5 EURES - Five European RES Heat Pilots

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5EURES Feasibility Study – North Karelia
(Project Report)

18.1.2006

Johanna Pulli, Timo Tahvanainen, Antti Ala-Fossi and Antti Asikainen

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<td>Timo Tahvanainen, Finnish Forest Research Institute, Joensuu Research Unit, P.O. Box 68, 80101 Joensuu, Finland. E-mail: <a href="mailto:timo.tahvanainen@metla.fi">timo.tahvanainen@metla.fi</a></td>
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<td><strong>Other information</strong></td>
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ABBREVIATIONS AND ACRONYMS

BENET  Bioenergy Association of Finland
BFB    Bubbling Fluidised Bed Boiler
CHP    Combined Heat and Power
DBH    Diameter at Breast Height
EFI    European Forestry Institute
ETS    Emission Trading Scheme
EU     European Union
EU15   European Union Member Countries, 200
FBC    Fluidised Bed Combustion
FFIF   Finnish Forest Industries Federation
FINBIO  Bioenergy Association of Finland
FMA    Forest Management Association
FSA    Finnish Sawmills Association
MAF    Ministry of Agriculture and Forestry
MC     Moisture Content
ME     Ministry of the Environment
FFRI   Finnish Forest Research Institute
MTC    Ministry of Transport and Communication
MTI    Ministry of Trade and Industry
NC     North Carelia
NCP    North Carelia Polytechnic
NCREC  North Carelian Regional Environment Ce
OPET   Organisations for the Promotion of Energy
Oy     Ltd.
Oyj    Ltd. listed on stock exchange
REF    Recycled Energy Fuels
RES    Renewable Energy Source
SDEW   Small Diameter Energy Wood
SME    Small and Medium size Enterprises
TEKES  Technology Development Agency of Finland
TTS    Work Efficiency Institute
WENET  Wood Energy Association
VTT    Technical Research Centre of Finland
VMI    Forest Inventory
NAI    Net Annual Increment (definitions)
GAI    Gross Annual Increment (definitions)
GDP    Gross Domestic Product

UNITS AND CONVERSION FACTORS

<table>
<thead>
<tr>
<th>CONVERSION FACTORS (source: Elekrowatt Ekono, 2005; VTT, 2000)</th>
<th>MWh</th>
<th>loose m³</th>
<th>solid m³</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>INDUSTRIAL RESIDUES</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>solid m³</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bark</td>
<td>1,71</td>
<td>2,86</td>
<td>1</td>
</tr>
<tr>
<td>sawdust</td>
<td>1,90</td>
<td>3,33</td>
<td>1</td>
</tr>
<tr>
<td>other chips of ind. origin</td>
<td>2,00</td>
<td>2,50</td>
<td>1</td>
</tr>
<tr>
<td>loose m³</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bark</td>
<td>0,60</td>
<td>1</td>
<td>0,35</td>
</tr>
<tr>
<td>sawdust</td>
<td>0,57</td>
<td>1</td>
<td>0,30</td>
</tr>
<tr>
<td>other chips of ind. origin</td>
<td>0,80</td>
<td>1</td>
<td>0,40</td>
</tr>
<tr>
<td><strong>FOREST FUELS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>harvested residues</td>
<td>2,08</td>
<td>2,5</td>
<td>1</td>
</tr>
<tr>
<td>small diameter trees</td>
<td>2,08</td>
<td>2,5</td>
<td>1</td>
</tr>
<tr>
<td>stumps</td>
<td>2,22</td>
<td>2,5</td>
<td>1,00</td>
</tr>
<tr>
<td>MWh harvest residues</td>
<td>0,8</td>
<td>1</td>
<td>0,40</td>
</tr>
<tr>
<td>small diameter trees</td>
<td>0,8</td>
<td>1</td>
<td>0,40</td>
</tr>
<tr>
<td><strong>PEAT</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sod peat</td>
<td>1,4</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>milled peat</td>
<td>0,9</td>
<td>1</td>
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### DEFINITIONS (Karjalainen et al. 2004)

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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</thead>
<tbody>
<tr>
<td>Felling residues</td>
<td>Refers to the stem, crown and root biomass that is felled in commercial and uncommercial operations but not removed from the stand for utilisation. Felling residues = biomass felling - removals.</td>
</tr>
<tr>
<td>Felling, F</td>
<td>Average annual standing volume of all trees, living or dead, measured over bark to a minimum diameter of 0 cm (d.b.h.) that are felled during the given reference period, including the volume of trees or parts of trees that are not removed from the forest, other wooded land or other felling site. Includes silvicultural and pre-commercial thinnings and cleanings left in the forest and natural losses that are recovered (harvested). Biomass felling includes the total biomass that is felled, i.e., the stem, crown and root biomass.</td>
</tr>
<tr>
<td>Forest available for wood supply</td>
<td>Forest where any legal, economic, or specific environmental restrictions do not have a significant impact on the supply of wood. Includes areas where, although there are no such restrictions, harvesting is not taking place, for example areas included in long-term utilization plans or intentions.</td>
</tr>
<tr>
<td>Gross annual increment, GAI</td>
<td>Gross annual increment of growing stock volume: Average annual volume of increment over the reference period of all trees, measured to a minimum diameter breast height (d.b.h.) of 0 cm. Includes the increment on trees which have been felled or died during the reference period.</td>
</tr>
<tr>
<td>Growing stock, GS</td>
<td>The living tree component of the standing volume.</td>
</tr>
<tr>
<td>Natural losses, NL</td>
<td>Average annual losses to the growing stock during the given reference period, measured to a minimum diameter of 0 cm (d.b.h.) due to mortality from causes other than cutting by man, e.g., natural mortality, diseases, insect attacks, fire, windthrow or other physical damage.</td>
</tr>
<tr>
<td>Net annual increment, NAI</td>
<td>Average annual volume over the given reference period of gross increment less that of natural losses on all trees to a minimum diameter of 0 cm (d.b.h.). Net annual increment (NAI) = Gross annual increment (GAI) minus natural losses (NL)</td>
</tr>
<tr>
<td>Removals for commercial use</td>
<td>Annual removals that generate revenue for the owner of the forest or other wooded land or trees outside the forest. Includes removals of wood destined for domestic consumption after further processing, e.g., into sawnwood, fencing or construction material. Excludes removals of wood for direct auto-consumption, e.g., of fuelwood.</td>
</tr>
<tr>
<td>Roundwood balance, RB</td>
<td>Average annual volume over the given reference period of net increment less that of felling on all trees to a minimum diameter of 0 cm (d.b.h.). Roundwood balance (RB) = Net annual increment (NAI) minus fellings (F).</td>
</tr>
<tr>
<td>Roundwood production</td>
<td>Production of wood in a rough. Wood in its natural state as felled or otherwise harvested, with or without bark, round, split, roughly squared or in other form (e.g., roots, stumps, bars, etc.). It may also be impregnated (e.g., telegraph poles) or roughly shaped or pointed. It comprises all wood obtained from removals, i.e., the quantities removed from forests and from trees outside the forest, including wood recovered from natural, felling and logging losses during the period, calendar year or forest year. Commodity included are sawlogs and veneer logs, pulpwood, other industrial roundwood (including pitprops) and fuelwood.</td>
</tr>
<tr>
<td>o.b.</td>
<td>Overbark: Bark included into the volume of a tree.</td>
</tr>
<tr>
<td>u.b.</td>
<td>Underbark: Bark excluded from the volume of a tree.</td>
</tr>
</tbody>
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1. The region of North Karelia
1.1. Location, infrastructure and climatic conditions

North Karelia is Finland’s easternmost region, located between 62 -64° N and 28.5 – 31.5° E, with terrain ranging from 10 – 347 m a.s.l. (fig 1.). The continental climate is characterised by cold snowy winters, moderately warm summers, and moderate rainfall throughout the year and the climatic zone ranges from middle to southern boreal subzone (Rinne 1999). Variability is occasionally created by midlatitude cyclones from the North Atlantic bringing wind, cloudy weather and rain (Rinne 1999). Some of the more extreme weather conditions, i.e. very cold spells in winter or the warm weather in summer, often result from continental air masses arriving from the east (Rinne 1999).

Location of North Karelia region, subregions and municipalities

![Map of North Karelia](image)

Figure 1. North Karelia in EU15 (Pohjois-Karjalan palveluverkko 2005), location of municipalities and sources of livelihood (Pohjois-Karjalan maakuntaliitto 2005).

The sparsely populated North Karelia is somewhat geographically isolated due to large lakes surrounding the region and the approx. 300 km long border with Russian Federation. North Karelia consists of 16 municipalities, which have formed 3 administrative subregions (fig 1.). Despite the status as EU development area I and the high unemployment levels of over 15% (Pohjois-Karjalan TE-keskus 2005), North Karelia has become known as vibrant and one of the
rapidly developing rural areas in Finland. The main sources of livelihood are service sector, agriculture and forestry. The most important industries in North Karelia are plastics, metal, stone and wood processing industries, and also manufacturing, information and communications technology, and tourism (Pohjois-Karjalan maakuntaliitto 2005). The region is internationally renowned for its expertise in forestry, forest research, wood technology, plastics engineering, tools manufacturing and cross-border co-operation with Russia. The region also invests considerably on higher education and thus nearly 35% of Joensuu’s inhabitants are registered as students in one of the several educational institutions.

Forestry has traditionally been an important source of livelihood in North Karelia, not least due to the wide network of waterways, which are also connected to Gulf of Finland via Saimaa canal. The main railway track also runs right through North Karelia via Valtimo in the North and Kesälähti in the South, and there is also a secondary track connecting Joensuu directly towards central Finland. As transport intensive business sector, one of the demands of a vivid forest industry is a wide and well maintained road network. In addition to the numerous small private roads, there is a network of 5139 km of primary public roads and 4424 km of secondary roads, ie. 7% of the national secondary road network, within North Karelia (Rantala et al. 2003). With sufficient maintenance such a wide infrastructure is a valuable asset for logistics both in timber and by-product transport.

Table 1. Area and population data for North Karelia (Local Finland 2005).

