



Jussi Heinimö - Eija Alakangas

## Solid and Liquid Biofuels Markets in Finland – a study on international biofuels trade

IEA Bioenergy Task 40 and EUBIONET II  
Country Report of Finland



Lappeenranta University of Technology  
Department of Energy and Environmental Technology  
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Jussi Heinimö  
Lappeenranta University of Technology

Eija Alakangas  
Technical Research Centre of Finland (VTT)

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## PUBLISHERS

Lappeenranta University of Technology  
Skinnarilankatu 34, P.O. Box 20, FI-53851 Lappeenranta, Finland  
Tel. +358 5 621 11, fax. +358 5 621 2350

Technical Research Centre of Finland (VTT)  
Koivurannantie 1, P.O.Box 1603, FI-40101 Jyväskylä, Finland  
Tel. + 358 20 722 111, fax + 358 20 722 2598

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## **Abstract**

This study considered the current situation of solid and liquid biofuels markets and international biofuels trade in Finland and identified the challenges of the emerging international biofuels markets for Finland. The fact that industry consumes more than half of the total primary energy, widely applied combined heat and power production (CHP) and a high share of biofuels in the total energy consumption are specific to the Finnish energy system. One third of the electricity is generated in CHP plants. As much as 27% of the total energy consumption is met by using wood and peat, which makes Finland the leading country in the use of biofuels. Finland has made a commitment to maintain greenhouse gas emissions at the 1990 level at the highest during the period 2008–2012. The Finnish energy policy aims to achieve the target, and a variety of measures are taken to promote the use of renewable energy sources and especially wood fuels.

In this study, the wooden raw material streams of the forest industry were included the international biofuels trade in addition to biomass streams that are traded for energy production. In 2004, as much as 45% of the raw wood imported into Finland ended up in energy production. The total international trading of biofuels was evaluated at 72 PJ, of which the majority, 58 PJ, was raw wood. About 22% of wood based energy in Finland originated from imported raw wood. Tall oil and wood pellets composed the largest export streams of biofuels. The annual turnover of international biofuels trade was estimated at about €90 million for direct trade and at about €190 million for indirect trade. The forest industry as the biggest user of wood, and the producer and user of wood fuels has a central position in biomass and biofuels markets in Finland. Lately, the international aspects of Finnish biofuels markets have been emphasised as the import of raw wood and the export of wood pellets have increased. Expanding the use of biofuels in the road transportation sector would increase the international streams of biofuels in Finland. In coming years, the international trading of biomass for energy purposes can be expected to continue growing.

## Preface

Within the framework of the International Energy Agency's (IEA) bioenergy agreement, a new project titled Task 40 "Sustainable International Bioenergy Trade: securing supply and demand" started in 2004. The objective of the task is to develop the biofuels markets and identify the barriers to the trade in order to promote long-term biofuels trade at an international level in the direction of commodity markets. In the beginning of the year 2006, the countries participating in Task 40 collaboration were Belgium, Brazil, Canada, Finland, Italy, Norway, Sweden, the Netherlands and the United Kingdom. In addition, several industrial parties and international organisations (FAO, World Bank) are involved in the task, providing a platform for its effective implementation. The task has both short and long term objectives and it will contribute the market development at regional and international levels.

The EUBIONET - Efficient trading of biomass fuels and analysis of fuel supply chains and business models project (EIE/04/065/S07.38628) will be carried out during 2005-2007 and will analyse current and future biomass fuel market trends and biomass fuel prices. It also collects feedback on the suitability of CEN 335 solid biofuel standards for the trading of biofuels. The techno-economic potential of biomass is estimated until 2010 based on existing studies and experts opinions. In forest biomass, there is also co-operation with forest industry stakeholders (CEPI) to find a proper balance between forest industry raw material and bioenergy use to promote the application of new energy technologies by various measures.

This report studies and summarises the current status of biofuels markets in Finland and is composed in collaboration between the IEA Bioenergy Task 40 and the EUBIONET II project. The co-authors of the report are Mr Jussi Heinimö from Lappeenranta University of Technology and Mrs Eija Alakangas from VTT. This work is financed by EIE programme, Finnish Ministry of Trade and Industry and ClimBus technology programme of Finnish Funding Agency for Technology and Innovation (Tekes).

Utrecht, April 2006

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Jussi Heinimö

Eija Alakangas

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# List of abbreviations and terms

## Abbreviations

### Symbols

CO <sub>2</sub>	carbon dioxide
e	electrical
th	thermal

### Units

A	ampere
°C	Celsius degree
€	Euro
g	gram
h	hour (=3600 seconds)
ha	hectare
J	joule
l	litre
m	metre
m <sup>3</sup>	cubic metre (solid cubic metre unless other mentioned)
t	metric ton
yr (yrs)	year (years)
W	watt
%	percent

### Prefixes with exponent values

c	centi	10 <sup>-2</sup>
d	deci	10 <sup>-1</sup>
k	kilo	10 <sup>3</sup>
M	mega	10 <sup>6</sup>
G	giga	10 <sup>9</sup>
T	tera	10 <sup>12</sup>
P	peta	10 <sup>15</sup>
E	exa	10 <sup>18</sup>

## Terms

### Bioenergy

Bioenergy refers to energy derived from biofuel.

### Biomass

Refers to the biodegradable fraction of products, waste and residues from agriculture (including vegetal and animal substances) and forestry and related industries, as well as the biodegradable fraction of industrial and municipal waste. In Finland peat is classified as a slowly renewable biomass fuel.

### Biofuel (=biomass fuel)

Fuel produced directly or indirectly from biomass. The fuel may have undergone mechanical, chemical or biological processing or conversion or it may have had a previous use. Biofuel refers to solid, gaseous and liquid biomass-derived fuels.

**Forest fuel**

Wood fuel in which raw material has not previously had another use. Forest fuel is taken from the forest and processed directly for energy use. Forest fuels can be fuels from logging and thinnings and can be made from forest residues as well as stumps and rootstocks.

**Forest residues**

Woody residues consisting of branches, tree tops, brushwood and small trees not harvested or removed from logging sites in commercial wood stands, as well as material resulting from forest management operations.

**Fuel wood; energy wood**

Wood fuel, in which the original composition of wood is preserved.

**Fuel peat**

A peat product intended for energy production. Fuel peat is a local, indigenous, solid fuel, which is used as milled peat or sod peat as well as peat briquettes and pellets.

**Herbaceous biomass**

Biomass from plants with a non-woody stem and which dies back at the end of the growing season.

**Logging residues**

Woody biomass residues created during harvest of merchantable timber. Logging residues include tree tops with branches and can be salvaged fresh or after seasoning.

**Log wood**

Cut fuel wood, in which most of the material has a length of 500 mm or more.

**Milled fuel peat**

Fuel peat produced by milling peat from the surface of the peatland and by drying. Drying is normally done at the peat site by solar energy. Milled fuel peat is non-homogeneous in particle size and mainly contains pulverous peat as well as peat particles of various sizes. In addition to peat material, milled peat may also contain limited amounts of non-decomposed or poorly decomposed coarse plant parts (bog wood, shrubs, sheathed hare's-tail cotton grass, etc.) as well as limited amounts of impurities.

**Peat**

Peat is decomposed material, which has accumulated in waterlogged conditions. A substantial proportion consists of dead organic, plant-based matter. It is a slowly renewable natural resource for which there are many uses, particularly in energy and horticulture. Its carbon content and calorific value, particularly those of highly decomposed peat, make it suitable for use in energy. Its cellular structure, low pH and low nutrient status, particularly those of slightly decomposed sphagnum peat, make it suitable for use in horticultural growing media.

**Pellet**

Fuel in the form of short cylindrical or spherical units. Fuel pellets are usually produced from cutter shavings, dried sawdust and powder. Pellets are usually 8–12 mm in diameter and 10–30 mm in length, with a moisture content of less than 10%.

**Pulp chips**

Wood chips that can be used regarding its quality as raw material in pulp manufacturing. Pulp chips are made from bark free raw materials.

**Pulpwood**

Round wood suitable for manufacturing pulp. Not usually good enough for sawmilling. Pulpwood is usually wood that is too small, of inferior quality to be used for sawmilling. The commonly applied minimum diameter for pulpwood in Finland is 6–9 cm.

**Raw wood**

Round wood and imported pulp chips and sawdust used as raw material in forest industry.

**Recycled wood fuels**

Recycled wood fuels include post-society wood fuels like demolition wood, wood casings and other waste wood.

**Refined fuel**

Biofuel that has been treated mechanically or chemically to homogenise its properties. e.g. pellets, briquettes and pyrolysis oil are refined fuels.

**Renewable energy sources**

Refers to renewable non-fossil sources (wind, solar, geothermal, wave, tidal, hydropower, biomass, landfill gas, sewage treatment plant gas and biogas) Peat is not included in the statistics of renewable energy sources presented in this report.

**Sawdust**

Fine particles created when sawing wood. Most of the material has a typical particle length of 1 to 5 mm.

**Sod peat**

Fuel peat produced by extracting peat from the peatland, by processing it mechanically to sods (e.g. cylindrical, wave-like). Drying the sods is carried out by solar energy and mainly done at the peat site. The peat sods are fairly homogeneous in diameter or shape, while the length of the sods may vary. Sod peat also contains variable amounts of fines formed in the production and treatment stages, as well as coarse particles and limited amounts of impurities.

**Solid recovered fuel (SRF), recovered fuel (REF)**

Solid fuel prepared from non-hazardous waste to be utilised for energy recovery in incineration or coincineration plants and meeting the classification and specification requirements laid down in CEN/TS 15359. "Prepared" here means processed, homogenised and upgraded to a quality that can be traded amongst producers and users.

**Wood chips**

Chipped woody biomass in the form of pieces with a defined particle size produced by mechanical treatment with sharp tools, such as knives. Wood chips have a subrectangular shape with a typical length of 5 to 50 mm and a low thickness compared to other dimensions.

**Wood fuels, wood based fuels, wood-derived biofuels**

All types of biofuels originating directly or indirectly from woody biomass.

**Wood processing industry residues**

Woody biomass residues originating from the wood processing as well as the pulp and paper industry, like bark, cork residues, cross-cut ends, edgings, fibreboard residues, grinding dust, particleboard residues, plywood residues, sawdust, slabs, and wood shavings.

**Wood shavings; cutter shavings**

Shavings from woody biomass created when planing wood.

**Woody biomass**

Biomass from trees, bushes and shrubs. Forest wood, wood processing industry residues, fibreboard residues, particleboard residues, plywood residues, and used wood are woody biomass.

# 1. Introduction

Traditionally, biofuels have been used at the local level and utilised close of the production area. The situation has begun to change as biofuel consumption has been on the increase, and the markets of bioenergy at various levels are developing and the international biofuels trade is currently growing strongly. Interest in the research and development of bioenergy trade at an international level has increased. This is indicated by several published research articles and recently launched international projects.

In many countries, biomass is a relatively new fuel, but its consumption and markets are nevertheless growing rapidly towards the international level. Often there is no proper information available on internationally traded biomass streams, their volumes and prices. Information on the current status of international biomass trade can be obtained from country specific policies, regulations and targets for biomass use.

There are decades of experience available in Finland on developing bioenergy markets from the utilisation of local waste streams to the present international trading of refined biofuels. In Finland, cross-border biomass streams have been on the increase during the past decade. The foreign raw wood which the forest industry has imported primarily for raw material has become a more important source of bioenergy. The production of wood pellets started in the late 1990s and has since been on the increase. More than 80% of the produced pellets in Finland have been exported.

The export and import volumes of biofuels in Finland have previously been investigated in 1999 within the AFB-net project (Vesterinen & Alakangas, 2001). A compendious study carried out in autumn 2004 on biomass export and import streams and the reasons behind them for the IEA Bioenergy Task 40 was a starting point for this report (Ranta & Heinimö, 2004). This study presents an analysis on the solid and liquid biofuels markets in Finland and discusses the challenges of international biomass markets for Finland. The main emphasis of the study is on the solid biofuels stream. This report is a part of the Finnish contribution to Task 40 collaboration and EUBIONET II.

In the beginning of the report, a brief overview of the Finnish energy system is given. In Chapter 3, the Finnish energy policy and policy measures on bioenergy are described. In Chapter 4, the domestic markets of biofuels including production, potential, market actors and prices are considered. Chapter 5 focuses on the determination of the cross-border biomass streams including indirectly traded biomass streams in the form of the forest industry's raw wood. The challenges and possibilities of emerging biofuels markets are discussed in Chapter 6.

## 2. Finnish energy system

### 2.1 Facts about Finland

The relatively cold climate, the low population density, the structure of the industry and natural resources of the country are factors that have effected the development of the Finnish energy system. These factors, caused mainly by natural conditions, are increasing the energy demand.



*Figure 1. Location of Finland.*

Almost the entire national territory of Finland is located between 60 and 70 degrees northern latitude, and a quarter of its surface area lies north of the Arctic Circle (Fig. 1). The mean annual temperature in Southern Finland is 4 to 5°C, in Lapland –2 to +3°C. In January, the mean annual temperature in the northern two thirds of the country is –10 and –15°C, in southern Finland it is –5 to –10°C. Even in southern Finland, 30% of the annual precipitation stems from snow, which remains on the ground for about four months. Under the cold climate remarkable amounts of energy is needed for heating buildings. In the winter season, there is a very limited amount of full daylight, necessitating electric lighting until late morning and as of early afternoon. The growth season is four months long. Correspondingly, the population-weighted average number of heating degree-days for Finland is 5 000, much higher than the figure for Sweden and Norway (4 000). Thus, Finland has the coldest climate in Europe. (Kostama & Alakangas, 2004)

Finland is large and sparsely populated: with a total area of 338 145 km<sup>2</sup>, it is the fifth largest country in Europe and has a population of 5.2 million, i.e. 17 people per square kilometre. More than two thirds of the Finns live in urban areas and only 1.6% north of the Arctic Circle. A low population density and a vast sparsely populated area causes long average transportation distances, and the fuel consumption in transportation in Finland is larger than in densely populated countries. More than three-quarters (68%) of the country is covered by boreal coniferous forests, and 10% by lakes and other water systems; only 9% is cultivated area. Productive forestland is the most valuable natural resource of Finland. Large forest resources have been one factor enabling the development of the forest industry cluster in Finland that among other things incorporates the chemical and metal industry serving the forest industry. The forest and paper, metal and engineering and chemical industries represent about 80% of Finland's industrial production. These industries are very energy-intensive. (Kostama & Alakangas, 2004)

## 2.2 Energy consumption and supply

One of the strengths of Finland's energy economy is the variety of the production structure, where no source of energy plays a particularly dominating role. Increasing the use of renewable energy sources is an explicit goal of the Finnish energy strategy. Renewable energy sources<sup>1</sup> are important both in limiting carbon dioxide emissions and in ensuring the security of the Finnish energy supply. Moreover, the utilisation of renewable energy sources, especially bioenergy, has positive effects on employment at the local level.

The only indigenous energy resources in the country are hydropower, wood, peat and wind energy. Oil is the most important source of primary energy (Fig.2). In 2004, renewable energy sources accounted for 25% (372 PJ) of all energy consumption in Finland. The percentage of wood energy was 20%, the rest of the renewable energy being mostly hydropower. The proportion of renewable energy sources in energy consumption in Finland is the third highest in the European Union<sup>2</sup> (EU), and as regards bioenergy, the highest one. Also nuclear power belongs to the Finnish energy system accounting for 16% of the primary energy in 2004. The new fifth nuclear power unit

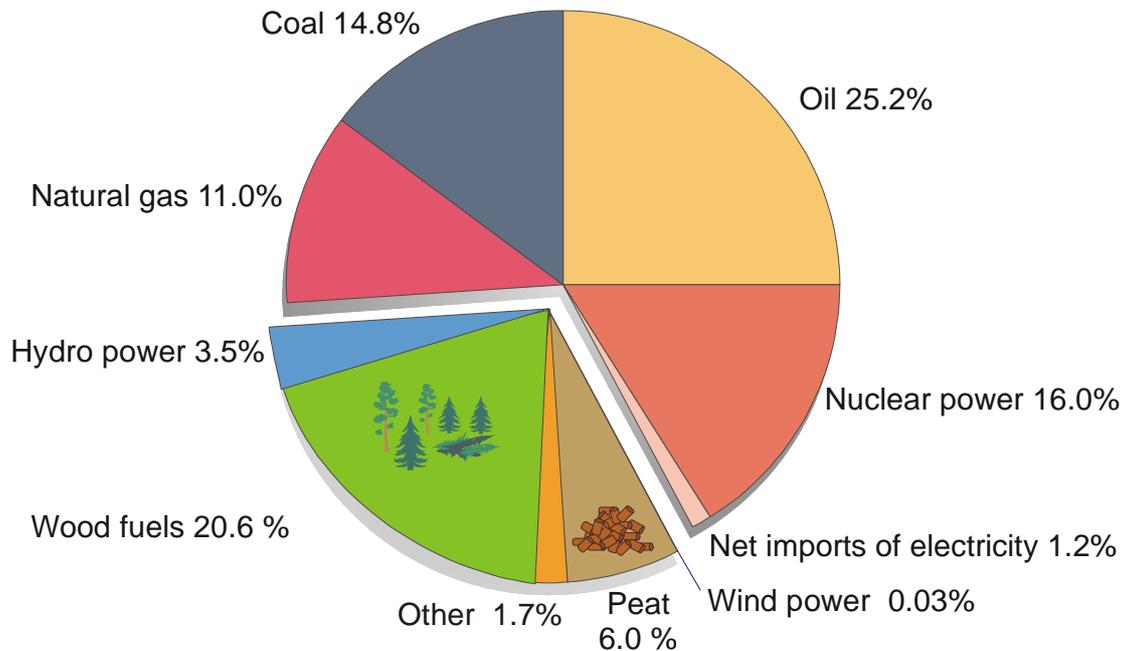
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<sup>1</sup> Peat is not considered as a renewable energy source in greenhouse gas accounting and official statistics.

<sup>2</sup> The European Union (EU) is an economic and political alliance of 25 European countries (Austria, Belgium, the Czech Republic, Cyprus, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden and the United Kingdom).

will start its operation in 2009. The natural gas consumed in Finland comes from Russia. The gas grid covers only part of southern Finland. (Statistics Finland, 2005)

In the Finnish energy balance the distribution into indigenous and imported energy sources is described in more detail in Appendix A.



*Figure 2. Primary energy sources in Finland in 2004 (The total use of primary energy in 2004 was 1 487 PJ). (Statistics Finland, 2005)*

In Finland, primary energy consumption per capita is high, 301 MJ/capita in 2003 (IEA, 2006). This is due to the severe climate, long distances, high standard of living and energy intensive structure of the industry. Industry consumes about half of all energy, which is the highest proportion among the OECD countries (IEA 2004). The forest industry accounts for more than half of the industrial energy consumption. Transport and space heating consume about one fifth each. The final share includes domestic, agriculture, and construction business (Fig. 3). (Statistics Finland, 2005)

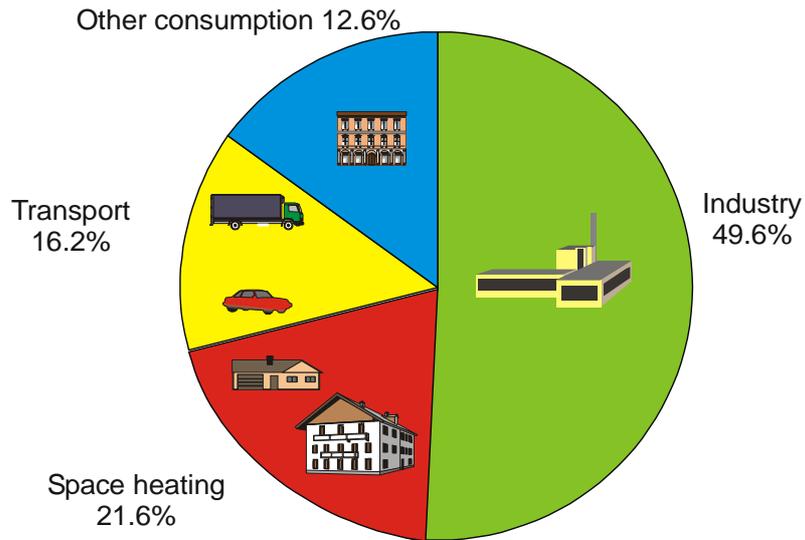


Figure 3. Final energy consumption by sector in Finland in 2004 (Total 1 125 PJ).  
(Statistics Finland, 2005)

### 2.3 Electricity sector

Electricity makes up 25% of Finland's total energy consumption. Industry consumes more than half of the electricity (Fig. 4) (Statistics Finland, 2005). The peak loads in electricity consumption take place in winter due the cold climate. Finland has the highest electricity consumption per capita in the EU, 16.4 MWh/capita in 2003 (IEA, 2006).

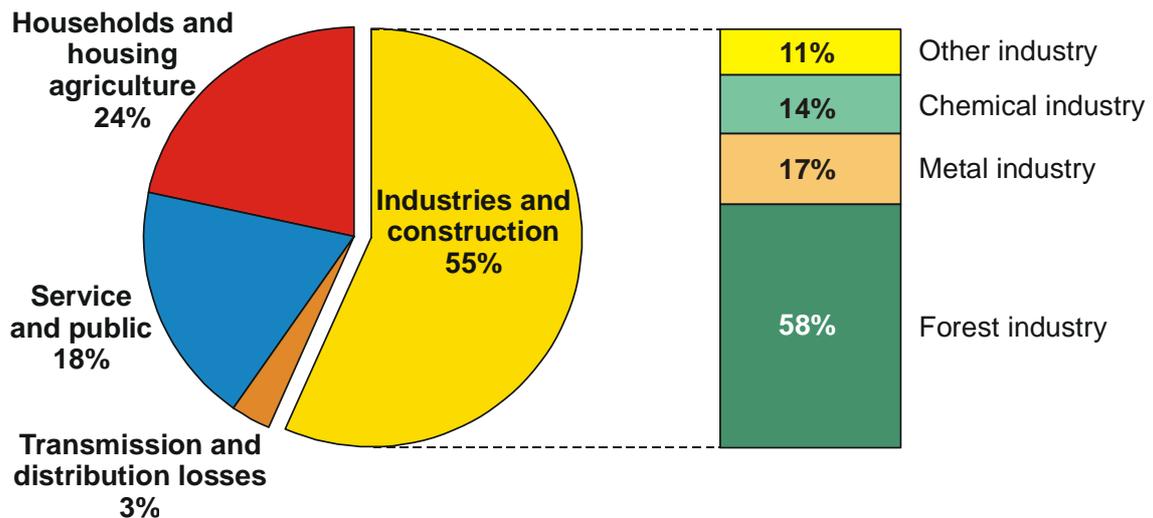
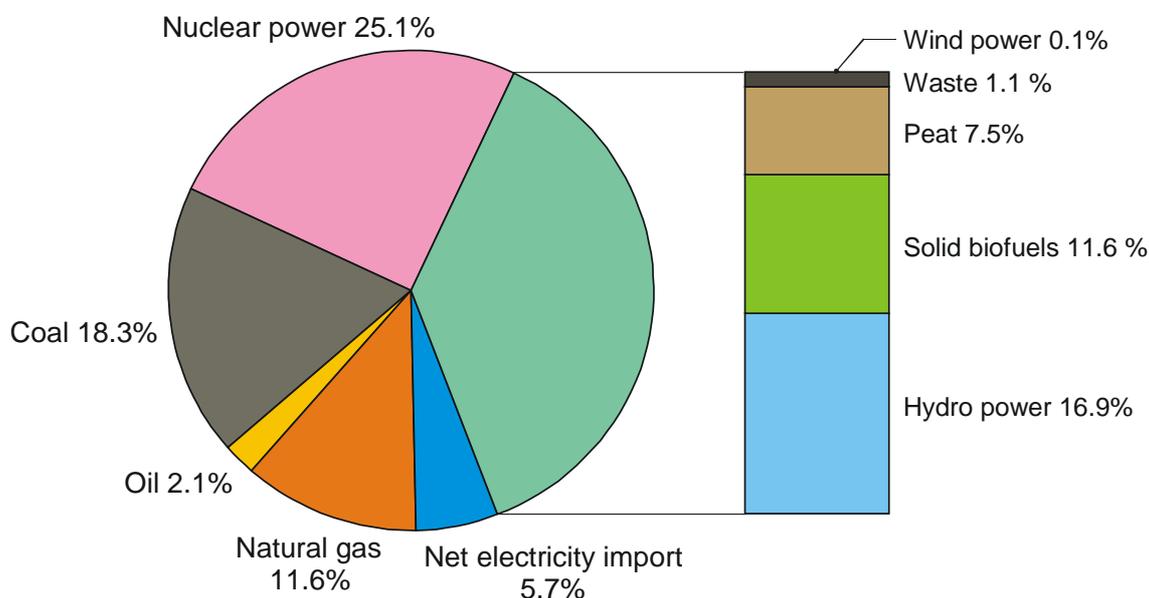


Figure 4. Electricity consumption by consumer groups in 2004 (In total 87.0 TWh).  
Data source: Statistic Finland.

The electricity production structure in Finland is versatile and no generation form or fuel is particularly dominant. The electricity is generated in about 400 power plants by using different energy sources and production technologies. Finland's total domestic electricity production amounted to 82.1 TWh in 2004. Of this amount, 25.0 TWh came from renewable energy sources and 28.2 TWh from CHP. These figures are, however, partly overlapping: approximately 10 TWh of electricity was produced in biomass CHP plants. Renewable energy sources covered 28.7% of the total electricity supply. Most of the electricity from renewable energy sources consists of hydropower (14.9 TWh) and biomass CHP. The total amount of wind power in 2004 was 0.1 TWh. Primary energy sources in Finnish electricity production are shown in Figure 5. (Statistics Finland, 2005; Association of Finnish Energy industries, 2006)



*Figure 5. Primary energy sources in electricity production in Finland in 2004. (Total supply of electricity 87.0 TWh, domestic production 82.1 TWh and net import of electricity 4.9 TWh.) (Statistics Finland, 2005)*

Finland was the third country in Europe after Britain and Norway to initiate the opening-up of its electricity market to competition. The liberalisation of the electricity market in Finland started in 1995 and was completed in 1998. Through the Electricity Market Act, all consumers can freely purchase their electricity from the power company of their choice (Council of State, 2004b). Finland, Sweden, Norway and Denmark constitute the Nordic electricity market, where electricity generation and sales are under competition. The electricity trade takes place in the Nordic Electricity Exchange (Nord Pool). In Finland, the sales activity of electricity does not require a licence and about 75 retailers of electricity operate in the market (The Energy Market Authority, 2006). Free electricity markets have given the energy utilities an incentive to establish trademarks

and develop brands. Environmental aspects have been one factor in the branding of electricity products.

