-plants in Central Finland in 2004 (Yitalo 2005).

<table>
<thead>
<tr>
<th></th>
<th>1000 m$^3$</th>
<th>GWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest residue chips</td>
<td>413</td>
<td>788</td>
</tr>
<tr>
<td>Wood residue of industry</td>
<td>148</td>
<td>274</td>
</tr>
<tr>
<td>Sawdust etc.</td>
<td>195</td>
<td>404</td>
</tr>
<tr>
<td>Bark</td>
<td>847</td>
<td>1475</td>
</tr>
<tr>
<td>Other solid biofuels</td>
<td>39</td>
<td>76</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1642</strong></td>
<td><strong>3017</strong></td>
</tr>
</tbody>
</table>

In small houses and estates the small wood consumption was as fuel was 398 000 m$^3$ (830 GWh). The use of wood rejects for heating was 84 000 m$^3$ (175 GWh).

Other biofuels which have local importance are reed canary grass (13.8 GWh), pellets and briquettes (21.6 GWh) and biogas (15.5 GWh).

In table 9 is shown prices for several wood fuels in the years 2003 and 2004.

Table 9. Prices for wood fuels in 2004 and 2003 at plant without VAT (Yitalo 2005).

<table>
<thead>
<tr>
<th>Wood fuel</th>
<th>€/bulk-m$^3$ 2004</th>
<th>€/MWh 2004</th>
<th>€/bulk-m$^3$ 2003</th>
<th>€/MWh 2003</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest residue chips</td>
<td>7.60</td>
<td>9.90</td>
<td>7.90</td>
<td>9.80</td>
</tr>
<tr>
<td>Wood residue of industry</td>
<td>6.35</td>
<td>7.95</td>
<td>5.90</td>
<td>7.35</td>
</tr>
<tr>
<td>Sawdust etc.</td>
<td>4.95</td>
<td>8.05</td>
<td>4.55</td>
<td>7.30</td>
</tr>
<tr>
<td>Bark</td>
<td>4.80</td>
<td>7.85</td>
<td>4.60</td>
<td>7.50</td>
</tr>
</tbody>
</table>

3.4 EXAMPLES OF THE PLANTS

3.4.1 Municipal CHP-plant in Jyväskylä

Fortum Heat and Power (60%) and the City of Jyväskylä own the local heat generation company, Jyväskylän Energiantuotanto Oy (Opet Finland 2003). Company owns several boilers and heating stations. Oil-fired heating stations operate mainly as control units during peak output in wintertime of district heat. Power plant boilers of Rauhalahiti
and Savela are both in Jyväskylä. Fortum owns a large fluidised bed boiler that generates steam for the plywood mill of Schäuman Wood Oy and district heat for the community of Säynätsalo. All these boilers are biomass-fired.

The Rauhalahti CHP-boiler generates backpressure district heat for the City of Jyväskylä and its neighbourhood, process steam for M-Real Kangas Paper Mill (350 GWh) and electricity to Nordic grid. Return water of district heating network is used to heat Viherlandia, the nearby large commercial greenhouse. Steam can also be generated by an oil fired boiler of Rauhalahti (second boiler). The aim is to generate the base load with the main boiler.

**Fuel handling at plant**

Lorries bring fuel to two receiving stations (design capacity of fuel flow is 150 - 200 t/h). There are two unloading stations, one for wood fuels and the other line for milled peat. Coal is carried by train to the coal yard of the power plant and forwarded by a wheeled loader to the process when needed.

In wintertime peat is brought to the unloading station in three shifts. About 90 lorries can be unloaded (120 m³, the biggest ones 160 m³) in a day. The largest material flow on the conveyors is 100 t/h. At the busiest time 3.6 lorries are unloaded in an hour. The unloading station is continuously staffed in winter (three shifts) and in one or two shifts in summer. There is also a camera monitoring system in the area.

Sampling for later quality tests is performed on the basis of the recommendation given in the peat/wood quality instructions. The lorry drivers take the fuel samples manually, about 4 l/load.

**Feeding process description of Rauhalahti**

At the peat receiving station, the fuel is pre-screened with disc screens. The screenings are disposed to the yard for crushing. The pre screened fuel is conveyed with belt conveyors to a separate screening building equipped with a disc screen and a crusher. The screened peat is conveyed with an ascending conveyor into a round bottom intermediate storage, which is discharged with a screw unloader. The wood fuel receiving station have two unloading lines, one for wood chips/sawdust and another for stumps, loose logging residues, logging residue bundles and other uncrushed wood. These are crushed and screened before intermediate storage.

From the storages the fuel is lifted with belts to two feeding bins. One bin is discharged with an apron conveyor and the other with a screw unloader to a belt conveyor and further to a scraper conveyor. From there the fuel falls to a rotary airlock feeder and flows forward via feeding tubes to three sites on both sides of the boiler.

A separate belt conveyor line feeds coal through a roller screen crusher to a coal bunker. From the bunker coal flows to mill and further through a textile filter to pulverized-coal bunkers. Coal is taken from these bunkers for pulverised fuel burners. It is also possible
to feed coal from the pulverised coal bunkers through the peat line to the fluidised bed of the boiler.

The fuel receiving station is equipped with a weighing system. The process is controlled with a Damatic system. The screw unloaders of the peat and wood storage are controlled by level indicators of the boiler bins (radiation counter) on the basis of the boiler load. Homogenisation and blending of different fuels is carried out with separate fuel feeding systems to boiler. If the number of the flows is sufficient the flows are mixed in the subsequent conveyor system. There are two A-frame feeding bins for the boiler. The fuel is distributed by a chain conveyor into the bins.

There is a sprinkler system at the unloading station, in conveyor lines and in the storage. The conveyor lines are also equipped with a temperature-detector wire and gas detectors (CO). Inert gas is available for boilers feeding bins and feeding lines when needed.

The number of employees in Rauhalahti CHP-plant is around 50. About 10 working years is used for maintenance.

**Combustion technology**

The main boiler of Rauhalahti plant was commissioned by Tampella Power (present Kvaerner Power Oy) in 1986, figure 10. This pulverized combustion boiler was converted into a fluidised bed boiler in 1993.

![Figure 10. Originally pulverized peat and coal boiler of Rauhalahti CHP-plant converted in 1993 to BFB (Bubbling fluidized bed)- combustion. Steam: 110 kg/s 135 bar 533 °C, Fuels: Peat, wood, coal and oil (Opet Finland 2003).](image)
About 1 000 tons of sand is consumed in the fluidised bed per year. Melting of ash has not occurred. However, deposits were formed on superheaters when the combustion of fresh forest chips was started. Steam production and consumption are stable in winter. In summer, the demand of steam varies more. Process scheme is in figure 12.

By changing the combustion method from pulverized peat/coal combustion to bubbling fluidised bed combustion the capacity of the boiler increased from 265 to 295 MW and the use of wood chips became possible. Due to the increased share of wood based fuels the emissions have reduced: SO₂ emissions from 355 to 214 mg/MJ, NOₓ emissions from 247 to 145 mg/MJ and particles from 68 to 8 mg/MJ. Also the fire safety has improved and odour emissions, caused by the pulverized combustion of peat drying, has been solved.

![Process scheme of Rauhalahti CHP-plant](image)

*Figure 11. Process scheme of Rauhalahti CHP-plant (Opet Finland 2003).*

Fortum Service Company has obtained an ISO 9002 certification for usage and maintenance of power plants. In the environmental aspects, the Rauhalahti power plant follows the ISO 14 001 standard and for occupational health and safety the BS 8 800.