<table>
<thead>
<tr>
<th>North Karelia</th>
<th>% of total</th>
<th>no. of municipalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total surface area</td>
<td>21 585 km²</td>
<td>100 %</td>
</tr>
<tr>
<td>Forestry area</td>
<td>15 960 km²</td>
<td>&gt; 70 %</td>
</tr>
<tr>
<td>Fresh water</td>
<td>3 803 km²</td>
<td>&lt; 18 %</td>
</tr>
<tr>
<td>Population density</td>
<td>approx. 170 000</td>
<td>approx. 9.5 person / km²</td>
</tr>
<tr>
<td>Pielisen Karjala subregion</td>
<td>32 749</td>
<td>4</td>
</tr>
<tr>
<td>Joensuu subregion</td>
<td>115 360</td>
<td>14</td>
</tr>
<tr>
<td>City of Joensuu</td>
<td>57 558</td>
<td>49</td>
</tr>
<tr>
<td>Keski-Karjala subregion</td>
<td>21 322</td>
<td>8</td>
</tr>
</tbody>
</table>

1.2. Current energy markets in North Karelia

In Finland, circa 20% of total primary energy (6.7 Mtoe) and 11% of electricity consumption is derived from woodbased fuels (Hakkila 2004). Most of North Karelias heat energy is produced by 3 large plants, E.ON owned CHP in Joensuu, Outokumpu CHP and a chemical pulpmill Enocell in Uimaharju. Rest of the demand is served by municipal district heat plants, some smaller scale service sector boilers and numerous residential boilers. The numerous mechanical wood processing industries in the area produce their own energy from the wood waste and direct the excess to another sector of the company or to woodfuel market.
The use of woodbased fuels accounted for 72% of the total 6404 GWh heat and power production already in 1999: 48% from forest industry liquid residues (black liquor) and 24% from solid woodfuels (Itä-Suomen energiatoimisto 2001). According to East Finland Energy Agency, in 2001 there were some 44 heat and power plants in North Karelia, with a total of 173 MW power and 847 MWh of heat production capacity (Itä-Suomen energiatoimisto 2001). The same report states that in 1999 North Karelia was 83% self sufficient in power production, and 45% of it’s own power production is from woodbased fuels, rest is mainly peat and oil use. Most of the heat production is industrial origin (66%) and only a third is produced in district heating or further combined heat and power (CHP) plants. Industry also consumed 94% of the total amount of energy generated by woodbased fuels in the region.

Since 1999, the most significant change in North Karelia’s industrial energy markets has been Joensuu Energia Oy’s CHP (now E.ON, with 100-120 MW heat and 55-80 MW power capacity) plants transfer to bubbling fluidised bed boiler in 2000, which has facilitated a higher proportion of woodfuel use by the largest energy producer in the region (Hartikainen 2001). The proportion of peat and woodfuel in the fuelmix changes according to availability of woodfuel, price of power and emission allowances. However, even in years low for woodfuels the consumption is nearly 50%, from which approx. 20 % are forest fuels (Sormunen 2005). Therefore, the remaining capacity of North Karelia’s large plants to utilise woodfuels will be mainly restricted by factors other than combustion technology.

Each of the 16 North Karelian municipalities has at least one district heat plant using woodfuels (Karppinen 2005). The municipal sector plants use woodchips and wood processing industry residues as main fuel, sometimes cofiring with peat. The size, ownership, fuel supply, maintenance and market arrangements vary according to conditions in each municipality.

Residential houses commonly use either oil or traditional fire wood for space heating. Measured in quantity of wood consumed, the total woodfuel use is by far highest in the domestic sector as most of it is in form of traditional firewood and thus low efficiency combustion (Karppinen 2005). Although North Karelia hosts one of Finland’s largest pellet factories in Ilomantsi, pellet use in domestic residential sector is still small-scale. There are some private and municipality owned buildings that have installed pellet boilers ranging from 5-500 kW in capacity, the most common size is a 50 kW boiler or which there are 20 in North Karelia (Kokkonen 2005). Vapo Oy pellet factory’s annual production has been ca. 35 000 tons until the expansion by autumn 2005. Prices for pellets have varied from €100 – 145/ton for buyers of over and under 10 ton loads (Kokkonen 2005) to €260/ton for the smallest bags via retailers. 

For the service sector woodenergy solutions, there is a nationally organised network of heat energy entrepreneurs that sell heat energy services produced by the customers own system. This system of in-house energy solutions that allow the owner to concentrate on core business was initiated for space heating of service sector buildings but has recently expanded to industrial use in some extent (Motiva 2003). Heat energy entrepreneurs usually use domestic energy i.e. wood chips, pellets or peat and 4 of the municipal district heat plants are also customers of the heat energy entrepreneurs’ network in North Karelia.
1.3. Future trends in North Karelia energy markets

Increasing support for renewable energies in both national and international policies, has promoted woodenergy use and influenced investment plans in North Karelia. Although North Karelia’s total heat demand is unlikely to increase rapidly and existing industrial heat production with woodfuel utilisation capacity depends on other than technological issues, there are some plans for construction of further industrial heat and power capacity to use woodfuels.

According to an investment plan based estimation commissioned by Eastern Finland Energy Office, North Karelia’s consumption of woodbased fuels other than black liquors would increase by 35% from 1999 to 2010. This would mean an increase in total annual use of solid wood fuel, from 1568 GWh in 1999 to 2124 GWh by 2010 or roughly 1 Mm³ annual use of woodchips by 2010. Main part of the increase occurred with E.ON CHP plants renewal to BFB technology, but the rest is expected to realise in roughly 50 GWh for each other types of use i.e. in district heating, industrial back pressure, and process steam production plants. The plans are well developed for establishment of a new heat plant of approx. 35-50 MW capacity in Puhos, Kitee, in connection with the surrounding industrial estate and possibly a waste incinerator (Suomalainen 2005). The new plant would use woodfuel to varying proportions, depending on the remaining fuelmix.

Above all, the industrial sector woodfuel use will be increasingly influenced not only by the EU ETS, rising oil and thus Nordic network electricity prices but also variations in forestry industry production, as has been recently confirmed in Finland during the strike of paper- and pulpmill workers. Overall, the use of woodenergy in North Karelian industry is still expected to increase slightly, with larger proportion of the fuel being delivered directly as forest fuel.

The municipal district heat plants are more sensitive to local heat demand. As North Karelia’s population balance has traditionally been negative, expansions in capacity are unforeseeable in the near future for most municipal plants. Those relying on woodfuel from open markets will be more sensitive to woodfuel price volatility expected with increasing competition on woodfuels. Some of the municipalities are owned by co-operatives including forest owners and such plants should be able to pass on some of the increasing costs to customers, and yet sell heat at competitive prices.

Within the residential and service sectors, the expected trend is increasing conversion of old oil boilers to either pellet or woodchip boilers. Vapo Oy pellet factory in Ilomantsi is currently under reconstruction to double production and install technology for using materials with higher moisture content (MC). The production is planned to resume in autumn 2005 with annual capacity of 70 000 tons. There have also been some experiments in making pellets from peat, which would increase the added value of pellet exports from North Karelia and Finland in general. Already most of the total annual 260 000 tons of pellets production in Finland is exported and only 40 000 tons is sold in domestic markets (Ruha 2005). The use and characteristics of pellets are still poorly known by the retailers in Finland, which may be one of the reasons why the level of utilisation in Finland is still far behind that of Sweden. Therefore the market for small-scale both service sector and residential firewood, pellet and woodchip boilers
seems attractive within the area of such a strong forestry industry and expansion in local pellet production. Although at residential and service sector scale the fuel switching can also be very slow without considerable national scale marketing and/or investment grant efforts.

Table 2. Possible factors effecting developments in North Karelian energy markets.

<table>
<thead>
<tr>
<th>Possible influential factors</th>
<th>Impact on woodenergy</th>
</tr>
</thead>
<tbody>
<tr>
<td>EU Emission Trading Scheme</td>
<td>heat &amp; CHP plants &gt; 20 MW</td>
</tr>
<tr>
<td>EU directive on Waste Incineration</td>
<td>plants currently burning waste</td>
</tr>
<tr>
<td>Variations in Forestry Industry Production</td>
<td>heat plants, pellet production</td>
</tr>
</tbody>
</table>

2. Current structure and knowledge level of stakeholders*

* names and contact details of organisations are provided in separate Appendix 1.

2.1. Authorities

The Ministry of Trade and Industry (MTI) is responsible for national implementation of energy and climate strategies, and efficiency of energy markets. MTI Division for Renewables and Energy Efficiency is in charge of fiscal instruments for renewable energy policy and the main national authority for energy conservation, efficiency, promotion of renewables and energy technology. The MTI is supportive of biomass energy, also due to its potential to aid the industry to reduce emissions in the time frame required by the Kyoto Protocol and European Union (EU) Emissions Trading Scheme (ETS). MTI has formulated Action Plans for RES since 1990’s and has set a target for 50% increase from 1997 levels by 2010 (MTI 2000). Some regions have also established Regional Energy Agencies, which aim to promote energy efficiency and utilisation of RES within their own territories.

The Ministry of Agriculture and Forestry (MAF) administers financial support and aims to ensure diverse and sustainable use of renewable resources, protect the health of plants and animals and maintain vivid rural development. MAF is convinced about the future opportunities for biogas and biodiesel production, although bioethanol production on the contrary is believed not to become viable without significant tax reliefs. From all bioenergy sources in Finland, MAF is especially supportive of woody biomass and agricultural biomass developments. MAF develops and oversees the nowadays continuously evolving Forest Management Programmes as a tool for the implementation of its aims. The current Forest Management Programme until 2010, also encourages the use of forest fuels.

MAF participates in funding a variety of organisations involved in bioenergy developments. The 13 Regional Forest Boards, Forest Development Centre TAPIO, Finnish Forest Research Institute METLA are all subsidiaries of the MAF. TAPIO is a national advisory centre for professionals and organisations, and the Regional Forest Centres act as local advisory centre for forest owners and others. Regional Forest Centres advise with management plans, carry out forest improvement actions, assess the development of regional forest resources, administrate grants and enforce forest legislation. The Finnish Forest Research Institute (METLA) produces high quality
scientific research about forestry, forests, trees and forest soils to industry, decision makers and the general public. Metla’s social task is to promote economically, ecologically and socially sustainable management and utilisation of forests and forestry, through high level scientific research.