The non-governmental nature conservation organisations of Norway, Sweden and Finland have introduced an ecolabel (environmental label) for electricity. The primary objective of these labelling systems is to increase the sustainability of energy consumption and to improve public awareness of the environmental impact of energy production. In Finland, the ecolabel is known as Norppa (Saimaa ringed seal) and is given to ecoenergy. The Finnish Association for Nature Conservation has set criteria concerning the origin and energy sources used in the production of labelled electricity. For wood fuels used in the production of labelled electricity, the verification of the origin including the type of raw material used (chips from a regeneration cut, chips from small-sized stemwood from silvicultural cuttings, etc.) is required. In Finland, ecolabelled electricity has been available since 1998. In 2004, the total generation of labelled electricity was 2.3 TWh and the sales were 0.4 TWh. At the end of 2005, a total of 17 companies were offering ecolabelled electricity. (The Finnish Association for Nature Conservation, 2004; The Finnish Association for Nature Conservation, 2006)

The Finnish electricity grid is connected to the Swedish and Norwegian main grids. The Finnish main grid is also connected to the Russian grid in a direct current connection for the import of electricity. Depending on the market situation, electricity is exported or imported from other Nordic countries. Finland has been a net importer of the electricity due to import from Russia. The importation from Russia is based on long-term contracts. (Statistics Finland, 2005; Association of Finnish Energy industries, 2006)

## **2.4 Heat sector**

In Finland, industry is the largest consumer of heat. During the past five decades, a vast district heating sector has been developed in the country. In industry, heat is consumed for heating and evaporation in processes. Available heat loads in industry and in the district heating sector enabled the effective utilisation of combined heat and power production (CHP). The annual heat consumption in industry is approximately 240 PJ. The forest industry is the largest consumer of heat with an annual consumption of over 170 PJ. The manufacturing processes of chemical pulp, paper and board are the major heat consumers in the forest industry. The shares of the chemical and metal refining industry are respectively about 32 PJ and 12 PJ annually. (Energiaverkko, 2003)

Because of the cold climate in Finland, it is necessary to heat houses for most of the year. About one fifth of the energy consumed in Finland is used for heating buildings. Almost half (48%) of the net effective heating energy of residential, commercial and

public buildings comes from district heating. Oil heating (18%), electric heating (17%), wood heating (12%) and other forms including heat pumps and natural gas (5%) cover the rest. (Statistics Finland, 2005)

District heating was started in the largest cities of Finland in the 1950s and 1960s, and in smaller towns after the oil crisis in the 1970s. Most of the district heating utilities are owned by municipalities. The sales of district heat are an extensive business. The turnover of district heating was about €1 140 million in 2004. District heating systems cover practically all densely populated areas of Finland, where the sale of district heating is profitable. (Kostama & Alakangas, 2004; Association of Finnish Energy industries, 2005)

In 2004, as much as 202 PJ of fuels were used and 120 PJ of heat produced in the district heating sector. In the same year, 15.1 TWh of electricity was generated in the CHP plants of the district heating sector. The fuels used in CHP and in district heating production vary from municipality to municipality. The most common fuels were natural gas, coal and peat. Oil amounted to 4%, wood and wood residues to 11% and others to 4% (Fig. 6). In the future, the fuel mix will change considerably and natural gas and wood will largely be used as substitutes for coal, oil and peat. (Statistics Finland, 2005)

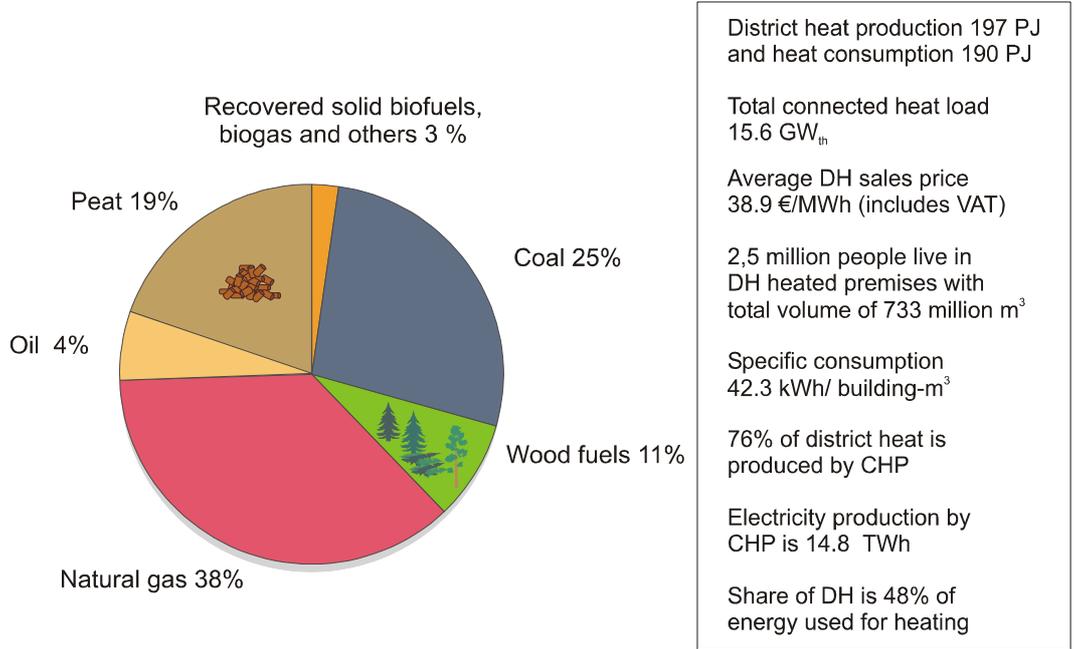


Figure 6. Use of fuels in the production of district heat and power in 2004. Total use of fuels 202 PJ (Association of Finnish Energy industries, 2005, Statistics Finland, 2005)

## 3. National energy policy

### 3.1 Targets of the energy policy

The energy and climate policy carried out in recent years has been based on the National Climate Strategy approved by the government in 2001. After completion of the strategy, however, the operating environment of the energy and climate policy has undergone so many changes that, in summer 2003, the government started to revise the National Climate Strategy taking into account the EU Directive on emissions trading (2003/87/EC, Act 683/2004) and the Kyoto mechanisms. The revised National Climate and Energy Strategy was given to the parliament as a government report in the end of November 2005. (Ministry of Trade and Industry Energy Department, 2005; Lensu & Alakangas, 2006)

According to the trend outlined in the strategy, the diversity of the Finnish energy system and the security of the energy supply will be preserved, or even improved. The volume of indigenous energy sources, and their share of the total energy consumption, will be increased during the period 2005–2025. The share of renewable energy will increase remarkably; on the whole, the share of bioenergy will also rise. Imported energy will account for a smaller percentage of the total consumption; this is mainly because of the substantial fall in the amounts of coal and oil used. In contrast, the share of natural gas will rise.

The objective of the Strategy is that the total energy consumption of renewable energy grows by at least one fourth by 2015 and by at least 40% by 2025. Renewable energy could then account for almost one third of the primary energy. The use of forestry chips, agrobiomass fuels, biogas and small-scale use of wood are promoted through energy policy measures. The actions envisaged by the Strategy increase the use of these energy sources to a considerable extent, by 65% from 2003 to 2015, and by about 80% by 2025.

Peat has an important role in the Finnish energy system, and the target is also to secure peat utilisation in CHP production. In 2005, when emission trading started, the use of peat in electricity production has decreased because peat has a higher CO<sub>2</sub> emission factor (milled peat 105.9 gCO<sub>2</sub>/MJ, sod peat 102 gCO<sub>2</sub>/MJ and coal 94.6 gCO<sub>2</sub>/MJ).

The Finnish government parties have agreed that the electricity tax imposed on industry and greenhouses will be lowered and that domestic biofuels are to be supported as a part of the new Energy and Climate Strategy. The tax support granted to electricity production will be abolished as regards electricity production by black liquor and other

industrial wastes and by-products. Technology development and respective financing remains the major tool in the attainment of the energy and climate policy objectives. Public funding for investments and R&D projects will be maintained at least at the previous years' level, which has been around €100 million/yr.

Energy saving measures are underpinned by the objective and obligations imposed by the EU directives. As far as possible, national implementation is based on voluntary actions, such as energy savings agreements, energy audits and programmes specific to a sector or measure. The economic subsidies targeted at the development and implementation of energy efficient technology and innovative modes of operation play a central role in this respect. The target is to obtain 5% additional savings in energy consumption by 2015, compared to a situation with no new measures taken.

Annual emissions during 2008 and 2012 should not exceed those in 1990 (Fig. 7). During the period of 2000–2004, emissions have been in maximum 20% higher than in 1990. In 2004 total greenhouse emissions were 81.4 million tons of carbon dioxide. The National Allocation Plan for Finland allows 70.5 million tons of carbon dioxide emissions in the emission trading sector, which is not enough in the future, and the additional need is estimated to be about 11 million tons of carbon dioxide. Using the Kyoto flexibility mechanisms, the state will be prepared to procure 10 million tons worth of emission reductions on the whole, with an annual average of 2 million tons. (Ministry of Trade and Industry Energy Department, 2005)

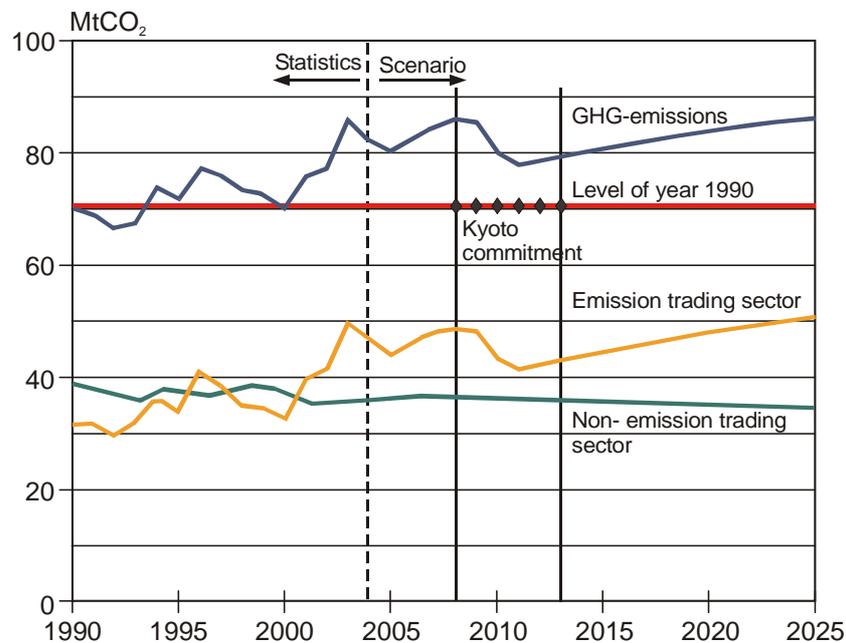


Figure 7. Targeted emission reduction in Finland and scenario for 2025. (Ministry of Trade and Industry Energy Department, 2005)

## **3.2 Measures to implement the energy policy**

Implementation of the Energy and Climate Change Strategy calls for financial support measures. Technology R&D and implementation of new technologies are the main measures in aiming at economically competitive solutions for the open energy market. Also, taxation, investment aids, regulations and norms support the fulfilment of the target. In addition, the administrative barriers to the use of renewable energy will be removed, voluntary agreement schemes introduced, and information dissemination and the efficiency of education and training improved.

### **3.2.1 Research and development**

The competitiveness of renewable energy sources will be promoted through investment in long-term technology research and development. The obstacles to getting the R&D findings and results onto the market will be lowered by supporting projects aimed at the commercialising of new technologies.

The Finnish Funding Agency for Technology and Innovation (Tekes) is the main public financer of technology R&D. Renewable energy technologies, belonging to the sustainable development solutions, are in the strategic focus of Tekes. Various national technology programmes and projects have involved RES technologies, the main focus being on bioenergy. Tekes funding for the renewable energy R&D amounted to more than €15.5 million in 2004 (Fig. 8). The total funding for renewable energy and climate change technology has been €60–70 million annually. In the Energy and Climate Change Strategy, technology development and respective financing remain the major means towards the attainment of energy and climate policy objectives. A strong investment will be made in innovations mitigating climate changes, with a special focus on competence areas that are strong from the Finnish point of view. The public funding appropriated to business-driven projects will be maintained at least at the previous years' level (about €60 million annually).

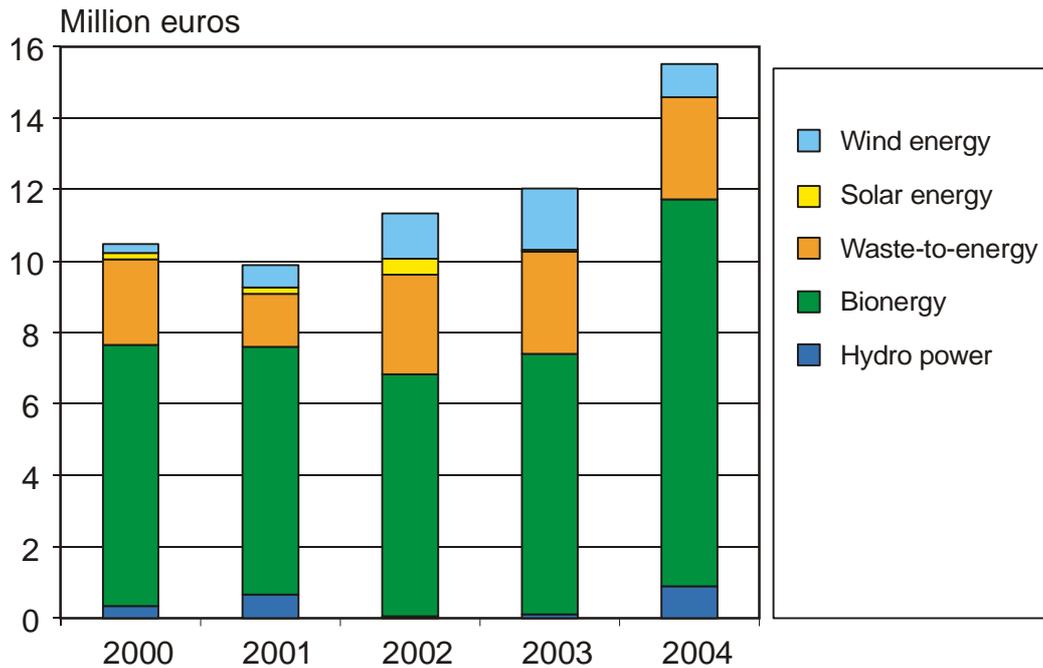


Figure 8. Funding for renewable energy and waste-to-energy technologies.  
Data source: Tekes.

Research on renewable energy sources is carried out by governmental contract research centre, VTT and several universities in Finland.

### 3.2.2 Energy taxation

Taxation is one of the main instruments related to climate change and the environmental policy in the Nordic countries. Finland was the first to impose a carbon-based environment tax in 1990 by introducing a CO<sub>2</sub> tax on fossil fuels. In heat generation, solid biofuels, such as wood fuels, biogas and solid recovered fuels, are not taxed. Fossil fuels have a tax, which is based on the carbon content of the fuel. In the generation of electricity, the tax is levied on electricity generated/consumed and not on the fuels used for the generation of electricity. A tax subsidy for electricity production by renewable energy sources was introduced in 1997. Unlike in some other countries, industry in Finland was not entitled to deduct the carbon/energy tax, but has lower electricity tax than private consumers and the public sector.

In CHP, the tax was split into two components in combined generation of electricity and heat production. The fuels used for heat generation are calculated by the amount of heat produced. The consumption of heat fuels is calculated by multiplying the heat amount generated by the factor 0.9. The tax paid by the consumer on the electricity produced with wood-based fuel CHP (<40 MVA) was refunded as a subsidy to the producer 4.2 €/MWh. In the new Energy and Climate Change Strategy this support is proposed not to

be granted for black liquors and other industrial wood residues. To compensate this support, the electricity tax for industry is proposed to lower from its current level. Electricity production by agrobiomass (e.g. straw, reed canary grass) is not supported in the national strategy because it is already supported under the common agricultural policy (CAP) of the EU.

Likewise, the support for the producers of wind power, electricity producers by biogas and small-scale hydro power (<1 MW) and by forest residues is 6.9 €/MWh. For solid recovered fuels (SRF), the support for electricity production is 2.5 €/MWh, which is calculated so that 60% of SRF is biodegradable (60%\*4.2 €/MWh) (Fig. 7 and 8).

In heat generation, no tax is levied on wood fuels, biogas and SRF. The CO<sub>2</sub> tax as of the year 2003 is €18.05 per ton of CO<sub>2</sub>. Also the CO<sub>2</sub> tax for natural gas is 50% lower than its CO<sub>2</sub> factor specifies (Table 1).

Peat, which in Finland is considered a slowly renewable biomass fuel, was taxed at a lower rate (0.44 €/GJ, 1.59 €/MWh) until 1 July 2005. If the consumption of fuel peat in heat production was less than 25 GWh (90 TJ) it was tax-free. The CO<sub>2</sub> tax for fuel peat is not levied as of 1 July 2005.

*Table 1. Energy taxes as of July 2005. Ministry of Trade and Industry.*

Product	Unit	Basic tax	Surtax	Excise tax	Security of supply fee
Motor petrol					
- reformulated sulphur free	EUR c/l	53.85	4.23	58.08	0.68
- other grade		56.50	4.23	60.73	0.68
Diesel oil					
- sulphur free	EUR c/l	26.83	4.76	31.59	0.35
- other grade		29.48	4.76	34.24	0.35
Light fuel oil	EUR c/l	1.93	4.78	6.71	0.35
Heavy fuel oil	EUR c/kg	-	5.68	5.68	0.28
Coal	EUR/t	-	43.52	43.52	1.18
Natural gas	EUR c/m <sup>3</sup> (0°C)	-	1.82	1.82	0.084
Fuel peat	EUR/MWh	-	1.59 <sup>1)</sup>	1.59 <sup>1)</sup>	-
Tall oil	EUR c/kg	5.68	-	5.68	-
Electricity					
- class I	c/kWh	-	0.73	0.73	0.013
- class II	c/kWh	-	0.44	0.44	0.013

<sup>1)</sup> Eliminated since 1 July 2005.

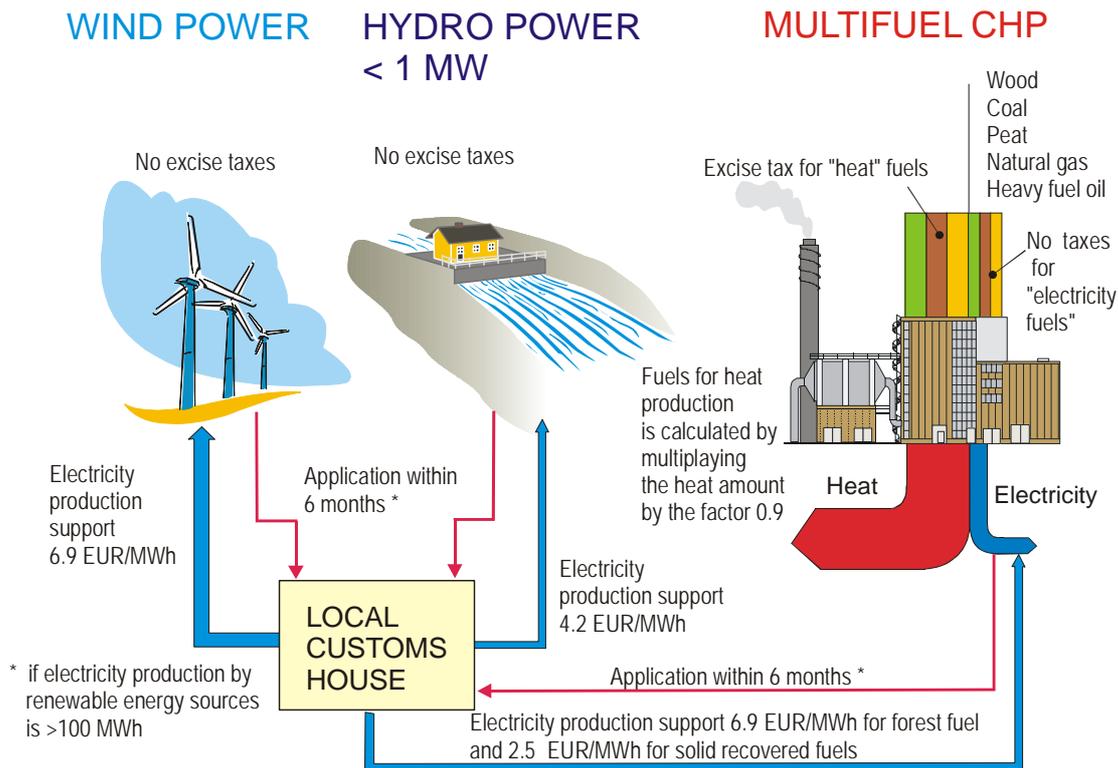


Figure 9. Examples of implementing energy taxation in different type of plants.

Source: VTT

### 3.2.3 Investment grants

Subsidies granted for energy investments, development projects and energy conservation constitute an important means of implementing the National Energy and Climate Change Strategy. A particularly important function of the subsidies is to promote the use of renewable energy sources, and to reduce the environmental impacts arising from energy generation and use.

The Council of State's new decision (625/2002, EUVL C37/2001/) sets the following maximum percentages for the assistance granted to different types of renewable energy projects:

- Energy investment studies, 40/50%
- Wind and solar energy investments, 40%
- Other investments in renewable energy, conventional technology (renovation and modernisation projects) 30% and for innovative projects 40%.

Projects involving innovative technology have the priority when energy support is

granted. Investment grants are allotted for companies and communities, not for private persons or state organisations. In 2004, in total €31.2 million was available for energy supports and 70% was granted to renewable energy investments. In addition, € 2.3 million of the Structural Funds was used for energy investments. In the new Energy and Climate Change Strategy, this support will be kept at the same level (€30 million). Also the abolition of energy subsidies paid to the Emission Trading sector, excluding those paid to technology and experimental projects, was proposed in the strategy. New technology refers in this context to both pilot technologies and progressive technologies already on the market. Outside the emission trading sector, the traditional technology projects can still obtain state support. (Ministry of Trade and Industry Energy Department, 2005)

Part of the energy aid for renovating block and row houses was allocated also to renewable energy. The total fund for energy renovations in buildings in 2004 was €17 million. The state did not support earlier energy investments for private persons, but the government finds it important to speed up the introduction of non-emission and low-emission forms of heating in small houses. For this purpose, a study was conducted focusing on whether the current subsidies could be targeted to investments aiming at heating system changes in small houses, or alternatively, whether the tax deduction granted for household services could be extended to cover these investments. (Ministry of Trade and Industry Energy Department, 2005) This study was completed in the beginning of 2006. The government decided to support replacement of light fuel oil with pellet heating, heat pumps, district heating or solar heating during the years 2006 and 2007. Total support will be €14 million. Support will be granted by municipalities for 15 000–20 000 houses based on applications. The support will be €700–1 000 per house (Maaseudun tulevaisuus, 2006).

### **3.2.4 Support for the forestry and agriculture sector**

In the Act on the Financing of Sustainable Forestry, non-industrial, private forest owners are entitled to seek governmental grants for the afforestation of understocked areas, prescribed burning, the tending of young stands, the harvesting of energy wood, forest recovery, fertilisation etc. Loans can be granted for joint ventures involving improvement ditching and forest road construction.

The state supports of the harvesting costs of thinnings from young stands. In year 2004, the total public support for the harvesting of energy wood from young stands amounted to €4.7 million. The support to forest owners for forestry operations ranges between 210.5–294.7 €/ha when employing outside harvesting services and farm has a forestry plan, and 168.4–252.6.0 €/ha, if the forest owner do not have a forest plan. Support for

wood fuel harvesting is 3.5 €/m<sup>3</sup> and forest transportation 3.5 €/m<sup>3</sup>, the total support being 7 €/m<sup>3</sup> (about 1 €/GJ). In 1999, the subsidisation of harvesting and use of fuel wood was improved. At the end of the year 1999, a new support scheme was introduced by the Ministry of Agriculture and Forestry to cover also the chipping costs. This “chipping support“ (1.7 €/loose m<sup>3</sup>, about 0.6 €/GJ) is paid for chips produced from trees harvested from young stands and to the organisation or the farmer delivering the chips to the plant. In the new Energy and Climate Change Strategy this support is planned to be €6 million annually during the period 2008–2012. (Ministry of Trade and Industry Energy Department, 2005)

The Finnish Ministry of Agriculture and Forestry finances development projects that promote the use of wood energy and gives investment, start-up and development support to enterprises, partly financed by the European Agricultural Guidance and Guarantee Fund through the Regional Rural Development Programme (ALMA), Objective 1 Programmes and to some extent also the Leader+ Programme. The aim of the financing is to put in order the whole energy production chain from the forest to the production plant. The primary beneficiaries of these projects are farm enterprises and so-called chain enterprises co-operating with farms (employment not more than 5 person-years).

During the present EU financing period 2000–2006, in total € 35 million has been granted for different development projects. The support granted to energy enterprisers, mainly as investment aid, amounted to about € 9 million and that granted to farm heating stations amounted to about € 15 million. The support granted from national funds for heating station investments of farms has been on average €5.3 million/yr.

### **3.2.5 Information dissemination and training**

Information, education and motivation hold the key position especially with respect to attitudes. It is easier to carry out other promotion measures if they are supported by information activities and guidance.

The Finnish Ministry of Trade and Industry has channelled the main part of the funds to energy information through Motiva Oy. During 2008–2012, the proposed total funding for information dissemination and training in renewable energy sources and energy conservation is €2.5 million annually. The support for information dissemination on energy and climate change was €3.4 million in 2004.

The ministry started in 2002 the Climate Change Information Programme, and 40 different projects have been carried out within this programme ([www.ilmastonmuutos.info](http://www.ilmastonmuutos.info)).