**Biomass and other fuels of the CHP-plant**

The fuels of the main boiler are milled peat, wood fuels (sawdust, bark, cutter chips, forest chips and stumps) and coal, table 10.

Oil is also used to some extent. The modification of the boiler made burning of wood fuels passable. At present about 30% of the fuel flow is wood. In addition, burning of small amounts of source separated, crushed recycled fuel (REF) with wood is being tested.
The average moisture content of milled peat has been around 45% and the net calorific value about 10 MJ/kg. The moisture content of wood fuels has ranged from 45 to 50% and the net calorific value from 7 to 9 MJ/kg.

Table 10. **Consumption of fuels, TJ, at Rauhalahti CHP-plant in 1994 - 2004.**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Peat</td>
<td>5086</td>
<td>5166</td>
<td>5231</td>
<td>5195</td>
<td>4860</td>
<td>4147</td>
<td>4115</td>
<td>4676</td>
<td>3938</td>
<td>4765</td>
<td>3402</td>
</tr>
<tr>
<td>Wood</td>
<td>698</td>
<td>781</td>
<td>925</td>
<td>1228</td>
<td>1303</td>
<td>1400</td>
<td>1537</td>
<td>1217</td>
<td>1872</td>
<td>2052</td>
<td>2135</td>
</tr>
<tr>
<td>Coal</td>
<td>12%</td>
<td>13%</td>
<td>15%</td>
<td>19%</td>
<td>22%</td>
<td>21%</td>
<td>25%</td>
<td>19%</td>
<td>30%</td>
<td>28%</td>
<td>34%</td>
</tr>
<tr>
<td>Oil</td>
<td>72</td>
<td>47</td>
<td>29</td>
<td>25</td>
<td>165</td>
<td>492</td>
<td>349</td>
<td>180</td>
<td>40</td>
<td>43</td>
<td>158</td>
</tr>
<tr>
<td>REF</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>328</td>
<td>76</td>
<td>68</td>
<td>140</td>
<td>378</td>
<td>572</td>
</tr>
<tr>
<td>Total</td>
<td>6095</td>
<td>6012</td>
<td>6199</td>
<td>6462</td>
<td>6350</td>
<td>6552</td>
<td>6119</td>
<td>6307</td>
<td>6235</td>
<td>7256</td>
<td>6347</td>
</tr>
</tbody>
</table>

*Coal storage has been reduced intentionally

REF = recycled fuel from source separated dry waste

http://www.fortum.fi/document.asp?path=14020;14028;14029;14055;14211;14214;15920;19314;19444&level=4

About 50 different fuel suppliers take care of the fuel procurement, of which about 30 are suppliers of wood fuels. Vapo Oy is the primary deliverer of peat (50%). Fortum itself also produces some milled peat (13%) that is used for own energy generation as well. Sawdust/bark and cutter chips come mainly from sawmills in Central Finland and other mechanical wood processing industry in the neighbourhood. The use of forest chips has increased from 234 TJ in 1999 to 335 TJ in 2002.

The forest chips are produced by local entrepreneurs using mostly roadside chipping systems. Current use of forest chips is about 5% of total fuel use. The transportation distance from forest to plant is up to 70 km. Loose forest residues, logging residue bundles and stumps can be received thanks to a new stationary crusher has built in 2002.

In 2004 the annual fuel consumption of the Rauhanlahti boiler was about 1800 GWh. The share of wood-based biomass was 34%. The future goal is to increase the annual biomass share, particularly by using forest residue chips and stumps.

**Ash handling**

The bottom ash of the boiler is dropped into water on a wet slag conveyor. The wet slag conveyor lifts extinguished slag up onto a scraper conveyor, which lifts the material to the ash bin. From the ash bin the ash drops to a transport platform. Wear problems have occurred in the scraper conveyor of dry slag (rails, chains, idlers and drive wheels). Fly ash is conveyed into a fly ash bunker by pneumatic conveyors. There is a damping screw at the discharge of the bunker. The pneumatic conveyor lines wear out.

Ash is used presently for foundation and landscaping in the adjoining ground near the power station.

**3.4.2 Industrial CHP-plants of Jämsä**
In southern part of Central Finland UPM-Kymmene has in the valley of Jämsä River two large pulp and paper mills. During the two last decades the use of bioenergy has increased in the energy plants of the region.

The power plant at the Kaipola (OPET Finland 2000a) mill has three steam boilers. Most of the steam is generated by a 100 MW fluidised bed boiler. Oil-fired boilers are used as reserve boilers. Biofuels account for more than 50% of all fuels, with peat and oil used as supplementary fuels. Approximately one per cent of the thermal energy produced is sold to the external district heating distribution system.

The biofuel boiler of UPM Kaipola paper mill started operation in October 1991. The boiler is Kvaerner Power combined fluidized bed and pulverized coal fired boiler, figures 12 and 13. The boiler produces 144 tons steam per hour. The plant output is 104 MWth/26 MWc.

The paper mill's power plant generates energy using the latest solid fuel combustion technology. The main fuels are bark, sludge from effluent treatment, deinking sludge and peat, figure 14. Oil is used as start-up and reserve fuel. In 2002, biofuels accounted for 54% of all fuels used at Kaipola. The Kaipola mill has used forest fuels, mainly logging residues, at the power plant since 1997. As a result, the carbon dioxide emissions from fossil fuels used in energy production decreased by 210,000 tonnes during the period 1997–2002. A decision to build a stump crushing line to Kaipola was made in summer 2005. After that the share of biofuels will increase 70% and carbon dioxide emissions decrease one third. Use of by-products of sawmills will grow from 400 000 bulk-m³ to one million cubic meters.

Thanks to modern, efficient flue gas treatment, emissions of dust, sulphur dioxide and nitrogen oxides into the air are extremely small and well controlled. The power plant was built to meet new NOx standards (150 mg/MJ fuel input).

Figure 12. Power plant of Kaipola (OPET Finland 2000a).
Figure 13. Kvaerner Power combined fluidized bed and pulverized coal fired boiler at Kaipola (OPET Finland 2000a).

Figure 14. Consumption of fuels at Kaipola CHP-plant (Anon. 2002).
Another biofuel-fired (Anon. 2002) CHP-plant in the Jämsä region started in 2002. New 200 MW fluidised bed boiler was commissioned at the Jämsänkoski mill of UPM. The remaining four power plant boilers now serve as reserve boilers. The power plant was incorporated into a new limited company, Jämsänkosken Voima Oy, from which the paper mill purchases process steam and back-pressure power. About 5% of the thermal energy, generated by the power plant, is delivered into the district heat distribution system and to the neighbouring enzyme plant of Genencor International Oy.

Forest fuels have gained considerable importance in replacing fossil fuels of the mills of UPM at the Jämsä River valley. The concept of forest fuels refers to logging residues, i.e. the branches and tops of trees, small trees from clearings and first thinnings as well as stumps, figure 15. The new power plant at Jämsänkoski has been a pioneer in the harvesting of stumps and their use a source of energy.

![Diagram](image)

*Figure 15. Proposed use of biofuels at Jämsänkoski and Kaipola 2002 (Anon. 2002).*

The power plant investment at Jämsänkoski was based on the experience obtained at Kaipola in the procurement and use of forest fuels. On the basis of several studies, a decision was made on using of stumps in by the side of other forest fuels. The use of stumps also increases the opportunities for using other forest fuels. During the winter months damp logging residues have caused problems, but the stumps remain dry throughout the year. In 2002 the use of stump wood corresponded to an energy output of 30 GWh.