Ministry of Transport and Communications (MTC) is responsible for transport policy and energy use. MTC representatives participate in MTI led workgroups on advancement of renewable energy use and energy efficiency.

Ministry of the Environment (ME) is responsible for sustainable development, environmental protection, residential housing policies and landuse planning. ME oversees the Regional Environment Centres, which aim to promote biodiversity, quality of life and sustainable use of natural resources, in close collaboration with local people and institutions. The challenges of the Regional Environment Centre in North Karelia (NCREC) are focused on continuous assessment of forestry industry impacts on the environment. Research is also carried out in collaboration with Republic of Karelia across the Russian border.

The local governments of each municipality are the main administrative and decision making bodies for each specific area, within the framework of national and international policies. The Regional Council of North Karelia is a public regional authority by national law, owned by the 16 municipalities. The Regional Council aims to promote impartial development initiatives and sustainability in collaboration with national and local government, local industry, institutes, and other organisations. It is responsible for co-ordination and management of regional funds, regional landuse planning, safeguarding regional interests and creating infrastructure for skills and learning.

2.2. Educational, and Research & Development Organisations

North Karelia, and the surrounding area, have a wide network of organisations involved in bioenergy R&D and education. The University of Joensuu, renowned for its high level of forestry research, offers courses in wood energy technology, procurement and marketing and is involved in international bioenergy research. Together with the University of Joensuu, Lappeenranta University of Technology has started a new international Masters programme in Bioenergy Technology. Lappeenranta University of Technology provides the expertise for combustion side by research and education into power plant engineering, heat and power utilisation, environmental techniques and management. University of Joensuu focuses on bioenergy fuel supply chains by specialising in sustainable forestry, wood biomass production with environmental and socio-economic considerations as well as aspects of related policies and markets.

The European Forest Institute (EFI), based in Joensuu, hosts a network of forest research institutes with wide interests including development of bioenergy. North Karelia Polytechnic (NCP) runs vocational qualification in Woodenergy Advisory and a higher curriculum in Energy Studies, and collaborates internationally on development of educational services for bioenergy industry. NCP is currently developing a Centre of Expertise for Bioenergy aiming to produce a
strong R&D, and educational base to offer practical support for bioenergy applications and use the created knowledge for continuing education in the field. Valtimo Forestry school offers vocational degrees in mechanical harvesting and so produces qualified forest machine operators. Joensuu Regional Development Company (JOSEK Ltd.) offers consulting for business planning, for e.g. with a promotional project which aims at developing North Karelia into a model region in woodenergy use (WENET).

Other national organisations for bioenergy R&D include for e.g. Technology Development Agency of Finland (TEKES), Technical Research Centre of Finland (VTT), Metsäteho Oy and Motiva Oy. Motiva Oy is a national renewable energy marketing organisation. Metsäteho is owned by the forestry industry companies to perform R&D into forest operations and practice. VTT is impartial expert organisation which carries out R&D in technical fields and has expert advisors located in relevant regions. The subdivision VTT Processes has been an accountable leader of the finnish bioenergy technology programmes. Although TEKES been responsible for the implementation of energy technology programmes (Helynen 2004) since 1995, it also promotes innovation and new technologies in Finland via funding especially risk adverse projects and welcomes partners from abroad, thus providing a gateway to finnish innovation. TEKES is the main a public funding organisation for technical R&D in Finland. Together with VTT and Motiva Oy, TEKES participates in Organisations for the Promotion of Energy Technologies (OPET), an EU Framework Programme for Research and Development, which aims at energy efficiency and emissions reduction. TEKES also has a subsidiary branch and regional experts in Joensuu, at The North Karelia Employment and Economic Development Centre (TE-keskus).

2.3. Associations

Many of the above organisations are members of The European Bioenergy Network, previously Agricultural & Forest Biomass Net, an association which was established in 1995 for promotion of biomass in energy production.

Finnish bioenergy related national level associations include Energy Industries (FEI), Forest Industries Federation (FFIF), Sawmills Association (FSA), Work Efficiency Institute (TTS), Transport and Logistics Association (SKAL), The Trade Association of Forestry and Earth Moving Contractors, Bioenergy Association (FINBIO) and Wood Energy Association (WENET). The national Forest Management Association is mainly an advice centre, supported by funds collected by national law, which also sets a legal requirement for the establishment of such association to foster the interest of forest owners specifically. It has a regional subdivision in North Karelia, which can, on request, act as intermediary for establishing relationships with procurement contractors, and access to heat entrepreneurs and demand markets.

The Finnish Energy Industries is an industry association which looks after the production, procurement, transmission, distribution and sales of electricity, district heating and cooling. It is also involved in design, implementation, operation, maintenance and construction of networks and power plants. FFIF fosters the operational conditions of the wood processing industry and presents the industry in social and economic negotiations. FSA is independent information service run for and funded by the numerous SMEs in the sawmilling industry.

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TTS provides agriculture, forestry and domestic services related R&D and educational material. WENET promotes specifically woodenergy and use of woodchips nationally, with the added focus on North Karelia as the forerunner in woodenergy.

2.4. Woodenergy Industry in North Karelia

2.4.1. Industry involved in woodfuel procurement

There are private SMEs based in North Karelia to service each step of the supply chain to end user of woodenergy. From the countries many forestry machinery producers, Kesla Oy, Pentin Paja Oy, Mantsinen Group Oy, Waratah-OM, and John Deere Forestry (former Timberjack Oy) have manufacturing facilities in North Karelia.

The cost efficiency of forest fuel procurement in Finland stems from its integration into forestry and forest industry operations. Woodfuels are generally derived either as a part of silvicultural improvement in young stands, as harvest residues from final fellings or as a by product of wood processing industry. The three large forest industry companies UPM, Stora Enso and Metsäliitto Co-operative, generally seek to obtain contracts with forest owners for standing stock, although at the time of thinning or final harvest the owner may sell to any company. The company either dispatches energy wood directly to a distributor or utilises it internally in pulp and sawmills or processing sectors. Sawmills, pulpmills and other wood processing industries generate waste which can be further utilised as woodenergy.

Vapo Oy produces and distributes biofuels nationwide. One of Vapo’s largest pellet production plants is located in Ilomantsi. Biowatti Oy, formerly part of Metsäliitto, deals with roundwood procurement companies, and organises distribution and marketing of wood residues from the producer to heat and electricity plants, board and pulp industry, pellet manufacturers, and also for composting landscaping and agricultural materials.

In addition to the big players, numerous SMEs offer services related to woodfuel procurement, transport, and plant maintenance. There are 3 well known internet forums matching suppliers to smaller scale consumers operating in North Karelia, namely www.mottinetti.com & www.klapiforum.com and www.pelletforum.com for exchanges of information and trade in firewood and pellets, respectively.

2.4.2. Industry and manufacturing for utilisation of woodfuels

North Karelia also has some heating plant manufacturers for smaller capacities. Rakennustempo Oy designs, manufactures and markets heavy machinery and equipment to the range of 200-2000 kW of power. JPK-Tuote Oy designs and delivers pellet heat plants, imports some bioenergy technology and constructs thermal units of 50 -3000 kW of power. Tulikivi Corporation and Nunnauunit Oy manufacture soapstone fireplaces and stoves. The Joensuu CHP plant is owned by E.ON and managed by Fortum Services. Rest of the region is supplied by smaller power and heat plants with ownership varying from industrial corporation to full ownership by the local
municipality or joint venture of the two sides. Tecwill Granulators Oy of Joensuu has developed a system for granulating the ash resulting from combustion for easier recycling of the ash back in to the forests.

2.5. Legislation, taxes, and level of regional woodenergy expertise

Finland was the first country to introduce carbon tax on fossil fuels already in 1990. Due to the deregulation of electricity markets, the tax basis was later changed from primary fuel consumption to electricity produced (Kara 2004). Electricity produced by RES has received a partial tax refund since 1997 (Helynen 2004). From start of 2003, the refund has been 0.69 cents/kWh for wind and forest chips, 0.25 cents/kWh for recycled fuels (REF) and 0.42 cents/kWh for all other RES fuels, including wood, woodbased fuels, under 40MVA plants using peat for CHP, process heat and some waste gas (Kara 2004). Thus woodbased fuels are not taxed in heat production, and in power production the tax is returned according to final energy produced. For CHP the tax is applied according to fuel consumption and based on calculation standards where total fuel use is divided to heat and power production equally, irrespective of the specific proportions of fuels used for power of heat, and multiplying thermal output by 0.9 (Kara et al. 2004).

Forest fuel procurement is supported by subsidies. The national Kemera law (engl. law about subsidies for sustainable forestry) has since 1997, provided the opportunity for forest owners to apply for financial assistance for operations related to energy wood procurement. Kemera contains three forms or support: 1) subsidy for improvement of young stands when thinnings are to be used for energy 2) collection of stump biomass with ground preparation 3) subsidy for chipping the woody material which has been used for energy. For the woody material which is produced as a result of silvicultural improvement in young stands, is dispatched to a third party, the Kemera law facilitates a refund of 7€/m³ for collection and forwarding expenses. If the harvest is carried out by workforce that would otherwise need to be supported by unemployment benefits, there is a further possibility of 1,7 €/m³ (Metsäkeskus 2005). The conditions include a minimum batch volume of 20 m³, shifting by the side of the long distance transport route, and a submission of a certificate to the local Forest Board about dispatching wood for energy purposes. The subsidy for chipping is paid for the party that delivers chips to the user. Some of the conditions are area specific, for e.g. in North Karelia, specific rules for usage of stump are not published as there aren’t any stationary chippers yet which would allow for stump use for energy. The national Kemera law is also currently under review in EU to be expanded for harvest residue collection during 2006, however due to delayed EU administration it is no longer likely to be enforced or have impact this year (Karppinen 2005). Furthermore, the complete Kemera Law will be restructured in 2007, which strongly influences current and future developments.

