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MARKET OF BIOMASS FUELS IN FINLAND

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Market of biomass fuels in Finland

IEA Bioenergy Task 40 and EUBIONET III - Country report of Finland 2009

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Abstract

This study considered the current situation of solid and liquid biomass fuels in Finland. 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 solid biomass fuels in the total energy consumption are specific to the Finnish energy system. Wood is the most important source of bioenergy in Finland, representing 20% of the total energy consumption in 2007. Almost 80% of the wood-based energy is recovered from industrial by-products and residues.

As a member of the European Union, Finland has committed itself to the Union's climate and energy targets, such as reducing its overall emissions of green house gases to at least 20% below 1990 levels by 2020, and increasing the share of renewable energy in the gross final consumption. The renewable energy target approved for Finland is 38%. The present National Climate and Energy Strategy was introduced in November 2008. The strategy covers climate and energy policy measures up to 2020, and in brief thereafter, up to 2050. In recent years, the actual emissions have exceeded the Kyoto commitment and the trend of emissions is on the increase. In 2007, the share of renewable energy in the gross final energy consumption was approximately 25% (360 PJ). Without new energy policy measures, the final consumption of renewable energy would increase to 380 PJ, which would be approximately only 31% of the final energy consumption. In addition, green house gas emissions would exceed the 1990 levels by 20%. Meeting the targets will need the adoption of more active energy policy measures in coming years.

The international trade of biomass fuels has a substantial importance for the utilisation of bioenergy in Finland. In 2007, the total international trading of solid and liquid biomass fuels was approximately 77 PJ, of which import was 62 PJ. Most of the import is indirect and takes place within the forest industry's raw wood imports. In 2007, as much as 21% of wood energy was based on foreign-origin wood. Wood pellets and tall oil form the majority of export streams of biomass fuels. The indirect import of wood fuels peaked in 2006 to 61 PJ. The foreseeable decline in raw wood import to Finland will decrease the indirect import of wood fuels. In 2004–2007, the direct trade of solid and liquid biomass fuels has been on a moderate growth path. In 2007, the import of palm oil and export of bio-diesel emerged, as a large, 170 000 t/yr biodiesel plant came into operation in Porvoo.

Foreword

The objective of the IEA Bioenergy Task 40 “Sustainable International Bioenergy Trade: securing supply and demand” is to support the development of sustainable international trade of bioenergy, recognising the diversity in resources and biomass applications. The Task aims to provide an outstanding international platform to make inventories of available information and experience, provide new analyses and set the agenda and initiate a host of new activities relevant for developing sustainable biomass markets and trade worldwide. In the year 2009, the countries participating in Task 40 collaboration were Austria, Belgium, Brazil, Canada, (The European Commission), Finland, Japan, Italy, Norway, Sweden, the Netherlands, the United Kingdom and the USA. In addition, several industrial parties and international organizations (such as FAO) are involved in the Task, providing a platform for its effective implementation.

The EUBIONET III project will in the long run boost sustainable, transparent international biomass fuel trade, secure the most cost efficient and value-adding use of biomass for energy and industry, boost investments on best practice technologies and new services on the biomass heat sector and enhance the sustainable and fair international trade of biomass fuels. The EUBIONET III project is coordinated by VTT and will run 2008–2011.

This report studies and summarises the current status of biomass fuels markets in Finland, being an update of the previous Task 40 and EUBIONET Finnish country reports published in 2006 and 2008. The co-authors of the report are Mr Jussi Heinimö from Lappeenranta University of Technology and Mrs Eija Alakangas from VTT.

Varkaus, August 2009 Jyväskylä, August 2009

Jussi Heinimö Eija Alakangas

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1. Introduction

Strivings to mitigate climate change and reduce CO_2 emissions are the most important factors driving the utilisation of renewable energy sources in energy production. Most industrialised countries have committed themselves to a significant decrease in green house gas emissions under the Kyoto Protocol. As renewable energy is not always competitive against fossil energy, renewable energy is commonly promoted by means of energy policy measures such as energy taxation and subsidies. Globally, biomass[1] is the most important source of renewable energy, covering currently about 10% of the total primary energy consumption [1]. Often, biomass is the most competitive option to increase the use of renewable energy sources. During the coming decades, biomass has the option to become a more important source of energy in many parts of the world. In several areas, existing biomass resources are underutilised and in many areas have the potential for a remarkable increase in the production of biomass for energy purposes. Biomass has traditionally been utilised at a local level close to the production area. The situation has begun to change, as biomass consumption has been on the increase in industrial applications within the heat, power and road transport sectors. The markets of industrially used biomass for energy purposes are developing towards international commodity markets – wood pellets and fuel ethanol being examples.

Finland has long-standing traditions in the utilisation of biomass in energy production, and bioenergy[2] plays an important role in the Finnish energy system. The country is one of the world's largest importers of raw wood; consequently a significant proportion of biomass fuels[3] produced and consumed in the forest industry physically originates from abroad. Finland is also a significant exporter of wood pellets. The export and import volumes of biomass fuels in Finland have previously been investigated in 2005–2006, when an extensive study was carried out for determining import and export volumes of biomass fuels and investigating the challenges related to the issue [2, 3]. In this paper, the previous analysis of the Finnish situation regarding markets and international trade of biomass fuels is updated. The most recent data that was available dates back to halfway through the year 2009. The report is a part of the Finnish contribution to Task 40 collaboration and EUBIONET III.

The structure of this paper is as follows. Section 2 gives an overview of the role of bioenergy in the Finnish energy system. Section 3 describes the Finnish energy policy and policy measures on bioenergy. Section 4 discusses biomass fuels in indigenous markets. Section 5 focuses on the international biomass fuels trade. The most important biomass fuels import and export streams are reviewed in Section 6. The summary and conclusions of the paper are presented in Section 7.

[1] This refers to the biodegradable fraction of products, wastes, and residues from agriculture (including vegetable and animal substances) and forestry and related industries, as well as the biodegradable fraction of industrial and municipal waste.
[2] This refers to energy derived from biomass fuel.
[3] Fuels produced directly or indirectly from biomass. The biofuel may have undergone mechanical, chemical, or biological processing or conversion or may have had a previous use. The term refers to solid, gaseous, and liquid biomass-derived fuels.

2. Biomass fuels in the Finnish energy system

2.1 Energy demand and energy sources

Finland is a large and sparsely populated state: with a total area of 33.8 million ha, it is the fifth largest country in Europe and is located between 60 and 70 degrees northern latitude (Figure 1). Finland has a population of 5.3 million, i.e. 17.5 people per square kilometre[4]. Forestry land covers 87% of the country's land area (30.4 million ha), only 9% (2.8 million ha) is used for agriculture and the remaining 4% consists of housing and urban development and transport routes. The relatively cold climate, low population density, structure of industry and natural resources of the country are factors that have affected the development of the Finnish energy system. These factors, caused mainly by natural conditions, are increasing the energy demand.

Figure 1. Location of Finland.

Imported fossil fuels – oil, coal, and natural gas – have a major role as a primary energy source in the Finnish energy system, accounting for almost 50% of the total primary energy supply (Figure 2) [4]. The only significant indigenous energy resources in the country are wood, peat[5], hydropower, and wind energy. In 2007, renewable energy sources accounted for 25% (364 PJ) of all energy consumption (1 470 PJ), which was the third highest proportion in the EU [4, 6].

[4] Population density counted for land area.
[5] In Finland, peat has been defined as a slowly renewing biomass fuel [5]. It is not considered a renewable energy source in official statistics and in greenhouse gas accounting.

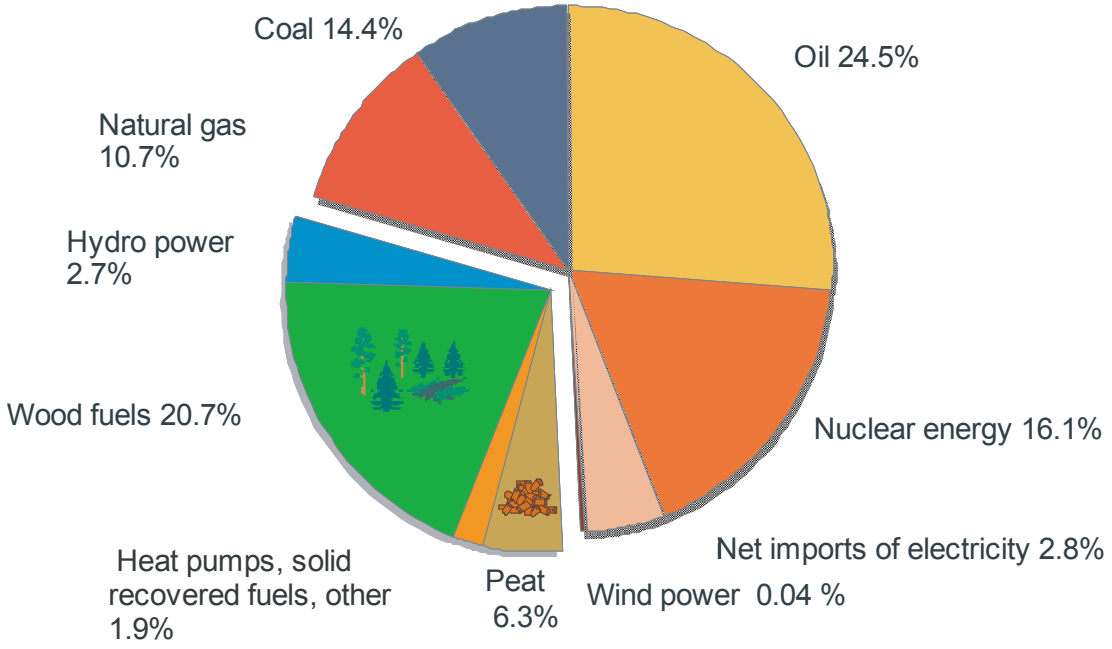

Figure 2. Primary energy sources in Finland in 2007. (The total use of primary energy in 2007 was 1 470 PJ). [4]

In Finland, primary energy consumption per capita is high, 300 MJ/capita in 2006 [4]. For comparison, in the same year the corresponding figure for the EU-27 countries was 154 MJ/capita [4]. The cold climate, long distances, high standard of living and energy intensive structure of industry are factors that result in high specific energy consumption. In Finland, industry consumes nearly half of all energy (Figure 3), which is the highest proportion among the OECD countries [7].