The aim at the Jämsä River Mills (Anon. 2002) is to increase the use of forest fuels by 2005 to 500 GWh. This accounts for 25% of the total fuel demand and corresponds to a reduction of 190,000 tonnes in fossil carbon dioxide emissions. Rytkönen (2005) writes in his article that at present the power station of Jämsänkoski now consumes 40% of wood in energy production (forest residue chips, small wood and especially stumps). The use of forest fuels corresponds to 550 GWh.
The use of stumps for energy production has also proved to be a beneficial in terms of forest management. The lifting of stumps reduces forest management costs caused in connection with soil preparation and forest planting. In addition, it is an efficient method of preventing root rot, a disease which causes the most significant damage to spruce forests in Finland. As a dry fuel stump chips can co used with more moisture including materials in heating.

The environmental impacts of the procurement of forest fuels are not all known yet, but they are being actively examined. UPM-Kymmene has participated in a number of research projects and has prepared its own environmental recommendations for forest fuel procurement.

3.4.3 Municipal heating plant in Saarijärvi

The Saarijärvi plant (OPET Finland 2000b) consists of 4 MW<sub>th</sub> bubbling fluidised bed boiler (BFB) made by former Sermet Oy (now Wärtsilä Finland Oy), figure 16. The boiler system includes approximately 1.5 MW condensing boiler (for flue gas condensation) and absorption heat pump. Typical power balance for a heat pump: hot (regenerator) 115 - 105°C/750 kW, cold 40 - 23°C/530 kW, heated DH water 42 - 62°C/1 280 kW. Values vary according to firing condition, fuel type and moisture content.

![Figure 16. Schematic picture of the municipal heating plant (BFB) at Saarijärvi (OPET Finland 2000b).](image)

The BFB boiler with heat storage accumulator (20 MWh, 4 - 5 hours heat production, 350 m<sup>3</sup>) and flue gas heat recovery are able to utilize the heat content of fuel efficiently. Due to absorption of the flue gas, the efficiency at Saarijärvi plant is significantly higher than the average. In solid fuel plants the temperature of flue gases is typically between 120 and 130°C. At Saarijärvi plant the temperature goes as down as to 15°C (min). So the flue gas temperature can be lower than outer air temperature. In standard conditions
flue gas temperature is 20 - 35 °C, which is about 20°C less than the temperature of the return water in district heating.

BFB-boiler of Saarijärvi and pre-handling system can utilise many kind fuels and their mixes. Main fuel is milled peat (moisture 35-45%). Other fuels are wood chips, bark, sawdust, sod peat and municipal wastes.

According to the measurements, the emissions of small particles (ESP) are less than 50 mg/m³n, the limit being 150 mg/m³n.

System has been in operation since October 1994. New absorption heat pump has increased the heat output to 6 MW. The plant provides district heat for the town of Saarijärvi through district heating network of 6.7 km. Annual heat generation is between 23 - 25 GWh. In the net is 103 buildings with volume of 550 000 m³.

Investment cost (2000) were about 1.7 million Euro for the plant and for the absorption of the flue gas 0.5 million Euro.

3.4.4 Other examples of heating centres

An example of team work in heating with wood fuels is Kyyjärven Energiaosuuskunta (Energy cooperation of Kyyjärvi). Cooperative (Opet Finland 2002) purchases the wood fuel from the local farmers, stores wood in a fuel terminal and takes care of heating the communal heat centre, which capacity is 0.9 + 1.5 MW. Length of the district heat net is 5.2 km. Cooperative sells heat to the people of village.

Wood pellet heat is used in Tarvaala (www.vapo.fi/fin/haku/index.php?id=508). A Pellet heat container heats at training centre 35 000 m³. Boiler is 700 kW and it is calculated, that 250 000 litres of light fuel oil is saved annually.

3.5 SMALL-SCALE USE OF BIOMASS FUELS

3.5.1 A small house with pellet heating

Break trough of wood pellet heating in small-scale use has been waited for several years. In Finland the number of small-scale pellet (25 – 200 kW) users is about 4000 and number of users grows steadily. One typical small user is referent Lauri Annalas detached house (Erkkilä & Kallio 2003). House has been heated four years with wood pellets. Reasons why pellet heating was chosen were environmental sound domestic fuel and cheap price of pellets.

Living area of the house is about 180 m². Indoors are heated with hot water tubes, which are under the floor. In every room there is a thermostat, which controls the temperature of the room trough an electrically controlled valve. Besides indoors, the garage and the storage, located in a separate building is pellet heated. Also the heating centre is in that
separate building and heat goes through tubes to the main building. The total heated area is 250 m² and in a year 8000 kg pellets is used.

Boiler is of type Ari-max 340 BIO (20 – 50 kW) made by Thermia Oy and the burner a stoker of Säättötuli Oy. Several parameters are used for control of the operation and power output of the burner. In summertime e.g. the boiler is used only for warming of hot water. Pellets are fed into burner from a silo through a short screw conveyor, equipped with a fire extinction system. Main storage of pellets is built in the upper floor of the garage. Storage is filled with a pneumatic delivery system and capacity of the storage is 10 000 kg of pellets. At present the pellets are moved from the storage to the small feed-silo in the heating centre manually, but automatic system has already been planned.

![Mr. Annala presenting a small-scale pellet burner, boiler and interim store.](image)

Pellets are delivered by Agrimarket marketing chain. During the filling of the pellet storage pneumatically and it occurs dust in the air, so the tightness of the storage has to be improved. Annala has been satisfied to the quality of pellets and the stoker burner has been very reliable.
The burner and its heat exchange surfaces are cleaned four times a year, when the boiler is still warm. Ash is removed simultaneously manually from the boiler. About 10 – 15 kg of ash is formed in a quarter of year. Ash is used as fertilizer in the garden. Burning head is cleaned twice a year. Cleaning and manual moving of pellets to the heat centre takes only a little time in a well functioning pellet heating system.

On countryside there are several farmers which use wood chips in their boilers. Usually the burner used is a stoker burner. Besides wood chips burners can use also pellets in cold winter days, because it is possible to use both wood chips and pellets with stoker.

3.5.2 Small heating centre with wood chip heating

At Pylkönmäki (OPET Finland 2000c) in small municipality 90 kilometres to the Northwest from Jyväskylä a health centre is heated by wood chips. The container heating plant with capacity of 160 kWth is owned by a local private entrepreneur, who purchases the fuel, wood chips, and carries out the heating and supervision work in the heating plant. The entrepreneur's family company buys wood from local forest owners and chips it and transports the chips to the plant.

The container consists of two modules, fuel storage module and a module including a boiler, a stack and conveyors. The roof of fuel storage can be opened by hydraulic power for filling. Drag conveyors are used for unloading in the fuel storage. Transportable container heating plant doesn't require regular basement.

The contract with the municipality of Pylkönmäki and the entrepreneur is based on 200 MWh annual heat production. There is a plan to extend a heating network, because the plant has a capacity of 400-500 MWh production per year. At the moment heated building volume is 2505 m³. Consumption of wood chips has been 1.8 bulk-m³/MWh and the fuel storage with capacity of 20 m³ has to be filled up biweekly. Maximum heat consumption has been about 1 MWh per day, so it is possible to heat a nearby terraced house by the container plant in the future. Old oil-fired heating equipment has been saved to be used as a reserve plant. Price of this kind of container heating plant was 163 EUR/kWth excluding VAT in 2000.