There are also some capital grants available via TE-keskus for farmers, heat and other entrepreneurs. These are case specific and also include financial assistance with pipeline networks for municipal plants. Other forms of support in Finland include strong R&D via technology programmes funded by TEKES, and for e.g. funds directed to technology transfer from research institutions to SMEs via TUPAS programme. Various levels of financial support
are directed via development and innovation funds of organisations such as MAF, Finvera and Sitra.

North Karelia has a high level of expertise in woodenergy owing to surrounding forests, natural and manmade transport connections, strong manufacturing and research base, and favourable early national policies. As energy demand is scattered but the resources are well managed, the future challenges thus lie in increasing small scale use within the region, and exporting feedstock, know-how and technology to other regions further afar.

3. Assessment of solid wood fuel feedstock potential

3.1. Forest resources and management

Over 7% of Finlands forest area is within North Karelia and nearly 90 % of North Karelias land area is under forest cover. On average there are 3,9 ha of forest per capita in Finland, for North Karelia the figure is are 8,9 ha. The per capita net annual increment of forest resources follows the same trend, in average for 15 m³ for the whole country and 42 m³ for the region of North Karelia, respectively. (Metsäkeskus P-K 2005). North Karelias area of expertise was officially defined as wood technology and forestry via the national R&D programme from 1999, which helped to focus each regions development on local area of expertise. Forest sectors significance continued to grow during the 1990’s, and during 2000-2001 the forest sector, ie. forestry and forest industry, contributed 8% to Finlands GDP, but as much as 18 % to the GDP of North Karelia (Centre of Expertise 2003).

The national forest programme aims to increase annual roundwood harvesting by 5-10 Mm³, in a sustainable manner, and the annual use of wood for energy by 5 Mm³ by the year 2010 MAF. The North Karelia regional forest programme aims at 200 000 m³ increase in annual harvesting by the year 2010, and is expecting most of it to come from increasing thinnings of young stands. The decisions of annually increasing harvesting volumes are based on geographically wide, long-term measurements which prove that growth of forests has accelerated during the last few decades all over Europe. Therefore, although harvest is slightly increased annually the overall turnover of biomass is still positive due to annual growth rates being higher than the total annual drain. Both growth and drain are also monitored thoroughly to ensure sustainable management. The species specific proportions may, however, vary according to demands the wood processing industry. During the last few years, harvests in North Karelia have concentrated on spruce plantations in private forests. The total volumetric drain of spruce has been somewhat higher than growth while pine and broadleaved forests have been vastly under utilised, especially in young age classes. Such small diameter wood reserves could be used as energy within the region or further afar.

Unlike in other parts of Finland, the proportion of forest owned by the large forestry companies is quite high in North Karelia (table 3.). Still most forests are owned by private forest owners. Increasing proportion of private owners are retired rural habitants or absent landowners. Such ownership structure might challenge efficient management targets, as it slows down decision making, the owners are less dependent on income from forests and thus do not have as high
motives or possibilities to carry out management tasks themselves as, for example, active farmers that used to own a lot of the private forests.

Table 3. Forest area, resources, species distribution and ownership in North Karelia compared to Finland as a whole.

**Forest resources of North Carelia and the whole of Finland.**
(source: FFR; VMI9 for North Carelia, VMI8 or VMI9 for Finland)

<table>
<thead>
<tr>
<th></th>
<th>North Carelia</th>
<th>Finland</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Forested area</strong></td>
<td>1,596 milj.ha</td>
<td>26,2 milj.ha</td>
</tr>
<tr>
<td>* productive forests</td>
<td>1,491 milj.ha</td>
<td>20,1 milj.ha</td>
</tr>
<tr>
<td>* non-productive forests</td>
<td>0,046 milj.ha</td>
<td>2,9 milj.ha</td>
</tr>
<tr>
<td>* wasteland + roads etc.</td>
<td>0,059 milj.ha</td>
<td>3,1 milj.ha</td>
</tr>
<tr>
<td><strong>Stock volume</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>on productive and non-productive forest areas</td>
<td>156,7 milj.m3</td>
<td>2,002 milj.m3</td>
</tr>
<tr>
<td>(102 m3/ha)</td>
<td>(97 m3/ha)</td>
<td></td>
</tr>
<tr>
<td><strong>Species distribution</strong></td>
<td>by volume on productive and non-productive forest areas.</td>
<td></td>
</tr>
<tr>
<td>* pine</td>
<td>50,8 %</td>
<td>46,9 %</td>
</tr>
<tr>
<td>* spruce</td>
<td>30,0 %</td>
<td>34,4 %</td>
</tr>
<tr>
<td>* birch</td>
<td>15,4 %</td>
<td>15,2 %</td>
</tr>
<tr>
<td>* other species</td>
<td>3,8 %</td>
<td>3,5 %</td>
</tr>
<tr>
<td><strong>GAI</strong></td>
<td>7,24 milj.m3</td>
<td>79,4 milj.m3</td>
</tr>
<tr>
<td>on productive and non-productive forest areas.</td>
<td>(4,7 m3/ha)</td>
<td>(3,03 m3/ha)</td>
</tr>
<tr>
<td><strong>Total drain</strong>, inc. natural loss (1996-2000)</td>
<td>5,47 milj.m3/v</td>
<td>66,69 milj.m3/v</td>
</tr>
<tr>
<td><strong>Ownership</strong> of forests</td>
<td></td>
<td></td>
</tr>
<tr>
<td>* private</td>
<td>53,2 %</td>
<td>53,7 %</td>
</tr>
<tr>
<td>* state</td>
<td>21,50 %</td>
<td>33,40 %</td>
</tr>
<tr>
<td>* other parties</td>
<td>5,00 %</td>
<td>5,10 %</td>
</tr>
<tr>
<td>* forestry industry</td>
<td>20,3 %</td>
<td>7,8 %</td>
</tr>
</tbody>
</table>

As shown by figure 2., the annual commercial harvest volumes in North Karelia, and tree type proportions from total harvest, have stayed similar within the last years and no major changes are expected. In 2004, the total annual commercial harvest was approx. 4,4 Mm³ from which pulpwood harvests accounted for just over (2,3 Mm³) and sawn timber just under 50% (2,0 Mm³), according to the trend that has also continued for years. Assuming that industrial fluctuations or raw material price variations do not reduce commercial wood procurement within North Karelia, the record of past harvests can be used for estimating the minimum quantity of forest fuels which are potentially available via cost effective energy wood procurement integrated into roundwood procurement.
3.2. Forest industry – companies and their products

Wood production, pulp- and paper industries together accounted for about 19 %, while forestry accounted for about 7 %, of the total value added industry in North Karelia in 2003. In total, the North Karelian forestry sector produced nearly 5 % of value added industry in Finland, and about 3 % of total value of finnish exports (Mäki-Hakola & Toivonen 2003). Such level of production in North Karelia is generated by a large pulpmill, a board mill and 7 other major wood processing units, names, main products and annual production capacities of which are listed below in table.

Table 4. Production units of the most significant companies operating forest industry production in North Karelia (production information is available on companies websites).
In addition to the larger production units listed above, there are numerous SMEs in wood processing or manufacturing of further processed wood products. Some of the larger SMEs were included in the survey on production of industrial process residues suitable for energy use, such as:

<table>
<thead>
<tr>
<th>Company name</th>
<th>Location</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anaika Components Oy</td>
<td>Kevätniemi</td>
<td>construction components</td>
</tr>
<tr>
<td>Kaivospuu Oy</td>
<td>Hammaslahti</td>
<td>sawmill for small diameter wood</td>
</tr>
<tr>
<td>Liperin Höyläämö Oy</td>
<td>Rinteelä</td>
<td>small sawmill</td>
</tr>
<tr>
<td>Outokummun Puu Oy</td>
<td>Kuusjärvi</td>
<td>small sawmill</td>
</tr>
<tr>
<td>Havukainen Oy</td>
<td>Puhos</td>
<td>small sawmill</td>
</tr>
<tr>
<td>Kidex Oy</td>
<td>Puhos</td>
<td>furniture factory</td>
</tr>
</tbody>
</table>

### 3.3. Potential of forest industry residues

The total annual production of process residues (ie. energy as secondary use) was surveyed by a questionnaire mailed to 5 sawmills and 6 wood processing companies. The most significant operators were identified via Finnish Forest Industries Federation, Finnish Sawmills Association and information about other significant wood processing industries was given by a local expert. Main questions concerned annual quantities of process residues, in-house utilisation of them, and the quantities and sell out prices of possibly unutilised residues. Most industries producing residues suitable for energy use have their own solid wood fuel boiler and can utilise residues on site, or have arranged to sell excess to nearby larger units. The results of the mail survey are shown in table 5.

Table 5. Annual production volumes, and volumes potentially available for markets, of industrial wood residues suitable for energy use.
3.4. Potential of logging residues from final fellings and small diameter energy wood from thinnings

The best cost-benefit ratios for collecting harvest residues are obtained when it is integrated into commercial harvesting. Therefore, when estimating the municipality specific potential for harvest residue resources, it is useful to concentrate on harvests of large forestry companies that dominate wood procurement. A collective proportion of the total annual harvest of three large companies in Finland (UPM, Stora Enso, Metsäliitto Group) has been estimated to about 80% at national level. North Karelia has a relatively low number of small private sawmills, yet considerable magnitude of forest industry consumption of raw material within and in the vicinity of North Karelia, that the proportion of the three large companies share of harvest within the region is estimated to be at least 80% of total harvest.

Small diameter energy wood is mainly collected from young stands that are thinned for the purpose of silvicultural improvement. Because it is a subsidised operation under the law for sustainable forestry (Act.(Kemera).12.12.1996/10 94, 1996 #38), the local authority on forest laws and grant administration holds reliable records on the stand areas where such thinning operations have been done.