The Ministry of Trade and Industry also finances a project on networking energy agencies through Motiva. The network of energy agencies has promoted the use of renewable energy sources regionally and locally. The activity in the bioenergy sector focuses on the use of chips, on heat entrepreneur actions, and on pellet heating. Information on successful experiences is disseminated to the regions of other agencies.

Finland has also trained advisors in wood energy. These advisors are working e.g. in all forest centres with project funding. The Ministry of Agriculture and Forestry has required forest centres to carry out wood energy advising activities as one of their tasks. The operation of the network has been encouraged, e.g. by organising theme days and by producing a service package for the Internet.

Information material has been produced also in the EU-funded ALTENER and Intelligent Energy (EIE) projects. Examples of successful case projects and reports e.g. on market actors and technologies have been published both in Finnish and English. A number of seminars, especially on pellets and small-scale use of wood, have been organised in Finland, and study tours abroad and to Finland have been arranged. The main part of the information material is published on the Internet.

The Ministry of Education has established a committee on training in the energy field for operating as a specialist organ in the development of vocational basic and advanced training for young people and adults and of training and education at polytechnics and universities. The committee has initiated a project on surveying the training needs and development in the energy field with the aim of integrating the topics of renewable energy sources and energy saving to training and education programmes. Bioenergy training is given as a part of energy technology studies in universities or institutes of technology, or in universities with forestry education. For example, the universities of Applied Sciences of North Karelia, Mikkeli, Jyväskylä and Satakunta offer courses specialising in bioenergy. Information on bioenergy is also disseminated by different associations and research organisations.

## 4. Indigenous markets of biofuels

### 4.1 Solid biomass fuels in general

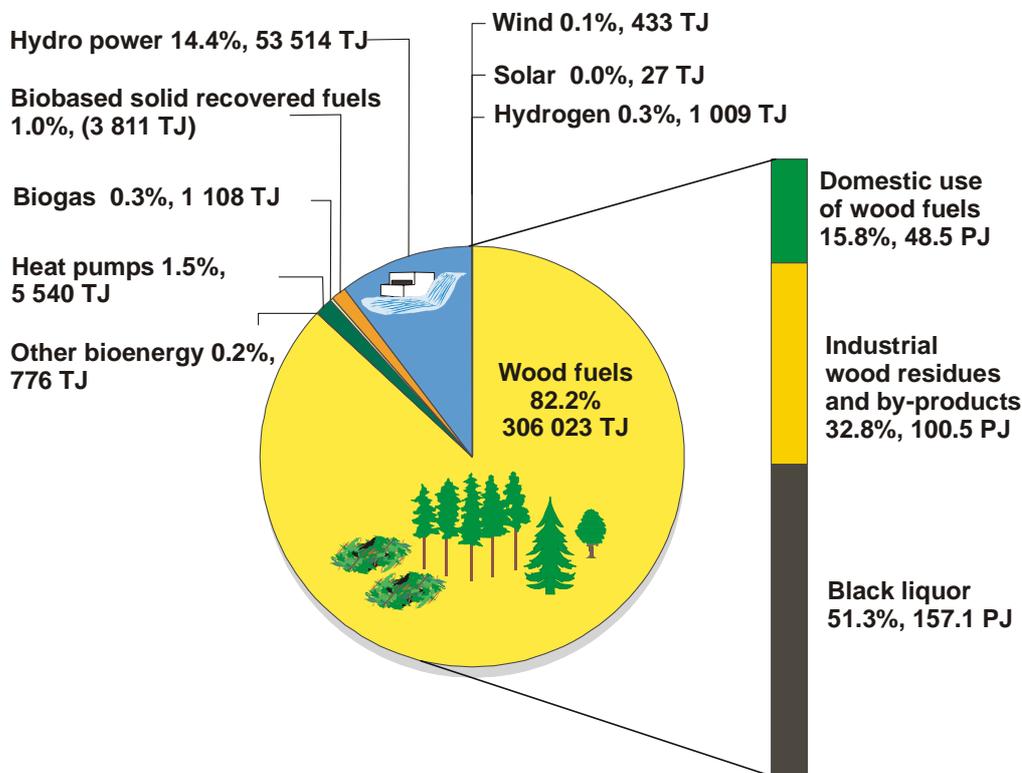


Figure 10. Use of renewable energy sources in Finland in 2004 (In total 372 PJ).  
(Statistics Finland, 2005)

Wood is the most important renewable energy source in Finland, accounting for 82% of renewable energy sources (Fig. 10). The main provider and user of wood-based energy is the forest industry, which obtains wood fuels at a competitive price in connection with raw material procurement or as a by-product of wood processing. Finnish forest companies have become worldwide players during the past two decades through several developing stages. Today the three largest Finnish forest industry companies are UPM, Stora Enso and Metsäliitto Group (M-Real, Finnforest, Botnia and Metsä-Tissue), and as the major users of wood they are strongly engaged in the biofuels markets.

In 2004, about 42 million m<sup>3</sup> of wood (306 PJ) is used annually for energy production in Finland, covering 20% of the total consumption of primary energy. Woody biomass is divided in the CEN classification (CEN/TS 14961) into three subgroups: forest and plantation wood, wood processing industry by-products and residues, and used wood (Fig. 11). Most of the wood-based energy is recovered from liquid and solid industrial

wood residues. So far, a modest (2.7 million m<sup>3</sup> in the year 2004), but rapidly growing share comes from forest fuels. (Statistics Finland, 2005; Ylitalo, 2005)

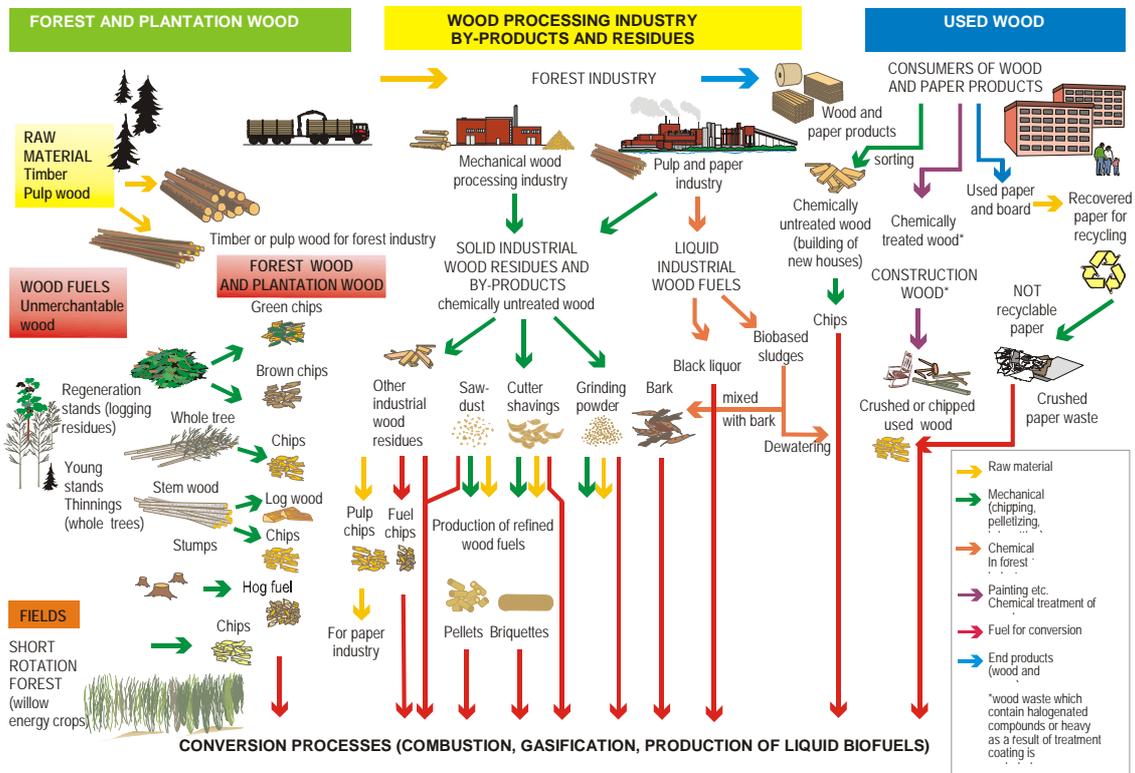


Figure 11. Classification of the wood-based fuels according to CEN/TS 14961. Source: VTT

Forests are the most important biomass source in Finland. The area of forestland is 26.3 million hectares equalling 86% of the country's land area. The growing stock of stem wood biomass was 2 090 million m<sup>3</sup> in 2004 and the growth of stem wood was 87.0 million m<sup>3</sup>. In the same year, the total drain of the growing stock that is composed of fellings and natural mortality was 69.9 million m<sup>3</sup>. The total stem wood removals were 61.2 million m<sup>3</sup> where 56.0 million m<sup>3</sup> was harvested as raw material in the forest industry and 5.2 million m<sup>3</sup> was directly used as firewood. In addition, about 0.7 million m<sup>3</sup> of stem wood and 2.0 million m<sup>3</sup> of forestry residues were utilised in the production of energy in heating and power plants. Since the 1970s, the total growth of stem wood has exceeded the total removals, and thus the total wood resources have increased over the past decades. (Finnish Forest Research Institute, 2005; Ylitalo, 2005)

In 2004, the total use of solid wood fuel (forest chips, bark, sawdust, industrial wood residues etc.) amounts to 14.4 million m<sup>3</sup>, of which the use of forest residues is 2.7 million m<sup>3</sup>. The National Forest Programme has set an aim to increase the annual use of wood for energy production by 5 million m<sup>3</sup> by the year 2010. (Ministry of Agriculture and Forestry, 1999; Ylitalo, 2005)

Finland has been actively involved in forest certification. The development of the Finnish Forest Certification System (FFCS) was started in 1996. The system was created specifically for the Finnish forest owner structure dominated by small-scale family forestry and it allows group certification. The FFCS includes in its requirements forest management and use and the chain of custody verification as well as the qualification criteria for external auditing. The FFCS sets 28 criteria for forestry. These deal with the economic, social and ecological sustainability of forest management and use. The criteria concern the planning and implementation of forest management, workers' rights, the training and advice provided to forest owners, and increasing young people's knowledge about forestry. Together the criteria are more stringent than the Finnish legislation and other regulations. Regional group certification is a voluntary system and it requires an audit carried out by an impartial party. Forest certificates complying with the FFCS have been awarded to all 13 Forestry Centre regions. The forest certificates currently cover 95% of forestland. Ownership of these forests is divided amongst over 300 000 people. The FFCS also includes the certification of the chain custody control system, which can demonstrate that a product includes wood fibre originating from a certified forest. The FFCS has been acknowledged by the Programme for the Endorsement of Forest Certification Schemes (PEFC), which allows products to be labelled with the PEFC logo. The first such products entered the market in 2000. The Forest Stewardship Council (FSC) certification system has been demonstrated in Finland. In 2005, FSC covered less than 1% of the forestland. (Finnish Forest Certification Council, 2006; Finnish Forest Industries Federation, 2006a)

In addition to wood fuels, peat is an important domestic source of bioenergy in Finland. Vast peat resources have enabled large-scale utilisation of peat in energy production. As much as 30% of the country's land area (9.1 million hectares) is classified as peatland and slightly over half of that area, 4.9 million hectares, has been drained and dried for forestry. Since the end of the 1970s, the consumption of fuel peat has been on the increase, and currently, Finland is one of the leading countries together with Sweden and Ireland in the utilisation of fuel peat. (Finnish Forest Research Institute, 2005; Statistics Finland, 2005)

In the accounting of greenhouse gas emissions, peat is defined as a non-renewable energy source and the CO<sub>2</sub> emissions include the use of peat in energy production in full. In 2002, the Ministry of Trade and Industry, the Ministry of Agriculture and Forestry and the Ministry of the Environment initiated a four-year and € 1.5 million research programme to examine the greenhouse gas effects of peat and peatland in Finland. The research programme provides information for the life cycle analysis of the energy use of peat. The ultimate objective of the programme is to give scientific grounds for improving the climate conventions' calculation rules regarding peat. The research findings also serve the development of national reporting on greenhouse gases.

A number of universities and research institutions are participating in the research. (Ministry of Trade and Industry, 2006c)

In the following, sections 4.2–4.5 focus on biomass fuels from the production side, including production potentials and current use. Later, sections 4.6–4.8 consider biomass markets more from the consumption viewpoint, discussing e.g. the users and prices of biofuels.

## **4.2 Forest wood**

### **4.2.1 Forest wood in heat and power plants**

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

The annual growth of above-ground forest biomass, including tops, branches and needles, is estimated at 110 million m<sup>3</sup> and the annual drainage of forest biomass at about 85 million m<sup>3</sup> (Ranta, 2002). In addition, there is remarkable biomass potential in the stump-root system below the stump cross-section.

The theoretical maximum annual production potential of forest fuel was evaluated at 45 million m<sup>3</sup> (324 PJ). The theoretical potential includes all residual biomass left in the forest in conjunction with timber harvesting and the small-tree biomass which is removed, or should be removed, for silvicultural reasons in the precommercial thinnings of young stands. The former is dependent on the markets of forest products, whereas the latter is free of market fluctuations. (Hakkila, 2004)

Only a part of the maximum forest fuel potential is recoverable. Many technological, socio-economic and environmental factors affect the availability. The Finnish Forest Research Institute (METLA) has calculated the annual technically harvestable potential of forest fuel for 11.4–20.0 million m<sup>3</sup> (82–144 PJ), including forest residues, small-size trees from thinnings and stumps (Karjalainen et al., 2004). In a study recently published by Lappeenranta University of Technology, the techno-economical potential of forest fuel in 2010 was evaluated at 86 PJ. The largest share of the potential comes from logging residues, 40 PJ (46%), whereas the share of stumps is 22 PJ (24%) and that of small diameter energy wood 25 PJ (30%) (Ranta et al., 2005).

In 2004, forest fuel utilisation in energy production was totally 18.9 PJ (2.7 million m<sup>3</sup>), representing 6.2% of the total wood fuels use, and was less than one fourth of the above-mentioned techno-economical production potential. The factors that limit the increase of the use of forest fuel are mainly economical, but the geographical factors have an effect on the situation, as well. The users of forest fuels are not always optimally located with regard to forest fuel resources. The balance between the supply and demand of solid wood fuels varies strongly regionally. Figure 12 shows the estimation of regional balances between the deliveries and demand of solid wood fuels (by-products and forest fuels) with different prices of CO<sub>2</sub> emission allowances in 2010. The location of plants using forest fuels in 1999 and 2004 are presented in Figure 13. (Ranta et al., 2005; Statistics Finland, 2005; Ylitalo, 2005)

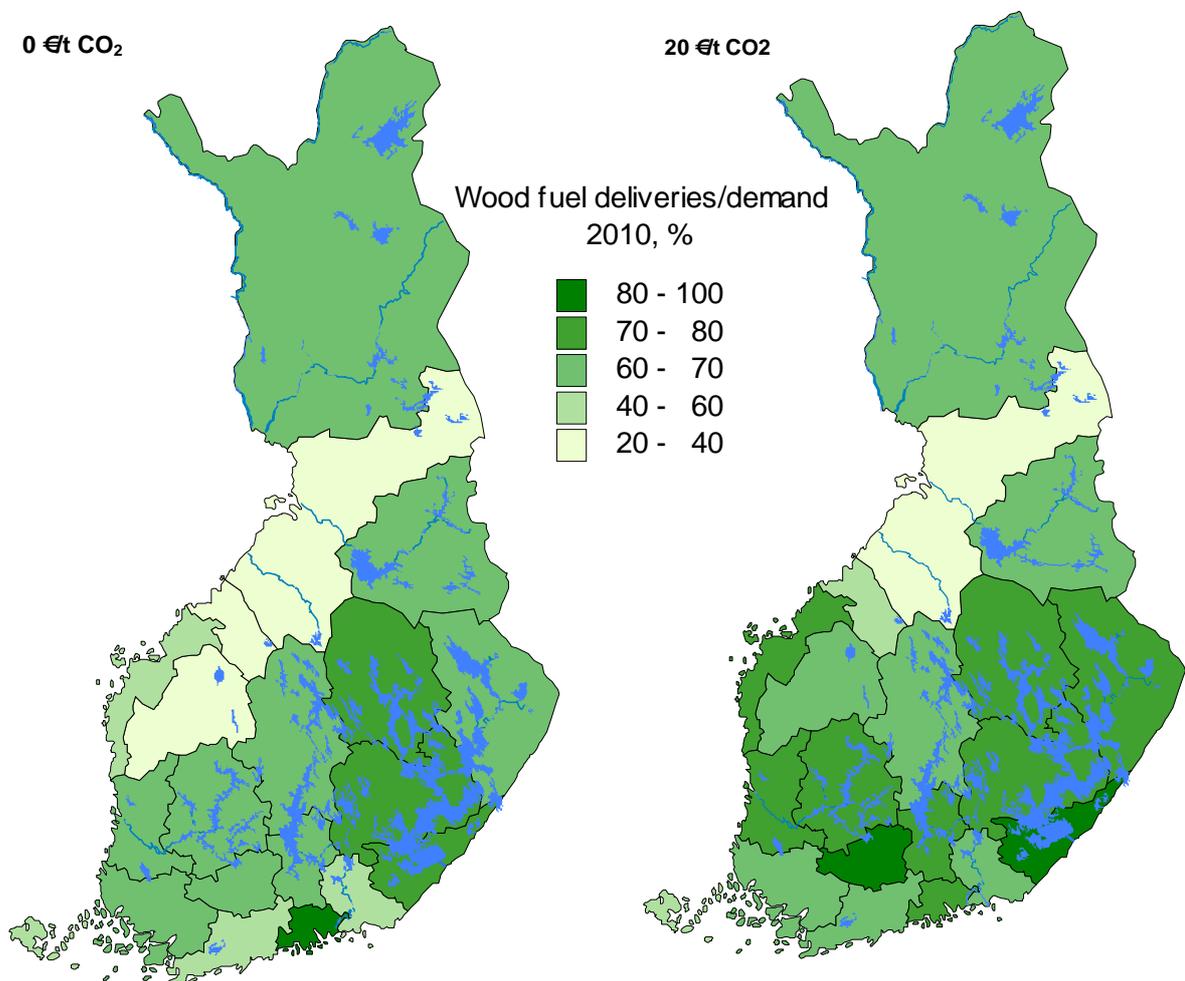
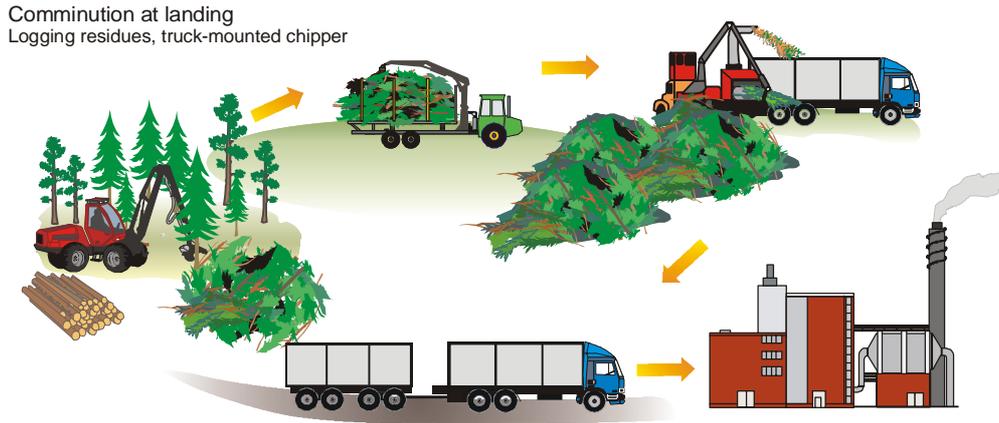


Figure 12. The wood fuel deliveries against the potential demand of wood fuels at provincial level in 2010 (Ranta et al., 2005).





Comminution at plant  
Logging residues

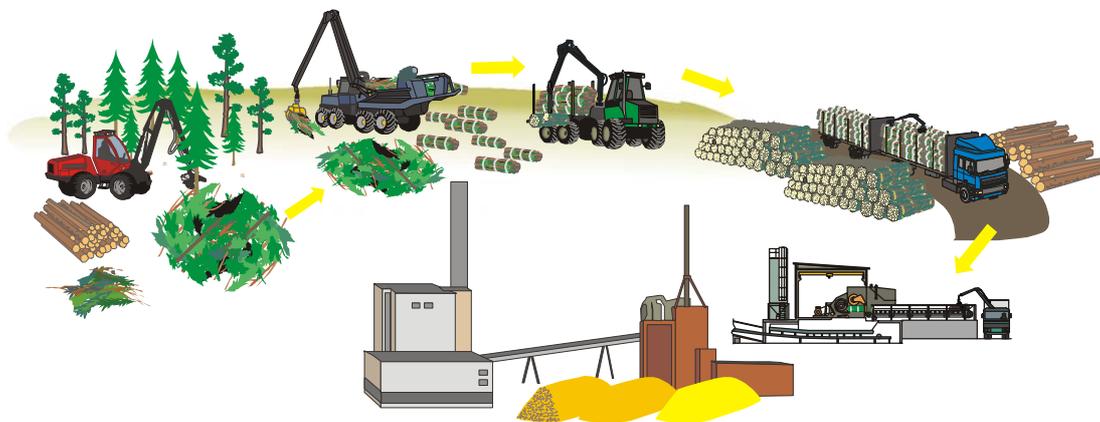


Figure 14. Forest residue harvesting by chipping at roadside and bundling technology.  
Source: VTT

Integrating the fuel and raw material supply chains makes it possible to decrease the costs of forest fuels. In Finland, the three largest forest industry companies are responsible for the procurement of more than 80% of all round wood. They operate nationwide and procure their wood through special forestry departments that contract the implementation to independent entrepreneurs. Since forest residues and logs are to be recovered as a by-product of industrial timber in final fellings, the integration of the procurement of round wood and forest chips has become a common solution for forest industry companies which, in practice, dominate the raw material resource of forest residues. Forest industry companies produce forest chips mainly for their own use, but also sell and supply forest chips to companies specialised in supplying wood fuels to district heating and other industrial users. Vapo Oy and Biowatti Oy are the largest actors in this field. In early thinnings, fuel is the primary product and pulpwood is only a side product, if it is recovered at all. The associations of forest owners together with local entrepreneurs have an important role in the production of forest chips from early thinnings and supplying forest chips for small heating plants. (Hakkila, 2004)

In the heating of small district heating plants and large separate municipal buildings such as schools, a heating entrepreneurship model has been used in fuel procurement and also in the operation and maintenance of boiler plants. Usually, heating plants are invested by municipalities or industry and often the boilers are renovated from light fuel oil use to wood fuels. The heating entrepreneur is a single entrepreneur, co-operative, limited company or entrepreneur consortia selling heat. Usually, these entrepreneurs are farmers and harvest small-sized wood on their own woodlots or purchase industrial wood residues or cutter shavings from the local wood processing industry. In 2005, the number of these entrepreneurs in Finland has increased to 250 using wood chips annually about 420 000 m<sup>3</sup> loose (1.2 PJ) (Fig. 15). The previous number does not include district heating companies or nationwide fuel suppliers, which offer the total service of heat supply. Average size of the boiler is less than 500 kW<sub>th</sub>.

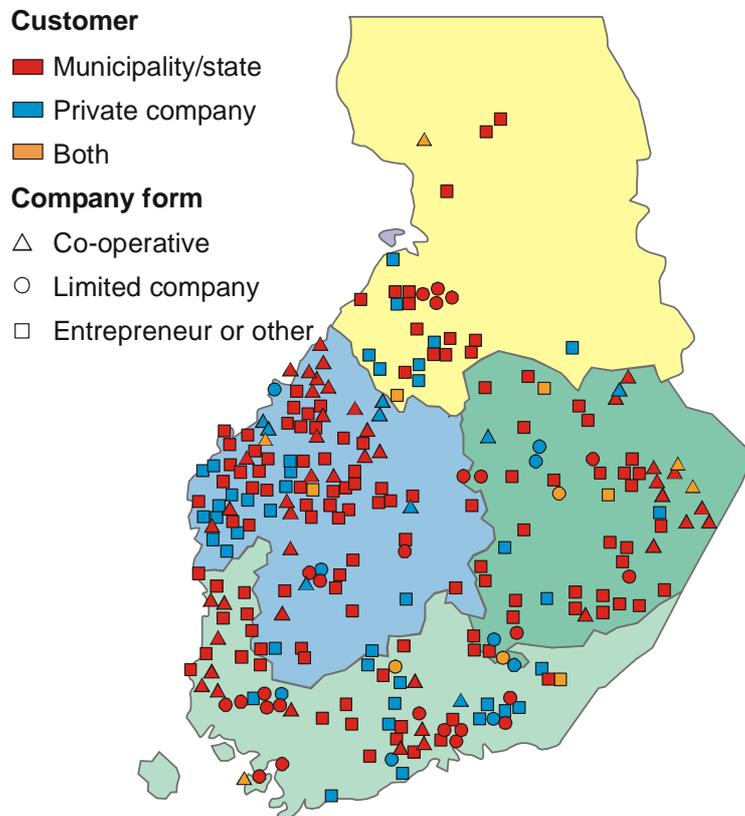


Figure 15. Location of small-scale wood chips heating plants (biomass entrepreneurship) in Finland. Data source: TTS Institute.

#### 4.2.2 Forest wood in small-scale use

Forest wood is the major source of wood-based fuels consumed in small-scale heating systems in Finland. In 2004, the total wood fuels use in small combustion was 48.5 PJ, consisting of firewood, 45.7 PJ, forest chips, 2.8 PJ, and wood pellets, 0.02 PJ.