In Central Finland there are several systems of 100 – 200 kW alike as described over heating of schools, greenhouses and municipal buildings. Fuel is either wood chips or pellets.
PRODUCTION TECHNOLOGIES OF BIOFUELS IN CENTRAL FINLAND

3.6 PRODUCTION OF FOREST FUELS

3.6.1 Forest residue production

Forest residue chips are used in growing amount as fuel of CHP-plants and larger heating centers. Logistics of delivery systems are sophisticated. There are two main sources for forest residue chips, final fellings and thinnings of the forest. Different production methods are described in the next chapters (Kallio & Leinonen 2005).

Felling is carried out on about 1.5% of Finland’s forest land each year. About half of this is for regeneration purposes and the rest are thinnings. The technology of wood procurement is based exclusively on the mechanized cut-to-length system. Both the deliming and cross-cutting of stems are carried out with one-grip harvesters at the stump. An exception is early thinnings where cutting is still commonly performed with a chainsaw (Hakkila 2004).

Harvesters were used in about 80% of all felling, and manual labour in 20%. The majority of the transportation within forests was done by forwarders and about 10% or less by agricultural tractor. In practice, all of Finland’s 3500 harvesters and forwarders are owned by small timber harvesting companies with just 1 - 6 machines. Harvesters nowadays include also equipment which can measure certain aspects of timber handling and the volume of timber harvested, which is largely done automatically at the time of felling (Finnish Forest Industries 2000).

Mass handling methods for trunks are sometimes used in Finland, mainly for first thinning, whereby the trunks are transported untrimmed to be chipped at the place of storage. This method may become more common especially in integrated harvesting of industrial wood and fuel wood (Finnish Forest Industries 2000).

3.6.2 Production methods of forest residue chips

The main methods used in Finland for production of forest chips are chipping at the roadside, at the terminal and at the mill. In minor scale it is used chipping at the terrain. There is also a new harvesting technology which is based on bundling of forest residues.

3.6.2.1 Chipping at the roadside landing -method

Logging residues are hauled to the roadside landing all year round from the surroundings of the terminal, figure 18. 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 in 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).

3.6.2.2 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 19, 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).
3.6.2.3 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 20. The container is emptied by tipping the chips into exchangeable containers at the roadside. The truck picks up the exchangeable containers and transports them to the power plant and returns the emptied containers to the landing (Leinonen 2004).

![Figure 20. Chipping at stand with terrain chipper (VTT).](image)

3.6.2.4 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 21.

![Figure 21. Bundled forest residue chipped or crushed at power plant (VTT).](image)
3.6.3 Stump production technology

A new type of fuel, the stumps, has been developed by the side of forest energy in Finland during the past five years. The use of stumps has increased especially at the plants, which have acquired an on-site crusher. The spruce predominant final cutting areas, from which the logging residues have first been harvested, form the best target for excavation of the stumps. Soil tillage, required by the regeneration of forests, is combined with stump excavation. The stumps form an enormous potential energy source, the share of the stumps in spruce predominant areas correspond to 25 - 30% of the volume of the stems. The energy content of the spruce stumps, harvested from the best sites, corresponds to 150 - 200 MWh per hectare, being more than the energy content of the logging residues harvested from the corresponding area. In addition to this the harvesting of stumps prevents the spreading of e.g. the root-rot fungi into the next tree generation (Leinonen et al. 2005).

Especially the pulp- and paper company UPM (Paananen & Kalliola 2003) has developed stump production technology in Central Finland. Production area is 2500 ha in Central Finland. Spruce stumps are more popular than pine stumps as fuel at UPM’s CHP-plants. Pre-dried and field split stumps are crashed at the plant with stationary hammer mills. New field splitting unit is under construction and may be in use at summer 2006. Modern stump trucks deliver loads of 170 m³ and transport of stumps in railway wagons is studied.

The utilisation of stump wood fuels has concentrated only to some large power plants, which have invested for their own stationary on-site crushers. Several Finnish power plants have planned to acquire stationary, effective crushers, so that in future the use of stumps will increase also in the other parts of country.

The production phases can be described by following series of figures 22 - 25.
Figure 22. The area for stump lift has to be chosen: All places are not suitable and all stumps are not lifted. The best areas are spruce dominating forest and nutrient rich, few mineral and stones including soil, where the logging residue is harvested (VTT).

Figure 23. There can be a delay of few months between logging and stump lifting. Best time for lifting is from May to November. Developing work is done all the time to advance the stump lifting techniques. Stump is shaken strongly during the lift, part of the soil and stones fallout and fill the pit. Lifting head can split big stumps to several parts and drying, cleaning, storage, transport and crushing at power plant become easier (VTT).
Figure 24. Stumps are stored in stocks over summer. Stumps dry and rains clean up them during the storage. It is wise to choose the stock place for easy transport. Special build big stump-trucks need much space on the forest roads. Also length of the boom, usually 7 m, makes requirements for construction and the place of the sump stock (VTT).

Figure 25. At the power plant the biggest problem is in the stumps existing (mineral-) soil, stones and other impurities. With right lifting techniques and choose of production places the amount of impurities can be diminish. On the other hand stump is dry and high heating value fuel (VTT).

3.6.4 Small-wood production technology

Pre-commercial thinning is usually done 10 – 20 years after regeneration. The first commercial thinning harvest is carried out about 30 – 35 years after regeneration, when the trees are 12 – 14 metres tall. The number of trunks in the growing stock is reduced to about 1000 per hectare. Significantly more of these first thinnings should be carried out than it is done today. This neglect considerably weakens the profitability of forest growth. In later thinnings the number of trunks is reduced in one or more stages to 450–550 trunks per hectare, before regeneration is later carried out (Finnish Forest Industry 2000).
The smaller the harvested trees are, the more profitable it is to harvest them manually (using a chain saw) using felling-piling method, figure 26. Delimbed and chipped small trees go to usually to small houses and chipped wood with branches to small heating plant.

Figure 26. Whole-tree chip harvesting chain from first thinning and first commercial thinning when only wood fuel chips are produced (VTT).

Besides making small tree chips young forest is used for production of chopped wood. It is an important fuel at countryside as well as in towns as a fuel in saunas, fireplaces and free time use. Nation-wide there are many dealers for chopped firewood and they are important merchantable fuels in Finland.

3.7 PEAT PRODUCTION TECHNOLOGY

3.7.1 Milled peat

Three production methods are used for milled peat production. They are Haku-, mechanical harvesting- and pneumatic harvesting -method. In one season production capacity is about 400 - 500 m³/ha milled peat (1 m³ = 0.9 MWh) depending on weather and production method. Peat machines towing tractors are rather powerful (140 – 200 kW) rubber wheeled farm and forest tractors. Most of the fuel peat is milled peat.

First, in all milled peat production methods, a peat layer of 10 – 20 mm is milled to dry, figure 27. The layer dries on bog surface in good climate conditions to moisture 40% in
about two days. The layer is turned two-three times during the drying process by a harrower, which is beneficial for the drying. A model has been made for the drying process in order to forecast the process and timing of the harrowing runs. After drying phase of the peat layer the harvesting methods differ from each other.