The estimation of the logging residue potential is based on proportions of the market fellings of main wood products in 2004:
- Total felling amount 4.4 million m³
- Log wood, 2 million m³
- Spruce log wood, 926 000 m³ (Metinfo 2005)

The total amount of log wood fellings was about 120 000 m³ lower than the aim of the Regional Forest Program (2006-2010), but the spruce log wood fellings were at same level as the target.
Logging residues and stumps were assumed to be collected only from the regeneration fellings and the collected tree species is spruce. It was estimated that about 75 % of spruce logs and about 44 % of spruce pulp wood are harvested from regeneration fellings. Proportions of the tops, branches, stem wood loss and stumps were estimated according to Hakkila’s biomass models. The proportion of suitable stands was estimated to be 65 % and the intake from the stands 70 %. Annual total potential of logging residues in North Karelia was estimated to be about 247 000 m³ and for stumps 118 000 m³.

Energy wood potential from thinnings is affected by the many things and because of that, two alternatives are presented. Energy wood potential from thinnings is based on the national forest inventories made by Metla. (Laitila et al. 2004). (Table 6).

Table 6. Forest chip production potential in North Karelia.

<table>
<thead>
<tr>
<th>Potential</th>
<th>MWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logging residues</td>
<td>513 500</td>
</tr>
<tr>
<td>Stumps</td>
<td>263 000</td>
</tr>
<tr>
<td>Thinning wood, lower</td>
<td>200 000</td>
</tr>
<tr>
<td>Thinning wood, higher</td>
<td>600 000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>976 000 - 1 376 000</strong></td>
</tr>
</tbody>
</table>

A moderate estimation of thinning wood is about 100 000 m³ annually which is 1/3 of the higher alternative. Thinning wood potentials and stands are affected by:
- Qualification requirements: total accumulation, energy wood accumulation, habitat type
- Logging methods: whole tree, delimbed whole tree, combinations of previous, development of technology
- Minimum diameters of industrial roundwood
- Prices for energy wood and industrial round wood, markets.

Harvesting costs for logging residues from regeneration fellings are still 1/3 cheaper than energy wood from thinnings. Subsidies (Kemera) for example for small wood thinnings, have an essential effect on wood flows.

In the higher alternative energy wood is mainly collected from mineral soils and includes small diameter stems and tree species which are not acceptable for industrial use. In the higher estimation:
- At least vaccinum myrtillus -habitat types and peatlands
- Accumulation of commercial roundwood ≤25 m³/ha
- Harvesting by whole tree method. (Laitila et al. 2004).

Estimations of potential thinning wood forests for energy production are between 2 000 and 6 000 hectares. In the Regional Forest Program the annual first thinning target is 18 000 hectares. Hence in the higher alternative more than 1/3 of the thinning stands could be include for energy wood harvesting.
There are remarkable differences within stands in North Karelia: In the south, center and western areas potential is focused on regeneration fellings, but in the eastern areas (large municipalities Ilomantsi, Lieksa and Nurmes) the biggest potentials are in the pine forests, which are waiting for the thinnings. In addition, Kemera subsidies are needed to keep procurement cost of energy wood from thinnings at about the same level than those for logging residues. In the figure 3 logging residue potential in North Karelia according to borders of Forest Management Associations is shown.

Figure 3. Forest Management Associations in North Karelia according to municipal borders. Municipal and association borders have some small differences in Koli area, because of the large lake areas (Pielinen).
Figure 4. Annual potential of logging residues and stumps from market fellings in 2004 and energy wood from thinnings according to Forest Management Associations. Thinning wood potential is same as the higher estimation. Estimation doesn’t cater the ownership of the forest and location of the potentials and end-users. (Tahvanainen et al. 2005).

Estimation of logging residue potential for Raja-Karjala includes also some other limitations:
- Limited numbers of potential users of energy wood
- Most of the young forests on the area are owned by the state or forest industry companies, which are not entitled to get Kemera subsidies

From the point of view of productivity of forests, large thinnings in the Raja-Karjala area, which are mostly located on peatlands should start in the near future. Demand for energy wood gives work and new possibilities for entrepreneurs.

3.5. Potential of agrobiomass feedstock

In Finland agrobiomass production has been developed mainly by Pohjolan Voima Oy and Vapo Oy. So far, the interest for agroenergy has been relatively low but it is expected to increase in the future. In summer 2005, there were about 60 private farmers cultivating a total of about 700 ha of reed canary grass in North Karelia. However, if Vapo’s own plots are included the total cultivated area for canary reed grass was about 2100 ha in 2005 (Romppanen 2005). Vapo aims to increase the area by about 1000 ha annually. Tests for combustion of reed canary grass for energy have been planned to take place in Ilomantsi, Lieksa and Outokumpu. As shown by table 7, there are two different agroenergy crop production zones within North Karelia. The region is divided into
production zone 4 to the north and production zone 3 to the south by a line between Polvijärvi and Värtsilä. (Regional Energy Agency of Eastern Finland 2004).

Table 7. Average yield of the selected agroenergy crops in the two different growing zones, with fertilization and without harvesting losses, tons/ha. (Growing zone; 3 = south, 4 = north, 1= dry matter, 2 = moisture as sold 9 %, 3 = harvested yield ). (Regional Energy Agency of Eastern Finland 2004).

<table>
<thead>
<tr>
<th>t/ha</th>
<th>Growing zone</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Reed canary grass$^1$</td>
<td>8,4</td>
</tr>
<tr>
<td>Willow$^1$</td>
<td>9,0</td>
</tr>
<tr>
<td>Rape$^2$</td>
<td>2,0</td>
</tr>
<tr>
<td>Straw$^{1,3}$</td>
<td>2,0</td>
</tr>
<tr>
<td>Reed canary grass (cutaway bogs, other arable fields)</td>
<td>6,0</td>
</tr>
</tbody>
</table>

From the total arable land area in North Karelia (about 85 000 ha), just over 90 % is cultivated and the rest is set-aside land. According to EU programme for the promotion of renewable energy EC , 10 % of agricultural area should be used for energy crop production. On the other hand, 10 % of currently cultivated fields are responsible for the excess of food crop production in Finland. Therefore, the land area potentially available for energy crop production is estimated as the sum of set-aside land and 10% of currently cultivated area. In addition to agricultural areas there are some land areas under 1 ha that are potentially available, but according to Swedish experience they are suitable for agroenergy production. Further potential could be provided by the future cutaway peatlands (Regional Energy Agency of Eastern Finland 2004).

The total potential of agricultural areas for energy crops, estimated according to Agroenergy Programme for Eastern Finland, is shown in table 8. The total potential cultivation area is estimated to be about 45 400 ha, and the largest potential is for reed canary grass as shown by tables 8-10 below.

Table 8. Areas potentially available for energy crop cultivation in North Karelia, ha. (Regional Energy Agency of Eastern Finland 2004).

<table>
<thead>
<tr>
<th>Current set-aside</th>
<th>Additional set-aside</th>
<th>Cutaway bogs in 2010</th>
<th>Other arable</th>
<th>Potential area for energy crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>ha</td>
<td>10 % of cultivated area</td>
<td>ha</td>
<td>ha</td>
<td>ha</td>
</tr>
<tr>
<td>North Karelia</td>
<td>8 000</td>
<td>7 700</td>
<td>1 700</td>
<td>25 000</td>
</tr>
</tbody>
</table>

Table 9. Technical potential of energy crop production in North Karelia, t/a. (Regional Energy Agency of Eastern Finland 2004).

<table>
<thead>
<tr>
<th>t/year</th>
<th>Reed canary grass</th>
<th>Willow</th>
<th>Rape</th>
<th>Straw</th>
<th>Reed canary grass, cutaway bogs</th>
<th>Reed canary grass, other arable</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Karelia</td>
<td>105 000</td>
<td>123 200</td>
<td>20 700</td>
<td>45 000</td>
<td>10 000</td>
<td>118 200</td>
</tr>
<tr>
<td>2010, GWh</td>
<td>Production potential</td>
<td>Utilization potential</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------</td>
<td>----------------------</td>
<td>-----------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reed canary grass</td>
<td>Willow</td>
<td>Reed canary grass and straw</td>
<td>Willow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>North Karelia</td>
<td>1 010</td>
<td>550</td>
<td>180</td>
<td>360</td>
<td>1 000</td>
<td></td>
</tr>
</tbody>
</table>

### 4. Problems in wood fuel utilisation

#### 4.1. Difficulties in wood fuel procurement and supply chain

Most plants are supplied by commercial wood chip distributors, others use local industrial residues or local energy co-operatives for harvest residues. One municipal plant has dedicated wood fuel procurement staff who deals with large forestry companies to integrate energy wood procurement with companies roundwood harvests. Such chains still require chipping arrangements and/or transport which both require financial inputs. One industrial plant reported the lack of space for storage as a limitation for ensuring timely deliveries, if the share of forest fuels is to be increased.

#### 4.2. Limitations on the use of solid wood fuels in DH and CHP plants

Heat and CHP plants in North Karelia already satisfy most fuel requirements with solid wood fuels. Although, with one exception, all the larger plants have an oil boiler to drive up the solid fuel unit, for peak and low demand, and as a backup. Such uses cannot be replaced by solid wood fuel boilers without considerable investments. Most grate technology users have not had big problems with wood fuel use, excluding the loss of efficiency due to wetness of wood chips. For the municipal plants, 6 out 8 reported wetness of wood fuels as a problem and the primary need for cofiring with peat. One new plant had had a problem with very dry chips. A DH plant uses mainly forest chips, but due to current problems with harvest residue chips, the municipality has plans to either, change fuel, install more oil capacity or upgrade to a new wood chip boiler.

Most of the municipality owned plants of capacity less than 5 MW, already use either 100% wood chips, or need to continue cofiring with peat for maintenance. Valtimo district heating plant is changing from using wood chips for 75% of all fuel, into 100% peat use.
All responders were also asked about interest on using stump chips. Most had prejudice about stump chip quality in relation to big particle size, mineral soil and charcoal content. Only three responders, E.ON Joensuu, UPM Joensuu Plywoodmill and Bakelite Oy, were interested in stump chips on the condition that harmful quantities of mineral soil could be avoided. Some were cautious about firing stump chip on grate as in too high temperatures mineral content was thought to burn onto the grate.