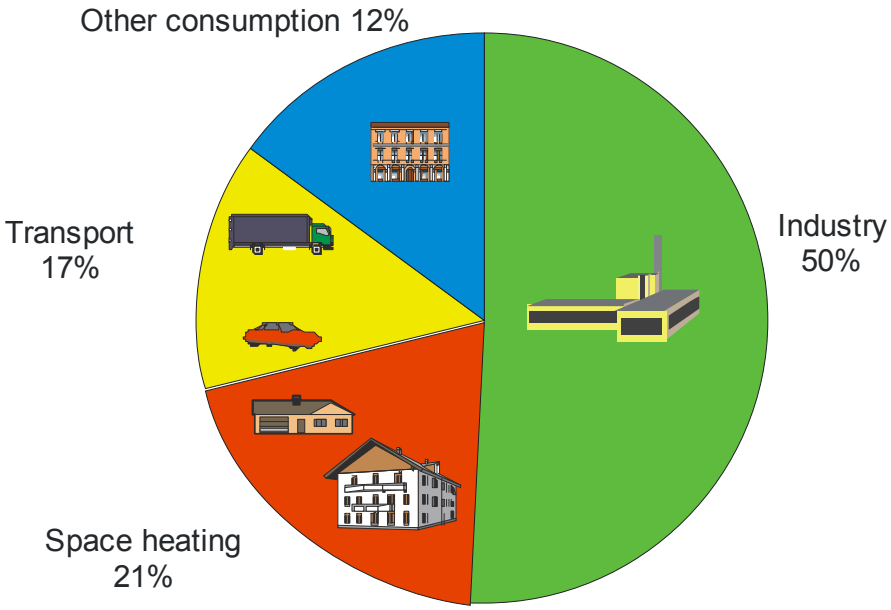

Figure 3. Final energy consumption by sector in Finland in 2007. (Total 1 132 PJ) [4]. Final energy consumption does not include losses of electricity and heat generation and fuel refining.

Wood together with fuel peat are the most important sources of bioenergy in Finland. The use of other biomass fuels, including agrobiomass, biogas, the biodegradable fraction of solid recovered fuels and liquid biomass in the road transportation sector, is negligible compared to wood and peat use (Table 1) [4].

Table 1. The consumption of biomass fuels in Finland in 2007. Data obtained from [4].

Fuel	Use in 2007 (PJ)	Share
Wood fuels:		
▪ Black liquor [a]	153.1	37.8%
▪ Solid wood processing industry by-products and residues [b]	73.5	18.2%
▪ Firewood	44.8	11.1%
▪ Forest fuels (forest chips)	21.9	5.4%
▪ Wood pellets	2.0	0.5%
▪ Wood fuels in total	295.3	72.9%
Biogas	1.7	0.4%
Solid recovered fuels (biodegradable fraction)	4.6	1.1%
Other bioenergy [c]	0.9	0.2%
Biomass fuels in road transport sector	0.1	0.0%
Fuel peat	102.3	25.3%
In total	404.9	100.0%

[a] Black liquor is a by-product from the wood pulp making process and contains non-fibrous wood matter and cooking chemicals. Energy production from black liquor is a solid part of the pulp making process.
[b] Includes bark, sawdust, wood residue chips and all other wood fuels excluded from other rows.
[c] Includes plant-derived and animal derived products (e.g. agricultural biomass and liquid biofuels).

2.2 Past development of biomass fuels use

The consumption of wood fuels and fuel peat has been on the increase during the past three decades (Figure 4). Until the second half of the 1970s, traditional firewood was the most important wood fuel. Since then, the use of wood fuels in heating and power plants has increased. The oil price shocks in the 1970s were a significant incentive for developing the energy use of peat. Finland is one of the leading countries together with Sweden and Ireland in the utilisation of fuel peat [8]. The main reason for the success of biomass fuels has been the positive development of the forest industry sector. During the past decades, there has been an increasing trend in the production of the forest industry, but the volumes of black liquor and solid by-products (bark, sawdust, industrial chips) vary annually according to the rate of forest industry production. E.g. in 2005, a several weeks' stoppage in the pulp and paper industry resulting from an industrial auction decreased the production of the forest industry and affected the use of biomass fuels. Biomass has become a more popular fuel in the district heating sector. It has been estimated that during the years 1997–2010 more than 100 heating and CHP plants including 860 MW_e of new additional capacity for electricity production from solid wood and peat fuels will be introduced [9]. In almost every case, peat and solid wood fuels are burnt in multi-fuel boilers designed for moist and varying quality fuels.

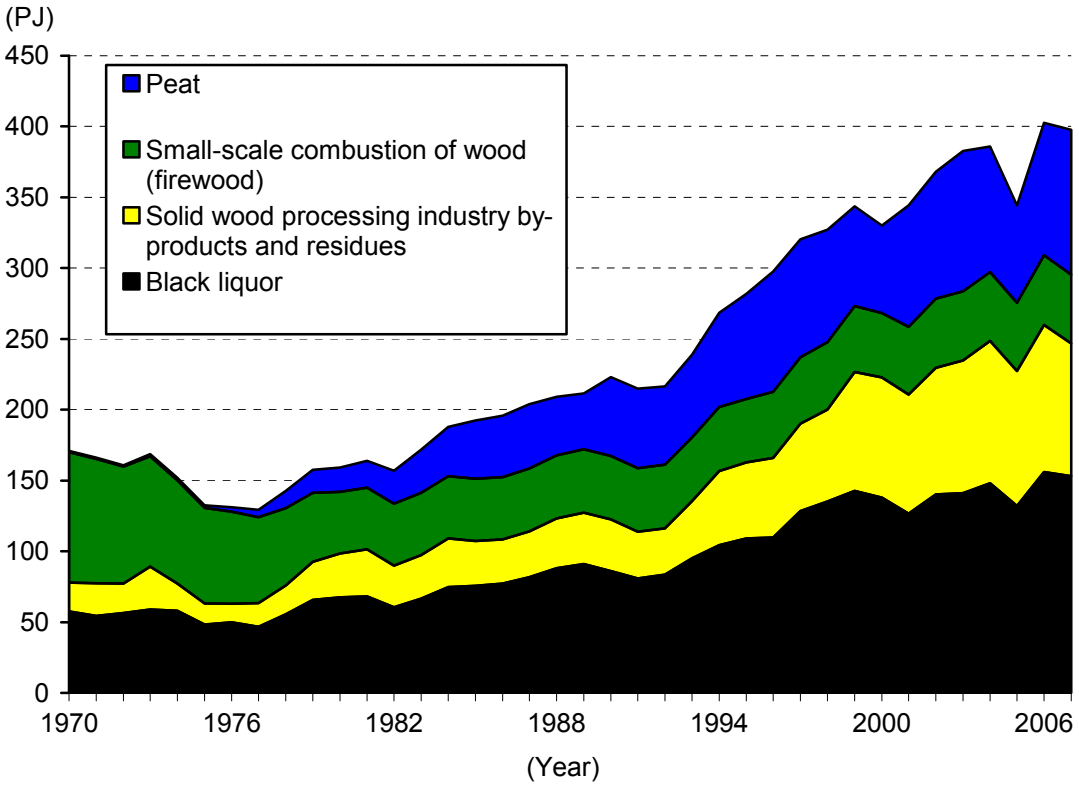

Figure 4. Consumption of wood fuels and peat in Finland in 1970 – 2007. Forest fuels consumed in heating and power plants are included in industrial wood residues and by-products[4].

3. Energy policy targets and measures

3.1 Commitments and goals

One of the goals of the Finnish energy and climate policy is to fulfil the international climate and environment commitments most crucial for the mitigation of green house gas emissions and for increasing the share of renewable energy sources in final energy consumption. In the Kyoto Protocol, as an EU member state Finland has committed itself to maintaining greenhouse gas emissions at the 1990 level, at the highest, during the period 2008–2012. In December 2008, the European Parliament and Council reached an agreement on a package with a target to reduce the Union's overall emissions of green house gases to at least 20% below the 1990 levels by 2020 [10]. Furthermore, the EU is ready to scale up this reduction to as much as 30% under a new global climate change agreement when other developed countries make comparable efforts. It has also set itself the target of increasing the share of renewable energy in the gross final consumption of energy to 20% by 2020. An increase in biofuels use in transport fuel consumption is included in the overall EU objective. The directive on the promotion of the use of energy from renewable sources (Renewable Energy Directive) is an essential part of the package. The directive establishes a common framework for the promotion of energy from renewable sources. It sets mandatory national targets for the overall share of energy from renewable sources in the gross final consumption of energy and for the share of energy from renewable sources in transport in 2020. The renewable energy target approved for Finland is 38%. [10]

In recent years, the actual emissions have exceeded the Kyoto commitment and the trend of emissions is on the increase (Figure 5). In 2007, the share of renewable energy in the gross final energy consumption was approximately 25% (360 PJ) [11]. Meeting the targets will need more active energy policy measures in coming years.

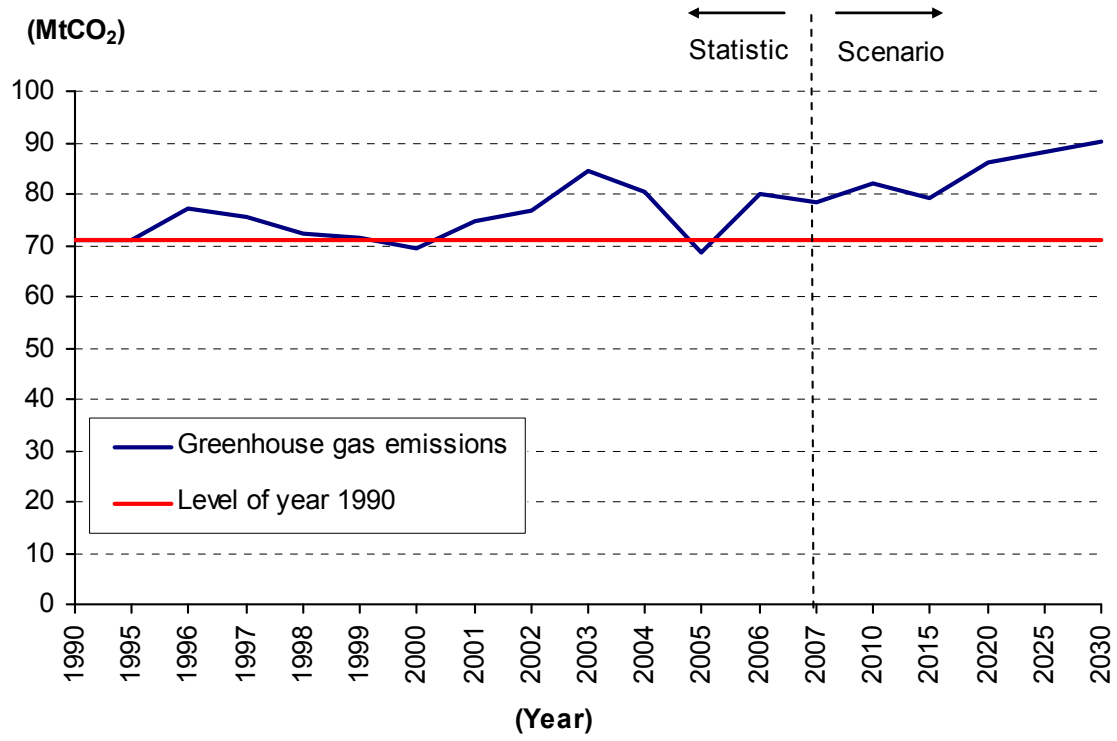

Figure 5. The realised greenhouse gas emissions in Finland and a scenario until the year 2030 compared to the 1990 level. Carbon sinks are not included in the figures. The scenario was compiled in 2008 and shows the trend with no new measures taken in climate policy. [11, 12]

The energy and climate policy carried out in Finland in recent years has been based on the strategies introduced in 2001, 2005 and 2008. The latest strategy was accepted by the Government in November 2008. This strategy covers climate and energy policy measures in great detail up to 2020, and in brief thereafter, up to 2050. According to the strategy, without new energy policy measures (baseline), the consumption of primary energy would increase from approximately 1 400 PJ to approximately 1 700 PJ in 2020. In the same period, final energy consumption would increase from circa 1 000 PJ to circa 1 300 PJ. According to the baseline scenario, the final consumption of renewable energy would increase to 380 PJ, which would be approximately only 31% of final energy consumption. By 2050, the total consumption of energy will increase further and, without new measures influencing consumption, consumption will be approximately one quarter higher in that year than at present. Greenhouse gas emissions would increase by as much as 30%. [12]

The objectives of the Climate and Energy Strategy are similar to those of the EU's strategy: environmental sustainability, security of supply, and competitiveness of the energy supply. The strategic objectives of the strategy for meeting the international commitments are halting and reversing the growth in final energy consumption so that, in 2020, final energy consumption will be approximately 1 100 PJ, i.e. over 10% less than the baseline. The longer-term vision entails a further decrease of at least one third of the 2020 quantity in final energy consumption by 2050. [12]

According to the strategy, the attainment of the 38% renewable energy target fundamentally depends on having final energy consumption enter a downward trend. Finland's natural resources would facilitate the additional use of renewable energy, but in order to realise this, the current subsidy and steering systems must be rendered more effective, and structures changed. Meeting the renewable energy target would require an intense increase in the use of wood-based energy, waste fuels, heat pumps, biogas and wind energy. As a new promotional method, a cost-effective feed-in tariff system, operating on market terms as far as possible, will be introduced. [12]

Finland is preparing itself to meet the objectives set for renewable energy through its own measures, without the flexibility mechanisms between member states as planned for in the Directive. Under the current notion, flexibility mechanisms will be based on voluntary cooperation between the member states so that they will have control over the use of those flexibility mechanisms. If necessary, Finland can utilise flexibility mechanisms. [12]

The starting point for our electricity sourcing is access to sufficient and moderately priced electricity with good security of supply, so that electricity sourcing simultaneously supports other climate and energy policy goals. The high share of the energy-intensive industry, and the long lighting and heating season are characteristic of our electricity consumption structure. In the construction of the power generation capacity, priority will be given to plants that do not emit greenhouse gases, or ones with low emissions, such as combined power and heat plants using renewable fuels, and financially profitable and environmentally acceptable hydro and wind power plants. Furthermore, Finland prepares for constructing additional nuclear power. [12]

3.2 Present measures to implement the energy policy

The Government have employed funding of research and development projects, energy taxation, tax relief, production subsidies for electricity and forest chips and investment subsidies as financial measures to implement the energy policy. During 2007 and 2008, two new measures were introduced: the feed-in tariff for peat condensing power in spring 2007 and the obligation to supply biomass fuels to the transport markets at the beginning of 2008.

Generally, the Finnish financial incentives to utilise biomass in energy production are at quite a moderate level compared to some other EU countries that apply considerably stronger financial measures. In addition, the support system of bioenergy has been almost constant for several years.

Research and development

The competitiveness of renewable energy sources is promoted through investment in long-term technology research and development. Obstacles to getting the R&D findings and results onto the market will be lowered by supporting projects aimed at the commercialisation 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 sustainable development solutions, are in the strategic focus of Tekes. Various national programmes and projects have involved RES technologies, the main focus being on bioenergy. Tekes funding for bioenergy research and demonstration amounted to some € 24 million in 2007, which was € 10 million more than in the previous year [13]. The total funding for renewable energy and climate change technology has grew from € 62 million in 2006 to € 118 million in 2007 [13]. According to the new Climate and Energy Strategy, research and innovation activities will be in a pivotal role for achieving the targets of the strategy. The public resources for basic research and the development, introduction and commercialisation of new technologies and innovations will be will be doubled from the current level by the year 2020 [12].

Energy taxation and tax relief

Taxation is one of the main instruments related to climate change and the environmental policy (Table 2). In Finland, a carbon based environment tax for fossil fuels has been imposed since 1990. In heat generation, solid biomass fuels are not taxed. Fossil fuels have a tax which is based on the carbon content of the fuel. Fuels used for electricity generation are not taxed, but an electricity tax is imposed on the consumption of electricity. In CHP, 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. Unlike in some other countries, industry in Finland is not entitled to deduct the carbon/energy tax, but has a lower electricity tax than private consumers and the public sector. In Finland, energy taxes have slightly risen at the beginning of 2008. [14, 15]

Table 2. Energy taxes as of 1 January 2008 [14, 15]

Product	Unit	Excise tax	Security of supply fee	Total Tax
Motor petrol [a]	€ c/l	62.02	0.68	62.70
Diesel oil [b]	€ c/l	36.05	0.35	36.40
Light fuel oil	€ c/l	8.35	0.35	8.70
Heavy fuel oil	€ c/l	6.42	0.28	6.70
Coal	€/t	49.32	1.18	50.50
Natural gas	€/MWh	2.016	0.084	2.10
Fuel peat	€/MWh	0	0	0
Tall oil	€ c/kg	6.7	0	6.7
Electricity				
- class I [c]	€ c/kWh	0.87	0.013	0.883
- class II [d]	€ c/kWh	0.25	0.013	0.263

[a] *Reformulated sulphur free*
[b] *Sulphur free*
[c] *Other consumers*
[d] *Industry*

Production subsidies for electricity

The production subsidies for renewable electricity were revised in 2006 because the start of emission trading has made the operating environment more favourable for renewable energy sources. Since the beginning of 2007, the aid for electricity produced from wood and fuel timber products was abolished, except for electricity produced from forest chips (Table 3).

Table 3. Subsidies for electricity production since the start of 2007 [14].

Source of energy	Production subsidy of electricity, (€ c/kWh)
Wind	0.69
Biogas	0.40
Forest chips	0.69
Recovered fuel	0.25

Feed-in tariff for peat condensing power

The act on the feed-in tariff for electricity produced from fuel peat in large, over 120 MVA condensing power plants came into force at the beginning of May 2007 [16]. The purpose of the Act is to give priority in the running order of power plants in the Finnish power system to condensing power plants which are fuelled by domestic fuel peat over condensing power plants which use coal, natural gas and fuel oil. In practice, the feed-in tariff covers four large power plants using fuel peat. In the feed-in tariff system, an additional price for electricity fed into the grid is defined twice a year. The additional price depends on the market prices of coal, CO_2 emission allowances and energy peat. It is paid to peat electricity producers and is collected from the customers of the national main grid company. In 2007, the realised feed-in tariff was approximately € 1.2 per MWh, and about 1 200 GWh of peat electricity was eligible for the feed-in tariff. [17]

Investments 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 new Government 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 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 2007, in total € 30.7 million was available for energy supports. The figure includes € 0.5 million in grants from the European Regional Development Fund. The volume of energy support was about € 4 million lower than in the previous year. [13]

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 [18]. The Ministry of Agriculture and Forestry pays support in accordance with the law on forestry financing for the harvesting and forestry transport of timber sold for fuel as part of the management of young plantations. The aid for harvesting fuel wood is € 7 per solid cubic meter. Support of € 1.7 per loose m^3 may be obtained for chipping fuel timber. In 2007, a total of € 5.7 million was spent on fuel timber harvesting and chipping support. [13]

Obligation to distribute biofuels to the transport market

For the year 2010, the Finnish Government has fixed a national target of 5.75% for biofuels used in power road traffic. This objective will be achieved by the distribution requirement laid down in a law that has entered into force on 1 January 2008. The law obliges distributors of transport fuels to supply a minimum volume of biofuels annually for consumption. This minimum volume increases year-on-year so that in 2008 it will be at least 2% of the total energy content of biofuels, petrol and diesel supplied for consumption by a fuel distributor. In 2009, this share will be at least 4% and in 2010 and subsequent years it will be at least 5.75%. So, the obligation satisfies the reference figure for 2010 in Directive 2003/30/EC. [13]

The obligation system is meant to be flexible for distributors, with a view to optimum cost-efficiency. The obligation relates solely to the total quantity of biofuels, so the distributors can themselves meet their obligation by introducing biofuels to replace petrol or diesel at a ratio of their choosing, within the limits of quality standards. The law does not regulate the origin of the biofuels. Distributors may transfer all or part of their obligation to another company on a contractual basis. Irrespective of contracts, all distributors are accountable to the Government for meeting their obligation, either on their own account or through a third party. If a distributor fails to meet his or her obligation, the customs authorities will impose a fine. [19]

4. Indigenous markets of biomass fuels

4.1 Wood and peat fuels

Wood and peat covers over 95% of the biomass fuels use in Finland. The energy use of wood and peat in different sectors in Finland in the year 2007 is summarised in Table 4. The forest industry represents the largest producer of wood fuels, but the industry is also a major user of wood fuels. Almost two thirds of wood fuels use takes place in the forest industry. Wood is the most important fuel at forest industry mills, accounting for about 75% of their fuel consumption [20]. 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.

Table 4. End use of wood and peat by end user groups in 2007, in PJ.

Fuel / End use sector	Forest industry	District heating	Small-scale use [c]	Other industry & users	Total
Black liquor	153.1	0	0	0	153.1 [4]
Solid wood processing industry by-products and residues [b]	37.6	14.5	0	21.4	73.5
Firewood	0	0	44.8	0	44.8 [4]
Forest fuels [a]	6.3 [21]	8.8 [22]	2.8 [4]	4.0	21.9 [4]
Wood pellets [d]		0.5	1.0	0.5	2.0
Total wood	197.0 [20]	23.8 [4]	48.6 [4]	25.9	295.3 [4]
Fuel peat	13.0 [20]	42.3 [4]	1.1 [4]	45.9	102.3 [4]

[a] *Excludes firewood.*
[b] *Includes bark, sawdust, industrial chips, briquettes, recovered wood and all other wood fuels excluded from the other columns.*
[c] *Includes the use of forest chips by farms and detached house properties.*
[d] *Data obtained from [4]. The consumption of wood pellets between district heating and other users is an estimate by the author.*

The first district heating networks in Finland were built in the 1950s, and district heating has become the most important heating form in space heating, covering currently half of the net effective heating energy of buildings [4]. District heating networks cover, in practice, all towns and larger densely populated areas, and the potential to construct new networks is limited. As in the forest industry, combined heat and power (CHP) production is widely applied in district heat production. CHP based heat production composed 72% of the total district heat production in 2007 [4]. The imported fossil fuels natural gas (34%) and coal (25%) are the main fuels in the district heating sector [4]. The natural gas grid covers the southern part of the country, and gas comes from Russia. In the Helsinki metropolitan area and in the largest cities close to the coast, district heat production has been based on natural gas and coal. Peat and wood fuels are more commonly used inland, and they had 21% and 12% shares in 2006, respectively [4].

Firewood has always been an important fuel in the heating of buildings in Finland. The consumption and the importance of firewood as a heating source declined towards the 1970s due to the introduction of modern heating sources such as oil, electricity and district heating. Since the 1980s, the consumption of firewood has been on a moderate increase. At present, wood stoves and fireplaces are commonly used as auxiliary heat sources in detached houses. About 60% of single-family houses use wood for heating. [23]. Most wood fuels for small-scale heating systems are burnt in stoves that are used as an auxiliary heat source. Efficient heat-retaining stoves have become very popular in the past few years, and they are currently the most common

type of stoves. In Finland, the total number of stoves and fireplaces for firewood is 2.9 million according RTS Tutkimus Oy, of which 1.55 million situated in single-family houses [24]. Wood is commonly used as the main fuel in central house heating systems in farms and larger buildings in sparsely populated areas, and according top Statistics Finland about 250 000 systems of this kind exist in the country. Most of the systems use wood chips and split logs, whereas wood pellets are burnt in approximately 20 000 boilers [25]. Use of wood logs were 4.9 million solid m^3, wood chips 0.5 million solid m^3 and wood residues 1.3 million solid m^3 in 2007 in single-family houses [26].

4.2 Biofuels in the road transport sector

The annual total fuel consumption of the road transport sector has increased moderately in past years (Table 5). The consumption of gasoline has remained constant, but instead, the consumption of diesel fuel has increased. The consumption of biolfuels has been negligible. In 2002–2004, the consumption of biofuels was based on fixed term pilot projects where bio-ethanol was used in blends with gasoline. In addition, small-scale trials on the production of bio-diesel and biogas for use as a transportation fuel have also been carried out [27]. After these projects, the consumption of biofuels dropped to zero in 2005. In spring 2006, Finland's largest seller of transport fuels, Neste Oil, began selling E98 grade petrol that was blended with 2–5% ethanol in Southern and Central Finland [19]. In 2007, the share of bio-ethanol in biofuels consumption was over 90%. Achieving the 5.75% target share set for biofuels in road transport in 2010 will require approximately a 10 PJ annual use of biofuels.

Table 5. Fuels consumption in road transport in 2000–2004 and the proportion of liquid biofuels. [4]

	Fuels in road transportation, total	Gasoline	Diesel fuel	Liquid biofuels	
(Year)	(PJ)	(PJ)	(PJ)	(PJ)	(%)
2000	153	76	77	0	0
2001	156	77	78	0	0
2002	159	79	80	0.033	0.02
2003	161	79	82	0.176	0.1
2004	166	80	86	0.186	0.1
2005	167	80	86	0	0
2006	169	80	89	0.034	0.02
2007	174	80	94	0.076	0.04

Despite the insignificant domestic consumption of biofuels in road transportation, the production of transport biofuels has been on the increase over the past years. In 2004, Neste Oil started the production of ETBE[6] at its Porvoo refinery. The ETBE plant's production capacity is 100 000 tons per year. The ethanol contained in ETBE is imported from Brazil and the end-product is mixed with petrol for export. Furthermore, Neste Oil has developed a technology to produce high quality bio-diesel, equivalent to good-quality fossil diesel from tri-glycerides (vegetable oils and animal fats). The first large-scale, 170 000 ton (approximately 7 PJ) per year biodiesel plant based on the above mentioned technology entered into production in Porvoo in 2007. A second

[6] Bio-ETBE (ethyl-tertio-butyl-ether) is an additive that enhances the octane rating of petrol (replacing lead and benzene in unleaded petrol) and reduces emissions. ETBE is produced by combining bio-ethanol and fossil isobutylene.

similar plant will be ready at the end of 2009. During 2008–2011, Neste Oil will construct two large biodiesel plants abroad: a 500 000 t/yr plant in Singapore and a 800 000 t/yr plant in Rotterdam. [19, 28]

In 2007, the St1 oil company introduced the production of fuel-ethanol from wood industry waste, scrap and by-product flows based on its Ethanolix concept. In the Ethanolix concept, a number of small-scale ethanol plants (capacity of 1–2 million litres per year) are located alongside raw material sources and produce 85% ethanol that is transported to a centralised dehydration plant that produces 99.8% ethanol. The two first Etanolix plants are located in Lappeenranta and Närpiö and the next two plants will be taken into operation in Vantaa and Lahti during the year 2009. The dehydration plant opened in 2008 in Hamina. The plant's capacity is 44 million litres of 99.8% ethanol a year, which will be blended with petrol. [13, 29]

Ongoing intensive development work aims to commercialise second generation transport biofuel production technology. Neste Oil and the forest industry company Stora Enso have established the joint venture NSE Biofuels with the purpose of building an industrial pilot plant at the Stora Enso Varkaus mills. The plant will be ready in 2009 (Figure 6). The idea is to produce raw biodiesel from woody biomass at the trial plant, and then process it into commercial fuel at the Neste Oil Porvoo refinery. [19] Another forest industry company, UPM, has announced that it will focus strongly on second generation bio-diesel and that it intends to become a remarkable second-generation biofuel producer. UPM collaborates with Carbona, a subsidiary of the Andritz group, on the development of technology for biomass gasification and synthetic gas purification. [30] Furthermore, the Vapo group, the largest peat producer company in Finland, is targeting for the production of second generation bio-diesel from peat and wood and has launched a separate development project [31]

Figure 6. NSE Biofuels' demo plant under construction at the Stora Enso Varkaus mills. (Photo Stora Enso)

4.3 Potential to produce biomass for energy

The total volume of forestry industry by-products depends directly on the production rate of forest products. Energy production from black liquor is a solid part of the chemical pulping process, and black liquor has no alternative use. Solid by-products consist of pulp chips, bark, sawdust and industrial chips, and they are utilised both as raw material and in energy production. Pulp chips as a whole and a part of sawdust are utilised as raw material in pulp mills. Sawdust is also the primary raw material for particleboard and fibreboard mills. The rest of the solid by-products are used in energy production. It has been estimated that the wood use and production of the forest industry in Finland will decrease about 25% by 2015 from to the prevailing level in 2007 [32]. Correspondingly, the volume of the forest industry by-products available for energy purposes would decrease. In addition, the estimated increase in pellet production will redirect a part of the sawdust stream from power and heating plants to pellet factories [33].

Forest chips from logging residues, stump and root wood and small-diameter energy wood constitute a large and underutilised biomass fuel potential, and the largest share of the future growth of biomass fuels production will consist of forest chips.

Agrobiomass and biogas have had minor importance as biomass fuels and there is some potential to increase their use, but not on the same scale as forest chips. The outlook of agrobiomass utilisation for energy purposes depends largely on the agricultural policy and the future use of agricultural land. The productivity of agricultural land is weak due the cold climate.

Peat is internationally a poorly known fuel, but it has a significant role in the Finnish energy system. The climate and natural geography create favourable conditions for peat growing in Finland. The Geological Survey of Finland has estimated the employable energy reserve of peat at 48 EJ and the area suitable for peat production purposes about 1.2 million ha [34]. Approximately 60 000 ha is utilised annually for fuel peat production [33]. The upcoming consumption of energy peat depends on the development of the prices of emission trade, and policy measures will be needed to maintain the use of peat at its current level.

The current use, production potential and estimated use of major biomass fuels are compared in Table 6. The production potentials indicated in the table are based on various studies, and they indicate technical, and in some cases techno-economical, production potentials where several factors that constrain the production possibilities were taken into account. The production of forest industry residues and by-products depends directly on the realising production of forest industry. The production potentials for firewood, agricultural biomass and biofuels in the road transport sector were not available in the literature. The lowest limit of the range presents the anticipated use of biomass fuels in the year 2015 if energy subsidies and taxation remain equal to those in 2009. The upper limit represents a realistic consumption of biomass fuels in 2015, which could be achieved by a more intensive application of energy policy measures. In the worst case, during the next years the use of wood fuels may decline, resulting mainly from the decrease of wood use and production in the forest industry.

Table 6. The current use, production potential and prospective use of the most important biomass fuels in Finland.

Fuel	Use in 2007 [4] (PJ)	Production potential (PJ/yr)	Estimated use in 2015, (PJ/yr)
Black liquor	153.0	-	111-140[a]
Solid processing industry by-products and residues	73.5	-	61-79[b]
Forest fuels (forest chips)	21.9	80-140[c]	51-71[d]
Firewood	44.8	50 [e]	43-47 [12]
Wood pellets	2.0	9-27[f]	2-7[g]
Biogas	1.7	8-64 [35]	2-8 [35]
Agricultural biomass	0.9[h]	54[i]	1-6[g]
Biofuels in road transport sector	0.1	-	16[j]
Fuel peat	102.5	-	72-86 [12]
In total	395.0	-	359-460

[a] The lower value is an estimate by the authors, resulting from a decrease anticipated in the production of the forest industry [32]. The upper value is an estimate presented in the Finnish Climate and Energy Strategy 2008 [12].
[b] The lower value is based on the assumption that sawdust is almost entirely used as a raw material of pulp and pellet mills [36]. The upper value is from [12]
[c] The theoretical maximum production potential was evaluated at 45 million solid-m^3 (324 PJ) [37]. The range is based on studies by Hakkila, 2004, Karjalainen et. al., 2004, and Ranta et al., 2005 [37-39].
[d] Estimated by the authors based on scenarios presented in [12, 40]
[e] Source: VTT / EUBIONET III project.
[f] This equals 0.55-1.5 Mt/yr pellet production. The lower limit is a production target of the Finnish pellet energy association for the year 2010 [41]. The upper limit was taken from [35] and is based on the estimate that almost all sawdust currently utilised as fuel outside sawmills is addressed for pellet production and in addition bark and agrobiomass is utilised to some extent in pellet production.
[g] The values are estimated by the authors based on estimated and targeted use (baseline and target volume) of pellets and agricultural biomass for the year 2020 presented in [12].
[h] Includes also animal derived biomass.
[i] The figure is from [35] and is 50% of the theoretical maximum potential.
[j] The EU biofuel directive (2003/30/EY) set the indicative target 5.75% for the proportion of biofuels used in road transportation in 2010, which would mean 9-10 PJ consumption of biofuels in road transportation. The corresponding 10% target for the year 2020 of the EU's Renewable Energy directive would mean approximately 22 PJ consumption of biofuels.

4.4 Prices of biomass fuels

Fuels used in the production of electricity are exempt from energy taxes, whereas in heat production taxes are levied on some fuels. In heat production, fossil fuels and tall oil are taxed and the total prices of the fuels consist of market prices and taxes. The 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. Wood pellets are less expensive than fuel oils, but are not competitive against coal in heat production (Figure 7). In a longer 15-year period, the price development of indigenous fuels (wood and peat) has been moderate and stable compared to prices of fossil fuels, which have fluctuated remarkably mainly due to world market prices.

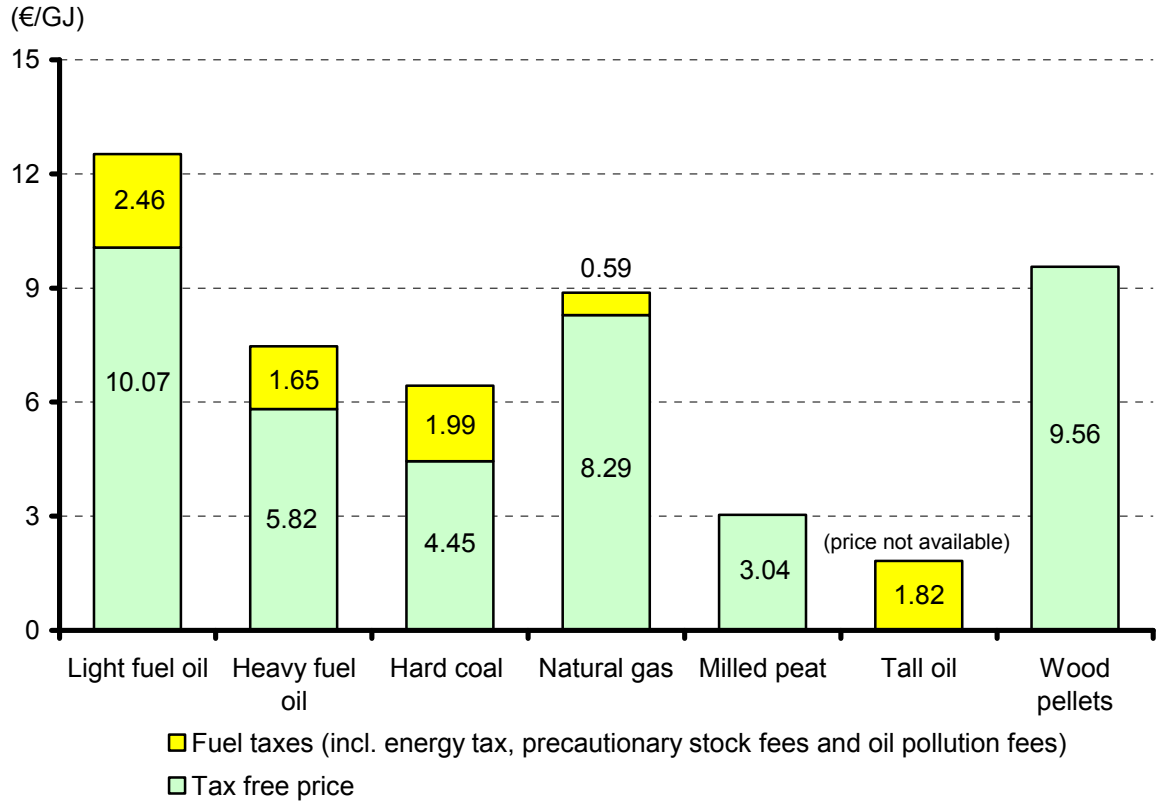

Figure 7. Fuel prices in heat production in December 2008 [42, 43]. The price of tall oil was not available.

In Finland, woody 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 biomass fuel potential. Increasing the use of forest fuels in heating and power plants has an important role in the Finnish energy policy in decreasing CO_2 emissions from energy production. In Finland, the use of forest fuels in heat and power plants has been increasing moderately since the 1980s. The increased consumption of forest fuels and strong development of 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 been on the increase (Figure 8). The measures of the domestic energy policy have boosted the demand for biomass fuels, which has caused an upward trend in prices of wood fuels in recent years. Since the beginning of 2005, the start of the trading of CO_2 emission allowances within the EU emission trading scheme has enhanced the paying capacity of power plants for biomass fuels, and forest fuels have been 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 has been on the increase in the production of forest fuels. A collapse in the prices of emission allowances in 2007 broke the long-lasting growth in the use of forests chips in energy production. In 2007, the use of forest chips was 17% lower compared to the volumes in 2006. Zero price emission allowances decreased the competitiveness of wood fuels when power plants increased the use of peat and fossil fuels [44].

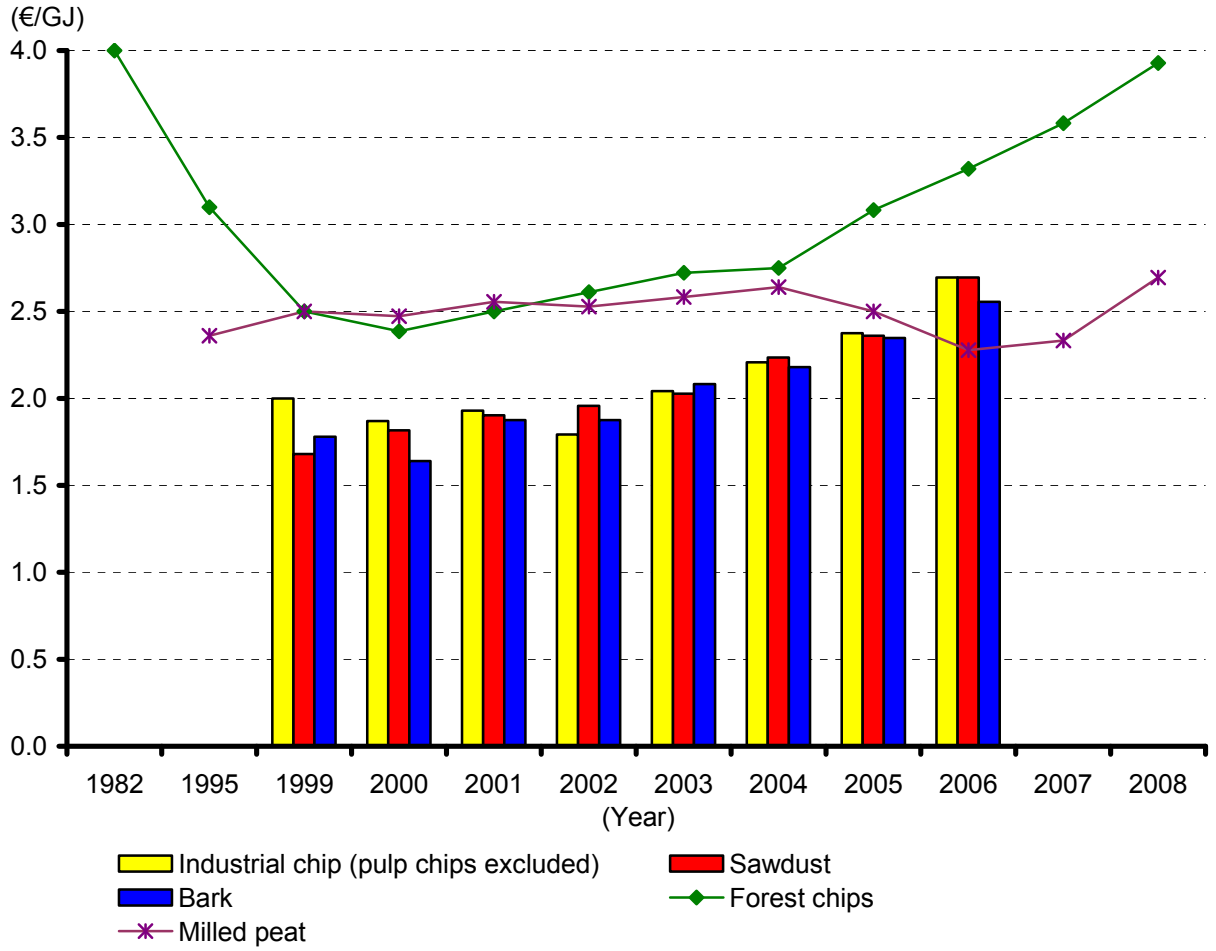

Figure 8. Wood fuels and milled peat prices delivered to plants in 1982–2008. Value Added Tax (VAT) excluded. Sources: Wood fuels, (years up to 1999 [45], years 2000–2006 [46-52], years since 2007 [43]; Peat [4, 43] . Prices of sawdust and bark since 2007 were not available because the Finnish Forest Research Institute no longer compiles statistics on wood fuel prices.

The growing demand for wood in energy production and the increasing paying capacity of energy production for wood have affected the other users of wood in various ways. A direct consequence has been the growing competition for wood between energy and raw material uses. In Finland, the competition for wood between 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 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. The increased demand for sawdust in energy production has raised its price. According to statistics, the price of sawdust has risen almost 50% between the years 1999 and 2006; see Figure 8. The increased price of raw material has weakened the competitiveness of particleboard and fibreboard manufacturers against manufactures operating in countries not participating in the emission trading.