*Figure 27.* In milled peat production the first and second production phases, milling and harrowing, are common for all harvesting methods (photos Vapo Oy).

**HAKU-method** is used usually on large production fields, where it is very effective during long fine weather periods. In HAKU-method dried peat layer is harvested to a ridge by a ridging unit, figure 28. Even a multi-harvest production is used. From ridge dry, milled peat is loaded to a peat trailer with a loader. Milled peat loader has been designed for loading and transferring peat. In addition to loading due to a transfer distance of even 20 meters, big loader can be used to move peat from one field to another. The long transfer distance allows peat to be moved from wet fields to fields with a better bearing capacity and improve loading. The milled peat loader can also be equipped with a sod peat screening capability and it can be used to sod peat production. Large peat trailers can carry 39 - 45 m$^3$ of peat to a stockpile. Trailer is equipped with rubber tires at the front and rear, and it can be equipped with either a normal or drive axle. With a drive axle, the trailer can be driven onto the stockpile. Tipping is performed on both sides. For increased efficiency, two trailers can be coupled one behind the other.

*Figure 28.* Fig. a) Collecting of milled layer is made even more effective by brushes located at the bottom of each ridging unit resulting high yield. Ridger is easily adjusted to suit field conditions with hydraulic adjustment. b) The transfer distance and sod peat accessory make the JKS-20-loader a very versatile and effective machine for transferring and loading peat. c) Trailers are equally suitable for transporting milled and sod peat (Photos Vapo Oy).
**Mechanical harvesters** are intended especially for remote production areas. A harvester is efficient machine because two simultaneous working phases - ridging and collecting - can be performed at the same time, figure 29. A front-mounted ridger allows ridging and collecting to be performed at the same time. Both ridging elements can be lifted up to make driving to stockpile area easier. As the mechanical harvester creates little dust, it is also suitable to use near rural areas.

![Figure 29. Mechanical harvesters (Photo Vapo Oy).](image)

**Pneumatic harvester**, figure 30, is an efficient production machine, especially when weather conditions are difficult. It can exert suction power to the dry surface of the milled peat layer through its suction nozzles. Pneumatic method is best suited to small production areas or as a supplement to other production methods. Suction heads are made of plastic to avoid the risk of fire. A pneumatic harvester is also environmentally sound, due to the effective dust collecting units behind the harvester.

![Figure 30. Pneumatic harvester (Photo Vapo Oy).](image)

After harvesting milled peat is stored in large **stockpiles**. They can contain as much as 50 000 – 100 000 m³ of milled peat. Volumes and quality of stockpiles are measured during the autumn and milled peat is used in large CHP-plants during the winter. Delivery to the plant is carried out on the basis of sophisticated logistic, based on the measuring results of the autumn. High price of CO₂-ton has diminished the use of milled peat.
3.7.2 Sod peat

Sod peat can be produced as a form of separate cylinders or as a waving cord of cylinders.

Production method, figure 31, includes following phases:

**Forming of sods.** Sod cutter cuts with a cut disk or screw peat material from deep of 30-50 cm for sod making. Moisture content of peat exceeds 80%.

The sod cutter moulds the peat mass with a screw and after that press and form through nozzles the peat mass to sods on bog surface to dry. Diameter of sods is 40 – 70 mm and their shape is a form of separate cylinders or a waving cord of cylinders.

**Harrowing.** Sod peat dries 1-2 weeks on the bog. During the drying the sod peat layer is turned once or twice upside down by a harrower. The working width of which is 19 meters. The objective is to decrease the moisture content of the sod peat to about 35%.

**Ridding.** Harvesting is similar as harvesting of Haku-method. A rigger pushes the sods onto the ridge. Same time small particles among sods are screened away with a disc screen, which discs are made from a special mould plastic.

**Loading and transport to the stockpile.** The sod peat ridges are loaded by the ridge loader into a bog trailer drawn by a tractor. The ridge loader includes also a screening unit.

**Stockpiling.** Sod peat is transported in bog trailers drawn by tractors to stockpiles on road side. Stockpiling is done in most cases with an excavator.

![Figure 31. Production sequence of sod peat production. a) making of sods, b) harrowing, c) ridding and screening, d) loading and transport to the stockpile, e) stockpiling (photos Vapo Oy).](image)

3.8 REED CANARY GRASS TECHNOLOGY

VTT together with MTT (Agrifood Research Finland), Vapo Oy and Pohjolan Voima Oy (Lindh 2005) have developed harvesting chains for reed canary grass (RCG) and straw. Both loose harvesting methods and baling methods were tested in the research. In both cases one harvesting chain was based on farm-scale equipment and the other chain on efficient heavy-duty equipment. In addition, the combustion of RCG and straw were studied. The existing transportation chains of peat and wood chips were utilized to determine production logistics.
Harvesting chains are based on existing farming equipments, figure 32. The combustion of RCG can be managed when spring-harvested RCG is used. The relatively high production costs compared to peat or coal can limit the use of RCG and straw. The competitiveness is better if compared with wood chips. Total production costs vary from 2.7 to 4.2 €/GJ without subsidies. Due to low energy content RCG and straw are only supplementary fuels: the typical energy share is 10% on a fuel blend, when chopped into pieces less than 5 cm. The annual RCG-harvest of Central Finland is bought by Vapo Oy and used at CPH-plant of Jyväskylä.

Figure 32. Harvesting of reed canary grass in spring (in May) by precision chopper on cut-over peatland (VTT).

3.9 PELLETISING AND BRIQUETTING

In Central Finland there is one small pellet factory at Keuruu. The annual production is about 3000 t/a (14 400 MWh). Raw material comes from main company Keurak Oy, which refines timber 35000 m³/a. The saw mill and pellet plant are integrated. Pellets made are used locally. An idea to make a pellet factory to Suolahti near Jyväskylä exists. In Finland there are 20 pellet mills, which can produce annually about 200 000 tons of wood pellet. Vapo Oy produces about 90 % of the pellets and sells them nationwide through the Agrimarket-chain.

The pelletising process has been described schematically in the figure 33. Most Finnish pellet presses use ring die for pelletising wood. There are also some flat die presses. The capacity for a press is 1 – 3+ t/h. Some of the pellet mills are integrated in the saw mills. Artificial drying unit is in five pellet mills.

Wood briquette production in Finland is about 35 000 t. German made Adelmann -presses makes briquettes at almost all Finnish briquette factories. Press works automatically without supervision. One machine is located at Pihtipudas in Central Finland. Press is integrated with a timber section of sawmill and it uses dry sawdust and cutter shavings as raw material. Annual production is about 1200 t (4.5 kWh/kg -> 5400 MWh) and briquettes are used locally partly in a heating plant (500 kW) and
greenhouses, farm houses and private houses. Stoker burners can use briquettes, but heating systems are not automated.

At VTT pellet and briquette research is concentrated in Jyväskylä.

![Figure 33. A schematic view of the pelletising process (VTT).](image)

### 4 BIOFUEL QUALITY AT POWER PLANT

The quality of chips is affected by many properties such as moisture content, net caloric value, energy density, foliage content, ash content and particle size. It is not only the averages that matter. Perhaps even more important is the random variation of properties. Variation occurs within a truck load, between truck loads, and according to the season. An important goal of the quality control is to reduce such variations (Hakkila 2004).

Different boilers demand different fuel properties. The larger the plant, the more tolerant it usually is of random variations in fuel properties. Even so, knowledge on fuel properties and careful control of quality are essential to the operational reliability and efficient combustion of all boiler systems, including the large CHP plants. The role of quality becomes more pronounced as the production of forest chips increases (Hakkila 2004).