According to the latest study on firewood consumption, conducted in the heating season 2000–2001, the consumption of firewood in detached houses, farms and summer cottages was 6.1 million m<sup>3</sup> (46 PJ). Firewood was used for heating in about 80% of the surveyed buildings. Small-scale use of wood has traditionally involved households and farms where the users themselves acquire the major part of the wood or do not pay any price for the fuel. About one fifth of the consumption of firewood was based on commercial firewood. Over 60% of commercial firewood was purchased as chopped. (Helynen & Oravainen, 2002; Sevola et al., 2003; Statistics Finland, 2005)

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

## **4.3 Wood processing industry's by-products and residues**

### **4.3.1 Solid wood processing industry residues**

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

Finland is the fourth largest sawn timber producer in Europe (FAOSTAT, 2006). Sawmill industry is the largest producer of solid wood processing residues for energy

production. There were about 90 sawmills with an annual production capacity above 20 000 m<sup>3</sup> of sawn timber. About 20 of the sawmills are located at the same site with pulp and paper mills and their by-product fuels are utilised inside the integrate for heat and power production. Only a few of the independent sawmills have own electricity production. The most of the sawmills produce heat for drying of sawn timber firing wood fuels in a heating plant and sell excess fuels outside to other heating and power plants. Figure 16 presents the materials and energy balances of a typical sawmill per one cubic metre of dried sawn timber. (Heinimö & Jäppinen, 2005)

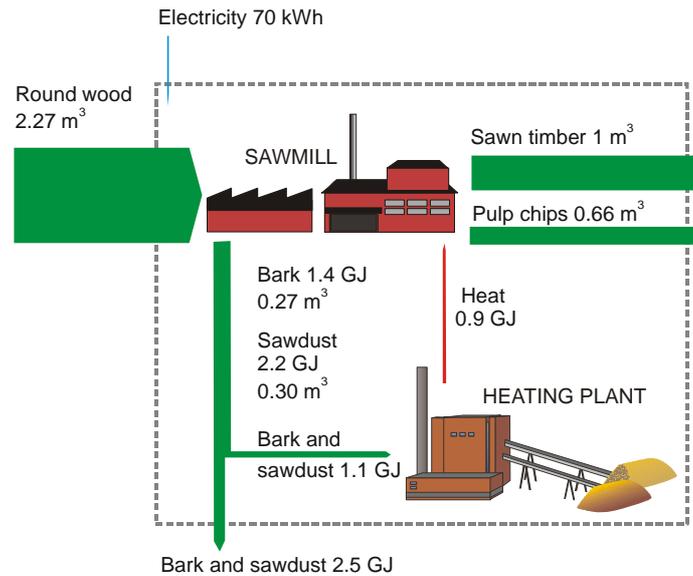


Figure 16. Material and energy balances of a typical sawmill for 1 m<sup>3</sup> of dried sawn timber. (Heinimö & Jäppinen, 2005)

In 2004, the consumption of solid wood processing by-products (industrial chips, bark and sawdust) in energy production was 77 PJ (Statistics Finland, 2005). The total theoretical supply of the forest industry's by-products in 2002 was estimated at 97 PJ and in 2010 at 101 PJ. The theoretical potential includes sawdust, bark and industrial chips, but excludes pulp chips. A part this supply potential is used as raw material for pulp, particleboard and pellet production. Over half of the energy use of by-products takes place on the site where they were produced and the rest constitutes the market supply of solid by-products. In the period between 2002 and 2010, the market supply of solid by-products from the forest industry for energy purposes was estimated at 40 PJ/yr. (Ranta et al., 2005)

### 4.3.2 Black liquor

Thanks to the extensive forest industry, black liquor represents the largest source of bioenergy in Finland. In 2004, the share of black liquor in the total energy consumption was 157 PJ equalling 51% of wood fuels use and almost 11% of the total primary energy consumption (Statistics Finland, 2005). Energy production from black liquor is a solid part of the chemical pulping process. Small diameter round wood, which is called pulpwood, and pulp chip and sawdust are used as raw material in the production of wood pulps. The wood material consists of two primary components: cellulose and lignin approximately in half. Lignin is a kind of glue that holds wood fibres together. In the chemical pulping process, a chipped wood material is cooked in a lye solution, which dissolves the lignin and leaves behind the cellulose. The cooking solution consists of cooking chemicals, and the lignin is burned in a recovery boiler for gathering the cooking chemicals and for utilising the energy of the dissolved wood material. As many as 19 pulp mills exist in Finland and their locations are presented in Figure 17. Most of the pulp mills are located on the same site with a paper mill.

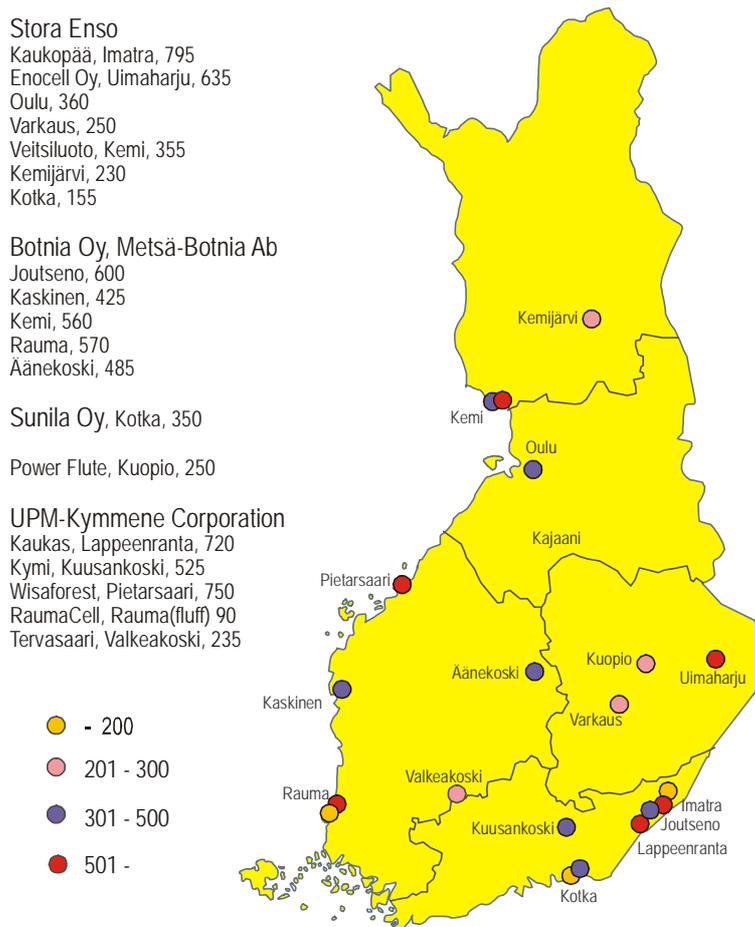


Figure 17. Finnish pulp mills (capacities in 1 000 tons).  
Source: Finnish Forest Industries Federation and Power Flute Oy

## 4.4 Fuel peat

Peat is composed in wet conditions from decomposed plant material. Due to the water-saturated environment and the absence of oxygen, the plant material does not decompose totally when a thin but continuously growing peat layer is composed. The rotation time of peat makes it different from wood biomass and fossil fuels. The renewal of peat is slow compared to, for example, the forest biomass after harvesting. The rotation speed of the forest is about a hundred years when the renewal of used peat bogs needs between 2 000 and 5 000 years. (Joosten & Clarke, 2002)

The climate and natural geography have given favourable conditions for peat growth in Finland. The Geological Survey of Finland (GSF) has estimated that the Finnish peat reserves suitable for production purposes cover about 1.2 million hectares. Less than 60 000 hectares are utilised annually for fuel peat production. The total employable energy reserve of peat was estimated at 48 EJ. The present annual growth of the Finnish peat resources has been estimated (Selin, 1999) to sink annually at least 15.4 million tons CO<sub>2</sub>. The same volume of CO<sub>2</sub> will be emitted if 145 PJ of fuel peat is burnt. The annual utilisation of fuel peat has been 58–90 PJ and was 89 PJ in 2004, corresponding to 6% of the total energy consumption. (Virtanen et al., 2003; Statistics Finland, 2005)

Three different types of peat fuels are used in energy production, milled peat, sod peat and peat pellets. Milled and sod peat can be produced only in summer time, because peat is dried in the field by solar energy. Harvested peat is stored in covered stockpiles. Vapo Oy and VTT are developing a new peat harvesting technology based on exploiting solar energy as effectively as possible. In this new method, peat is dried on an asphalted area known as a biomass dryer especially constructed for the purpose. The peat is spread out onto the asphalt using purposed-designed equipment that forms the peat into sods of optimal size for drying. The sun and wind dry the peat from above. The operation of the biomass dryer can be improved further by using solar panels. (Vapo Oy, 2006) The annual peat production can vary remarkably depending on weather conditions. Peat harvesting is not possible in wet conditions and the harvest can thus drop in rainy summers. The typical moisture content of milled peat is 47–51% and the average moisture of sod peat is 37–42% (Electrowatt-Ekono Oy, 2005). The average net calorific value of milled peat delivered to end-users is 9.0 MJ/kg and for sod peat 11.9 MJ/kg. Milled peat is used in power plants and in heating plants. Some sod peat is, in addition, used in space heating. Milled peat represents over 90% of the total peat production (Statistics Finland, 2005). In addition to fuel peat, 1–2 million m<sup>3</sup> of horticultural peat is produced annually<sup>3</sup>. Peat is easy to store even for several years, and

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<sup>3</sup> Here m<sup>3</sup> means loose peat cubic metres

it can be used for securing the fuel supply. Fuel peat has a rather constant moisture content year round, whereas wood fuels tend to be too moist during the winter when the demand for energy is the highest. When peat is blended with wood or herbaceous fuels, it stabilizes the average moisture content of the fuel.

In Finland, the most important peat producers are Vapo Oy and Turveruukki Oy. In addition, there is a myriad of private peat producers and subcontractors. Vapo Oy's fuel peat deliveries were 76 PJ in 2004 (Vapo Oy, 2005a). Peat producers also often deliver wood fuels to power and heating plants. VTT estimated in 2003 that the production of fuel peat directly employs more than 2 000 people in Finland and the jobs are located mainly in rural areas (Halonen et al., 2003).

Mires in Finland have been protected since the 1980s under the National Mire Protection Programme. The protected mires are included in different official protection programmes and totally 3.14 million hectares equalling 35% of the total area of peatlands are protected. All in all, 453 000 hectares are covered by a special mire protection programme – an area eight times larger than used for industrial peat production. Furthermore, there are many privately protected mires. This will preserve a suitable representative sample of Finland's rich biodiversity for the future.

## **4.5 Other biofuels**

### **4.5.1 Refined solid biomass fuels**

Briquettes and pellets are refined solid biomass fuels and they can be produced from wooden raw material and peat. In Finland, both products are manufactured and both raw materials used. Wood pellets have the largest share among these products at present.

Wood pellet production in Finland started in 1998. Since then pellet production has increased steadily and was 190 000 tons (3.2 PJ) in 2004. Dry by-products from the sawn timber refining industry are the major raw material in wood pellet production. Most of the pellet production has been exported. In 2004, the indigenous consumption of pellets was 47 000 tons. When comparing direct fuel prices in heat production, pellets are competitive against fuel oils, but are more expensive than coal. Consequently, pellets are used in applications where light fuel oil is an alternative fuel. However, the price difference in the total heating costs between pellets and fossil fuels has been relatively small, which has retarded the growth of the domestic consumption of pellets. At the end of 2005, there were 17 wood pellet factories in operation (Table 2, Fig. 18). Also some 20 000 tons (0.4 PJ) of peat pellets were produced in Finland. (Alakangas & Paju, 2002; Heinimö & Orava, 2002; Statistics Finland, 2005)

The most important player in the Finnish wood pellet markets is Vapo Oy, which has expanded its pellet business heavily in recent years and become the largest pellet producer Europe with an annual production capacity of over 500 000 tons. In the autumn of 2004, the company acquired Biowatti Oy's wood pellet business and has currently six wood pellet factories and six contract manufacturers in Finland. In addition, Vapo has pellet factories in Estonia, Sweden and Denmark. Vapo's Swedish subsidiary owns Såbi AB, which has three pellet factories. In Estonia, Vapo produces pellets through a pellet factory owned by its Estonian subsidiary. In September 2005, the company acquired Statoil's pellet production in Denmark. Statoil markets Vapo's pellets in Denmark. (Vapo Oy, 2005a; Vapo Oy, 2005b)

*Table 2. Wood and peat pellet factories and their estimated production capacities at the end of the year 2005. Source: VTT/Pellets for Europe -project*

	<b>Company</b>	<b>Location</b>	<b>Production capacity, [t/yr]</b>
1	Vapo Oy	Turenki	70 000
2	Vapo Oy	Ilomantsi	70 000
3	Vapo Oy	Vöyri	30 000
4	Vapo Oy	Kaskinen	30 000
5	Vapo Oy <sup>b)</sup>	Seinäjäjoki	60 000
6	Vapo Oy <sup>b)</sup>	Haapavesi	60 000
7	Luoman Wood Pellets Oy <sup>a)</sup>	Ylistaro	25 000
8	Scanpellet <sup>a)</sup>	Kärsämäki	12 000
9	Parkanon Pellet Oy <sup>a)</sup>	Parkano	10 000
10	Lapin Ekolämpö Oy <sup>a)</sup>	Keminmaa	10 000
11	Paahtopuu Oy <sup>a)</sup>	Ruovesi	10 000
12	Savon Bioenergia Oy	Rantasalmi	10 000
13	Formados Oy	Kuusamo	10 000
14	Jannpellet Oy	Paltamo	5 000
15	Länsi-Suomen Biopower Oy <sup>a)</sup>	Vammala	3 000
16	Keurak Oy	Keuruu	3 000
17	Punkaharjun Pelletti Oy	Punkaharju	2 000
	Total		420 000

<sup>a)</sup> Vapo Oy's subcontractor

<sup>b)</sup> Also the possibility to produce peat pellets

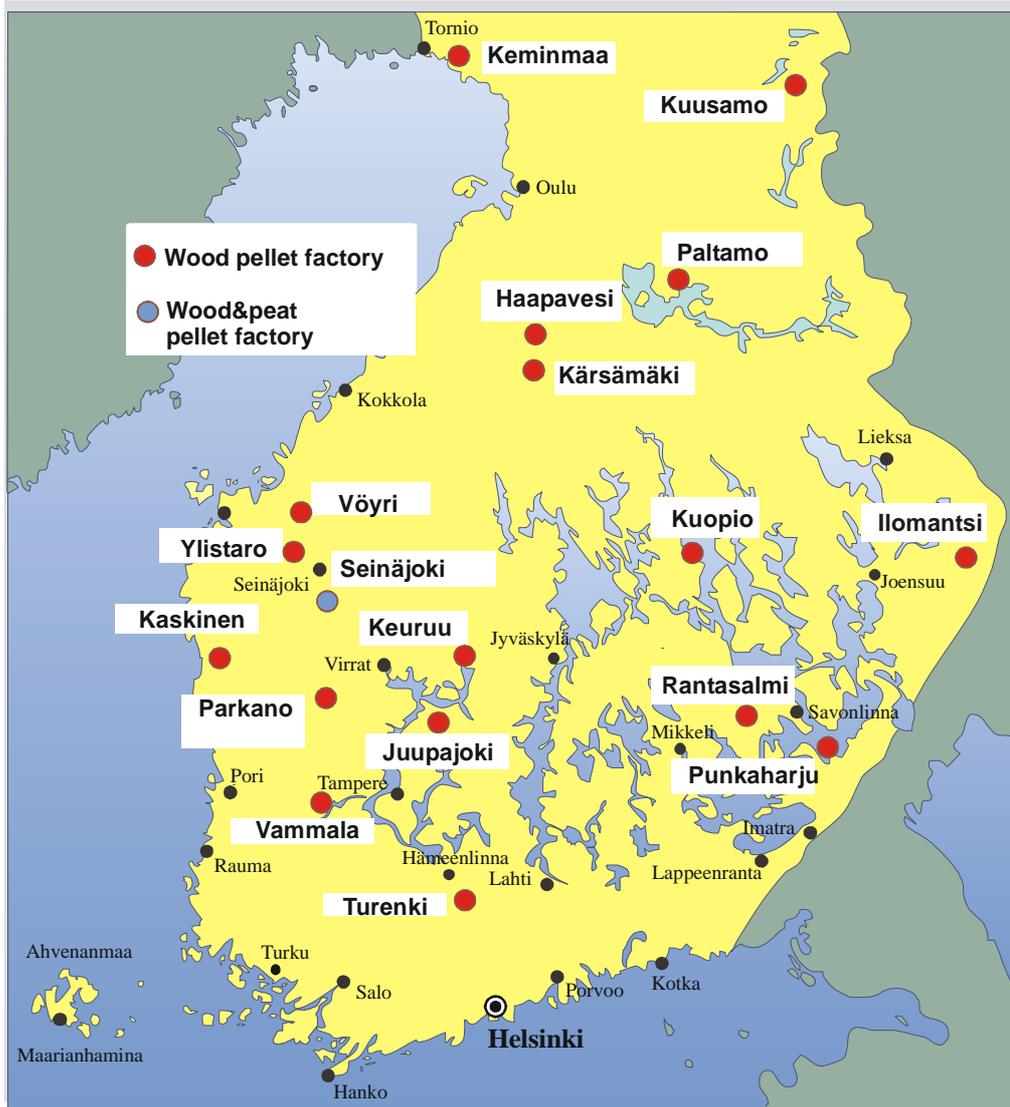


Figure 18. Locations of pellet factories in Finland.  
Source: VTT/Pellets for Europe project

The Finnish wood briquette production has been estimated at 35 000 tons equalling 0.6 PJ in 2000. Wood briquettes are manufactured in small units and the largest units produce about 5 000 tons briquettes annually. In 2000, a total of 21 wood briquette production units existed in the country (Kallio & Alakangas, 2002). The current production of wood briquettes is estimated constant compared to the year 2000 volume. Wood briquettes are mainly used crushed in larger CHP plants.

#### 4.5.2 Agricultural biomass

The total area of agricultural land in Finland is 2.2 million hectares. It is estimated that a maximum of 0.5 million ha of Finnish agricultural land will be in set-aside from

conventional farming over the next few years. This offers potential for alternative land use, e.g. non-food production. The set-aside land area was 241 000 hectares in 2005. (Ministry of Agriculture and Forestry, 2005)



*Figure 19. Reed canary grass (Phalaris Arundinacea). Photo: Vapo Oy.*

The greatest interest at present is in reed canary grass, which is perennial and renewable grass. The Finnish Agricultural Research Centre and VTT are studying reed canary grass cultivation on peat sites and set-aside land. Studies have shown that in Finnish conditions reed canary grass provides a better yield than any other grass grown for energy purposes. The annual yield is from 5.5 to 6.5 dry tons per hectare (90–108 GJ/ha). In 2004, reed canary grass was cultivated on an area of 8 700 ha (Fig. 19) and the yield was harvested from 2 000 hectares.

The target is to use reed canary grass in heating plants in a multifuel boiler in conjunction with peat and wood fuels, as shredded reed canary grass alone is too light. There are already dozens of heating plants in Finland with a combustion technique suitable for burning reed canary grass. Vapo also has plans to use reed canary grass as a raw material for pellets. VTT has calculated the utilisation potential based on 10% use of reed canary grass blended with peat or used in pellet production. VTT has estimated that Finland could utilise 19 PJ of reed canary grass in district heat, electricity and pellet production in 2010. This amount would require from 150 000 to 230 000 hectares of arable land or cut-over peatlands.

According to The Bioenergy Association of Finland (FINBIO) the annual use of straw in energy production is about 6 000 tons (0.07 PJ). The theoretical annual potential of cereal straw is about 1.8 million tons. About 10–20% of this potential could be used as energy (6 PJ). The expert group of FINBIO has estimated that about 9 PJ of solid agrobiomass could be used in the year 2010.

A working group lead by the Ministry of Agriculture and Forestry has set targets for the use of agricultural land in 2012. The aim is that the current 2.2 million hectares be used both for food and biofuel production. The working group has proposed that about 150 000 ha be used for growing cereal and oil plants for liquid biofuel production. The area proposed for reed canary grass is 50 000 ha (Ministry of Agriculture and Forestry, 2005).

### **4.5.3 Solid recovered fuels**

Municipal solid wastes (MSW) in Finland had traditionally almost totally been disposed at landfills until the end of the 1990s when the situation began to change due to new EU regulations on waste management. Finnish waste legislation is based on EU legislation, but in some cases includes stricter standards and limits than those applied in the EU as a whole. The National Waste Plan from 2001 targeted to achieve a 70% recovery rate of municipal solid waste by 2005. Most important regulations for the energy recovery of wastes are the Government Decision on landfill sites (861/1997) and Government Decree on waste incineration (362/2003). The Government Decision on landfill sites requires that landfill gas should be collected and used from landfills, which encourages also the energy use of the landfill gas. The EU directive on the landfill of waste (99/31/EC) aims among others to decrease the landfill disposal of the organic matter of municipal solid wastes. The Finnish national strategy on biodegradable waste from the year 2004 claims that a maximum of 75% of such waste can be disposed at landfills in 2006, a maximum of 50% in 2009 and a maximum of 35% in 2016. Biodegradable waste consists mainly of food waste, garden waste, paper and board waste, and 1.1 million tons of it was disposed at landfills in 2003. In Finland, the aim is to reduce amount of biodegradable waste disposed at landfills to 190 kg/inhabitant (35% of the total) in 2009 and to 130 kg/inhabitant (25% of the total) in 2016. This requires that an additional 650 000 tons of waste-derived fuels be used for energy recovery in 2009 and 800 000 tons in 2016. (Tekes, 2003; Kling, 2006; Ministry of Environment, 2006)

In Finland, the waste management is currently mainly based on the source separation of waste in order to produce raw materials for material recycling, and for the production of solid recovered fuels (SRF, REF) for energy production. Local authorities decide on sorting and collecting systems for source separation, and hence, the systems differ considerably in different areas of Finland. Paper and biowaste are today nearly always

source-separated in Finnish households and commercial buildings. Other fractions such as glass, scrap metals, board, etc., are source-separated in different bins in households or on kerbside collection sites. Companies must source-separate and recycle different waste fractions, depending on the amount of waste produced. Usually the companies producing e.g. over 20 or 50 kg/week paper, board, glass, scrap metal, and biowaste must source-separate these fractions.

The dry source-separated fraction from households and companies is processed into fuel in an SRF plant. The process usually comprises preliminary crushing when larger items are also removed, magnetic separators, screening, secondary crushing, and normally, a second magnetic separator and an eddy current for non-magnetic metal. There are about 20 waste recovery/sorting plants in operation in Finland and several smaller crushing plants for combustible industrial and commercial waste material. (Wilén et al., 2004 ).

The waste incineration directive (2000/76/EC) is targeted to reduce negative effects on the environment caused by the incineration waste. The directive set up the emission limits to waste incineration and coincineration plants.

In 2004, the total volume of municipal solid waste (MSW) was 2.4 million tons in Finland equalling 455 kg/capita. In the same year, 60% of total MSW volume was disposed at landfills, 30% was recovered as material, 8% (184 000 tons) was utilised as energy and 2% incinerated without energy recovery (Statistics Finland, 2006b). In Finland, there is only one waste incineration plant combusting solely waste. The plant is located in the city of Turku and it produces district heat for the Turku region. An increasing amount of SRF is burnt in Finland in cocombustion with wood, peat and coal. SRF is burnt in about 20 cofiring plants. Fluidised bed combustion is very fuel-flexible and particularly well suited for the cocombustion of high-quality and clean waste-derived fuels. High steam values, and consequently, high power production efficiency can be obtained when the share of SRF is kept at a level of 10–20%. In Lahti, a CFB gasifier is connected to a pulverised coal boiler fuelled with coal. The cogasification of SRF is cost-efficient and environmentally attractive. According to energy statistics, the total use of solid recovered fuels and fuels for energy production in 2004 was 8.5 PJ, of which the biodegradable fraction was 3.8 PJ (45%). (Wilén et al., 2004 ; Statistics Finland, 2005)

The transition period of the EU waste incineration directive (WID) ended at the end of 2005. Since the beginning of 2006, more stringent emission limits came into force. It had been estimated that the use of industrial waste or MSW derived fuels would end in most of the boilers that utilised SRF fuels. About half of the cofiring plants have announced that they will not continue the use of SRF in 2006. Nevertheless, 10 heating and power plant projects are being planned for SRF, but it will take some years until the

new boiler capacity that is designed for SRF fuels utilisation and that will meet the emission limits of WID will be taken into operation. Most of the plants in the planning phase are based on the cofiring of SRF with wood fuels and coal. The total amount of SRF of these plants is estimated to reach 750 000 tons. VTT estimated that when new heating and power plants fulfilling the requirements of the WID are in use, the use of SRF can range from 0.5 to 1 million tons in 2010. (Tekes, 2003; Kling, 2006)

#### **4.5.4 Used wood**

Used wood includes post consumer/post society wood waste, which shall not contain heavy metals or halogenated organic compounds as a result of treatment with wood preservatives or coating (CEN/TS 14961:2005). Demolition wood is not included in solid biofuels according to the CEN/TS 14961. Demolition wood is “used wood arising from demolition of buildings or civil engineering installations” (CEN/TS 14588:2003).

In Finland, used wood is usually collected from the building sector or from waste handling plants. This wood waste is not chemically treated; it is typically construction wood, presorted wood waste from retail shops and industry (e.g. pallets and other packing material), old furniture etc. In Finland used wood is mainly utilised in larger CHP plants cofired with peat and other wood fuels. Most of these plants are under emission trading, so used wood must be classified into two fractions: biodegradable and fossil. In 2004, the utilisation of used wood was 3.3 PJ, of which the biodegradable fraction was 90% (Statistics Finland, 2005).

#### **4.5.5 Biogas**

In Finland, biogas utilisation as an energy source has been on the increase during the current decade. The most important reason for this is the increased utilisation of landfill gases. In 2003, the total production of biogas was 114.5 million standard gas-m<sup>3</sup> equalling approximately 2 PJ. In 2004, the use of biogas in energy production was 1.1 PJ. Landfill gases were being collected at 27 landfills in 2003. At the same time, totally 15 biogas reactors existed at sewage water disposal plants in the municipal sector and in industry. The biogas was utilised mainly for heat and electricity production, but a small part was used as traffic fuel. Biogas production in the agricultural sector is not very common in Finland compared to many other countries, and only six biogas reactors exist on farms. The government’s new Energy and Climate Strategy calls for measures for utilising more biogas from farms. Jyväskylä Science Park has estimated the realistic techno-economic potential for biogas in energy production for 7.9–10.0 PJ in 2015. As much as 0.4–0.6 PJ of biogas could be produced from municipal solid waste, 2.4 PJ

from land fill gases, 0.2 PJ from residues in the food processing industry and 0.6 PJ from sewage water disposal. The greatest potential of biogas, 4.3–6.2 PJ, comes from the agricultural sector from straw, litter and energy crops from fields in set-aside. (Kuittinen & Huttunen, 2004; Asplund et al., 2005; Statistics Finland, 2005)

#### 4.6 Users of wood and peat fuels

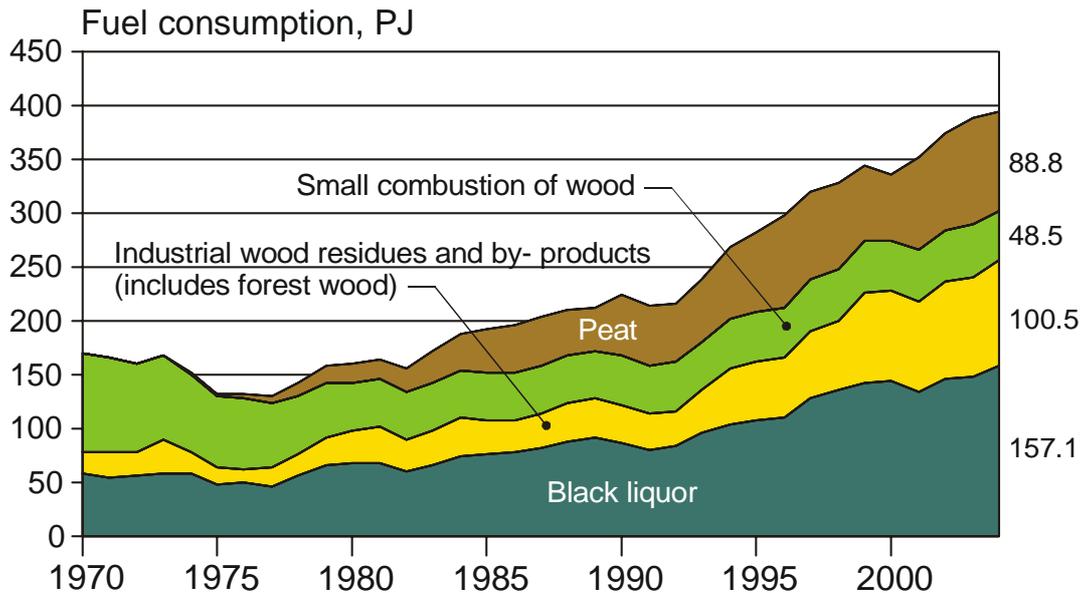


Figure 20. The consumption of wood fuels and fuel peat in Finland in 1970-2004. (Statistics Finland, 2005)

In this section, the user groups and the usage technologies of wood and peat fuels will be discussed. The consumption of wood fuels and fuel peat has been on the increase during the past three decades (Fig. 20). The main reason for this development has been the growth in the forest industry's production, which can be seen as the increased consumption of black liquor, industrial wood residues and by-products. During the past 10 years, more than 100 district heating plants and 500 MW<sub>e</sub> of new additional capacity for electricity production from wood and peat fuels were commissioned in Finland. The consumption of separate wood fuels and fuel peat between end-user sectors in 2004 is presented in Table 3.

Table 3. End-use of wood and peat by end-user groups in 2004. (Association of Finnish Energy industries, 2005; Statistics Finland, 2005; Ylitalo, 2005; Finnish Forest Industries Federation, 2006b)

Fuel/PJ	End-user group				Total
	Forest industry	District heating	Small-scale use <sup>c</sup>	Other industry & users	
Forest fuels <sup>(a)</sup>	6.5	5.9	2.8	3.7	18.9
Solid wood processing by-products and residues <sup>(b)</sup>	47.3	16.5	0.4	20.6	84.4
Firewood	0	0	45.3	0	45.7
Black liquor	157.1	0	0	0	157.1
<b>Total wood</b>	<b>210.9</b>	<b>22.4</b>	<b>48.5</b>	<b>24.2</b>	<b>306.0</b>
<b>Fuel peat</b>	<b>17.2</b>	<b>37.3</b>	<b>1.1</b>	<b>33.3</b>	<b>88.8</b>

<sup>(a)</sup> Excludes firewood

<sup>(b)</sup> Includes bark, sawdust, industrial chips, pellets, briquettes, recovered wood and other wood industry by-products and residues classified as wood fuels. The share of pellets and briquettes was estimated at 1.4 PJ

<sup>(c)</sup> Includes the use of forest chips by farms and detached house properties

## Forest industry

The forest industry represents the largest producer of wood fuels, but the industry is also a major user of wood fuels. Almost 70% of wood fuels are used in the forest industry. There are totally 28 paper mills, 14 paperboard mills, 19 pulp mills and about 90 industrial sawmills<sup>4</sup> in Finland. In many cases, paper, paperboard, pulp and saw mills are located on the same site, forming a forest industry integrate which allows efficient utilisation of raw material and energy. In many mills, a separate power production company manages the energy production. In most cases, the power producer owns, runs and maintains the power plant, and buys the fuels from the mill as well as necessary additional fuels from the market. Heat is then sold to the mill and in some cases to the district heating network, and any excess power is sold to the grid. (VTT, 2003; Finnish Forest Industries Federation, 2005)

Wood is the most important fuel for the forest industry and wood accounted for 75% of fuels consumed in the forest industry mills in 2004. In some mills, peat is used as a complement fuel and covered 6% of the mill fuels. There is a strong interconnection between the conditions of the forest industry and the markets of wood fuels. So far,

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<sup>4</sup> Includes the sawmills with annual production capacity at least 20 000 m<sup>3</sup> of sawn timber.

there has been an increasing trend in the production of the forest industry in Finland, but the volumes of black liquor and solid by-products (bark, sawdust, industrial chips) vary annually according to the rate of forest industry production. (Finnish Forest Industries Federation, 2006b)

### **District heating sector**

There are over 200 heat distribution utilities in Finland, and most of them produce at least part of heat by themselves. About 50 of them also produce electricity in connection with district heating. The total district heat capacity is 20.1 GW<sub>th</sub> and total connected heat load is 15.6 GW<sub>th</sub>. In 2004, the three largest district heating utilities in Finland were Helsingin Energia Oy, E.ON Finland Oyj and Tampereen Sähkölaitos. Some municipalities co-operate with power companies or local industries. CHP based heat production composed 76% of the total district heat production in 2004. Several medium-sized and small towns purchase district heat from CHP plants or industrial CHP plants owned by other companies, or produce it themselves in heat-only boilers. The share of wood and peat as fuel in the district heating sector was altogether 30% in 2004 (Fig. 6). Coal and natural gas are dominant fuels covering 63% of the total fuel use in 2004. District heating utilities have no direct access to wood fuel sources as the forest industry has. Thus district heating utilities often purchase wood fuels directly from independent sawmills and forest fuels from wood fuels supply companies. Some of the largest peat users have own peat production. (Association of Finnish Energy industries, 2005; Statistics Finland, 2005)

### **End-user technologies of solid biofuels in CHP plants**

In Figure 21, the 20 largest solid wood fuels users in 2002 are presented. All the plants are combined heat and power (CHP) plants and use fluidised bed combustion (FBC) technology. Their total efficiency is very high; often over 85%. Most of the plants operate within the forest industry and utilise by-product fuels from processes (bark, industrial chips and in some cases sawdust) and are providing heat and electricity for production processes. In 2002, these plants consumed totally 44 PJ of solid wood fuels. (Electrowatt-Ekono Oy, 2004a)

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

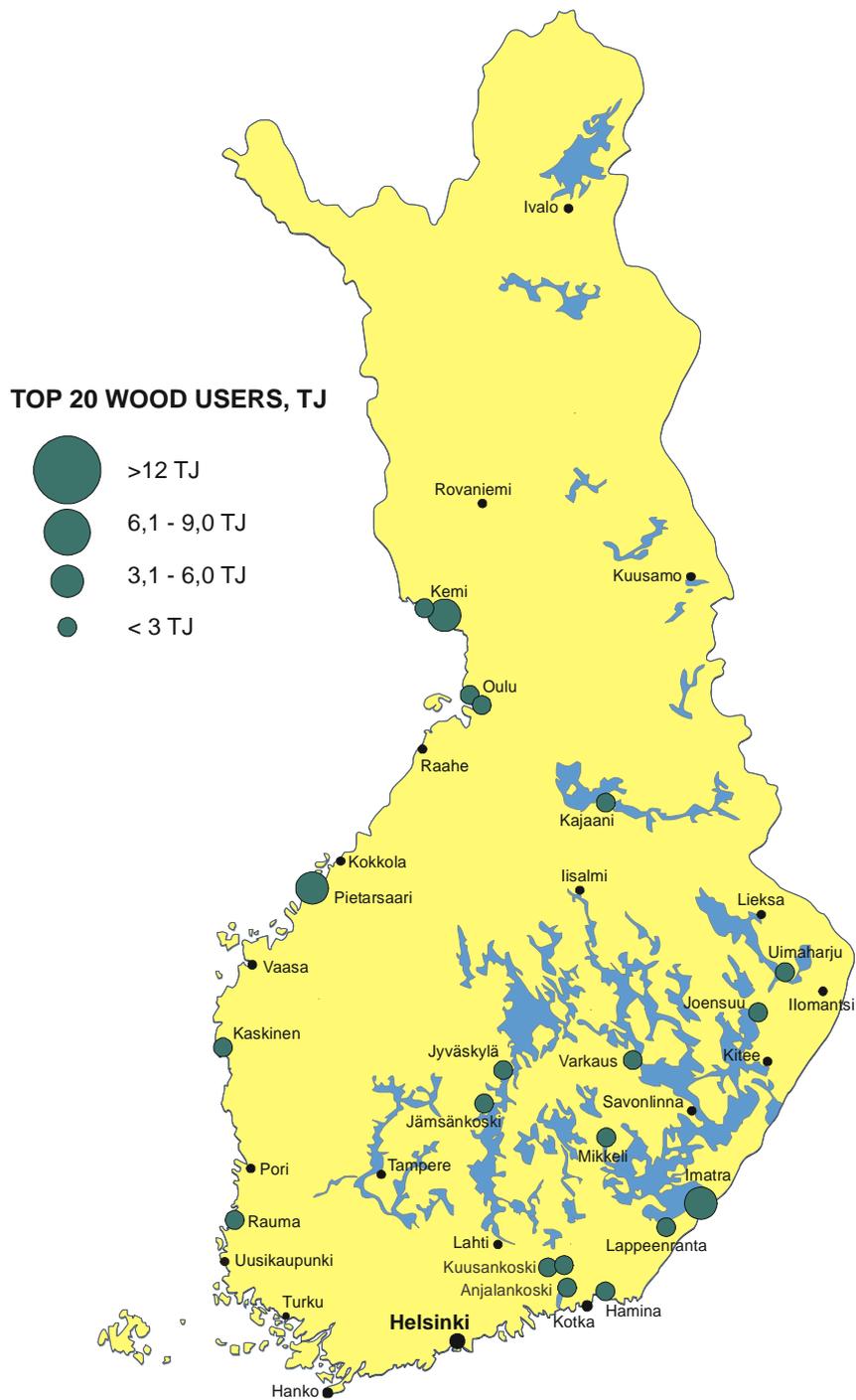


Figure 21. The 20 largest users of solid wood fuels in 2002.  
(Electrowatt-Ekono Oy, 2004a)

For decades, Finland has employed combined heat and power production (CHP), which operates at a high power-to-heat ratio. The proportion of the combined generation is among the highest in the world (34% of electricity supply). The first industrial cogeneration plants were built at the turn of the 1920s and 1930s. Cogeneration is the

natural choice in Finland since both heat and electricity are required in industrial as well as in municipal energy production. (Kostama & Alakangas, 2004)

Since the 1970s, Finnish boiler manufacturers have developed fluidised bed combustion (FBC) technology for the combustion of solid biofuels and other non-homogenous fuels with difficult properties such as uneven particle size and high moisture content. The FBC provides the ability to burn low-grade fuels and on-line fuel switching, and reduces the output of harmful emissions such as  $\text{NO}_2$  and  $\text{SO}_2$ . A wide range of fuels can be accommodated with high efficiency: wood chips, bark, peat, sludge, industrial and municipal waste, coal, oil and natural gas. The FBC technology has become the dominant technology employed in new larger biomass fired plants. In addition, a considerable number of traditional grate boilers and pulverized peat and coal boilers have been converted to FBC technology. Today FBC boilers for power plants are manufactured in Finland by Foster-Wheeler and Kvaerner Power. Alhomens Kraft's 240  $\text{MW}_e$  CHP plant (Fig. 22) is currently the world's largest power plant that uses biomass as the main fuel. Wood fuels and peat represent 90% of the fuels burnt in the 550  $\text{MW}_{th}$  circulating fluidised bed boiler of the plant. The plant produces heat for a UPM Kymmene pulp and paper mill and for a local district heat network.

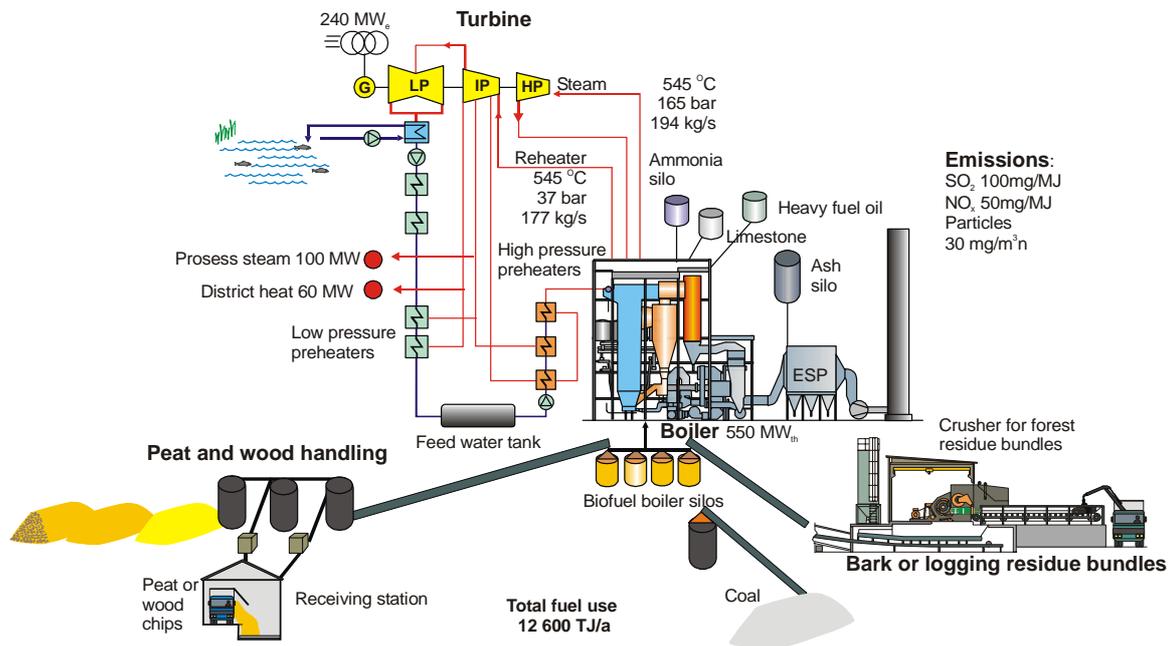


Figure 22. Process diagram and fuel handling of Alholmens Kraft Oy. Source: VTT

## Peat users

Peat closely resembles wood as fuel, and the two are often used together in heating and power plants. The use of peat mainly takes place inland in the proximity of peat resources. The 20 largest fuel peat users and their locations are presented in Fig. 23. Most of the largest peat users are also among the largest users of wood fuels. In 2002, the 20 largest peat users consumed a total of 69 PJ of energy peat. (Electrowatt-Ekono Oy, 2004a)

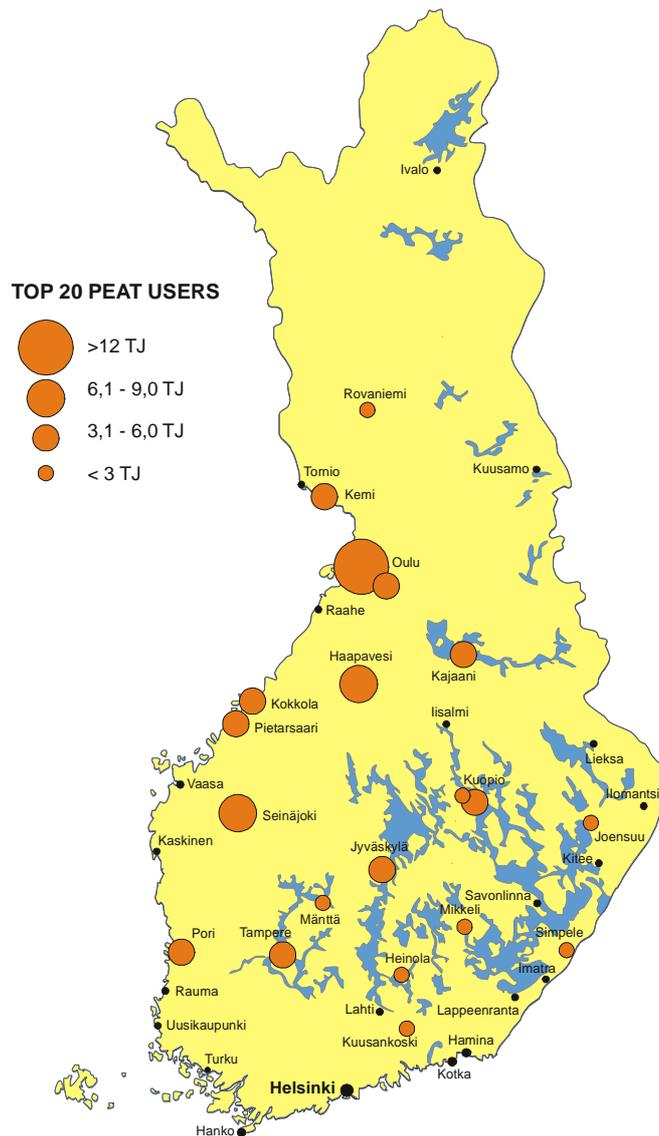


Figure 23. The 20 largest peat users in 2002. (Electrowatt-Ekono Oy, 2004a)

Peat has a high delivery reliability round the year and normally secures the fuel supply in power plants using solid wood fuels. Peat is harvested in the summer and stored in peat stacks. Stored peat can be delivered to the users year-round in compliance with the

demand. The availability of peat has neither a connection to timber harvesting nor the business conditions of the forest industry, as wood fuels have. Peat can be delivered also during the coldest days in winter when the production of forest fuels is unfeasible.

Peat used in combination with solid biofuels improves combustion by reducing corrosion and slagging in the boiler. Peat fits well as a cofiring fuel with forest fuels. Forest fuels used in high proportions have a tendency to cause slagging and chlorine corrosion on the heat-exchange surfaces of the boiler. This can be prevented by cocombustion of sulphur-containing fuels, such as peat. With the help of peat, the steam temperature can be increased and the efficiency of electricity generation significantly improved. Tests in the plants indicated that it would be favourable to cocombust 10–30% peat with forest residue chips. In addition, some peat is consumed in smaller heating plants and in the private sector. (Veijonen et al., 2003; Vainikka et al., 2004; Statistics Finland, 2005)

### **Small-scale consumers of wood fuels**

There are 2.6 million dwelling units in Finland, of which 1.1 million are single-family houses. The majority of wood fuels in small-scale heating systems are consumed as cut or split into a smaller size in batch-fired furnaces. The total number of stoves and fireplaces for firewood reaches almost two million; about one million of them are heat storing models. Usually a wood stove or fireplace is used as auxiliary heat source in single-family houses. According to Rakennustutkimus RTS Oy, 60% of single-family houses in Finland use wood fuels. (Statistics Finland, 2005; Statistics Finland, 2006a)

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

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

## 4.7 Biofuel prices

In Finland Statistics Finland, Electrowatt-Ekono Oy and METLA collect the prices of solid biofuels for statistical purposes. The Wood Energy Technology Programme started to collect information on forest fuel prices and use in heating and power plants as of the year 1999 (Hakkila et al., 2000). METLA has continued the work and has collected prices and use volumes of wood fuels from heating and power plants annually since the year 2000 for official statistics. Statistics Finland collects fuel prices from various sources for official statistics. The prices of wood fuels and milled peat delivered at plant sites in the years 1982–2004 are presented in Figure 24.

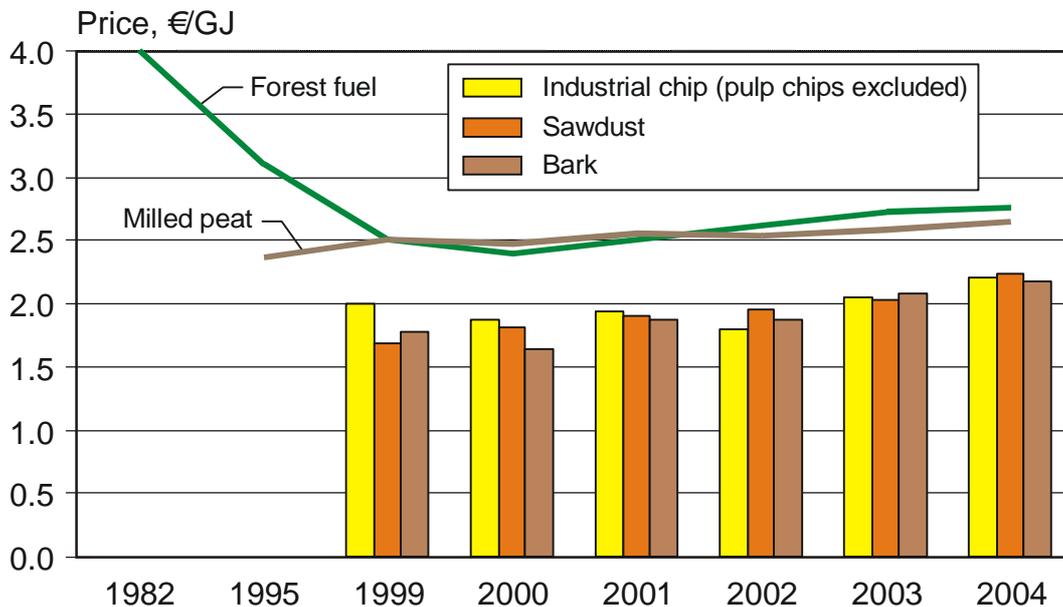


Figure 1

Figure 24. Wood fuels and milled peat prices delivered at plants in 2000–2004. (The price of milled peat includes energy taxes.) (Hakkila et al., 2000; Ylitalo, 2001; Ylitalo, 2002; Ylitalo, 2003; Ylitalo, 2004; Ylitalo, 2005)

Fuels used in the production of electricity are exempted from energy taxes, whereas in heat production some of the fuels are under energy taxation. In heat production, fossil fuels and tall oil are taxed and the total prices of the fuels consist of market prices and taxes (Fig. 25, see also Table 1). Energy taxation of fossil fuels changes the mutual competitiveness of the fuels based on market prices. The energy taxation has rendered the consumer prices of heating oils and coal more expensive compared to wood fuels. Official statistics on the prices of wood pellets are not compiled in Finland. VTT collected the Finnish prices of wood pellets in the EU-funded “Pellets for Europe” project ([www.pelletcentre.info](http://www.pelletcentre.info)). From March 2003 to January 2005, the price of wood pellets delivered as bulk material in lots of over 4 tons within a 150 km delivery distance was 135 €/t (8.0 €/GJ) including 22% value added tax (VAT). In the same

period the price of pellets delivered in bulk for industrial-sized users was 94.3 €/t (5.6 €/GJ), excluding VAT (European Pellet Centre, 2006). Wood pellets are less expensive than fuel oils, but are not competitive against coal in heat production. In the future, METLA will also collect statistics for wood pellets.

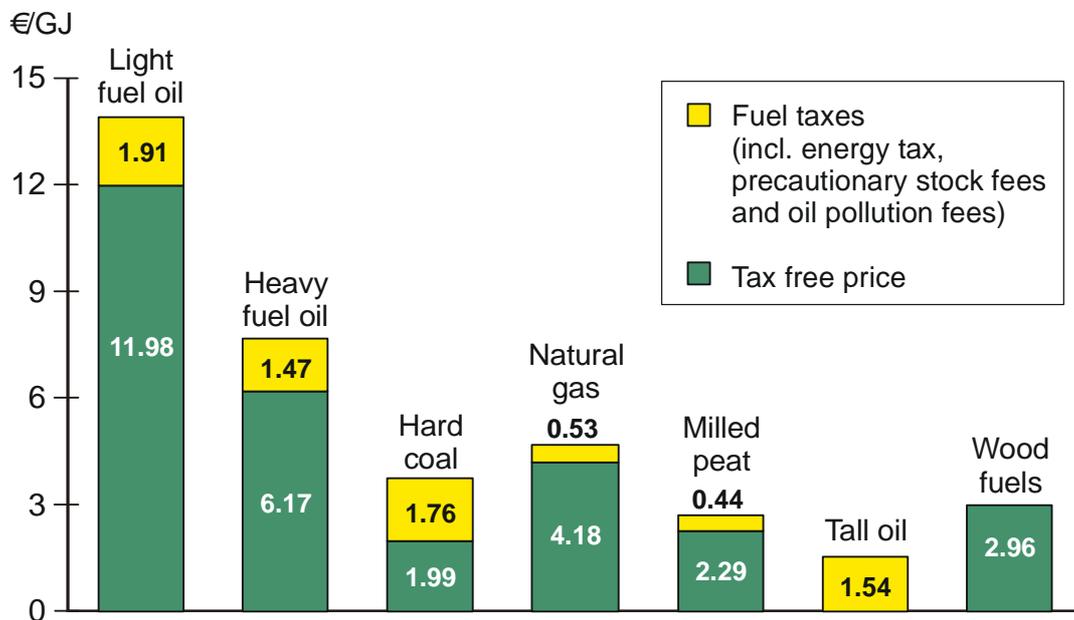


Figure 25. Fuel prices in heat production in 6/2005. Price of tall oil not available. (Council of State, 2004a; Council of State, 2005; Energy Review, 2005)

In a longer 15-year period, the price development of indigenous fuels (wood and peat) have been moderate and stable compared to prices of fossil fuels, which have fluctuated remarkably mainly due to world market prices (Fig. 26). The taxation of fossil fuels in Finland has for years been quite stable without substantial changes. The price of wood chips in Figure 25 is an average price of solid wood fuels combined from different sources, and differs from the prices in METLA's statistics.

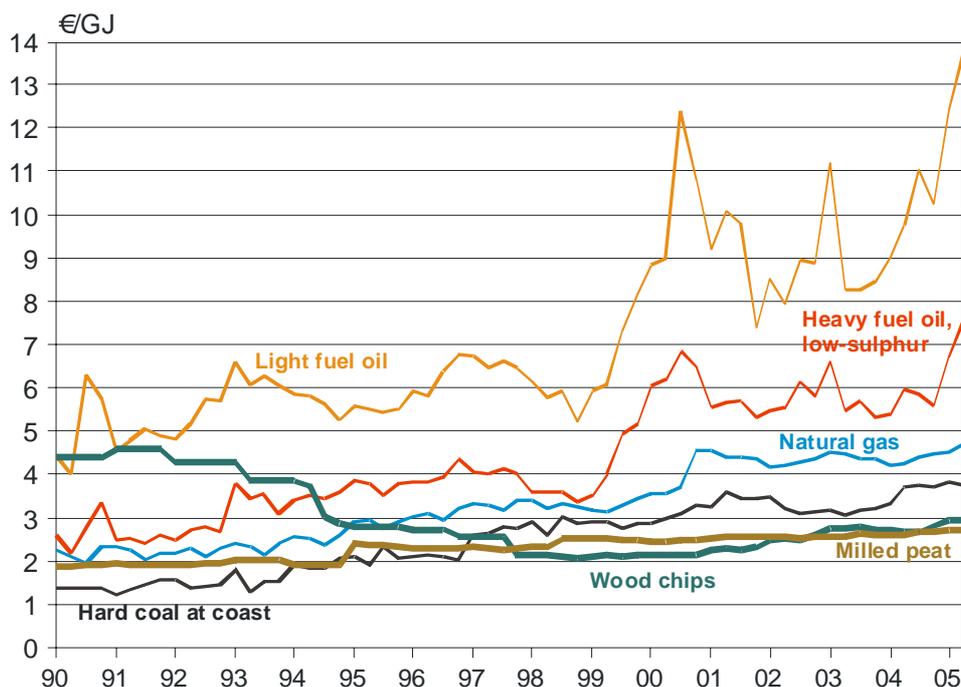


Figure 26. Consumer prices of fuels in heat production in 3/1990–6/2005 (The prices include energy taxes and exclude 22% value added tax). Data source: Statistic Finland

#### 4.8 Biofuels in the road transportation sector

The annual total fuel consumption of the road transport sector has increased steadily in past years in Finland (Table 4). The share of biofuels as traffic fuel has remained negligible and no proper markets exist for biofuels in road transportation. The consumption of biofuels has mainly been based on fixed-term pilot projects where bioethanol has been used in the blends with gasoline. In addition, small-scale trials on the production of biodiesel and biogas for use as a transportation fuel have also been carried out.

Table 4. Fuels consumption in road transport in 2000–2004 and the proportion of liquid biofuels. (Statistics Finland, 2005)

[Year]	Fuels in road transportation total	Gasoline	Diesel fuel	Liquid biofuels	
	[PJ]	[PJ]	[PJ]	[PJ]	[%]
2000	153	76	77	-	-
2001	156	77	78	-	-
2002	159	79	80	0.033	0.02
2003	161	79	82	0.176	0.1
2004	166	80	86	0.186	0.1

In Finland the taxation of biogas and biogas-driven vehicles was changed in 2004. Biogas used as motor fuel was exempted from excise duty and gas-driven vehicles received an exemption also from the power output taxation imposed under the vehicle taxation law (1281/2003), which is otherwise charged for all motor vehicles using fuels taxed less heavily than petrol, e.g. diesel-driven vehicles. Since the beginning of 2003, the excise duties<sup>5</sup> were been for gasoline € 58.1 c/l and for diesel fuel € 31.1 c/l. (Council of State, 2004a; Ministry of Trade and Industry, 2005)

In the pilot projects, oil companies have blended ethanol in gasoline with a share of 5 volume percent, at maximum, on an experimental basis. For the pilot projects a tax relief of €30 c/l has been granted for the ethanol share for a fixed period that ended at the end of 2004. The ethanol was purchased from the European and Brazilian markets. (Mäkinen et al., 2005)

Despite the insignificant domestic consumption of biofuels in transportation, the domestic production of liquid biofuels is increasing significantly in Finland. The Finnish oil company Neste Oil Corporation started the production of bio-ETBE (ethyl-tertio-butyl-ether) at its Porvoo refinery in 2004. ETBE is an additive that enhances the octane rating of petrol similarly to the fossil MTBE (replacing lead and benzene in unleaded petrol) and reduces emissions. ETBE is produced by combining bio-ethanol and fossil isobutylene (Enguidanos et al., 2002). The proportion of the bio-based component in ETBE is slightly less than half. Neste Oil has also another ETBE production plant in Portugal and company's total ETBE production capacity is approximately 150 000 tons per year. In addition to the ETBE production, Neste Oil is constructing a production plant of biodiesel at its Porvoo refinery. The plant will annually produce 170 000 tons of high-quality biodiesel from vegetable oils and animal fats. The production process of the bio-diesel blend (NExBTL technology) is developed by the company itself, and the production of bio-diesel will start in 2007. Both ETBE and bio-diesel production are mainly based on foreign raw material acquired from world markets. (Mäkinen et al., 2005; Neste Oil, 2006)

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<sup>5</sup> Does not include precautionary stock fee, oil pollution fee and 22% value added tax.

## 5. International biofuels trade in Finland

### 5.1 Cross-border biomass streams

In this chapter, the streams of international biomass trade in Finland will be discussed. Considering biomass in general using a large scope, it can easily be concluded that the majority of biomass trade takes place in the form of raw material or refined products instead of fuels. Raw biomass is usually traded for food, fodder or raw material purposes. Earlier studies on international biofuels trade have mainly focused on the biomass streams, which end up directly in energy production. In this study, the scope has been broadened to include some biomass streams used as raw material. The year 2004 was selected for review.

At first, cross-border biomass streams were considered by means of customs statistics, which give information on foreign trade. In the statistics, traded products are grouped based on EU's combined customs nomenclature, which gives eight digit CN (Combined Nomenclature) codes for different products. The statistics record the volumes and the values of the traded products. The foreign trade volumes and values of the product groups selected for the study are presented in Tables 5 and 6. The forest industry's wooden raw material streams have been included in the study, but forestry products have been excluded. The biomass used in the food and fodder industry as well as municipal wastes were excluded as their proportion in the Finnish energy balance was evaluated negligible.

*Table 5. Imported biomass streams in 2004. (Eurostat, 2005)*

	CN code(s)	Volume [t]	Price <sup>(b)</sup> [€/t]
<b>Round wood</b>	<sup>(a)</sup>	12 015 768	45.2
<b>Chips</b>	44012100, 44012200	1 458 672	53.4
<b>Sawdust of wood</b>	44013010	39 146	17.3
<b>Wood waste and scrap</b>	44013090	146 226	21.9
<b>Fuel wood</b>	44011000	110 463	17.6
<b>Tall oil</b>	38030010, 38030090, 38070090	57 690	192.9
<b>Peat</b>	27030000	46 660	28.7
<b>Ethanol</b>	22070000	23 355	529.2
<b>MTBE, ETBE, ...</b>	29091900	109 488	371.9

<sup>a</sup> 44032031, 44032039, 44032011, 44032019, 44032091, 44032099, 44039951, 44039959, 44034100-9910 and 44039995

<sup>(b)</sup> CIF price (cost, insurance and freight)

Table 6. Exported biomass streams in 2004. (Eurostat, 2005)

	CN code(s)	Volume [t]	Price <sup>(b)</sup> [€/t]
Round wood	<sup>(a)</sup>	474 578	81.9
Chips	44012100, 44012200	111 258	58.8
Sawdust of wood	44013010	515	227.3
Wood waste and scrap	44013090	164 261	89.9
Fuel wood	44011000	4 083	108.9
Tall oil	38030010, 38030090, 38070090	120 544	238.4
Peat	27030000	116 348	88.0
Ethanol	22070000	0	-
MTBE, ETBE, ...	29091900	8 308	606.9

<sup>(a)</sup> 44032031, 44032039, 44032011, 44032019, 44032091, 44032099, 44039951, 44039959, 44034100-9910 and 44039995

<sup>(b)</sup> FOB price (free on board)

Customs statistics can give rough figures on international biomass trade. Statistics do not differentiate the end-use purposes of the materials into energy use and raw material use, and various products can be included in the CN code. An example of this are wood pellets, which are recorded under the same CN code as wood waste. Energy and horticultural peat are recorded under the same code, as well. Several products of the chemical industry are recorded under the CN code 29091900. Biomass is used as raw material only for some of those products like in ETBE. The threshold values of intra-EU trade also bring uncertainty to the statistics. If the annual value of intra-EU trade undercuts the threshold value, the company does not need to report its foreign trade for the statistics. Thus occasional and small-scale foreign trade is excluded from the statistics. In Finland, the threshold value was €100 000 in 2004.

The statistics showed that the import of round wood is the largest cross-border biomass stream and that the total import stream is much greater than the export stream. The main biomass streams are comprised of wood and are used as raw material in industry. Some products, such as tall oil, ethanol and peat, can be used in energy production but in other purposes, as well. The Finnish forest industry is strongly export oriented; thus the production volume of the industry exceeds the demands of the small local markets for forestry products. The majority of forestry products produced in Finland is exported (Table 7). The forestry products would upturn the biomass trade balance if they were included the figures.

Table 7. Production and import of forestry products in 2004. (Finnish Forest Industries Federation, 2006b)

Product	Production	Export
Sawn timber	13.46 million m <sup>3</sup>	8.42 million m <sup>3</sup>
Pulp	12.62 million tons	2.35 million tons
Paper and paperboard	14.04 million tons	12.73 million tons
Plywood	1.35 million m <sup>3</sup>	1.23 million m <sup>3</sup>
Particleboard	0.45 million m <sup>3</sup>	0.24 million m <sup>3</sup>
Fibreboard	0.10 million tons	0.06 million tons

## 5.2 Indirect trade of wood fuels in forest industry

The Finnish forest industry is composed of a large set of mills with different types of processes using round wood, pulp chips and sawdust as raw material. Some of forest industry's processes produce by-products, which can be used both as raw material in other processes and as fuel in energy production. Pulp chips are the most important by-product for sawmills. Pulp chip equals pulpwood as a raw material in pulp making. The sales of pulp chip to pulp mills improves the economic of sawmills. The other by-product that pulp mills use as raw material is sawdust, but its quality as a raw material is lower compared with pulpwood and mills do not pay the same price for it as for pulp chips. Instead, sawdust is the major raw material for particleboard and fibreboard mills. Part of it is also used as a fuel in energy production in addition to bark in its entirety. The wood streams in the Finnish forest industry in 2004 are illustrated in Figure 27. Dry and fine-grained by-products from the upgrading industry, which uses sawn timber as raw material, are the main raw material for the wood pellet industry, which is thus excluded from the figure. Almost one fourth of the wood consumed in the forest industry is imported.

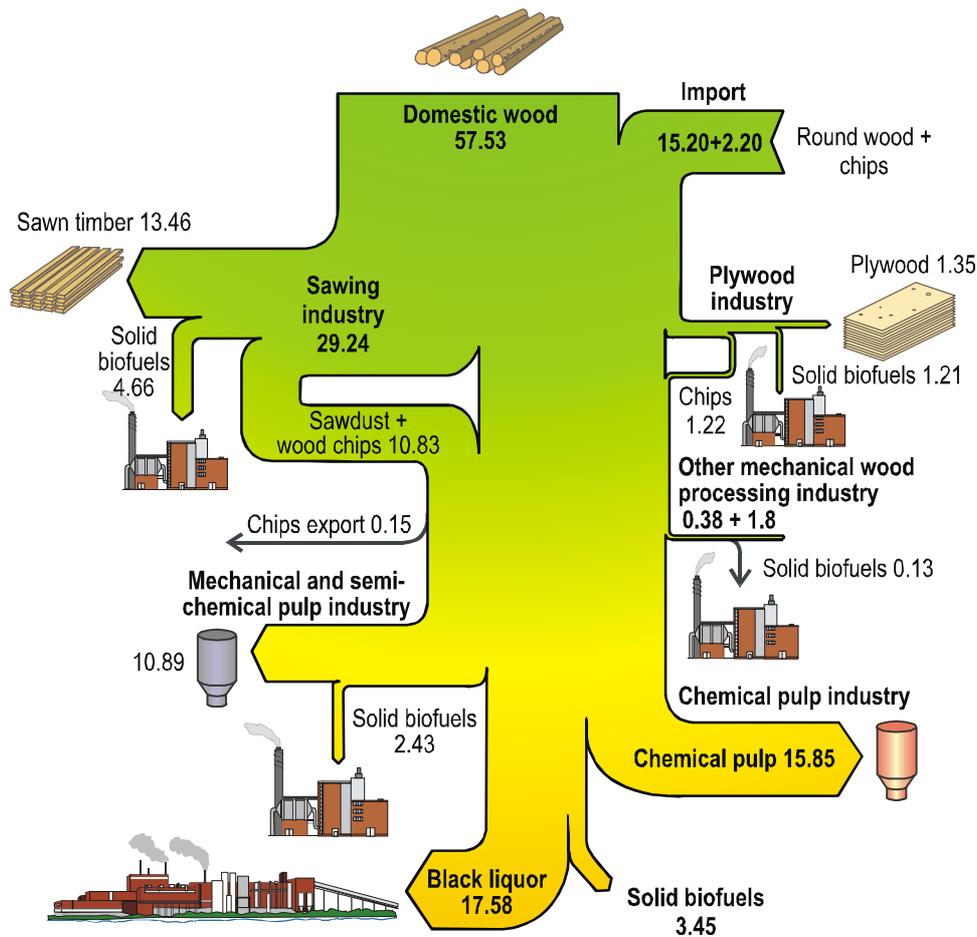


Figure 27. Wood streams in the Finnish forest industry in 2004.  
 Source: Lappeenranta University of Technology & VTT.

The forest industry imports wood primarily to be used as raw material. Nevertheless, during the manufacturing processes of the primary products a remarkable part of the raw wood ends up in energy production or is converted into by-products that are utilised in energy production. The biofuels importation of this kind is called in this report indirect import. In the following, the wood streams in the Finnish forest industry are discussed in more detail.

In 2004, the forest industry consumed altogether 74.7 million m<sup>3</sup> of raw wood, of which 17.4 million m<sup>3</sup> (23%) was imported. Table 8 presents the proportions of raw wood input streams in different sectors of the forest industry that ended up in energy production in 2004. The proportions vary from one year to another depending on the relative volumes of wood use between the sectors. Mechanical wood processing can convert wooden raw material into products more efficiently than chemical pulp making. (Heinimö & Ranta, 2005)

*Table 8. The proportions of the raw wood that ended up in energy production during or right after the manufacturing process of the main products in the Finnish forest industry in 2004.*

<b>Sector of forest industry</b>	<b>Round wood</b>	<b>Imported chips</b>
Sawmills	29.1%	-
Plywood mills	43.4%	-
Particle- and fibreboard mills	13.0%	0%
Other mechanical wood processing	44.8%	-
Chemical pulp mills	55.4%	49.5%
Mechanical and semi-mechanical pulp industry	20.6%	9.9%
<b>Total average</b>	<b>39.2%</b>	<b>42.6%</b>

The consumption of imported raw wood in the sectors of forest industry and the volumes of raw wood that ended up in energy production are presented in Table 9. In 2004, the forest industry imported a total of 17.4 million cubic metres of raw wood, of which 44.6% ended up in energy production. As much as 45% (6.82 million m<sup>3</sup>) of round wood and 43% (0.94 million m<sup>3</sup>) of pulp chips imported by the forest industry ended up in energy production. (Heinimö & Ranta, 2005)

*Table 9. Use of imported wood in the Finnish forest industry and the volumes used in energy production during or right after processing in 2004, values in 1 000 m<sup>3</sup>.*

<b>Type of industry</b>	<b>Round wood</b>	<b>Chips</b>	<b>Used in energy production</b>
Sawmills	3 699	0	1 075
Plywood mills	863	0	375
Particle- and fibreboard mills	2	8	0
Other mechanical wood processing	14	0	6
Chemical pulp mills	9 127	1 821	5 962
Mechanical and semi-mechanical pulp industry	1 495	373	345
<b>Total</b>	<b>15 200</b>	<b>2 202</b>	<b>7 762</b>

### **5.3 Indirect biofuels trade in other sectors**

The previous section stated that the imported raw wood comprises a large indirect import stream of biofuels in Finland. In addition, there are other products with trade patterns suggestive of indirect import of wood fuels in the forest industry. The following briefly illustrates the complicated patterns and difficulties in the determination of indirect trade of biofuels related to tall oil, ethanol and forestry products.

#### **Tall oil**

Tall oil is a by-product from the sulphite pulping process of coniferous wood. Tall oil has traditionally been a raw material for the tall oil refining industry, which distillates and processes crude tall oil into fatty acids, rosins and tall-oil pitch, which are used as raw material in the chemical industry. The heating value of tall oil is about 90% of the heating value of heavy fuel oil. Crude tall oil, distilled tall oil and tall-oil pitch can be used as fuel, as well. The annual crude tall oil production of Finnish pulp mills is approximately 250 000 tons, part of which is exported and be used in energy production. Tall oil refineries in Finland buy crude tall oil from pulp mills, but also import it. The utilisation of tall oil for heat production is uneconomical in Finland because of the energy tax imposed on the product, but the use of tall oil in heating processes in pulp mills is exempted from energy taxation. (Ministry of Trade and Industry, 2004)

#### **Ethanol**

In addition to the use as motor fuel, ethanol is commonly used as raw material in the chemical industry. In Finland, imported industrial ethanol has been used as a supplement of gasoline in the raw, and as raw material in the chemical industry and ETBE production.

#### **Forest products**

Forest products – pulp and paper, sawn timber and wood panels – are usually processed in the import countries into more refined final products, such as books, newspapers and packages. Wood material that once entered the import country can forward its way to a third country as final products. Eventually, most of the wood material ends up in recycling and energy production.

An interesting aspect is to consider the stream of forest products as a carbon stream. Forests bind atmospheric CO<sub>2</sub> and solar energy to woody biomass. After woody biomass is utilised as products, the bounded carbon is released into the atmosphere as

CO<sub>2</sub> from energy production or as landfill gas from the decay of products at landfills. In 1997, the total carbon stream of the raw wood forest industry consumed in Finland was in total 13 million tons, and 2 million tons of the volume originated from imported raw wood. As much as 60% or 7.8 million tons of carbon ended up in forestry products, which were to a great extent exported. In the same year, the fossil fuel use in the forest industry, the electricity bought in the industry and the transportation activities due to the forest industry caused CO<sub>2</sub> emissions equalling about 3 million tons of carbon. Consequently, Finland seems to be a net exporter of renewable carbon. (Korhonen et al., 2001; Wihersaari, 2005)

#### **5.4 Balance of international biofuels trade in Finland**

The information from the customs statistics and the determined forest industry's wood streams provided a starting point for the evaluation the energy balance of international biofuels trade. Custom statistics neither record energy streams nor separate products according to their end use purposes, and therefore, complementary information and assumptions on biomass streams were needed. The data used and the assumptions made in the calculations of the energy balance are described in the following.

The customs statistics records wood pellets under the CN code 44013090, which also includes waste wood. The export volume and the energy content of the pellets (157 000 tons, 2.65 PJ) were available from the Finnish energy statistics for the calculations. The import volume of pellets was evaluated at zero.

Horticultural peat forms a remarkable part of the peat export. The energy content of exported fuel peat, including peat pellets, available from energy statistics was used in the calculations. Nevertheless, there are no records of the import of fuel peat in the energy statistics. The information on the volume of imported fuel peat was received from an importer (Purontakanen, 2006). The net calorific value of imported fuel peat was evaluated at 10 MJ/kg. The year 2004 was exceptional in peat import. Normally, fuel peat is not imported to Finland.

The volumes of fuel wood and imported waste wood were taken directly from customs statistics. The applied heating values for them are 13.7 MJ/kg in exportation and 8.3 MJ/kg in importation.

The volumes of tall oil export and import were available from customs statistics and the heating value applied for tall oil was 36.9 MJ/kg, which is 90% of the heating value of heavy fuel oil. The traded tall oil volume was calculated in the balance as a whole.

In 2004, the production of ETBE in Finland was in total 48 000 tons, and the production was predominantly exported. In the same year, 23 800 tons of ethanol was used as raw material. Neste Oil's annual production capacity of ETBE in Finland is currently 85 000 tons (Nikkonen, 2006). The heating value used for ethanol was 27 MJ/kg. The import of ETBE was estimated at zero and the entire production volume of ETBE was calculated to have been exported in the energy balance.

The energy content of the indirectly exported and imported biofuels was determined based on the state of the streams, when they cross the border. The actual average density of imported raw wood was 790 kg/m<sup>3</sup> (Eurostat, 2005; Finnish Forest Research Institute, 2005). On this basis, the average moisture content was assumed to be 45% when the net calorific value is 9.4 MJ/kg. The net calorific values for wood chips and sawdust were assessed as 8.3 MJ/kg. A summary of the estimated export and import balance of biofuels in 2004, including peat, is presented in Table 10. It should be noted that many assumptions have been made in the determination of the balance and it should be regarded merely as indicative of the scale of international biofuels trade. The energy contents of tall oil and ethanol were counted based on their total trade volumes. However, in practice only a part of those products ended up energy production. The contribution of exported round wood, wood chips and sawdust that ended up in energy production was presumed equal to those imported.

*Table 10. Energy balance of international biofuels trade in 2004.*

	<b>Import [PJ]</b>	<b>Export[PJ]</b>	<b>Net stream[PJ]<sup>(a)</sup></b>
<b>Direct trade:</b>	<b>5.4</b>	<b>8.2</b>	<b>-2.8</b>
Wood pellets	0.0	2.7	-2.7
Fuel peat including peat pellets	0.5	0.3	0.2
Fuel wood	0.9	0.1	0.9
Wood residues	1.2	0	1.2
Tall oil	2.1	4.4	- 2.3
Ethanol	0.6	0	0.6
ETBE <sup>(b)</sup>	0	0.6	-0.6
<b>Indirect trade<sup>(c)</sup></b>	<b>56.0</b>	<b>2.4</b>	<b>53.6</b>
Round wood	50.7	2.0	48.7
Chips	5.2	0.4	4.8
Sawdust	0.1	0.0	0.1
<b>Total</b>	<b>61.4</b>	<b>10.5</b>	<b>50.8</b>

<sup>(a)</sup> *Import – Export = Net import*

<sup>(b)</sup> *Includes only the bio-based proportion, which is evaluated at equivalent to ethanol used as raw material.*

<sup>(c)</sup> *Raw materials of the forest industry*

During processing, wood can be moist or dry. Therefore, the actual heating values in energy production can differ from the value on the border. The total share of imported wood fuels in primary energy consumption in 2004 was estimated at 66.1 PJ, which equals 21.6% of the wood fuels consumption and is higher than in the previous table. The indirect import represented the largest share (64.1 PJ) of the total use of imported wood fuels (Statistics Finland, 2005).

Next, a view of the financial value of international biomass trade in Finland will be provided. In the beginning, attention is paid to the direct trade of biofuels. Table 11 gives an estimation of the financial value of the international biomass trade. The financial values for the products included in the direct trade in the previous table were adopted from customs statistics. The volumes of the products were taken either from the customs statistics or the previous table. The estimation gives the annual turnover of direct biomass trade of about €90 million. Wood pellets, fuel peat, fuel wood and wood residues are commodities that most probably are used entirely as fuel in energy production. The trade volumes of tall oil and ethanol were included in the turnover as a whole, but actually, a remarkable part of these products was used for other than energy purposes.

*Table 11. The financial value of international biomass trade in 2004.  
(Eurostat, 2005; Statistics Finland, 2005)*

	Import			Export		
	Volume [t]	Price <sup>(a)</sup> [€/t]	Value [M€]	Volume [t]	Price <sup>(a)</sup> [€/t]	Value [M€]
<b>Wood pellets</b>	0	-	-	157 000	89.9	14.1
<b>Fuel peat including peat pellets</b>	46 600	28.7	1.3	29 160	25.0	0.7
<b>Fuel wood</b>	110 400	17.6	1.9	4 083	108.86	0.4
<b>Wood residues</b>	146 000	21.9	3.2	7 261	89.9	0.7
<b>Tall oil</b>	57 700	192.9	11.1	120 544	238.4	28.7
<b>Ethanol</b>	23 800	529.2	12.4	0	-	0
<b>ETBE</b>	0	-	-	23 800 <sup>(b)</sup>	606.9	14.4
<b>Total</b>			<b>30.2</b>			<b>59.1</b>

<sup>(a)</sup> The prices are from foreign trade statistics, see tables 4 and 5, except for exported fuel peat which price was set to (2.5 €/GJ).

<sup>(b)</sup> The ETBE production was 48 000 t. The share of the bio-based component in ETBE was evaluated at 23 800 t, which equals the volume of ethanol used as raw material

The financial value of indirect biomass trade is more complicated to evaluate; thus the imported raw wood is acquired for use as raw material. An essential point is the cost allocation of raw wood between the shares that end up in energy production and in

products. Various methods in cost allocation give different values for the import. According to the customs statistics, the value of imported raw wood was €600 million in 2004. In the same year, 44.6 % of imported raw wood ended up in energy production. This gives a higher estimation for the financial value of the indirect biofuels import, €270 million. The other and more realistic estimate involves applying the statistical price of wood fuels to indirectly imported wood fuels. In 2004, the statistical price of wood fuels was 2.96 €/GJ (see Fig. 26). In the same year, the share of imported wood fuels in primary energy consumption was 64.1 PJ, this gives an estimation of €190 million for the financial value of the indirect biofuels import.