Most of the industrial heat and CHP plants use residues from their own production as main fuel. Only 2 out of the 7 industrial heat and CHP producers use grate technology and the rest use some type of FBB combustion technology. Thus wetness of wood fuels was not such a big problem, but the main limitations for increasing use of wood fuels were financial, logistical and technical. As long as price for their own production residues does not cover replacing fuel costs, they have limited need to use forest fuels. However, future availability of sawdust was considered a potential limitation. The potential gap left by sawdust needs to be replaced and forest chips would be an option, considering that price and quality are suitable. For one plant, replacing oil use with wood gasification technology could be considered, if both oil and EUA prices keep increasing and there would be for e.g. capital grant or low interest loan for the risky investment in new technology. In another plant, a recently discovered corrosion problem is suspected to result from the significantly increasing share of forest fuels during the last few months.

5. Assessment of the biofuel market potential in the region
5.1. Current levels and future potential of wood fuel consumption

According to Metla statistical bulletin, the annual solid wood fuel consumption in North Karelian heat and CHP plants has increased from 1856 GWh in 2000 to 2133 GWh in 2004. The use of different solid wood fuels in heat and CHP plants (except minimal use of REF or pellets) is shown below by figure 5.

![Figure 5. Development of solid wood fuel use in North Karelia, 2000-2004. (Metinfo 2005).](image-url)
Various sources were used to create a comprehensive list all significant DH, industrial heat and CHP plants within the region. The sources included Eastern Finland Energy Agency, Regional Council, Regional Environmental Centre, Regional Forest Centre, and Metla’s statistical department. The resulting list was verified by asking staff at technical departments of the 19 municipalities to confirm existence and ownership arrangements of energy production units within their area, and also a presence of any other significant heat production capacity, especially enterprises that use an old oil boiler. Eventually, plants with over 5 MW of total heat production capacity on solid fuels were interviewed about the current level of fuel use, experiences on quality, availability, and technical potential for increasing the use of forest fuels. The total annual fuel consumption by the plants included in interviews, was 2929 GWh, excluding waste and black liquor. Peat accounted for 20% of and oil over 10% of the total fuel use, and annual consumption of solid wood fuels for surveyed plants was is over 90% of the total for North Karelia reported by Metinfo (2005).

Most plants utilise FBB or moving grate technology, and one has a biomass gasification system. Tables 11 shows current fuel use and estimated technical potential for increasing forest fuels in the largest heat and CHP producing plants in North Karelia. Largely due to the vivid forestry industry and lack of gas pipe networks in the region, the level of biofuel consumption is already very high in North Karelia. Because all DH, CHP plants and most large industrial heat plants already utilise solid wood fuels and peat, increasing biofuel consumption requires growth in demand and investments into new technology and plants. Therefore, the current technological feasibility of increasing forest fuel use in particular was surveyed for North Karelia instead and the estimations are shown in table 11.
Table 11. Current annual fuel consumption, (except black liquor, waste and liquid gas) and technical potential for increasing forest fuel use at the most significant heat, DH and CHP plants in North Karelia.

<table>
<thead>
<tr>
<th>Name of Plant and Owner</th>
<th>Municipality</th>
<th>Capacity (MW)</th>
<th>HEAT: solid (+ liquid) / POWER</th>
<th>Combustion technology for solid fuels</th>
<th>Annual fuel consumption (MWh/yr)</th>
<th>Technical potential for increasing forest fuel use, MWh/a</th>
</tr>
</thead>
<tbody>
<tr>
<td>E.ON Kontiosuo Heat &amp; Power, * CHP</td>
<td>JOENSUU</td>
<td>120 (+45 (+145)) / 54</td>
<td>FBB</td>
<td>65,990</td>
<td>0</td>
<td>85,232</td>
</tr>
<tr>
<td>UPM Joensuu Plywood Mill, * CHP</td>
<td>JOENSUU</td>
<td>27 (+18) / 3.5</td>
<td>grate</td>
<td>0</td>
<td>62,898</td>
<td>15,710</td>
</tr>
<tr>
<td>STORA ENSO Pulpmill &amp; Ulmaharju Sawmill, * CHP</td>
<td>LIEKSA</td>
<td>300 (+30) / 107</td>
<td>BFB</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Board mill, Pankakoski Sawmill, Kitee</td>
<td>KITEE</td>
<td>10 + 5</td>
<td>m.grate</td>
<td>0</td>
<td>18,976</td>
<td>0</td>
</tr>
<tr>
<td>VAPO OY Kevätniemi (Sawmill), * CHP</td>
<td>LIEKSA</td>
<td>22 (+30) / 8</td>
<td>CFB</td>
<td>0</td>
<td>0</td>
<td>62,343</td>
</tr>
<tr>
<td>Pellet Factory, * CHP</td>
<td>ILOMANTSI</td>
<td>19.9 (+ neg.) / 3.5</td>
<td>FBB</td>
<td>43,578</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>MUNICIPALITY OWNED Nurmesen Lämpö Oy</td>
<td>NURMES</td>
<td>14 (+ 21)</td>
<td>FBB + grate</td>
<td>618</td>
<td>8,957</td>
<td>30,768</td>
</tr>
<tr>
<td>Outokummun Energia Oy OUTOKUMPU</td>
<td></td>
<td>10 (+22)</td>
<td>FBB</td>
<td>27,000</td>
<td>0</td>
<td>12,600</td>
</tr>
<tr>
<td>Rääkkylä DH RAAKKYLÄ</td>
<td></td>
<td>5 (+ 2.5)</td>
<td>m.grate</td>
<td>15,619</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Polvijärvi POLVIJÄRVI</td>
<td></td>
<td>4.3 (+ 2.3)</td>
<td>m.grate</td>
<td>12,744</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Juuka DH JULKA</td>
<td></td>
<td>5.6 (+ 8)</td>
<td>m.grate</td>
<td>13,305</td>
<td>469</td>
<td>0</td>
</tr>
<tr>
<td>Kiteen Lämpö Oy</td>
<td>KITEE</td>
<td>6 (+ 8)</td>
<td>gasification</td>
<td>26,295</td>
<td>8,607</td>
<td>0</td>
</tr>
<tr>
<td>SME, &gt; 5MW Liperi Dairy Oy</td>
<td>LIPERI</td>
<td>6,4 (+ 5)</td>
<td>m. &amp; s. grate</td>
<td>5,922</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Bakelite Oy</td>
<td>KITEE</td>
<td>7 (+7, +7 liquid gas)</td>
<td>FBB</td>
<td>17,786</td>
<td>0</td>
<td>938</td>
</tr>
<tr>
<td>TOTAL for North Carelia</td>
<td></td>
<td></td>
<td></td>
<td>228,857</td>
<td>99,907</td>
<td>292,103</td>
</tr>
</tbody>
</table>
5.2. Development of solid wood fuel prices

National average prices for 4 different types of solid wood fuels are given by Metla statistical bulletins (table 12). In 2000, forest chips were nearly 3 € more expensive per MWh, than bark as the cheapest solid wood fuel. Average prices of bark and sawdust have grown by over 30 and 20 %, respectively, compared to 2000 prices. Industrial chip prices have also continued to grow although at a slower rate. By 2004, the price difference between the three types of industrial residues seems to have stabilised to roughly similar levels, around 8 €/MWh. Forest chips are still significantly more expensive at around 10 €/MWh but due to the relatively slow rate of price increase, the gap to industrial residues has decreased to about 2 € per MWh.

Table 12. National average prices for solid wood fuels by loose m³ and MWh, from 2000 to 2004.

<table>
<thead>
<tr>
<th>Solid wood fuel type</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>m³ loose MWh</td>
<td>m³ loose MWh</td>
<td>m³ loose MWh</td>
<td>m³ loose MWh</td>
<td>m³ loose MWh</td>
</tr>
<tr>
<td>Bark</td>
<td>3.70</td>
<td>5.90</td>
<td>4.15</td>
<td>6.76</td>
<td>4.20</td>
</tr>
<tr>
<td>Sawdust</td>
<td>4.05</td>
<td>6.55</td>
<td>4.20</td>
<td>6.85</td>
<td>4.40</td>
</tr>
<tr>
<td>Industrial Chips</td>
<td>5.55</td>
<td>6.70</td>
<td>5.35</td>
<td>6.95</td>
<td>5.15</td>
</tr>
<tr>
<td>Forest Chips</td>
<td>6.50</td>
<td>8.60</td>
<td>6.95</td>
<td>9.00</td>
<td>7.55</td>
</tr>
<tr>
<td>Average across types</td>
<td>4.30</td>
<td>6.60</td>
<td>4.70</td>
<td>7.20</td>
<td>4.85</td>
</tr>
</tbody>
</table>

Figure 6. Illustrates the development of solid wood fuel prices according to loose-m³ and MWh. Reviewing the price development in both units reveals the importance of fuel consistency. For the three types of industrial residues, MWh prices follow the trend for loose-m³. Forest chips, however, seem to suffer from less consistent energy content per loose-m³, which together with a sensitive supply chain system leads to changes in cost price production, high prices, and price instability.
Generally, prices of all types of solid wood fuels have increased since 2000 and so has the ability of big consumers to pay for wood. Similar development is expected to continue as demand for all types of solid wood residues grows in light of European emission trading scheme, and demands from value added production of both energy (pelletising) and wood products.

5.3. Promising sites for increasing forest chip consumption

A Puho energy project which is being planned for the industrial area in Kitee, has the largest potential by a single site for increasing forest fuel use in North Karelia. Plans are well developed for establishing a plant around 35-50MW heat capacity possibly with a CHP (Suomalainen 2005). The plant would supply the industrial area demand and also DH for the municipality of Kitee. A good part of fuel would be available on site as industrial residues but forest fuels would also be used. If however, the project does not go ahead, some of the industry soon faces investments decisions to maintain their own energy production, which could also provide further opportunities for forest fuels although in a smaller scale. Also in Kitee town centre, there are two municipality owned factory sheds which are currently heated by oil and could be promising sites for wood fuel consumption, ie. Marimekko Oy and Karhu Sporting Goods Oy.