The most important single quality factor is the moisture content of chips. Moisture content is a direct cost factor, and it is taken into account in the pricing of the fuel. Excessive moisture content results in a price reduction, while low moisture content brings a bonus. It affects the heating value, storage properties and transport costs of the fuel (Hakkila 2004).

A common goal is to maintain the moisture content of forest chips below 50% at large plants and below 40% at small plants. In 2001, average moisture contents remained considerably below these target limits during the summer, but during the winter the
limits were exceeded slightly. The annual average was 48% and 38% for large and small plants respectively, figure 34 (Hakkila 2004).

![Figure 34](image_url)

**Figure 34.** Monthly variation of the moisture content of forest chips in 2001. Averages of 4 large power plants and 7 small heating plants (Impola 2002, Hakkila 2004).

Besides moisture there are also other important fuel properties. Energy density refers to the amount of energy per unit volume of load space in a truck or storage pile. In 2001, the average energy density of forest chips arriving by truck at large power plants was 0.77 MWh/m$^3$ loose. Variations in moisture content caused seasonal fluctuations (Figure 35).

During combustion the contents of metal alkaloids and chlorides in wood needles are unusually high. Depending on the combustion conditions, the alkali metals can be oxidized or they can form sulphates or chlorides and create harms on boiler surfaces. In using of blends of peat with chips, sulphates are formed instead of chlorides, and the risk of corrosion is avoided.
The content of ash is less than 0.5% in proper wood, but in bark it is 6 - 7 times and in foliage 6 - 11 times higher. In practice, the yield of crude ash is higher, as forest chips contain impurities such as sand, and the ash may also contain char. (Hakkila 2004).

![Energy density graph](image_url)

*Figure 35. Monthly variation of energy density of forest chips in 2001. Averages of three large plants (Impola 2002, Hakkila 2004).*

If international trade of forest fuels becomes common in the future and the forest fuels are transported over long distances, it may become profitable to refine biomass into pellets or liquid fuels. To promote the trade of biofuels European solid biofuel standards (CEN TC 335) are under preparation (Alakangas 2005). Aim is that the customer and the vendor can unanimously define the quality of solid biofuels.

5  **BIOFUEL INDUSTRY**

5.1  **BIOFUEL PRODUCERS IN CENTRAL FINLAND**

**Vapo** Group consists of the Parent Company Vapo Oy, comprising Vapo Energy, which produces biofuels and environmental peat, Vapo Power, which generates heat and power, and Vapo Biotech, the environmental business. The subsidiary Vapo Timber Oy processes timber, and Kekkilä Oyj produces and markets growing media and fertilizers. In 2004 Vapo Group’s turnover was EUR 527.7 million and it had 1 814 employees.

**Vapo Energy** is the leading producer and supplier of biofuels in the Baltic region. Vapo 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 horticultural and environmental peat.

In Sweden Vapo is represented by its wholly owned sub-group Råsjö Torv AB and its subsidiary companies. In Estonia, Vapo owns the biofuel and energy company AS Tootsi Turvas. In 2004 Vapo Energy had a turnover of EUR 256.7 million, and a personnel of 845 in total. Vapo Energy supplied 25 TWh of biofuels, 2.9 million m³ of environmental peat products and 336,000 tonnes of pellets.

**Kotimaiset energiat ky** (Domestic fuels) –company is the largest deliverer of forest residue chips. Annual production capacity of the forest residue chips is 500 000 bulk-m³. Chippers are special equipment and they make quality chips all year round regardless of raw material. Ten persons work at the company and besides that there are seasonal workers. Stock of equipments includes 5 lorry chippers and 2 lorries with trailers.

**Biowatti Oy** (www.biowatti.fi/) is a nation wide fuel wood producing and delivering company. Company has also an office in Jyväskylä and activities in Central Finland.

### 5.2 PELLET MANUFACTURERS IN CENTRAL FINLAND

**Vapo Oy** is very big pellet manufacture, about 180 000 t/a in Finland. It has no pellet factories in Central Finland. Vapo pellets are delivered through Agromarket merchant chain to customers in the area.

**Keurak Oy** makes about 3000 t/a pellets. It is a manufacture, which pellets are used mostly locally at Keuruu district.

### 5.3 BOILER MANUFACTURERS IN CENTRAL FINLAND

At Keuruu HT Enerco Oy and at Saarijärvi Thermia Oy are the two larger boiler and burner manufacturers in Central Finland.

**Thermia Oy** (www.thermia.fi/) manufactures wood boilers with three different burning techniques. Top fired boilers are traditional boilers that are filled from the front. Bottom fired boilers are filled from above and are equipped with a large wood storage box. The efficient and clean burning is based on a total afterburning of the smoke gases. Reverse fire boilers are efficient wood boilers with smoke gas fan. The burning process is efficient, clean and is easy to use. All wood boilers have to be attached to an accumulator tank where the heat is stored between heating periods.

The manufacturing programme of Thermia also includes round accumulator tanks to be used in connection with wood heated boilers. The benefits of the round shape are optimal water circulation and easy handling. The accumulator sizes are designed so that they will fit through existing boiler room doors. The accumulator can be rolled on place!
The Thermia BeQuem pellet burner can be applied to a current heating boiler or a pellet boiler can be acquired, which alternative gives all the advantages of pellet heating at once.

The working area of **HT Enerco Oy** (www.htengineering.fi/yritys.html) is production of bioheating equipment. Plants are located at Haapamäki district of Keuruu town and in Alahärmä. Product palette includes Tulimax-bioenergy boilers 20 – 500 kW both own Velmax- and Swedish PellX 20 – 50 kW-pellet heating systems. HT Enerco Oy is an active actor in bioenergy branch, especially in development of wood pellet heating systems.

**HT Engineering** is a daughter company of HT Enerco Oy. HT Engineering plans pellet factories and heating centers.

**Hehkupelletti Oy** has been pellet production at Saarijärvi. Nowadays company imports pellet heating systems.

**Tulostekniikka Oy** (www.tulostekniikka.com) company at Karstula does planning and building of biomass heat centers of 500 – 2000 kW.

### 5.4 MANUFACTURES OF FOREST PRODUCTION EQUIPMENTS

**Moisio Forest Oy** (www.moisioforest.com/eng/esittely.htm) is a Finnish family-owned company located in Viitasaari. Moisio Forest Oy specialises in forestry work and in the manufacture and design of forest machines.

Moipu -harvesting heads and Moipu Feed Rollers, are internationally patented, high quality products that are the result of challenging product development and decades of practical experience of forest machine contracting. Clients of the company include the leading Finnish and international forest machine companies.

**S & A Nisula Oy** (www.sanisula.fi/uk/etusivu.htm) is Finnish company developing and producing harvester heads and other mechanical wood harvesting related products. Main products are combination heads and main partners are Komatsu Forest and Valtra. Firm is located in Halli at Jämsä.

**Profi-Forest Oy**: Production of Nokka-harvesters began at the end of 80s at industry area of Muurame and in 1990 production continued in present estate. Nokka 16WD, Nokka 6WD ja Nokka Profi harvesters are well known at domestic markets and in several European countries in thinning cuts. At the moment new harvester model Profi 500 is the main article of the production of Profi-Forest Oy.