## 5.5 Logistics and market actors of international biomass trade

Finland's geographical location and the characters of the traded products have affected the transportation forms in foreign trade. In addition, the cold climate sets challenges for transportation systems. The country is confined in the west and south to the Baltic Sea. The majority of the Finnish foreign trade has been carried out with overseas partners. In 2004, the total volume of foreign trade was 109 million tons (Fig. 28). The export was 42 million tons and forestry products covered over half of the total export, 22 million tons. Sweden, Germany and the United Kingdom were the largest export countries. The majority of the import consists of industrial raw materials and fuels. In 2004, the total import of goods was 67 million tons and the share of raw wood was 14 million tons. Half of the total import, 33 million tons, originated from Russia. (National Board of Customs, 2005)

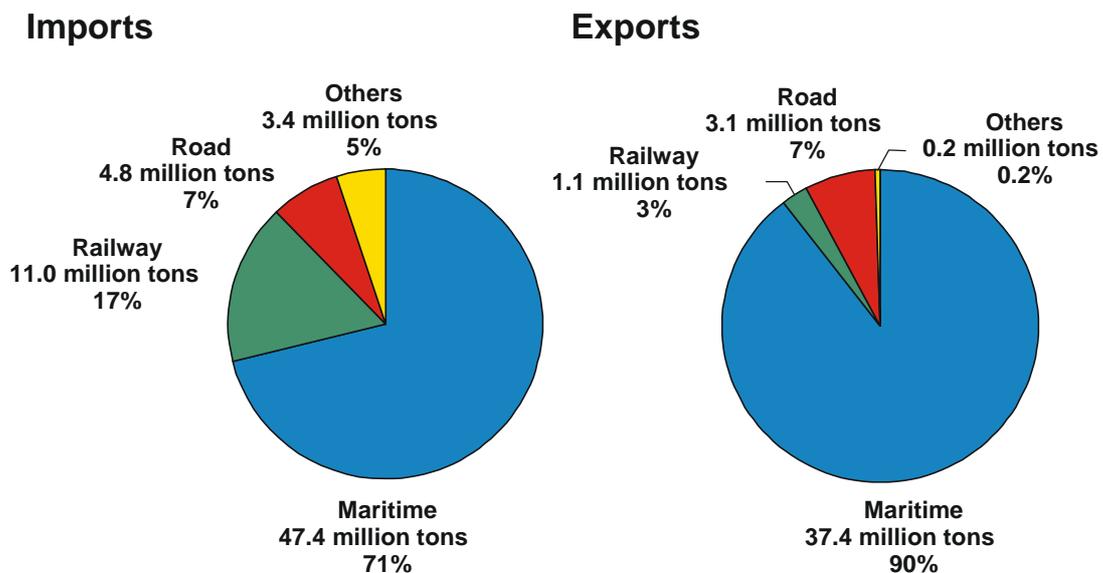


Figure 28. The transportation of the Finnish foreign trade in 2004 by transportation form. (National Board of Customs, 2005)

Maritime transport is the most important form of transport for the Finnish foreign trade. Large export items in maritime transports include paper, sawn timber and metals. Raw wood for the forest industry, minerals, chemicals, metals and scrap for the metal refinement industry, and crude oil for the oil refinement industry are the most common products imported by sea. Foreign maritime transports are handled in 55 Finnish ports; there is a slight annual variation in the exact number. About ten of the ports are located inland. Even though the number of ports is high, 75% of maritime transports are handled in the ten largest ports. Most of the ports are municipally owned general ports, and in addition, there are numerous private industrial ports that have been founded to serve the transport needs of nearby industrial establishments. There are 23 winter ports with guaranteed icebreaking assistance. The deepest fairways are the ones leading to Sköldvik (15.4 m), Kotka (15.3 m) and Pori (15.3 m). Fairways with a depth of 13 m lead to Inkoo, Hanko and Naantali. Relatively good road connections are available to each Finnish port, and railway connections have also been established where they are needed. (Viitanen et al., 2003)

After the maritime transport, railway transports are the second largest form of transportation in foreign trade covering 11% (12 million tons) of the trade. The majority of railway transportations, 11 million tons, were for import. Industrial raw material and raw wood were the largest import groups in railway transport. The rail-width of the Finnish railway network is equal to the Russian railways. This enables the effective utilisation of railways in foreign trade transportation between the countries. Three connecting points (Vainikkala, Imatrankoski and Niirala) between the Russian and Finnish railways are in operation and they are located in South-Eastern Finland. The Finnish railway network has no direct connections to the railway networks of its other neighbouring countries Sweden and Norway. (National Board of Customs, 2005)

In the international biofuels trade, the largest streams in Finland are the import of raw wood, due to the indirect import of biofuels, and the export of wood pellets. The logistics of these products in foreign trade will next be discussed in more detail.

Most of the raw wood import of the forest industry is originated in Russia. Railway transport is the most commonly used mode of transportation in the raw wood import equalling over half of the total import. The share of waterway transport was about 25% and the share of road transportation about 20% in 2004 (Fig. 29). Most of the ports utilised in the import of raw wood are located at forest industry sites.

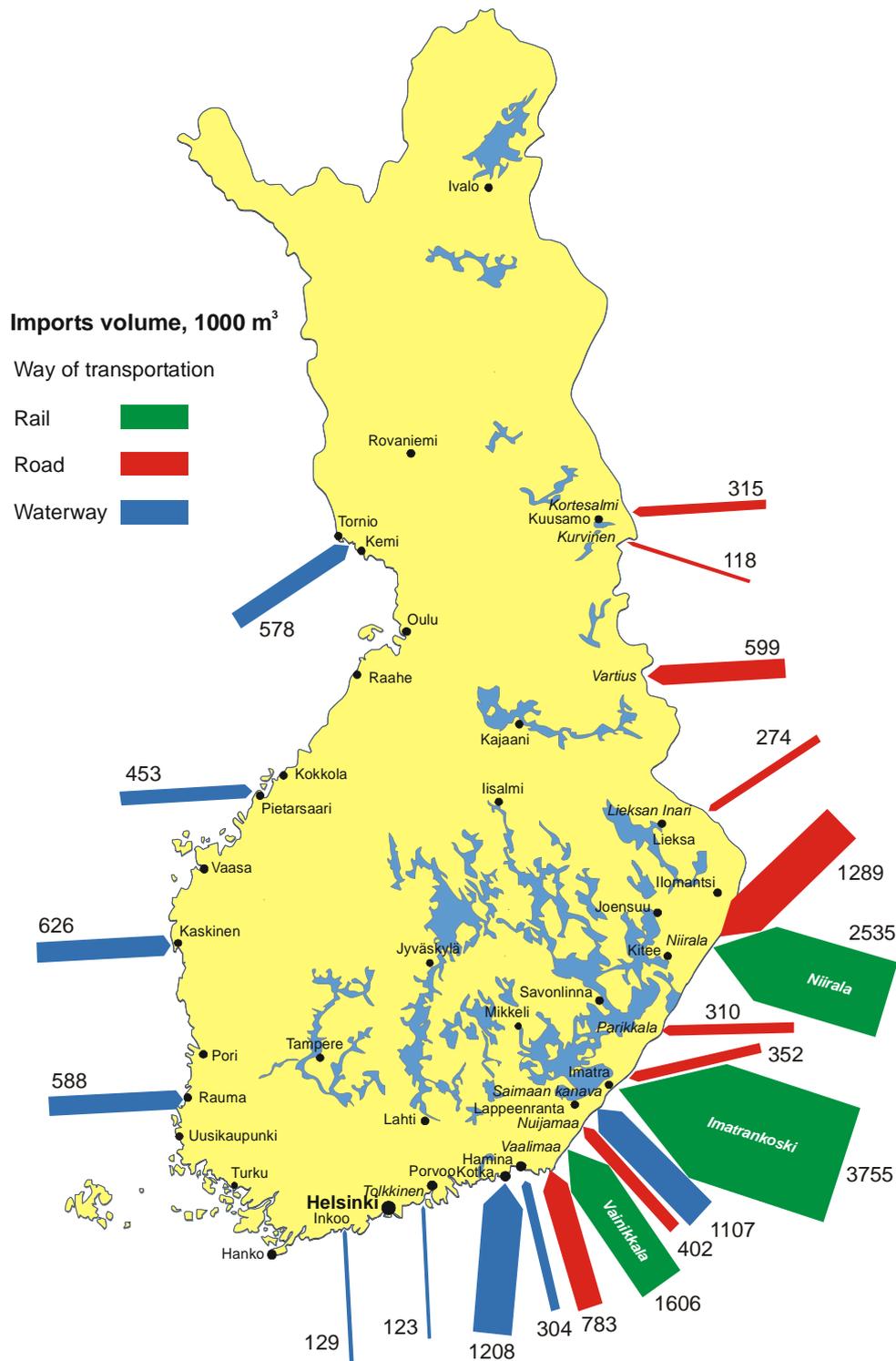


Figure 29. Imports of round wood and wood residues by port and check point in 2004. (Finnish Forest Research Institute, 2005)

In accordance with the EU directive 2000/29/EU on protective measures against the introduction into the Community of organisms harmful to plants or plant products and against their spread within the Community, all the coniferous timber imported from

Russia has to be inspected since 1 March 2005. A phytosanitary certificate given by the authorities of the export country is required for imported round wood lots that are imported from outside the EU. The documents of timber lots are surveyed and 1% of the timber is inspected manually in the field. (Plant Production Inspection Centre, 2004; Plant Production Inspection Centre, 2005)

The wood pellets are exported almost totally by means of maritime transport. As bulk material, wood pellets are relatively easy to transport and ports suitable for dry-cargo vessels and barges can be utilised in the transportations. Available indoor storage and material handling equipment for dry bulk in a port facilitate the loading of pellets into the vessel. There is plenty of underutilised port capacity in Finland available for the handling and transportation of pellets. At least the ports of Oulu, Kokkola, Kaskinen, Inkoo, Loviisa and Joensuu are used in their export (Ruha, 2006).

## **6. Challenges and possibilities of international biofuels markets**

### **6.1 Import of raw wood**

Finnish forest industry consumes more wood than it can acquire from the domestic timber market. Currently, Finland holds the third position after China and Japan as one of the largest round wood importers in the world (Finnish Forest Research Institute, 2005). The import of raw wood represents the largest stream of imported biofuels in Finland. Nearly half of the imported raw wood is consumed in energy production during or immediately after processing in the forest industry. In this section, the historical background, present situation and future challenges of the raw wood import in Finland are further discussed.

The Finnish forest industry has long traditions in the import of raw wood. Over the past forty years, the annual raw wood consumption of the forest industry has almost doubled from 40 million m<sup>3</sup> to 74 million m<sup>3</sup> (Fig. 30). A part of the increased wood demand has been supplemented by foreign raw wood, and the import of raw wood was increased from 3 million m<sup>3</sup> to 17.4 million m<sup>3</sup> in the same period. Over the past decades, foreign raw wood has thus become a more and more important raw material for the forest industry. In 2004, the proportion of imported raw wood reached 23% of the forest industry's total wood consumption when in 1965 the proportion was 8%. The forest industry expects an annual increase of 1.5% in its wood consumption in the near future (Finnish Forest Industries Federation, 2006b).

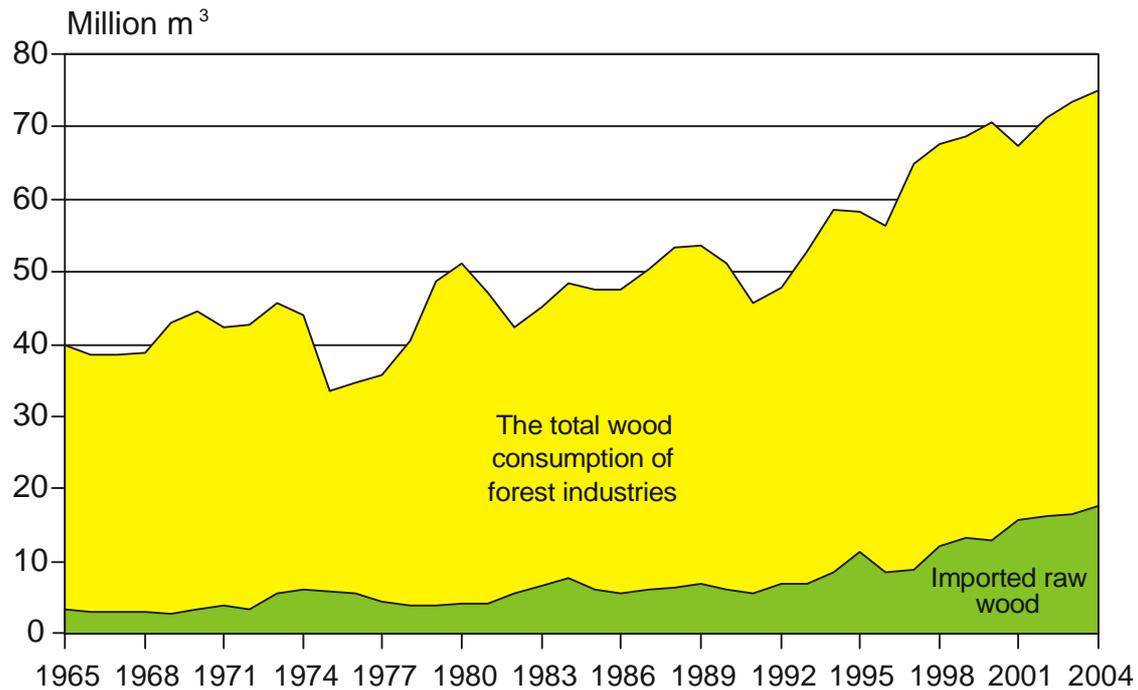


Figure 30. Raw wood importation and total wood consumption of forest industry in Finland 1965-2004. (Finnish Forest Research Institute, 2005)

The increased growth of the Finnish forests has been a factor that has enabled the increase in the domestic wood use of the forest industry. The annual growth of the Finnish forests has been on the increase since the 1950s, and the total growth has exceeded the total drain since the 1970s. The annual growth of stem wood was 87 million m<sup>3</sup> in 2004. METLA has determined the annual sustainable stem wood removals from Finnish forests as 69 million m<sup>3</sup>. In 2004, the total commercial stem wood removals were 56 million m<sup>3</sup>, which means that about 80% of the sustainable harvesting potential was utilised. In Finland, private non-industrial owners have a relatively high share, 67% of the total forest resources. The proportion of the state is 20% and the rest belongs to companies and other owners. The total number of forest owners is about 900 000, and the number of forest properties larger than 1 hectare is 440 000. The structure of the forest ownership is certainly a factor that constrains the volume of commercial round wood harvesting and sets challenges for the round wood procurement of the forest industry. (Finnish Forest Research Institute, 2005; Finnish Forest Research Institute, 2006)

In 2004, about 70% of the round wood import in Finland was composed of pulpwood and the rest consists of logs. Deciduous pulpwood is the most important imported wood species. Down to the production structure of the forest industry, the consumption of deciduous pulpwood exceeds the current supply potential of indigenous forests. In 2004, about 60% of the round wood import was deciduous pulpwood, mainly birch, but also aspen for pulp mills. Currently, more than half of the deciduous pulpwood the industry

uses comes from abroad. Imports of softwood logs, mainly by sawmills located close to the Russian border, have increased substantially in recent years due to a sharp increase in the sawmilling capacity. (Finnish Forest Research Institute, 2005)

The imported raw wood originates almost totally from the area of the former Soviet Union (Russia and the Baltic states). In 2004, Russia was the major source of foreign raw wood providing 80% of the total raw wood import. The share of the Baltic countries was 13%. Other countries from which raw wood was imported in 1989–2004 included e.g. the United Kingdom, Sweden, Uruguay, Germany and Belarus. (Eurostat, 2005)

Russia possesses about 20% of the world's forest resources and has some 880 million ha of forestland. The commercial utilisation of the forest resources in Russia is still modest. The annual growth of the forests is almost 1 billion m<sup>3</sup>. In 2003, the total volume of the fellings was 174 million m<sup>3</sup> and consisted of final fellings (126 million m<sup>3</sup>) and intermediate and other fellings (48 million m<sup>3</sup>). The sustainable allowable cut for final fellings in Russia is about 550 million m<sup>3</sup>. The most intensive utilisation of forests takes place in the north-western part of Russia where the rate of fellings is 40% of the planned cuts. (Karvinen et al., 2005)

The Russian forest industry was badly blooded by the transition to market economy at the beginning of the 1990s, resulting in the collapse of the production volumes and the demand in the internal markets as well as the stagnation of investments in the industry. The regression continued until 1998 when the devaluation of the rouble and favourable world market conditions turned the trend. Most of the forest industry mills were from the Soviet era. The low productivity, labour-intensiveness, the wasteful use of raw material and energy, and high environmental strain are typical drawbacks of the obsolete technology. Currently, half of the production of the forest sector is exported and the export forestry sector represents 4% (7 billion U.S.\$, €5.8 billion) of the total export. The export consists of products with a low processing degree and they are based mainly on raw materials, transportation, energy and low-cost labour. Raw wood has been the most important export article of the Russian forest sector for years. The export of raw wood has been on the increase since the 1990s and the export volume of raw wood was 40 million m<sup>3</sup> in 2003. China (35%), Finland (33%), Japan (12%) and Sweden (7%) are the largest buyers of Russian raw wood (UNECE, 2005). The import of forest products to Russia was about 2.4 billion U.S.\$ (€2 billion) in 2003 and consisted of more upgraded products than the export. (Dudarev et al., 2002; Karvinen et al., 2005)

The largest unexploited forest resources and the increasing demand for forestry products, especially in Russian internal markets, offer conditions for increasing the production and the share of products with higher added value. Nevertheless, the lack of

funds, unstable business environment and defective forest road network hinder the development of the forest sector. In Russia, forests are owned by the state, and the logging rights are sold and the forests are rented to the private sector. Until recently, only the largest and foreign-owned companies have been able to renew their production facilities or build new production capacity. Also Finnish forestry companies are expanding their activities in Russia and have built several sawmills in North-West Russia. It can be assumed that in the long term the companies will also invest in pulp and paper mills in North-West Russia, which means that the part of the forest industry's production capacity based on imported wood will be moving from Finland to Russia. (Dudarev et al., 2002; Karvinen et al., 2005)

Forest industry companies have normally organised the importation of raw wood through their own wood procurement organisations or subsidiaries established for the purpose, and they also operate through foreign subsidiaries, jointly-owned companies and long-term partners. Also, forestry companies have acquired Russian companies that own logging rights in Russia. In addition, wood supply and import organisations serve other mills of their owners located abroad.

In 2004, the company specific volumes of imported wood for the largest importers were Stora Enso 8.0 million m<sup>3</sup>, UPM 5.3 million m<sup>3</sup> and Metsäliitto approximately 3.5 million m<sup>3</sup> (Metsäliitto, 2005; Stora Enso Metsä, 2005; UPM Metsä, 2005). The Finnish forest industry aims at ensuring that the imported wood comes from sustainably managed forests, is legally logged and does not come from protected areas. The Finnish Forest Industries Federation's member companies check the origin and legality of imported wood. This enables them to verify that it has not been stolen or illegally logged from a protected area. The biggest importers base their verification on certified quality and environmental systems (ISO 9001, ISO 14001, EMAS). A third independent party, the certification body, ensures the effectiveness of the systems (Finnish Forest Industries Federation, 2005). For example, UPM requires a statement of origin for all imported wood deliveries from Russia and the Baltic states. In 2005, statements of origin were received for 97% of the volume supplied. Deliveries with no statement of origin were recorded as major non-conformities and corrective actions were agreed on with the suppliers (UPM, 2006).

## **6.2 The production, domestic use and export of wood pellets**

The production of wood pellets has grown rapidly since the first pellet mill started in 1998 (Fig. 31). The Finnish pellet industry has been founded on exportation. Nevertheless, there is a large utilisation potential for pellets to replace fossil fuels in energy production in Finland. In recent years, the domestic consumption of pellets has

increased, but was only about one fourth of the production in 2004. In the same year, the export of wood pellets was 157 000 tons. Sweden (56%), Denmark (23%) and the Netherlands (20%) were the main exporting countries of wood pellets. (Eurostat, 2005; Statistics Finland, 2005)

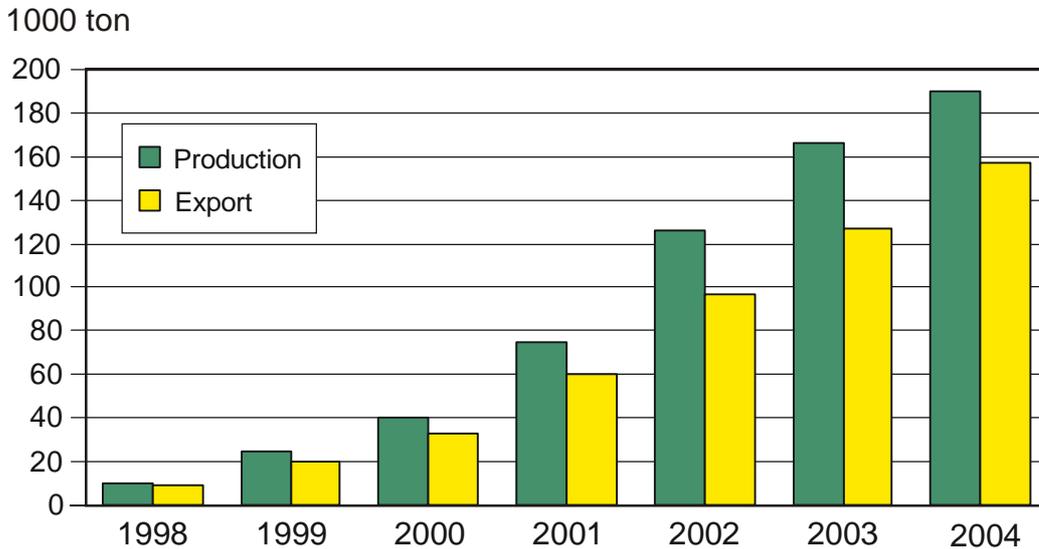


Figure 31. Wood pellet production and export in Finland 1998–2004. (Alakangas & Paju, 2002; Heinimö & Orava, 2002; Statistics Finland, 2005)

The fact that the taxation of fossil fuels in energy production or subsidies for electricity from biomass are at a remarkably higher level in the main exporting countries compared to Finland has made the exportation of pellets economical. In Sweden and Denmark, the taxation of fossil fuels in heat production is remarkably higher than in Finland and wood pellets are mainly used for substituting coal in the district heating and oil in space heating sectors. The Netherlands have strongly subsidised renewable energy sources in electricity production, and wood pellets are primarily cofired with coal in large power plants.

In 2004, the Finnish domestic consumption of wood pellets was 47 000 tons (0.8 PJ). Nearly half of this volume was consumed in small boilers under 25 kW<sub>th</sub> (Statistics Finland, 2005). The consumption of wood pellets is at a modest level compared to the usage potential. Annually about 50 PJ of light fuel oil is consumed for the direct heating of the dwellings (Statistics Finland, 2005). Estimations showed that the annual domestic consumption of wood pellets could be raised up to 1–1.5 million tons (17.5–26 PJ) by substituting a part of the consumption of light fuel oil for pellets (Vapo Oy, 2001; Asplund et al., 2005). The Finnish Pellet Energy Association has estimated that in 2010 there will be about 50 000 detached houses and a few thousand larger buildings using wood pellets (300 000 t/yr and 500 000 t/yr). The Pellet Energy Association has set the target of domestic pellet production to 550 000 tons in 2010 (Finnish Pellet Energy

Association, 2006). Currently wood pellets are made from dry and fine-grained by-products of the carpentry industry. The increasing pellet production will require remarkable use of sawdust as raw material. VTT estimated that the majority of the sawdust that is at the moment used in energy production would be consumed in pellet production in the 2010s (Table 12). The sawdust utilised in pellet production would be replaced by increasing the use of forest fuels, agrobiomass and solid recovered fuels in energy production. The prognosis is based on national targets for forest fuel (5 million m<sup>3</sup>), decreased production of sawn timber as of the year 2015, sawdust is entirely used for pellet production or other purposes and the fuel peat use for the production of condensing power is 9 PJ.

*Table 12. Estimated domestic demand of wood and peat fuels in plants using peat as the main fuel. (Flyktman, 2005)*

<b>Peat</b>	<b>2003</b>	<b>2010</b>	<b>2015</b>	<b>2020</b>
	<b>[PJ]</b>	<b>[PJ]</b>	<b>[PJ]</b>	<b>[PJ]</b>
District heating plants	4.7	5.4	6.5	6.8
Municipal CHP	33.8	41.0	41.8	41.4
Industrial CHP	25.6	28.8	29.9	30.3
Condensing plants	34.9	13.3	10.1	9.7
<b>Peat, all</b>	<b>99.0</b>	<b>88.6</b>	<b>88.2</b>	<b>88.2</b>
<b>Forest wood and industrial wood residues</b>				
Forest chips	10.8	33.1	45.4	50.8
Wood processing industry by-products and residues, sawdust	16.6	14.0	2.2	2.2
Wood processing industry by-products and residues, other	65.9	59.4	59.4	59.4
<b>Agrobiomass</b>	<b>0.0</b>	<b>1.8</b>	<b>1.8</b>	<b>1.8</b>
<b>Solid recovered fuels</b>	<b>1.4</b>	<b>1.8</b>	<b>1.8</b>	<b>1.8</b>
<b>Altogether</b>	<b>193.7</b>	<b>198.7</b>	<b>198.7</b>	<b>204.1</b>

The main obstacle to increasing the domestic consumption of pellets has been their weak competitiveness against other heating fuels. In the beginning of 2006 the Finnish government was considering the possibility to subsidise private sector investments in wood pellet heating systems (Ministry of Trade and Industry, 2006b). This would improve the competitiveness of pellets against fossil fuels and increase the domestic consumption of pellets. But on the other hand, the development of the international markets of wood pellets will affect the export volumes of wood pellets.

### **6.3 Growing competition for wood between material and energy uses**

In Finland, wooden by-products from the forest industry are fully utilised as raw material or in energy production, and their use cannot be increased unless the production volumes of the forest industry increase. Forest fuels from logging residues, stumps and small-diameter energy wood constitute a large underutilised biofuel potential. Increasing the use of forest fuels in heating and power plants has an important role in the Finnish energy policy in decreasing CO<sub>2</sub> emissions from energy production.

In Finland, the use of forest fuels in heat and power plants has been increasing moderately since the 1980s. Increased consumption of forest fuels and strong development of the technologies for forest fuel production within national technology programmes have lowered the prices of forest fuels during the 1990s. Since the turn of the millennium, the prices of forest fuels have slightly been on the increase (Fig. 24). The measures of the domestic energy policy have boosted the demand for biofuels, which has affected the upward trend of biofuel prices in recent years. Since the beginning of 2005, the start of the trading of CO<sub>2</sub> emission allowances within the EU emission trading scheme has enhanced the paying capacity of power plants for biofuels. Nowadays, forest fuels are to a greater extent produced at sites where the production costs are higher and the production has previously been uneconomical. Also the utilisation of costlier raw materials, small-diameter wood and stumps, in addition to logging residues is on the increase in the production of forest fuels.