Another significant development already in progress, which will affect forest fuel demand either directly or indirectly, is the expansion of Vapo Oy Pellet factory in Ilomantsi. The factories demand for raw material will almost double, which is likely to affect the extent to which other plants, for example Vapo Oy Sawmill in Kevätniemi and Stora Enso Board mill in Pankakoski use sawdust for their own energy production. The energy required for pellet production will also grow, and forest fuels face price and quality competition both with peat and reed canary grass.

Most municipality owned heat plants reported a technical possibility to increase forest fuel share at the expense of peat. It also became evident that even if price and quality of forest fuels would be favourable, most would still continue using some peat for maintenance reasons on grate boilers. In the two municipality owned plants with FBB technology even more of the current peat use could be replaced by forest fuels technically, and due to ETS incentive. The largest potentials for increasing forest fuel consumption in municipality owned heat plants would thus be in Nurmeisen Lämpö Oy and Outokumpu Energia Oy’s Lämpökkeskus Miiliu.

In the small and medium size industry sector, those three that have heat capacities over 5 MW and already use domestic fuels did not see large practical potential for increasing forest fuel use. Although a slight increase could be reached by replacing combustion of peat or process waste in Liperi Dairy and Bakelite Oy, respectively. However, those industrial units that still use oil boilers to generate heat would be the promising sites for the scope of this project. Staff at technical unit of each municipality were interviewed on the phone and asked about such sites. In Kesälanti area, there are two companies that apparently use fairly old oil boilers in the same area Kesälalaoen Maansiirto Oy and Parelco Oy. According to the phone survey, there are some suitable sized industries where old oil boilers are still in use and some have even made initial enquiries about changing into solid fuel technology.
6. Description of wood fuel harvesting technology
6.1. Harvesting technology for industrial roundwood

The cut-to-length-method (CTL) is the most used harvesting method in North Karelia. Almost all of the industrial roundwood is harvested using the CTL system. As a result the degree of mechanization in industrial roundwood fellings is high (figure 7). Figure 8 shows the average number of harvesters, forwarders and timber trucks employed in commercial roundwood production in Finland during 1982 and 2003.

![Figure 7. Degree of mechanization in timber fellings, 1985-2002. (Metinfo 2005, Metsäteho 2005).](image)

However, the total number of forest machines is larger. There are at least 1 800 harvesters and over 2 700 forwarders working in Finland. Due to the fact that some forest owners and farmers have their own machines, some of the forest machines are only used part-time. Forest contractors in North Karelia own more than 100 harvesters and over 100 forwarders, with some of them working outside North Karelia.

![Figure 8. The average number of the harvesters, forwarders and timber trucks employed in commercial roundwood harvesting in Finland 1982-2003. (Metinfo 2005).](image)

Harvester. Almost all the harvesters are one-grip harvesters, using the same harvesting head to carry out the all wood handling work phases in the forest (felling, delimming, bucking and
cutting). There are several models of booms and harvesting heads and therefore it is possible to assemble specific machines for different kinds of trees. Most of the machines are wheel-based, but there are also a few machines equipped with crawlers (excavator-based).

Forwarder. Forwarders are used to transport wood assortments to road-side-storage from where long-distance transport is organized. Forwarders are equipped with a constant load space and a boom loader. Forwarders usually have a hydrostatic-mechanical transmission and are equipped with different kinds of tyres, bogies or crawler systems.

Figure 9. One-grip harvester at the work in the forest. (Metla/Juha Laitila).
Harwarder. A harwarder can carry out both felling and forwarding operations using the same base machine. At the moment harwarders can be divided into two main classes according to their operational principle.

With the first type, felling and forwarding can be carried out during the same driving phase without changing the attachments. It is equipped with a so-called combi-harvesting head, which can be used for logging and loading.
With the second type, some of the attachments should be changed after the logging phase is finished and the forwarding phase begins (harvesting head and load space equipments). There can be differences also within the same main harwarder type (load space). Benefits of the harwarder are among other things less need of transportations between stands and flexibility of operations.
Wood truck. Industrial roundwood can be transported to the refinery mill by truck, train or waterway. Most of the wood is transported by truck and also the other transport methods are usually dependent on the use of trucks (from forest to train or waterway). Most of the mills have a possibility to receive wood by either trains, waterways or both.

The maximum weigh of trucks in Finland is 60 tonnes. Usually wood trucks are equipped with a removable grapple loader. On the 1.1.2005 there were a total of 169 timber trucks in North Karelia, 19 new trucks trucks were registered in 2004 (Metsätrans 2005). In tables 13-15 harvesting and transportation costs of industrial roundwood in Finland in 2004 are shown.


<table>
<thead>
<tr>
<th>Logs</th>
<th>Pine</th>
<th>Spruce</th>
<th>Hardwood</th>
<th>Pulpwood</th>
<th>Pine</th>
<th>Spruce</th>
<th>Hardwood</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvesting</td>
<td>€/m³</td>
<td>6,02</td>
<td>5,53</td>
<td>7,55</td>
<td>10,88</td>
<td>10,30</td>
<td>12,40</td>
<td>8,43</td>
</tr>
<tr>
<td>Long-distance transportation</td>
<td>€/m³</td>
<td>5,64</td>
<td>5,02</td>
<td>6,76</td>
<td>6,73</td>
<td>6,19</td>
<td>6,53</td>
<td>6,01</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Unit costs, €/m³</th>
<th>mill. m³</th>
<th>€ mill.</th>
<th>Thinning</th>
<th>Final felling</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Felling, total</td>
<td></td>
<td>25,0</td>
<td>137,92</td>
<td>9,59</td>
<td>4,06</td>
</tr>
<tr>
<td>Motor-manual</td>
<td></td>
<td>1,2</td>
<td>13,59</td>
<td>14,25</td>
<td>8,44</td>
</tr>
<tr>
<td>Mechanised</td>
<td></td>
<td>23,9</td>
<td>124,33</td>
<td>9,09</td>
<td>3,93</td>
</tr>
<tr>
<td>Forest haulage</td>
<td></td>
<td>25,7</td>
<td>83,07</td>
<td>4,04</td>
<td>2,93</td>
</tr>
<tr>
<td>Felling+haulage, total</td>
<td></td>
<td>39,0</td>
<td>328,73</td>
<td>12,71</td>
<td>6,82</td>
</tr>
</tbody>
</table>

Table 15. Long-distance transportation of roundwood in 2004. (Örn & Väkevä 2005).

<table>
<thead>
<tr>
<th>By road to mill</th>
<th>mill. m³</th>
<th>km</th>
<th>€/m³/km</th>
<th>€/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rail transportation sequence</td>
<td>36,73</td>
<td>107</td>
<td>0,050</td>
<td>5,93</td>
</tr>
<tr>
<td>1. By road to railway</td>
<td>7,86</td>
<td>284</td>
<td>0,030</td>
<td>8,58</td>
</tr>
<tr>
<td>2. Rail transportation</td>
<td>7,86</td>
<td>239</td>
<td>0,022</td>
<td>5,17</td>
</tr>
<tr>
<td>Water transportation sequence</td>
<td>1,74</td>
<td>315</td>
<td>0,024</td>
<td>7,57</td>
</tr>
<tr>
<td>Floating sequence</td>
<td>1137,00</td>
<td>341</td>
<td>0,020</td>
<td>6,86</td>
</tr>
<tr>
<td>Floating</td>
<td>1137,00</td>
<td>293</td>
<td>0,015</td>
<td>4,43</td>
</tr>
<tr>
<td>Barge transportation sequence</td>
<td>606,00</td>
<td>266</td>
<td>0,034</td>
<td>8,92</td>
</tr>
<tr>
<td>Barge transportation</td>
<td>606,00</td>
<td>223</td>
<td>0,028</td>
<td>6,21</td>
</tr>
</tbody>
</table>
6.2. Harvesting technology of wood fuels

In most cases, residues of the forest industry are used in the same mill area and therefore there isn’t a need for long-distance transportation. If needed, the residues are transported to the power plant using chips-trucks that are usually used to transport forest chips.

Figure 12. Supply chains of logging residues. (VTT/Eija Alakangas).

The main phases of woodchip procurement are purchase, cutting, off-road transport from stump to roadside, comminution, measurement, secondary transport from roadside to mill, and receiving and handling at the plant. The most important machines are different kinds of chippers, crushers, bundlers and energy wood harvesting heads with multitree handling. There are also different kinds of combinations, for example terrain chippers, truck-mounted chippers and combined machine for site preparation and residue collection.
Small diameter trees can be felled using a chainsaw. Special handles enable an ergonomic work position. Felling is directed towards the nearest stack, from where forwarders load the material and haul it to the roadside landing.
Mechanized felling & bunching of small trees has become more competitive due to machine development and new technological solutions. Mechanized fellings enable faster loading of material, since the stacks are bigger and closer to the forwarding trails. The base machine for felling machines is usually a small thinning harvester. Multitree handling improves the productivity by about 15 %. (Laitila et al. 2004).

Figure 13. Small diameter trees can be felled using a chainsaw with special handles. (Metla/Antti Ala-Fossi).

Bundling of logging residues is an extra cost, but it improves the productivity in off-road and on-road transportation. Bundling decreases overhead costs because residue logs are easy to integrate into the industrial roundwood flows. Chipping costs are low when the chipping is done at the power plant. The diameter of the bundles is 60-70 cm, with a length of 3m and weight of about
500kg. The energy content of one bundle is approximately 1 MWh. Bundling cost are about 4 €/bundle. Productivity is 20-25 bundles per operating hour in spruce-stands.

Figure 14. Bundling machine. (Metla/Juha Laitila).

Stumps can also be used for energy. However, impurities such as stones and soil can cause problems in the further processing of the material. Crushers must be used in the comminution of stumps and the boiler must be able to tolerate larger amounts of sand and other impurities.
Figure 15. Stump harvesting. (Metla/Antti Ala-Fossi).

Figure 16. Logging residues. (Metla/Antti Ala-Fossi).
A forest fuel production system is built around the comminution phase. The position of the chipper or crusher in the procurement chain largely determines the state of biomass during transportation. Communion could be carried out in terrain, at landing, at terminal or at power plant.

Comminution in terrain. Only one machine is needed in the forest; it undertakes both chipping and forwarding. The chipper unloads chips into a container at the roadside. Compared to chipping at the landing, there are fewer interactions between chipping and trucking. The moving of the empty containers from site to site, however, generates extra costs. In addition, the payload of a container truck is considerably smaller than that of a chip truck with immovable load space.

![Forest machine based chipper on the stand. (S. Pinomäki Ky)](image)

Comminution at landing. Chipping at landing is the most common method to produce chips in Finland. It enables the use of heavy chippers and also the trucking distance of material is cost efficient due to the higher density of material than, for instance, by loose residues. Chipping at landing calls for large storages and good landings, since two large vehicles must be able to operate. Chipping at landing is a typical hot chain operation, which means that the chipper’s productivity and machine failures effect on the trucking and vice versa. If the chipper is broken, the truck has to wait. If there are no trucks at the landing, the chipper is idling.
Figure 18. Roadside chipper linked with farm tractor. (Mella/Antti Ala-Fossi).
Comminution at plant. Forest fuels can also be transported to the end use facility before comminution. Road transport is competitive only at relatively short transport distances due to the low net payload (low density of material). This supply chain calls for effective, centralized chipping at plant and suits well for large forest industries. Stumps are transported with purpose built stump trucks. Similar trucks can be used also for residue transportation.
At short transport distances, systems with low payloads can be competitive. In small procurement areas farm-tractor based transport and chipping systems could be useful, but if the procurement area is bigger, the truck-based transport and chipping systems are more useful. Longer distances call for higher payloads and chipping or bundling of material must be done before transportation.
The selection of harvesting technology for forest energy calls for information on raw materials, their availability, terrain conditions and infrastructure. When relatively small amounts are harvested, only small investments in machinery can be made. For instance, equipments designed for farm tractors can be used. On the industrial scale, purpose built machines are usually most...
competitive. The price relationship between different procurement technologies changes depending on the harvested amounts.

6.3. Harvesting technology of agrobiomasses

From a technical point of view the cultivation of reed canary grass on peatlands does not differ from that on mineral soils, and normal farming equipment and work phases can be used. Reed canary grass can be harvested by baling or by loose chopping. Chopping is carried out with different types of forage choppers. The precision choppers commonly used, can only work with cut growth or must be equipped with an optional mowing unit. Some choppers have a moving unit on their standard models. (Lindh et al. 2005).

Round baling has proven to be the most effective harvesting technology of reed canary grass. Machinery is commonly available from contractors and in farms. Baling has also the advantage of greater density for transportation. The harvesting of reed canary grass is done without chopping blades, which is estimated to reduce harvesting losses by 15 %, when the machinery is correctly adjusted and driving speed is not too high. The bales are stored on the roadside under plastic cover. Harvesting of reed canary grass is preferably done in the spring when the combustion properties are the best. Chopping and mixing of the biomass is done at the plant or in terminals. (Regional Energy Agency of Eastern Finland 2004).

Harvesting of straw is done immediately after harvesting of grain in the autumn. However, the rainy weather poses a risk to get the biomass harvested dry. (Regional Energy Agency of Eastern Finland 2004).

In Finland the existing transport equipment for peat can be used to transport agro biomasses. Due to the low density of the material, the loads are smaller than those of peat or wood chips (typically 7000 kg). Therefore, also the economical transport distances are shorter. The mass of a round bale is about 10 000 kg and that of large rectangular bales is about 14 000 kg. The benefit of large bales is that timber trucks can be used for transportation, and separate loaders are not needed. (Lindh et al. 2005).

The production costs of the agro biomass harvesting can be divided between normal farming and agro biomass production because the same machines can be used. According to harvesting tests, the total production costs of reed canary grass are about 15 €/MWh (Lindh et al. 2005). Without the productive value of the field the production costs are about 10 €/MWh. The share of actual harvesting costs is about 3,4 €/MWh, and with long distance haulage about 5,9 €/MWh at a distance of 30 km. (Lindh et al. 2005).

The total production costs of the straw are about 6,3 €/MWh with a heavy-duty precision chopper, 7,1 €/MWh for a farm-scale precision chopper, 6,4 €/MWh for round bales and 5,7 €/MWh for heavy-duty rectangular baler including the transportation to the power plant (30 km). The baling methods do not include the cost of separate chopping of bales, which is calculated to be about 3,9 €/MWh, if a round bale chopper is used. (Lindh et al. 2005).
7. Recommendation for the regional biofuel strategy
7.1. Targets for wood fuel use in 2010

Target for the use of forest chips, presented here, are based on the National Forest Program 2010 (1999) and Programme for promoting renewable energy made by the Ministry of Trade and Industry (2002). According to the Programme for promoting renewable energy the use of forest chips should increase four times from the year 2001 until 2010. In North Karelia the use of forest chips was about 160 000 MWh in 2001, thereby the target in 2010 is about 640 000 MWh (320 000 m$^3$). In the National Forest Programme the use of forest chips is estimated to increase to 5 million m$^3$ until year 2010. If the use of forest chip production develop in the same ratio than market fellings all around Finland and there wouldn’t be any areal structural differences in the stands, the proportion of North Karelia would be over 8 % from the national level. This means over 800 000 MWh and 400 000 m$^3$ of wood. The production target of forest chips in North Karelia for the year 2010 is 750 000 MWh (about 375 000 m$^3$). Source for the production are shown in the table 16. (Tahvanainen et al. 2005).

Table 16. Target for wood fuel use in 2010 in North Karelia: Sources. (Tahvanainen et al. 2005).

<table>
<thead>
<tr>
<th>Source</th>
<th>Target 2010</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logging residues</td>
<td>337500</td>
<td>45,0%</td>
</tr>
<tr>
<td>Stumps</td>
<td>187500</td>
<td>25,0%</td>
</tr>
<tr>
<td>Thinning wood</td>
<td>225000</td>
<td>30,0%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>750000</strong></td>
<td><strong>100,0%</strong></td>
</tr>
</tbody>
</table>

7.2 Target for chopped fire wood and pellets in 2010

Small scale use of firewood means usually chopped firewood and forest chips, which are burnt in stoves or small boilers in small houses or farms. In Finland, a rather new method are wood pellets, which are replacing especially light oil. Pellets are also used as a backup fuel in the bigger heating plants. In North Karelia, the total use of small fire wood was about 360 000 m$^3$ in 2001 (Metinfo 2005).

According to the Programme for promoting renewable energy the target for small scale use of firewood is a 21 % growth from the year 2001 to 2005 and 46 % to 2010. In North Karelia the target is to increase the use by 75 000 m$^3$ until 2010 which means about 21 % growth. Most of the increment (about 40 000 m$^3$) is coming from commercial chopped firewood. Increment of delivered delimbed firewood is about 20 000 m$^3$. The rest of the increment comes from chips and chopped firewood, being used on farms (20 000 m$^3$) and rapidly increasing use of pellets (15 000 m$^3$). (Tahvanainen et al. 2005).
## 8. Selection of cases

### 8.1. Three heat or/and power plants of different size classes and suitable production chains for their fuel procurement

#### 8.1.1 Puhos

Puhos is located 70 km south from Joensuu near the Southern border of North Karelia region in municipality Kitee. Puhos is a village with a large industrial park. Several companies (particle board, clue factory etc.) have plans to replace their existing heat and steam boilers with a joint CHP plant of about 30 MWth. The plant would utilize both industrial wood residues and forest chips.

The centre of Kitee municipality has also a plan to replace an existing forest fuel powered district heating plant with a larger heating or CHP plant. Either of the plants or both of them together will be chosen for piloting and for estimating the availability of forest fuels.

#### 8.1.2 Eno and Ilomantsi municipalities

Eno is located 50 km and Ilomantsi 70 km North-East from Joensuu. Both municipalities have been active in developing the use of wood energy: Eno being pioneer in promoting heat entrepreneurship and building up district heating in main villages, and Ilomantsi having a new integrated CHP plant and pellet factory.

Wood energy is highly prioritized in the municipal strategies and the decision makers want to have more detailed information on the wood fuel resources on municipality level for further steps. Municipalities are planning to develop a municipal level bioenergy strategy. One of the municipalities will be chosen as pilot case after more detailed discussions with the local actors.
8.1.3 Train transport of wood fuels to South Karelia

North Karelia has bigger resources of energy wood than the potential for using these fuels within the own territory. This case study is theoretical calculation of possibilities to transport energy wood from North Karelia to surrounding regions. In the South Karelia there is a concentration of large forest industry mills and other energy intensive industry. Those mills have also good connections from North Karelia by road, railway and waterway. This case study includes calculations of different transport methods and gives information of costs.
REFERENCES


Karppinen, H. 2005. Bioenergy Manager. North Karelia Regional Forestry Board. [Personal communication 27.06.2005]


Sormunen, T. 2005. Production manager. Fortum Services Oy. [Personal communication 15.06.2005]


APPENDICES
APPENDIX 1.

List of key players for development wood energy use in North Karelia.

National and Regional Authorities

Ministry of Trade and Industry
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Ministry of Agriculture and Forestry
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Educational, and Research & Development Organisations

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Associations

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Finnish Forest Industries Federation
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FINBIO, Bioenergy Association of Finland
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TTS, Work Efficiency Institute
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Regional Organisation of North Karelian Enterprises
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Mottinetti
www.mottinetti.com

Pelletforum
www.pelletforum.com

Klapiforum
www.klapiforum.com

EUBIONET
www.eubionet.net
Industry

1) Industry for woodfuel procurement

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John Deere Forestry (former Timberjack Oy)
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UPM Puhto Board Mills

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Stora Enso Timber Kitee Sawmill
Stora Enso Timber Uimaharju Sawmill
Stora Enso Pankakoski Mills
Stora Enso Enocell Pulp Mill, Uimaharju

Metsäliitto Co-operative
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2) Industry for utilisation of woodfuels

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