**Metso-Metalli Oy** (www.arbro.fi/temp/indexenglish.html) is founded in 1992. Main products are Arbro-Stroke, special painting- and metalwork. Besides that company is marketing Joutsa Siim-forest trailers and loading facilities, forest trailers and loading devices.
Arbro-Stroke is a stroke harvester which fells, delimbs and cuts trees to length. Arbro-Stroke can be easily installed on a standard log loader and is especially meant for thinning operations but due to its properties can handle also bigger tasks. The harvester has superior quality Arbromatic-automation which makes the production highly efficient. The exceptional measuring device is standard equipment. Most common farm tractors have enough hydraulic power to operate with the Arbro-Stroke harvester.

AFM-Forest Ltd (http://www.afm-forest.fi/) is a Finnish company. Company has 10 years of experience in manufacturing of single grip harvesters. Machines meet the requirements of different working conditions all over the world, from Scandinavian to tropical forests in Brazil or Australia. Over 90% of products are exported abroad. Machines are working successfully in both in softwood and hardwood operations, figure 36, including debarking at the stump.

Figure 36. AFM harvester heads are specialized heavy duty attachments for forest operations utilizing slew type track based machines. Because of the designed flexibility and versatility AFM heads can easily be installed on different types and models of base machines to achieve the best results in efficiency and productivity (http://www.afm-forest.fi/).

Valtra Oy Ab develops, makes, markets and maintains Valtra-tractors world wide in Suolahti. Valtra Oy Ab belongs to international AGCO-company from the beginning of 2004. In 2003 company’s turnover was EUR 852 million and it had 2 600 employees, of which 850 persons worked in Central Finland. Valtra has done former tractors for forest work, but at the moment profile is low at this section. One can bye forest equipments to Valtra farming tractors from subcontractors and separate makers.

6 RESEARCH AND EDUCATION

6.1 TECHNICAL RESEARCH CENTRE OF FINLAND, VTT

VTT is an impartial expert organization that carries out technical and techno-economic research and development work. VTT also produces information services.
VTT is the leading European research and development unit in the field of bioenergy and it is developing also distributed energy concepts. VTT’s activities cover the whole bioenergy chain from harvesting and handling of biomass-based fuels to energy production technologies. In Jyväskylä works about 60 experts in different research projects.

Energy production section (www.vtt.fi/pro/pro2/indexe.htm) VTT has several activities in different research areas; wood and peat production, liquid biofuels, heat production, fluidized-bed combustion, gasification and gas cleaning, distributed energy and fuel cells. More detail of the research and development work is told on the www-pages of the company.

6.2 UNIVERSITY OF JYVÄSKYLÄ – BIOENERGY ACTIVITIES

University of Jyväskylä educates of new bioenergy experts to VTT and bioenergy companies. University participate local bioenergy work by training experts in summer schools and producing papers and poster conferences and exhibitions about different studies. BENET Bioenergy Network, which is managed by Jyväskylä Science Park, participate also University of Jyväskylä and several other companies.

University makes also research work:
1. Biogas area: several projects for example an EU project, local co-operation, local pilot plant activities (Mustankorkea).
2. Biomass area: several projects dealing with distributed heat and power production with small scale units. Strong co-operation with other universities and VTT.

6.3 JYVÄSKYLÄ POLYTECHNIC (JAMK) / INSTITUTE OF NATURAL RESOURCES

Institute of Natural Resources gives education of agrology at Saarijärvi and works actively in development of countryside in Central Finland and outside world. Institute participate several EU-financed studies both as administrator and as expert.

Bioenergy centre (BDC) is an education- and developing centre of production of biomass fuels. Centre is situated in Kolkanahti of Saarijärvi. Bioenergy centre gives education to students of vocational school and students of second degree. Besides that BDC gives to experts an international complementary training. As R&D-services Bioenergy Centre does fuel analyses, measuring and tests for drying units and boilers and delivers information e.g. to people, who plan to build a private house equipped with log wood- or pellet heating. Bioenergy centre has a permanent exhibition, where is presented different forms of biomass energy and products of equipment makers.

7 EMPLOYMENT EFFECTS OF BIOMASS FUELS

The region of Central Finland is regarded as the leading bio energy market in Finland. Bio fuels, especially forestry based wood fuels, are consumed largely in several power and heating plants. Large number of people is involved in the fuel production chains.
One motive to contribute on bioenergy is employment opportunities. Some studies have been made about the employment effects based on single production chains. Typically contractors and biofuel suppliers serve several plants and production chain (Paananen 2005).

Information was collected from the years 1995 to 2004 in the study of Paananen (2005). The research was limited to the Central Finland region and was divided into seven phases: supervision and management work, operations at the cutting site, terrain transportation, chipping and crushing, road transportation, operations at the plant, and research and training work.

Direct employment effect of forest fuel production had risen from few dozens of man-years in 1995 up to 151 man-years in 2004, figure 37. It generated about 60 permanent jobs. In addition, research and training work employed around 40 all-year jobs. The total employment effect in 2004 was 251 man-years, figure 38. The 151 man-years produced about 825 000 MWh forest fuels, so every 5 600 MWh forest fuels generate one all-year job in these conditions. Because most of the jobs are not full time jobs, it can be estimated that more than 1000 people were involved in forest fuel production in Central Finland in 2004.

Figure 37. Development of employment in the production of forest residue chips in Central Finland in the years 1995 – 2004 (Paananen 2005).

The Central Finland Bioenergy strategy aims to 1600 GWh forest fuel consumption in year 2010. It will mean about 450 all-year jobs in Central Finland (Paananen 2005).
Figure 38. Employment effect of the production of forest residue chips in Central Finland in 2004 (Paananen 2005).

Table 11. Estimation of work places in energy sector of Central Finland in 2000 (Helynen et al. 2003).

<table>
<thead>
<tr>
<th>Activity Description</th>
<th>Man-years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production of fuels, transportation and refinery, both wood and peat, no traffic fuels</td>
<td>500</td>
</tr>
<tr>
<td>Production, selling and delivery of electricity</td>
<td>500</td>
</tr>
<tr>
<td>Energy production of industry</td>
<td>200</td>
</tr>
<tr>
<td>Production, transportation and delivery of district heat</td>
<td>200</td>
</tr>
<tr>
<td>Machine making</td>
<td>500</td>
</tr>
<tr>
<td>Planning</td>
<td>50</td>
</tr>
<tr>
<td>Research, training and education</td>
<td>150</td>
</tr>
<tr>
<td>Building</td>
<td>No estimation, large variation</td>
</tr>
<tr>
<td>Total</td>
<td>2100</td>
</tr>
</tbody>
</table>

Helynen et al. (2003) evaluated the total energy sector of Central Finland and they got an estimate of about 2000 work places in 2000, table 11. However, the estimate is rough. Biggest opportunities for extra workplaces are in machine production and fuel production, transportation and refining. Especially in fuel production and heat services.
of estates offer workplaces at rural areas and part time work in farm and forestry working people.

Estimation of employment effect of all biofuels was made by VTT (Halonen et al. 2003). In forest residue production for whole country 4400 MWh/man year is equal with results of Paananen (2005).