5. International biomass fuels trade in Finland

5.1 Indirect trade of biomass fuels

The forest industry procures wood primarily for use as raw material. In many cases, the wood is imported from other countries. In the manufacturing of primary products, a significant amount of the raw wood ends up in energy production or is converted into by-products that are utilised in energy production. In this paper, biomass purchase and use of this kind is defined as indirect import of biomass fuels, and corresponding export is referred to as indirect export of biomass fuels. The above-mentioned wood streams jointly constitute the indirect trade of biomass fuels.

An investigation of wood streams in the forest industry is needed for determining the status of the indirect import of wood fuels. For that purpose, wood streams in energy production, raw material use and final products were calculated for the branches of the Finnish forest industry by means of an Excel-based spreadsheet model. The principle of the model is described in detail in source [2]. The model takes into account the differences between the various branches in the efficiency of conversion of wood into products, and uses branch-specific consumption volumes of round wood, imported pulp chips, and indigenous wood by-products in the forest industry and the production volumes of sawn timber and plywood as initial data. The above mentioned data came from Finnish forestry statistics. Wood stream calculations were performed for the years 2004, 2005, 2006 and 2007.

The calculations for the major wood streams in the Finnish forest industry in 2007 are presented in Figure 9. Dry by-products from the upgrading industry, which uses sawn timber as raw material, have been the main raw material for the wood pellet industry. The share of sawdust in the raw material of wood pellets has increased during the past years and the share of sawdust in 2007 was estimated to be approximately 50% of a total pellet raw stream of 0.7 million solid m^3. In 2007, 21% of raw wood used in the forest industry was imported, and in total, 40% of the raw wood volume was converted into black liquor and solid biomass fuels.

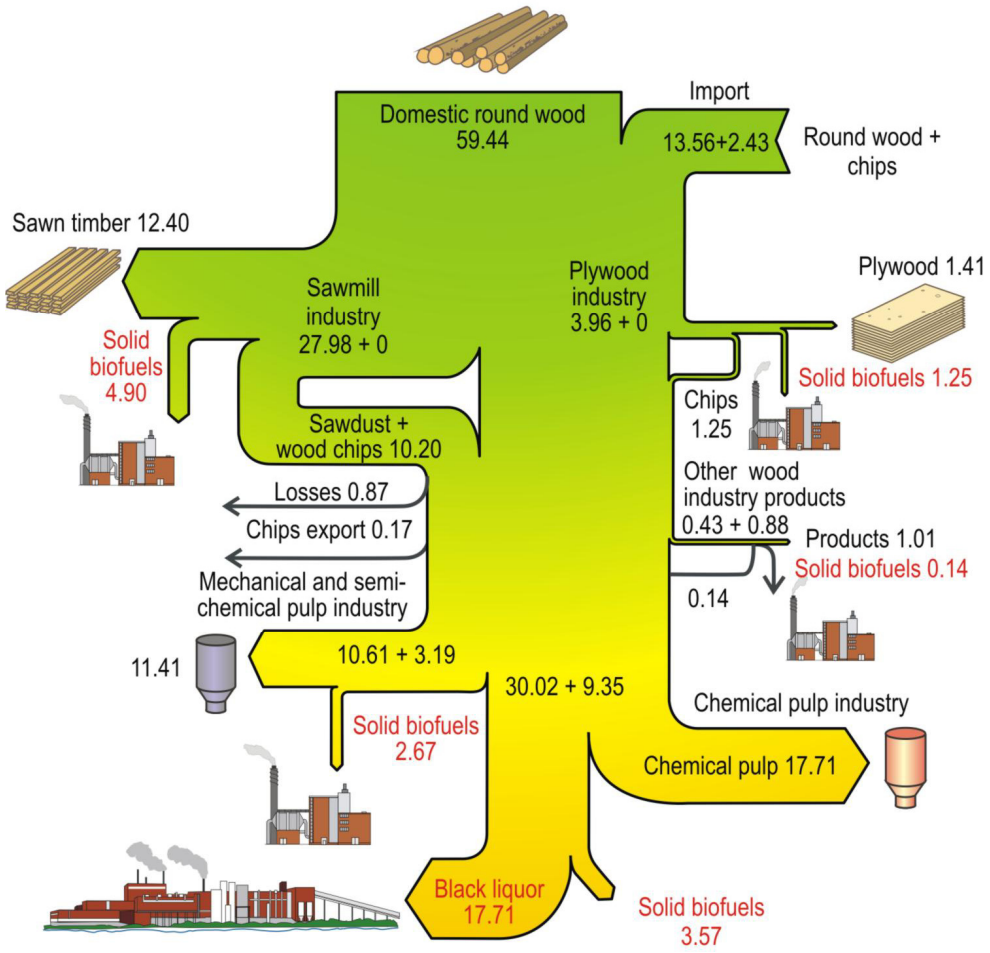

Figure 9. Wood streams in the Finnish forest industry in 2007, in million solid m^3; round wood includes bark. Figure: J. Heinimö (Lappeenranta University of Technology) & E. Alakangas (VTT)

5.2 Biomass fuels import and export in Finland in 2004–2007

Similarly to raw wood, a part of imported and exported forest products, food, and fodder streams end up as energy. Determining to what extent a country's bioenergy production is based on these products is troublesome, and they were thus excluded from the study. The study covers all remaining biomass streams, which can be categorized as follows:

- Biomass fuels (products traded for energy production, such as fuel ethanol, wood pellets, and firewood)
- Raw materials that are traded for the manufacture of biomass fuels (e.g. sawdust and pulpwood used in pellet production or pre-processed biomass that is used in the production of transport biofuels)
- Raw wood (wood matter used in the manufacture of forest products)

First, cross-border biomass streams were considered in view of foreign-trade statistics. The information was obtained from the EUROSTAT database, which can be accessed freely over the Internet [53]. The product groups selected in the investigation and their Combined Nomenclature (CN) codes are presented in Table 7.

Table 7. The CN codes of the products included in the investigation.

Product	CN code(s)
Round wood	44032031, 44032039,44032011, 44032019, 44032091, 44032099, 44039951, 44039959, 44034100 …44039910 and 44039995
Chips	44012100, 44012200
Sawdust from wood	44013010
Wood waste and scrap[a]	44013090
Fuel wood (firewood)	44011000
Tall oil	38030010, 38030090, 38070090
Peat	27030000
Ethanol	22071000, 22072000
MTBE, ETBE	29091900
Palm Oil	15111010

[a] *Includes solid wood processing industry by-products and residues and wood pellets. As of April 2009 wood pellets have own CN code: 4401 30 20*

Information on the volumes of import and export streams from the Foreign Trade Statistics and the wood streams determined for the forest industry provided a starting point for evaluating the energy balance of international biomass fuels trade. The product-specific data used and the assumptions made in the calculations of import and export balances of biomass fuels are presented as a summary in Appendix I. The export and import balances of biomass fuels determined for 2004–2006 are presented in Table 8. In Finland, the direct import and export of biomass fuels, being mainly composed of wood pellets and tall oil, have a minor importance compared to the total consumption of biomass fuels. The largest biomass fuels streams are composed of raw wood. The indirect import of wood fuels was on the increase during the period under investigation.

Table 8. Import and export balance of biomass fuels in Finland in 2004–2007, in PJ. The total calorific values were calculated based on the state of the streams across the border.

	Import				**Export**			
Stream (PJ) / year	**2004**	**2005**	**2006**	**2007**	**2004**	**2005**	**2006**	**2007**
Direct trade	**5.38**	**5.48**	**6.45**	**7.97**	**8.15**	**8.38**	**8.40**	**11.10**
▪ Wood pellets	0.00	0.00	0.00	0.00	2.65	3.27	3.26	3.14
▪ Energy peat	0.47	0.26	0.11	0.59	0.29	0.60	0.26	0.54
▪ Fuel wood	0.92	0.94	0.90	0.81	0.06	0.04	0.08	0.08
▪ Wood residues	1.21	1.26	1.16	0.69	0.06	0.21	0.02	0.15
▪ Tall oil	2.14	2.03	3.21	3.14	4.45	3.87	4.46	4.91
▪ Ethanol	0.64	0.99	1.06	0.76	0.00	0.00	0.00	0.00
▪ ETBE [b]	0.00	0.00	0.00	0.00	0.64	0.39	0.31	0.28
▪ Palm oil	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00
▪ Bio-diesel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00
Indirect trade	**56.01**	**57.58**	**61.16**	**55.16**	**2.40**	**3.02**	**3.08**	**3.13**
▪ Round wood	50.71	52.08	55.52	49.85	2.00	2.56	2.61	2.37
▪ Chips	5.16	5.25	5.26	4.87	0.39	0.45	0.35	0.37
▪ Sawdust	0.14	0.25	0.37	0.45	0.00	0.00	0.12	0.39
Total	**61.39**	**63.06**	**67.60**	**62.47**	**10.55**	**11.40**	**11.48**	**14.24**

[a] Includes only the bio-based proportion, which is evaluated the same as ethanol used as raw material.

Foreign-origin wood energy as a proportion of Finnish primary energy consumption in 2004–2007 was calculated by means of the methodology described in [2], and the results are depicted in Table 9. The results differ from the figures presented in Table 8. One explanation for the difference is the fact that the actual calorific values of imported wood in energy production differ from their values across the border.

Table 9. Foreign-origin wood energy in primary energy consumption in Finland in 2004–2007

Year	Foreign-origin wood energy in primary energy consumption	Percentage from total wood fuel consumption
2004	64 PJ	22%
2005	66 PJ	24%
2006	73 PJ	24%
2007	63 PJ	21%

6. Overview of the major import and export streams of biomass fuels

In Finland, wood pellet export is the largest export stream of biomass fuels. Accordingly, raw wood import represents the largest import streams related to biomass fuels. These streams are outlined in the following.

6.1 Export of wood pellets

Wood pellet production in Finland started in 1998. The Finnish pellet industry was founded on export supplying pellets to Sweden, where pellet markets were developing rapidly at the time. Since then, pellet production has increased steadily, climbing to 376 000 t (6.3 PJ) in 2008 (Figure 10). The majority of Finnish pellet production has been consumed abroad. The number of export countries of pellets has increased resulting from booming pellet markets in Europe. In addition to Sweden, Finnish pellets have been exported to Denmark, the Netherlands, the UK and Belgium.

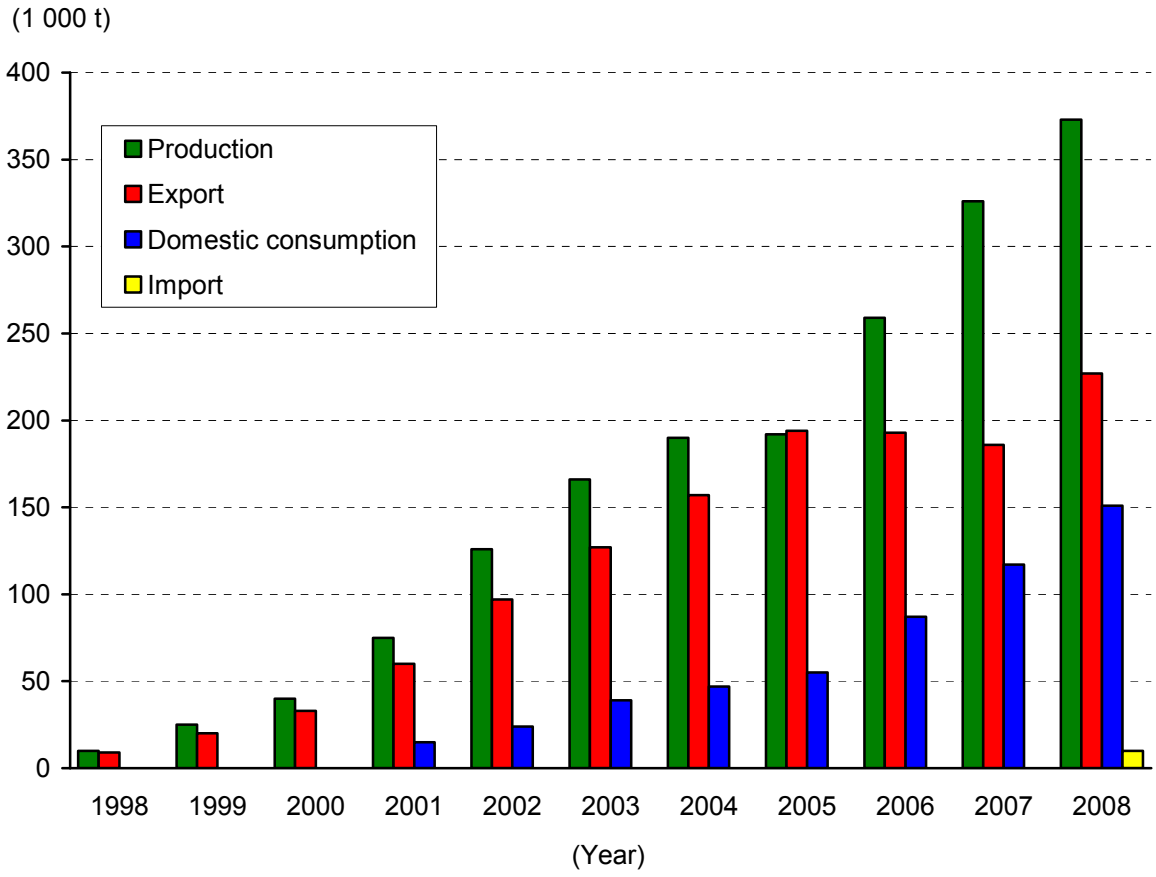

Figure 10. Wood pellet production, domestic consumption, and export in Finland in 1998–2008. In 2005, the export surpassed production resulting from a change in stocks. [54-56]

At the beginning of 2009, there were 24 wood pellet mills in operation (Figure 11). The total production capacity of the pellet mills is approximately 715 000 t/yr.

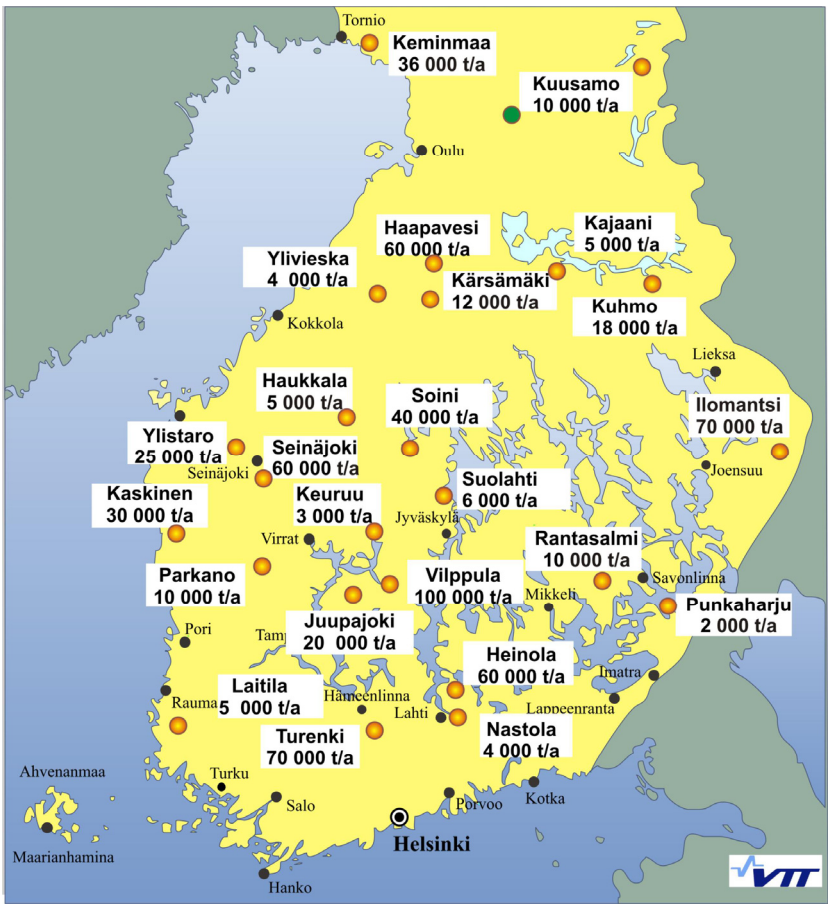

Figure 11. The locations and production capacities of Finnish wood pellet mills at the beginning of 2009.

In 2008, the export of wood pellets was 227 000 tons. Sweden (45%), Denmark (31%), the United Kingdom (10%) and Belgium (8%) were the main countries of export for wood pellets [53]. In 2008, the statistics reported the import of wood pellets to Finland for the first time. Imported pellets came most probably form Russia and the Baltic states.

In 2004–2008, the domestic consumption of wood pellets more than trebled, but was still in 2008 less than half of the production. The number of private small-scale pellet users in 2009 was estimated at 20 000 [25]. In 2008, about half of the domestic consumption of pellets in Finland took place in small boilers, the thermal output of which was less than 25 kW [55]. Pellets have not been competitive with heavy fuel oil or coal as fuel in heating and power plants, and they are mainly used in applications where light fuel oil is an alternative fuel, typically in the heating of dwellings. Previously, pellets were mainly manufactured from dry by-products from the sawn timber refining industry. This has allowed simpler processes for manufacturing pellets without drying the raw material. Recently established new pellet mills are equipped with a drying process, and they utilise moist raw materials.

In the main destination countries, the considerably higher taxation of fossil fuels in energy production and the subsidies for electricity from biomass have made the exportation of pellets economical. In Sweden and Denmark, the taxation of fossil fuels in heat production is remarkably higher than it is in Finland, and there wood pellets are mainly used for substituting coal in district heating and oil in space heating. The Netherlands have heavily subsidised renewable energy sources in electricity production, and wood pellets are primarily co-fired there with coal in large power plants.

The consumption of wood pellets is still at a modest level in Finland compared to the usage potential. Approximately 50 PJ of light fuel oil is consumed for the direct heating of Finnish dwellings each year [4]. Estimations have showed that the annual domestic consumption of wood pellets could be raised to 1–1.5 million tons (17.5–26 PJ) by replacing a part of the consumption of light fuel oil with the use of pellets [35]. In addition, a remarkable although less economically feasible potential use for pellets lies in substituting coal in power plants. In recent years, the average consumption of coal in energy production in Finland has been approximately 200 PJ [4]. Coal-fired power plants using pulverised combustion, e.g. in the Helsinki metropolitan area, could increase their use of pellets to even 2–3% of their fuel use without great technical changes in the burning systems if pellet use becomes economically competitive with coal. The largest Finnish coal-fired power plants are found in coastal areas with their own coal ports, which could be used for shipping pellets, if needed.

6.2 Import of raw wood

The Finnish forest industry has long traditions in the import of raw wood. During 1976–2006, the annual raw wood consumption of the forest industry has almost doubled, from 40 million solid m^3 to 75 million. In the same period, the volume of imported raw wood has multiplied, climbing from 8% to 25% of the total wood consumption of the forest industry. The growth in total wood use and raw wood import has been the strongest from the mid-1990s onwards (Figure 12).

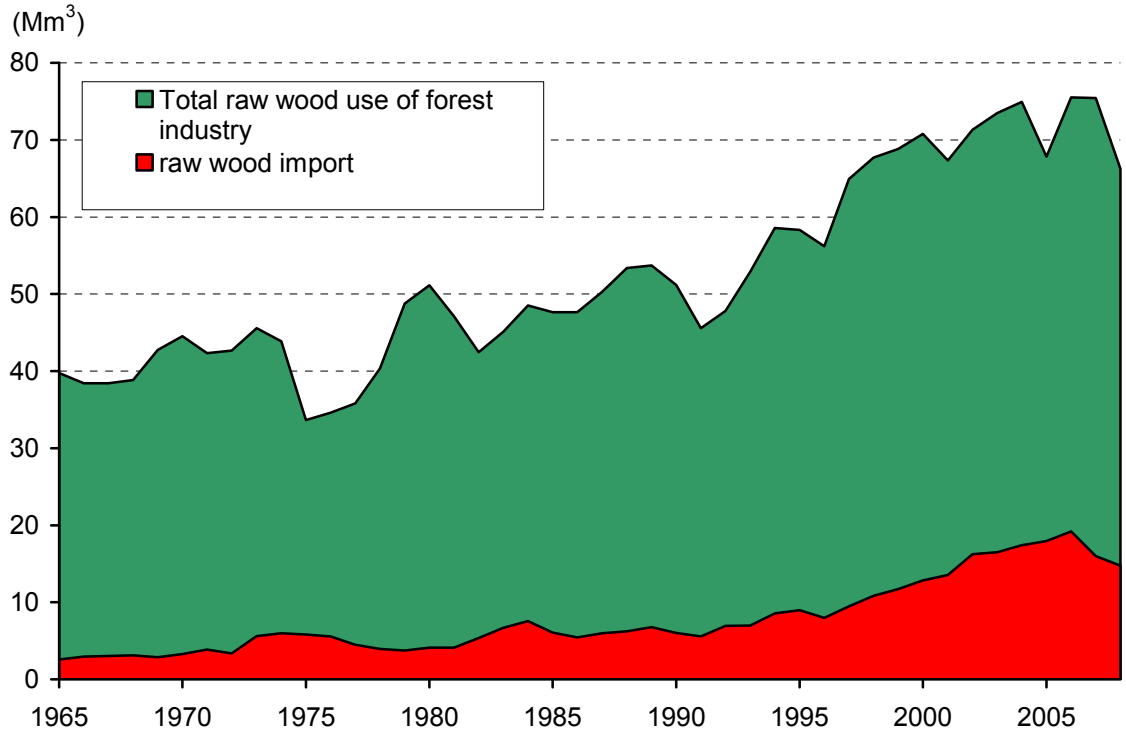

Figure 12. Raw wood use of the forest industry and raw wood import in Finland, 1965–2008 [20, 55]

In Finland, birch pulpwood has been the most important timber assortment in raw wood imports. The boom of Russian raw wood import to Finland started in the early of 1990s, when the transition to a market economy had harmed the Russian forest industry greatly, resulting in the collapse of round wood demand in Russia. Despite the positive development of Russia's forest

industry during the past years, the commercial utilisation of forest resources in Russia is still modest.

Currently, Finland holds the third position, after China and Japan, among the largest round wood importers in the world [57]. The imported raw wood has originated almost totally from the area of the former Soviet Union (Russia and the Baltic states). In 2007, Russia provided 66% of the total raw wood import, the share of the Baltic countries was 17%, and 8% came from Sweden [55].

In 2007, the trends of the raw wood use and raw wood import of the forest industry declined due to an emerging structural change in the Finnish forest industry. During 2007 and 2008, the industry shut down unprofitable old capacity, and operations have been consolidated into the most competitive units in Finland. One factor in the capacity cut of the forest industry has been the preparation for increasing costs of raw wood, especially imported raw wood. Russia is raising the export duties of round wood in 2007–2011. The major factor in the increasing export duties in Russia is to develop the domestic forest industry instead of the export of unprocessed raw wood. By 2009, the duties will have been raised gradually by 80% compared to the prevailing level at the beginning of 2007, increasing approximately € 50 / solid m^3 in the price of exported round wood, which was expected to cause a collapse in Russian raw wood import to Finland [58]. In November 2008, Russia postponed the planned increase of the duties for 9–12 months.

The latest forecast estimates that the total raw wood use will decline to 50–60 million m^3/yr and the raw wood import to 2–5 million m^3/yr by 2020 [40, 59].

7. SUMMARY AND CONCLUSIONS

This study considered the current situation of biomass fuels markets in Finland. The cold climate, low population density, energy-intensive structure of the industry and natural resources of the country have 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 biomass fuels in the total energy consumption are specific to the Finnish energy system.

Wood is the most important source of bioenergy in Finland, representing 20% of the total energy consumption in 2007. Forestland covers almost 90% of the country's land area, and the national 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: almost 70% of wood fuel consumption takes place in the forest industry.

Finland has committed itself to the Union's climate and energy targets, such as reducing its overall emissions of green house gases to at least 20% below the 1990 levels by 2020, and increasing the share of renewable energy in the gross final consumption. The renewable energy target approved for Finland is 38%. The present National Climate and Energy Strategy was introduced in November 2008. The strategy covers climate and energy policy measures up to the year 2020, and in brief thereafter, up to 2050. In recent years, the actual emissions have exceeded the Kyoto commitment and the trend of emissions is on the increase. In 2007, the share of renewable energy in the gross final energy consumption was approximately 25% (360 PJ). Without new energy policy measures, the final consumption of renewable energy would increase to 380 PJ, which would be approximately only 31% of final energy consumption, and the green house gas emissions would exceed the 1990 levels by 20%. Meeting the targets will need the adoption of more active energy policy measures in coming years.

The indigenous production potential of bioenergy is not utilised in its entirety. Forest chips from logging residues, stump and root wood and small-diameter energy wood constitute the largest underutilised biomass potential. There is also potential to increase the use of agrobiomass and biogas, but not on the same scale as forest chips.

The study showed that Finland is a large net importer of biomass fuels. Most of the import is indirect and takes place within the forest industry's raw wood imports. Wood pellets and tall oil form the majority of export streams of biomass fuels. The international biomass fuels trade has a substantial importance for the utilisation of bioenergy in Finland. In 2007, the total international trading of solid and liquid biomass fuels was approximately 77 PJ of which import was 62 PJ. Most of the import is indirect and takes place within the forest industry's raw wood imports. In 2007, as much as 21% of wood energy was based on foreign-origin wood. Wood pellets and tall oil form the majority of export streams of biomass fuels. The indirect import of wood fuels peaked in 2006 to 61 PJ. The foreseeable decline in raw wood import to Finland will decrease the indirect import of wood fuels. In 2004–2007, the direct trade of solid and liquid biomass fuels has been growing moderately. In 2007, the import of palm oil and the export of bio-diesel emerged, as a large, 170 000 t/yr biodiesel plant came into operation in Porvoo.

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A summary of the data used and the assumptions made in the calculations of the balances of international biomass fuels trade

Direct trade:	
Wood pellets	▪ The export and import volumes came from Energy Statistics data [4] ▪ Wood pellets were assumed to be manufactured from indigenous wood.
Energy peat, including peat pellets	▪ Horticultural peat accounts for a remarkable proportion of peat exports. ▪ Foreign Trade Statistics information includes peat import and export but does not distinguish between energy and horticultural peat. ▪ The Energy Statistics information includes the export of fuel peat but does not offer data on fuel peat import. ▪ The export volumes and the total calorific values of fuel peat were from Energy Statistics [4]. ▪ The import volumes of peat were from Foreign Trade Statistics. ▪ Peat import was assumed to be composed entirely of fuel peat. ▪ The net calorific value of imported fuel peat was evaluated at 10 MJ/kg. ▪ The average moisture content of fuel peat was assumed to be 50%.
Fuel wood (Firewood)	▪ Import and export volumes were obtained from Foreign Trade Statistics information [53]. ▪ The calorific values applied were 8.3 MJ/kg in import and 13.7 MJ/kg in export. ▪ The moisture content applied was 50% in import and 25% in export.
Wood residues	▪ The import volume was from Foreign Trade Statistics [53] ▪ Foreign Trade Statistics records wood pellets under the CN code 44013090, which also includes waste wood. The export volume of wood residues was evaluated at 7 000 t in 2004, 25 000 t in 2005, 3 000 t in 2006 and 18 000 t in 2007, which was the total export under CN code 44013090, with the export of wood pellets subtracted. ▪ The moisture content and calorific value of wood residues were evaluated at 50% and 8.3 MJ/kg, respectively.
Tall oil	▪ Import and export volumes were taken from Foreign Trade Statistics values. ▪ The calorific value applied for tall oil was 36.9 MJ/kg, which is 90% of the calorific value of heavy fuel oil. The traded tall oil volume was calculated in the overall balance.
Ethanol	▪ The import volume for energy purposes was evaluated at 23 800 t in 2004, 36 600 t in 2005, and 39 200 t in 2006, which equals the volume of ethanol consumed in the production of ETBE as announced by the manufacturer [60, 61]. For the year 2007, the import volume of ethanol (28 000 t) was obtained from trade statistics [53] ▪ The export volume of ethanol was taken from Foreign Trade Statistics information. ▪ The calorific value used for ethanol was 27 MJ/kg.
ETBE	▪ According to the manufacturer, the production of ETBE in Finland totalled 48 000 t in 2004 and the production was predominantly exported [60]. ▪ According to the manufacturer, exports of ETBE were 29 100 t in 2005 and 23 100 t in 2006 [61]. ▪ In the calculations, the indigenous consumption of ETBE in 2004 was estimated at zero and the entire production volume of ETBE was calculated to have been exported. ▪ The export of ETBE in 2007 was evaluated at 21 000 t based on foreign trade statistical information (export recorded under CN code 29091900). ▪ The bio-component percentage of exported ETBE was assumed to be 50% (concerning years 2005-2007). ▪ The calorific value of the bio-based component of ETBE was assumed to be similar to that of ethanol used as raw material.
Palm oil	▪ Palm oil is the major raw material of bio-diesel production in Finland. The import value of palm oil import was available from foreign trade statistics (€ 26 million in 2007). ▪ The import volume of palm oil was evaluated based on the average import price of palm oil to EU27 states in 2007 (€ 480/t) at 54 000 t. ▪ The calorific value used for palm oil was 37 MJ/kg.
Bio-diesel	▪ The consumption of biofuels in road transport in Finland has been negligible (0.08 PJ in 2007) and almost the entire bio-diesel production have been exported. ▪ Bio-diesel export was evaluated to be equivalent to palm oil import in 2007.
Indirect trade:	▪ The total calorific value of the indirectly imported and exported biofuels was determined based on the state of the streams when they cross the border.
Round wood	▪ The actual average density of imported round wood was defined according to the recorded mass and volume as 790 kg/m^3 [62, 63]. On this basis, the average moisture content was assumed to be 45% when the net calorific value is 9.4 MJ/kg.
Chips and sawdust	▪ The net calorific value as received and the moisture content of wood chips and sawdust were assessed as 8.3 MJ/kg and 50%, respectively.
Export of raw wood	▪ The proportion of round wood, wood chips, and sawdust exported that ended up in energy production was presumed equal to that imported.

Market of biomass fuels in Finland
IEA Bioenergy Task 40 and EUBIONET III - Country report of Finland 2009

This report studies and summarises the current status of biomass fuels markets in Finland, being an update of the previous IEA Bioenergy Task 40 and EUBIONET Finnish country reports published in 2006 and 2008. 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 solid biomass fuels in the total energy consumption are specific to the Finnish energy system. Wood is the most important source of bioenergy in Finland, representing 20% of the total energy consumption in 2007. Almost 80% of the wood-based energy is recovered from industrial by-products and residues.
The international trade of biomass fuels has a substantial importance for the utilisation of bioenergy in Finland. In 2007, the total international trading of solid and liquid biomass fuels was approximately 77 PJ, of which import was 62 PJ. Most of the import is indirect and takes place within the forest industry's raw wood imports. In 2007, as much as 21% of wood energy was based on foreign-origin wood. Wood pellets and tall oil form the majority of export streams of biomass fuels. The indirect import of wood fuels peaked in 2006 to 61 PJ. The foreseeable decline in raw wood import to Finland will decrease the indirect import of wood fuels. In 2004–2007, the direct trade of solid and liquid biomass fuels has been on a moderate growth path. In 2007, the import of palm oil and export of biodiesel emerged, as a large, 170 000 tonnes biodiesel plant came into operation in Porvoo.

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