The growing demand for wood in energy production and the increasing paying capacity of energy production for wood affect the other users of wood in various ways. The first consequence has been the growing competition for wood between energy and raw material uses. In the following, the current and anticipated competition between material and energy use for various products and interconnections to international biofuels markets are illustrated. The products selected for discussion are sawdust, pulpwood and tall oil.

#### **Sawdust**

In Finland, the current competition for wood between the raw material and energy purposes mainly involves sawdust, which is used as raw material in particleboard and fibreboard mills, and several pulp mills. Sawdust is also a good fuel for heating and power plants and it can be used as raw material in the production of wood pellets.

For particleboard and fibreboard mills, sawdust is the major raw material representing about 95% of the total raw material volume, and for pulp mills it supplements pulpwood

and pulp chips as raw material. Statistic-based calculations on wood streams in the forest industry in 1998–2004 showed that a growing proportion of the by-products from sawmills and plywood mills has ended up in energy production. Particle and fibreboard mills have to procure raw material from biofuels markets and compete with energy producers. The increased demand for sawdust in energy production has raised its price. According to statistics, the price of sawdust has risen 23% between the years 2000 and 2004 (Fig. 24) (Ylitalo, 2001; Ylitalo, 2002; Ylitalo, 2003; Ylitalo, 2004; Ylitalo, 2005). Raw material represents 10–20% of the prices of particle- and fibreboard (Electrowatt-Ekono Oy, 2004b). Over half of the Finnish production of particleboard and fibreboard was exported. The increasing price of raw material weakens the competitiveness of particleboard and fibreboard manufacturers against manufacturers operating in countries where raw material is available at a lower cost.

### **Tall oil**

Tall oil is a by-product from the sulphite pulping process of coniferous wood. Tall oil has traditionally been a raw material for the tall oil refining industry, which distils and processes crude tall oil into fatty acids, rosins and tall-oil pitch, which are used as raw materials in the chemical industry. A total of 16 Finnish pulp mills produce tall oil, and the annual production of tall oil is estimated as 250 000 tons (~9.2 PJ). Two tall oil refineries exist in the country. They are located in Oulu (Arizona Chemical) and Rauma (Forchem) and are able to refine all tall oil from Finnish pulp mills. The annual turnover of the tall oil refineries is about € 120 million and they employ 150 people. Approximately 90% of refined tall oil products are exported and Finnish tall oil refineries have roughly a 20% share of the world markets of distilled tall oil products. Corresponding products are manufactured also from fossil oil. Tall oil refineries exist also in Sweden, Austria, the USA, Russia, France and Norway. The heating value of tall oil is about 90% of the heating value of heavy fuel oil, and crude tall oil, distilled tall oil and tall-oil pitch can also be used as fuel. (Electrowatt-Ekono Oy, 2004b; Ministry of Trade and Industry, 2004)

In Finland, tall oil also competes with heavy fuel oil and natural gas as the fuel for lime sludge reburning kilns in pulp mills. Energy tax is not imposed on the fuels used in sludge reburning kilns of pulp mills. Tall oil used in heat production is under energy taxation (~1.54 €/GJ), which made the use of tall in heat production uneconomical. The market price of tall oil follows the tax-free price of heavy fuel oil. To get raw material, the refineries have to buy tall oil at a price that beats the cost of alternative fuels for pulp mills. The price of tall oil also varies according to its quality. The energy taxation of tall oil aims to secure the availability of raw material for tall oil refineries. Electrowatt-Ekono estimated the price of raw tall oil at 170–230 €/t (4.6–6.2 €/GJ) for tall oil refineries in 2004. Along with the CO<sub>2</sub> emission trade, tall oil has become a more

attractive fuel for pulp mills. By burning tall oil instead of heavy fuel oil or natural gas, pulp producers receive valuable emission allowances. Finnish tall oil refiners reported about the increased market prices of tall oil in the autumn of 2005 when the price of CO<sub>2</sub> allowances soared at over 20 €/t (Laitila, 2005). Raw material is a significant expenditure for tall oil refineries. The share of raw material of the direct cost of final products was estimated as 60–70% and the increasing raw material prices directly affect the competitiveness of the tall oil refineries in the world markets. The indigenous energy taxation of raw tall oil in energy production can not inhibit the export. Tall oil is an attractive substitute or an additional fuel for heavy fuel oil in the countries where oil is highly taxed, and the export of raw tall oil may increase to countries which do not limit its energy use by taxes. (Electrowatt-Ekono Oy, 2004b; Ministry of Trade and Industry, 2004)

## **Pulpwood**

Pulpwood is the main raw material for pulp industry. In 2004, the Finnish pulp industry consumed 39.3 million m<sup>3</sup> of round wood and 13.1 million m<sup>3</sup> of pulp chips and sawdust (Finnish Forest Research Institute, 2006). Normally, the minimum top diameter of pulpwood is 6–9 cm. Pulpwood is available from final fellings and thinnings. According to statistics, the average stumpage prices in 2004 for pulpwood including bark from private forests were 12.5 €/m<sup>3</sup> (1.7 €/GJ)<sup>6</sup> for pine, 20.5 €/m<sup>3</sup> (2.8 €/GJ) for spruce and 12.0 €/m<sup>3</sup> (1.7 €/GJ) for birch (Finnish Forest Research Institute, 2005). Jaakko Pöyry Consulting estimated the average procurement costs<sup>7</sup> of pulpwood in 2003 as about 20 €/m<sup>3</sup> (2.8 €/GJ) (Jaakkola, 2004). Therefore, the estimation for the price of pulpwood delivered to the mill is 4.4–5.6 €/GJ. For comparison, the average price of forest fuels delivered to the plant was 2.75 €/GJ in 2004 (Fig. 24). It can be concluded that in Finnish markets there is still a crisp price difference between wood fuels and pulpwood.

In the future, the measures to promote the use of renewable energy sources will most probably increase the paying capacity of energy producers for biofuels. The stumpage prices of pulpwood in Finland are among the highest in Europe, and there is still a clear difference in the prices of energy wood and pulpwood. Nevertheless, the development of the international markets of biofuels in the long run will doubtless have an effect on the Finnish pulpwood markets. The situation will change when the prices of wood fuels

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<sup>6</sup> The net calorific value of pulp wood was assumed to be 7.2 MJ/m<sup>3</sup> (2 MWh/m<sup>3</sup>)

<sup>7</sup> Includes logging, transport and general costs and excludes the stumpage price

rise. The strong domestic energy policy measures and the domestic schemes of green certificate trading in various countries concurrent with the EU's CO<sub>2</sub> emission trading scheme are augmenting the electricity producers' paying capacity for biomass fuels remarkably.

The following example illustrates how the developing international bioenergy markets could engage the domestic biofuels and raw wood markets. The Netherlands have been among the countries that give the highest subsidies for electricity production from biomass in large power plants. In 2005, the larger, over 50 MW<sub>e</sub>, power plants received a 70 €/MWh<sub>e</sub> subsidy for electricity generated from biomass (Junginger & Faaij, 2005). In 2004, the market price of wood pellets delivered to Dutch power plants for cofiring with coal was 7–7.5 €/GJ (van Sambeek et al., 2004). The price is over double the price of wood fuels in Finnish heating and power plants.

The long-distance transport of biomass has been estimated in several studies as relatively inexpensive when carried out on a large scale using effective logistics. A study carried out in Utrecht University modelled various long-distance biomass fuels transportation chains and their costs (Hamelinck et al., 2003). In the study, the transport cost of pulpwood, including truck and maritime transportation and chipping, from a roadside of Scandinavian forest to a Dutch power plant was estimated at 60 €/t for dry matter, which for unbarked pulpwood equals about 3.3 €/GJ or 24 €/m<sup>3</sup>. In 2004, the roadside price for unbarked pulpwood (pine and birch) was in Finland about 23 €/m<sup>3</sup> (3.2 €/GJ) (Finnish Forest Research Institute, 2005). This gives a rough estimation of the total costs of pulpwood chips delivered to the plant for 6.5 €/GJ, which seems to be a competitive price against the price of wood pellets (7–7.5 €/GJ). The calculation excluded the effect of emission trading. Replacing a fossil fuel with biofuels in a power plant within the emission trading scheme gives the power producer valuable emission allowances, which can be for the market price on the emission markets. The burning of hard coal causes CO<sub>2</sub> emissions of about 94.6 t/TJ. During the two first months of 2006, the market price of CO<sub>2</sub> emission allowances has exceeded 20 €/t and under these circumstances the emission trading has boosted the use of biofuels in power plants significantly (Nord Pool, 2006). Nevertheless, for power plants moist and coarse-sized wood chips do not have the same features as pellets or coal, and various technical factors limit the cofiring of wood chips with coal.

Almost all of the European large-scale coal-fired power plants apply pulverised fuel combustion, which does not enable the use of wet and coarse biomass unless it is pre-treated by grinding and drying or unless remarkable technical changes are made to the burning system. There are boiler technologies available, such as FBC boilers, allow the use of a variety of fuel blends. However, a larger transition to a new boiler capacity in coal-fired power plants needs decades of time. In addition, the uncertainty about the

future policy measures for promoting biofuels restrains investments in biofuel-fired power plants. On one hand, the political measures to promote biomass use in energy production opens up feasible opportunities to convert fossil fuels to biomass in energy production, but on the other, especially national measures might have unforeseeable effects on the other industrial sectors using biomass.

#### **6.4 Domestic production vs. the import of biofuels for the road transportation sector**

The EU biofuel directive (2003/30/EC) set the indicative targets of 2% in 2005 and 5.75% in 2010 for the proportion of biofuels used in road transportation. The target of 5.75% in 2010 would mean biofuel utilisation of about 710–750 PJ in the EU. In the short run, bioethanol and biodiesel are the most interesting fuels for road transportation to meet the target of the directive. Currently, agricultural-crop-based ethanol and diesel are produced commercially for transportation fuels in Brazil, the USA and some EU countries. Some countries, e.g. Sweden, have implementation activities on the use of biogas in gas engine vehicles (Mäkinen et al., 2005). In 2004, approximately 84 PJ of bioethanol and biodiesel was produced in the EU. The production of biodiesel for the fuel market in the EU was about 71 PJ and that of ethanol roughly 13 PJ. In total, biofuels covered less than one percent of the fuel use of the road transport sector in the EU (IEA-AMF, 2005).

In Finland, the total annual fuel consumption of the road transport sector is currently 160–170 PJ, and the 5.75% target would amount to a biofuel consumption of approximately 9–10 PJ in road transportation in 2010. The domestic potential supply of biomass for the energy market is, in practise, sufficient for producing biofuels at the indicative target share set by the directive for 2010. Nevertheless, as a measure for reducing the emission of greenhouse gases, the large-scale utilisation of domestic biomass in the transportation sector is more expensive than in combined heat and power production and in the heating of buildings. (Mäkinen et al., 2005; Statistics Finland, 2005)

In 2005, VTT composed production scenarios for biofuels for transportation in 2010. According to the scenarios, the production of biofuels for the transport sector based on indigenous raw materials and first demonstration plants of new technologies could be 4.2–5.8 PJ corresponding to 2.5–3.5% of the estimated consumption of road transportation fuels in Finland in 2010. The assumed raw materials for biofuels production consist of grain, rapeseed and biogases from landfills, wastewater treatment plants and biowaste, as well as wood material, animal fats and recycled vegetable oils. The trading of rapeseed and grain take place according to the world market prices. The

Finnish conditions does not enable the competitive production of grain and rapeseed against the world market prices without remarkable agricultural subsidies, which are used to cover the gaps between cultivation costs and world market prices within the EU. Economic factors will most likely limit the areas for the biofuel production of agricultural biomass due to the need for high subsidies. In addition, the domestic production of biofuels has to compete with biofuels available from the European and the world markets. Otherwise, domestic raw materials and domestic production of biofuels offer better ecological performance compared to imported biofuels, but its value in money is difficult to determine. However, a significant share of biofuels for the road transportation sector, or raw materials for agricultural-crop-based ethanol or biodiesel production would possibly be imported to Finland. (Mäkinen et al., 2005)

Several factors affect the future development of biofuels in the road transportation sector in Finland, such as the government's commitment to the targets of the EU biofuels directive and the development in the market price of oil, the production technologies of biofuels and the paying capacity for biofuels in other sectors. However, policy measures such as tax relief and agricultural subsidies will play a major role in the future use of biofuels in road transport.

In 2004, the government set the national target for the portion of biofuels in the year 2005 at 0.1%. In autumn 2005, the Ministry of Trade and Industry established a task force to prepare a proposal for the measures needed for achieving the 5% share of biofuels in the road transportation sector and to estimate to what extent indigenous raw material could be utilised in 2010. The task force proposed the obligation to use biofuels as the primary measure. According to the task force, the share of biofuels in the road transport sector should be 1% in 2008, 2% in 2009 and 3% in 2010. The task force further states that it would theoretically be possible to achieve the target level of 5% by 2010, but 3% is realistic, considering biofuels availability, cost and costs. (Ministry of Trade and Industry, 2006a)

The proposed biofuels obligation would apply to all companies supplying transport fuels to the Finnish market. However, each supplier is free to decide how it will deliver the required biofuel percentage of all transport fuels supplied, and what biofuels it will use. The annual costs resulting from the obligation scheme in 2010 is estimated to total € 50–80 million, raising fuel prices by approximately € 3 c/l. Biofuels of domestic origin could represent about 2–3% of all transport fuel consumption in 2010 and, based on the exploitation of new technologies, up to 7–8% by 2020. However, according to the task force, it will not be possible to require that all of the needed biofuels be produced in Finland using raw materials of domestic origin. Suppliers may choose their range of biofuels on the market terms. (Ministry of Trade and Industry, 2006a)

## 7. Summary and conclusions

### 7.1 Summary

Biofuels have traditionally been used at local level and utilised close of the production area. The situation has begun to change as biofuels consumption has been on the increase. The markets of bioenergy at various levels are developing, and the international biofuels trade is growing strongly. In many countries, biomass is a relatively new fuel, but the consumption and markets of which in industrial scale applications are growing rapidly towards the international level. This study considered the current situation of biofuels markets in Finland and identified the challenges of emerging international biofuels markets.

The cold climate, low population density, energy-intensive structure of the industry and natural resources of the country affected the development of the Finnish energy system. The only notable indigenous energy resources are hydropower, wood, peat and wind energy. The fact that industry consumes more than half of the total primary energy, widely applied combined heat and power production and a high share of biofuels in the total energy consumption are specific to the Finnish energy system. One third of the electricity is generated in CHP plants and 27% of the total energy consumption is met by using wood and peat, which makes Finland the leading country in the use of bioenergy.

Finland has committed itself to maintain the greenhouse gas emissions at the 1990 level at the highest during the period 2008–2012. To meet this target, a National Climate Strategy was drafted during 1999–2001. The revised National Climate and Energy Strategy were finished in the end of 2005. According to a trend outlined in the strategy, the diversity of the Finnish energy system and the security of the energy supply will be preserved, or even improved. The volume of indigenous energy sources and their share of the total energy consumption will be increased during the period 2005–2025. Implementation of the energy and climate strategy calls for financial support measures. Technology R&D and the implementation of new technologies are the main measures in aiming for economically competitive solutions for the open energy market. Also, taxation, investment aids, regulations and norms support the accomplishment of the target.

Wood is the most important source of bioenergy in Finland representing 21% of the total energy consumption. Forestland covers almost 90% of country's land area, and the country's forest industry sector is extensive. Almost 80% of the wood-based energy is recovered from industrial by-products and residues. Due to the forest industry, black

liquor represents the largest source of wood energy. The forest industry is also the most important user of wood fuels, and almost 70% of wood fuels consumption takes place in the forest industry.

Biomass (raw material and fuels) is traded internationally in a variety of forms. The majority of international biomass trade takes place in another form than biofuels. Previous studies on international biofuels trade have mainly focused on the biomass streams that are used directly as fuels. In this study, the scope was broadened to include woody biomass streams used as raw material in the forest industry. At first, cross-border biomass streams in Finland in 2004 were studied by means of customs statistics. The statistics showed the largest biomass streams being composed of raw wood, which is used as raw material in the forest industry. Nevertheless, during the manufacturing processes of the primary products a remarkable part of the raw wood ends up in energy production or is converted into by-products that are utilised in energy production. As much as 45% of the raw wood imported into Finland ended up in energy production. The total international trade of biomass was evaluated at 72 PJ, of which the majority, 58 PJ, was traded with raw wood. About 22% of wood-based energy in Finland originated from imported raw wood. Tall oil and wood pellets comprised the largest export streams of biomass. The annual turnover of the international biofuels trade was estimated at €89 million for direct trade and at €190 million for indirect trade.

The annual raw wood consumption of the Finnish forest industry has almost doubled from 40 million m<sup>3</sup> to 74 million m<sup>3</sup> over the forty-year period 1965–2004. The annual sustainable volume of stem wood removals in Finland is currently 69 million m<sup>3</sup>. The realised commercial removals have been below the annual growth since the 1970s. In 2004, the total commercial stem wood removals were 55 million m<sup>3</sup>. The forest industry has supplemented a part of the increased wood demand by foreign raw wood and it has decades of experience of raw wood import. In 1965–2004, the annual raw wood import increased from 3 to 17.4 million m<sup>3</sup>. The structure of forest ownership, the production structure of the forest industry and the competitiveness of imported raw wood against indigenous round wood are factors behind the raw wood import. About 900 000 private non-industrial owners are in possession of almost 70% of the forest resources. This sets challenges for the wood procurement of the forest industry. Within the production structure of the forest industry, the consumption of deciduous pulpwood surpasses the current supply potential of indigenous forests, and currently more than half of the deciduous pulpwood consumed in the forest industry is imported. The fact that the taxation of fossil fuels in energy production or subsidies for electricity from biomass are higher in exporting countries compared to Finland has made the exportation of pellets and tall oil for energy production economical.

The development of international biofuels markets will continue, and changes can be anticipated in the balance of international biofuels trade in Finland. Imported raw wood has become an important source of bioenergy. The future development of raw wood import will have an influence on local biomass markets. The Finnish wood pellet industry has been founded on export, and currently more than three fourths of the wood pellet production is exported, but at the same time there is a large domestic usage potential to replace fossil fuels. The policy measures at different levels to promote the use of renewable energy sources in energy production are increasing the competition for biomass between the raw material and energy uses. In addition to national measures, the international trading of CO<sub>2</sub> emission allowances and the national energy policies in foreign countries affect the development of biofuels markets and the competition for wood between energy and raw material uses. Road transport is one of the sectors where the use of biofuels is required to increase. In Finland, there will be sufficient biomass resources for achieving the 5.75% target share for biofuel use in the road transport sector set by the EU directive. Nevertheless, the Finnish climate does not enable the competitive production of grain and rapeseed against the world market prices without remarkable agricultural subsidies and a significant share of biofuels for the road transportation sector, or raw materials for agricultural-crop-based ethanol or biodiesel production would possibly be imported to Finland in the future.

## **7.2 Conclusions**

In Finland, the biomass markets constitute a large and complicated system where wood plays a major role as the largest source of biomass. The forest industry as the most important user of wood, and the producer and user of wood fuels has an essential position in the biomass and biofuels markets in Finland. There has been for decades a strong international engagement in Finnish biofuels markets through raw wood import. In the present decade, international aspects have been emphasised as the import of raw wood and the export of wood pellets have increased. In coming years, the international trade of biomass for energy purposes can be expected to continue growing. The competition for wood will increase, as well. The rapid changes in energy policy measures can increase the paying capacity of the energy sector for biofuels and may have unforeseeable effects for other sector using biomass as raw material. These effects and their significance should be recognised before introducing new policy measures.

In this study, the status of international biofuels trade was evaluated based on the information available from different statistics complemented by several assumptions and information collected from market actors. Some products, such as tall oil, ethanol and peat, can be used for other purposes than as fuel, and this brings inaccuracy to the calculations. In addition, the definition of the scope of the study has affected the results.

Raw wood used in the forest industry was included the study, but forest products were excluded from the calculations of the biomass trade balance. If forest products had been included, the balance would have changed considerably. The trade streams of other bio-based products used in the food and fodder industry and wastes were excluded from the study, as their proportion in the Finnish energy balance was evaluated negligible.

The customs and energy statistics include a relatively vast amount of usable statistical information on international biomass trade in Finland. Finnish energy statistics include the export of wood pellets and fuel peat, and the volume of imported wood fuels in primary energy consumption. Nevertheless, the compilation of statistics on international biomass trade should be further developed to provide a better view of international biofuels trade. This study showed that the development of biofuels markets in neighbouring countries and on the European scale will have an effect on indigenous biofuels markets. Changing markets always open up possibilities, but present challenges, as well. An investigation of the effects on different sectors would help foresee and utilise the market possibilities and avoid the threats. In Finland, the indirect trade of biofuels is emphasised within the import of raw wood for the forest industry. International streams of wood and wood-based products and the indirect trade of biofuels have yet to be extensively studied and would offer interesting subjects for further research in order to learn more about biofuels markets.

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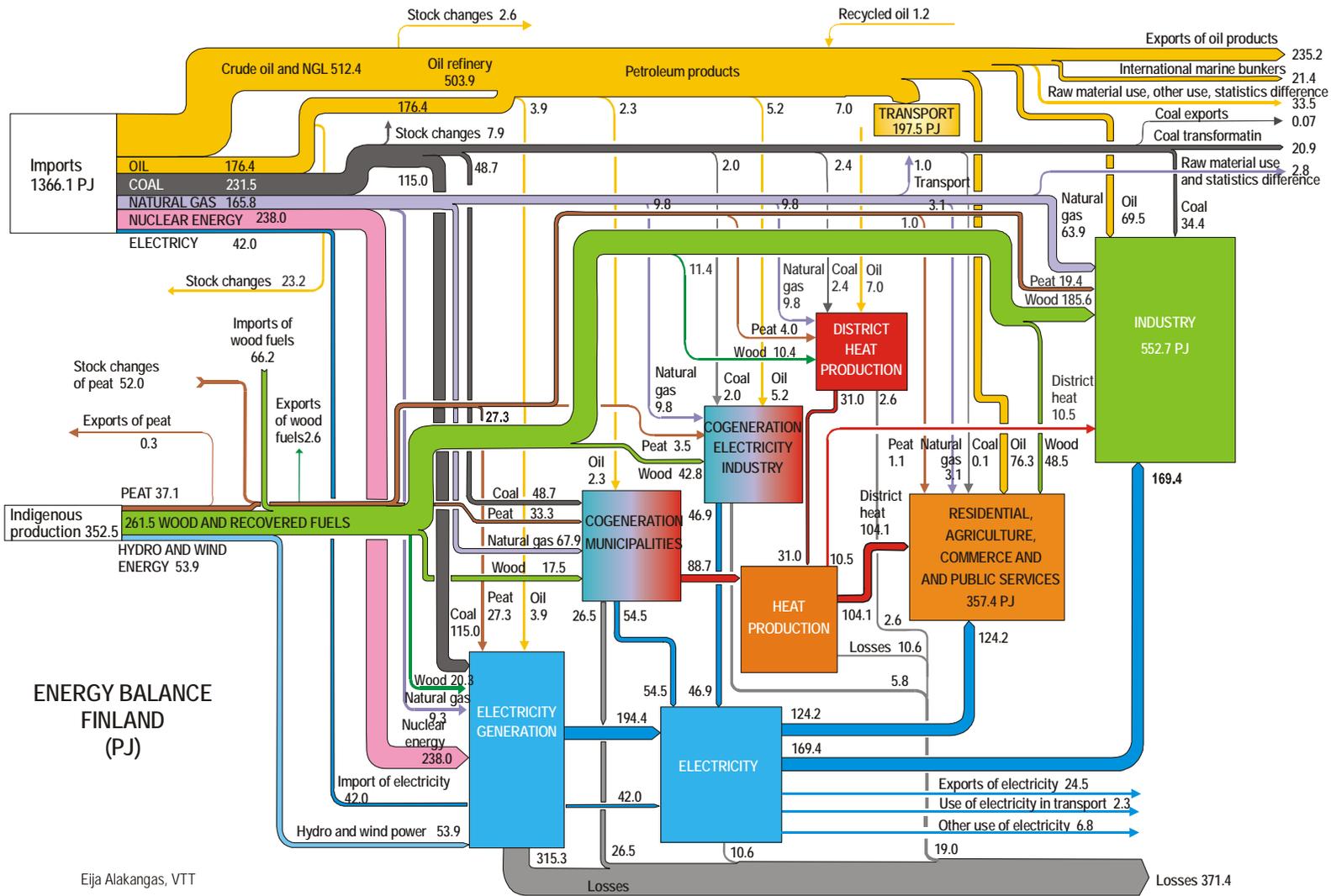
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# App. A. Energy balance in 2004





## **Solid and Liquid Biofuels Markets in Finland – a study on international biofuels trade IEA Bioenergy Task 40 and EUBIONET II**

This study considered the current situation of solid and liquid biofuels markets and international biofuels trade in Finland and identified the challenges of the emerging international biofuels markets for Finland. The fact that industry consumes more than half of the total primary energy, widely applied combined heat and power production (CHP) and a high share of biofuels in the total energy consumption are specific to the Finnish energy system. One third of the electricity is generated in CHP plants. As much as 27% of the total energy consumption is met by using wood and peat, which makes Finland the leading country in the use of biofuels. Finland has made a commitment to maintain greenhouse gas emissions at the 1990 level at the highest during the period 2008–2012. The Finnish energy policy aims to achieve the target, and a variety of measures are taken to promote the use of renewable energy sources and especially wood fuels.

In this study, the wooden raw material streams of the forest industry were included the international biofuels trade in addition to biomass streams that are traded for energy production. In 2004, as much as 45% of the raw wood imported into Finland ended up in energy production. The total international trading of biofuels was evaluated at 72 PJ, of which the majority, 58 PJ, was raw wood. About 22% of wood based energy in Finland originated from imported raw wood. Tall oil and wood pellets composed the largest export streams of biofuels. The annual turnover of international biofuels trade was estimated at about € 90 million for direct trade and at about € 190 million for indirect trade. The forest industry as the biggest user of wood, and the producer and user of wood fuels has a central position in biomass and biofuels markets in Finland. Lately, the international aspects of Finnish biofuels markets have been emphasised as the import of raw wood and the export of wood pellets have increased. Expanding the use of biofuels in the road transportation sector would increase the international streams of biofuels in Finland. In coming years, the international trading of biomass for energy purposes can be expected to continue growing.

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