There is also a fear and discussion do we get employees production of fuels, transportation and refinery, both wood and peat, in the future.
8 REFERENCES


### Appendix 1

**BOILERS OF COMMUNES AND INDUSTRY IN CENTRAL FINLAND**

Table 1. Boilers of communes and industry in Central Finland in 2003, production of heat and electricity and used fuels. Some information is missing. (M. Flyktman, VTT).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 = grade, 2 = fluidised bed</td>
<td>$\text{MW}_h$</td>
<td>$\text{MW}_e$</td>
<td>Forest residue</td>
</tr>
<tr>
<td>Jyväskylän Energiantuotanto, Rauhalahti, Jyväskylä</td>
<td>2</td>
<td>267</td>
<td>82</td>
<td>186.0</td>
</tr>
<tr>
<td>Kumpuniemen Voima Oy, Suolahti</td>
<td>2</td>
<td>45</td>
<td>3.7</td>
<td>0.0</td>
</tr>
<tr>
<td>Puulaakson Energia Oy, Karstula</td>
<td>1</td>
<td>10</td>
<td>0.95</td>
<td>0.0</td>
</tr>
<tr>
<td>Jämsänkosken Voima Oy, Jämsänkoski</td>
<td>2</td>
<td>186</td>
<td>46</td>
<td>270</td>
</tr>
<tr>
<td>UPM-Kymmene, Kaipola, Jämäsa</td>
<td>2</td>
<td>104</td>
<td>26</td>
<td>0.0</td>
</tr>
<tr>
<td>Äänevoima Oy, Äänekoski</td>
<td>2</td>
<td>157</td>
<td>35</td>
<td>200</td>
</tr>
<tr>
<td>FM Timber Team Oy, Pihtipudas</td>
<td>1</td>
<td>3</td>
<td>0.0</td>
<td>22.2</td>
</tr>
<tr>
<td>Fortum, Säynätaloo, Jyväskylä</td>
<td>2</td>
<td>25</td>
<td>0.0</td>
<td>104.0</td>
</tr>
<tr>
<td>Keuruu Voima Oy, Keuruu</td>
<td>1</td>
<td>10</td>
<td>0.0</td>
<td>62.3</td>
</tr>
<tr>
<td>Vapo Timber Oy, Hankasalmi, Hanksalmi</td>
<td>1</td>
<td>10</td>
<td>0.0</td>
<td>72.2</td>
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<tr>
<td>Joutsan Lämpö Oy (Suur-Savon Sähkö Oy), Joutsa</td>
<td>1</td>
<td>2.75</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Jämsän Energialämpö Oy, Kuorevesi</td>
<td>1</td>
<td>7</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Kannonkosken kaukolämpölaitos, Kannonkoski</td>
<td>1</td>
<td>1.2</td>
<td>2.5</td>
<td>0.9</td>
</tr>
<tr>
<td>Kinnulan kaukolämpölaitos, Kinnula</td>
<td>1</td>
<td>2</td>
<td>8.2</td>
<td>0.7</td>
</tr>
<tr>
<td>Kivijärvi, Kivijärvi</td>
<td>1</td>
<td>1.5</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Konneveden kunnan kaukolämpölaitos, Konnevesi</td>
<td>1</td>
<td>1.25</td>
<td>1.1</td>
<td>0.4</td>
</tr>
<tr>
<td>Kyyjärven Energiaosuuskunta Kyyjärvi</td>
<td>1</td>
<td>2.5</td>
<td>7.7</td>
<td>0.0</td>
</tr>
<tr>
<td>Multian saha Oy, Multia</td>
<td>1</td>
<td>4</td>
<td>27.5</td>
<td>0.0</td>
</tr>
<tr>
<td>Muuramen Lämpö Oy, Muuramea</td>
<td>1</td>
<td>4</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Petäjäveden Energia Oy, Petäjävesi</td>
<td>1</td>
<td>2.5</td>
<td>10.2</td>
<td>0.0</td>
</tr>
<tr>
<td>Pihtiputaan kunnan kaukolämpölaitos, Pihtipudas</td>
<td>1</td>
<td>2</td>
<td>16.3</td>
<td>0.0</td>
</tr>
<tr>
<td>Saarijärven Kaukolämpö Oy Saarijärvi</td>
<td>2</td>
<td>5</td>
<td>4.7</td>
<td>0.0</td>
</tr>
<tr>
<td>Toivakan kunta, Toivakka</td>
<td>1</td>
<td>0.7</td>
<td>3.4</td>
<td>0.0</td>
</tr>
<tr>
<td>Uuraine, Vattenfall, Urainen</td>
<td>1</td>
<td>1</td>
<td>3.5</td>
<td>0.0</td>
</tr>
<tr>
<td>Vapo Oy, Jyväskylän mlk</td>
<td>1</td>
<td>5.5</td>
<td>4.8</td>
<td>29.2</td>
</tr>
<tr>
<td>Vattenfall, Laukka, Laukka</td>
<td>1</td>
<td>5</td>
<td>21.2</td>
<td>0.0</td>
</tr>
<tr>
<td>Viitasaaren Lämpö Oy, Viitasaari</td>
<td>1</td>
<td>11</td>
<td>86.1</td>
<td>3.5</td>
</tr>
<tr>
<td><strong>Total sum</strong></td>
<td><strong>792</strong></td>
<td><strong>196</strong></td>
<td><strong>684</strong></td>
<td><strong>2331</strong></td>
</tr>
</tbody>
</table>

*) New plant
CONVERSION FACTORS FOR WOOD FUELS

Conversion factors

<table>
<thead>
<tr>
<th></th>
<th>GJ</th>
<th>MWh</th>
<th>toe</th>
<th>Gcal</th>
</tr>
</thead>
<tbody>
<tr>
<td>GJ (Giga joule)</td>
<td>1</td>
<td>0.28</td>
<td>0.024</td>
<td>0.24</td>
</tr>
<tr>
<td>MWh (Mega watt hour)</td>
<td>3.6</td>
<td>1</td>
<td>0.086</td>
<td>0.86</td>
</tr>
<tr>
<td>toe (ton – oil equivalency)</td>
<td>41.9</td>
<td>11.63</td>
<td>0.866</td>
<td>10</td>
</tr>
<tr>
<td>Gcal (Giga caloric)</td>
<td>4.19</td>
<td>1.16</td>
<td>0.1</td>
<td>1</td>
</tr>
</tbody>
</table>

Chips of pine, 1 m$^3$ (= 2.8 bulk-m$^3$) 7.5-7.7 2.1-2.2 0.18-0.19
Chips of birch, 1 m$^3$ (= 2.8 bulk-m$^3$) 8.7-9.6 2.4-2.7 0.21-0.23
Wood pellets, 600 – 700 bulk-m$^3$ >16.9 >4.7 >0.4

Kilo (k) = 1 000 = 10$^3$, Mega (M) = 1 000 000 = 10$^6$, Giga (G) = 10$^9$, Tera (T) = 10$^{12}$

Conversion factors

Industry by-product: Heat value (MWh/m$^3$ solid)
- bark: 1.71
- wood dust: 1.90
- industry chips: 2.00

Forest residue: Heat value (MWh/m$^3$ solid)
- forest residue chips: 2.08
- small wood: 2.08
- stumps: 2.22

bulk-m$^3$, m$^3$ loose
- 1 bulk-m$^3$ bark corresponds 0.35 m$^3$ solid
- 1 bulk-m$^3$ wood dust corresponds 0.30 m$^3$ solid
- 1 bulk-m$^3$ industrial chips corresponds 0.40 m$^3$ solid
- 1 bulk-m$^3$ forest residue chips corresponds 0.40 m$^3$ solid
- 1 bulk-m$^3$ small wood corresponds 0.40 m$^3$ solid

Sources: