LAPPEENRANNAN TEKNILLINEN YLIOPISTO
LAPPEENRANTA UNIVERSITY OF TECHNOLOGY

Teknillinen tiedekunta
LUT Energia

Faculty of Technology
LUT Energy

Tutkimusraportti *Research Report* **19**

Jussi Heinimö, Eija Alakangas

Market of biomass fuels in Finland – an overview 2009

IEA Bioenergy Task 40 and EUBIONET III - Country report of Finland 2011

Lappeenranta University of Technology
Faculty of Technology
Institute of Energy Technology
Research Report 19

Market of biomass fuels in Finland – an overview 2009

IEA Bioenergy Task 40 and EUBIONET III - Country report of Finland 2011

Jussi Heinimö
Lappeenranta University of Technology

Eija Alakangas
VTT Technical Research Centre of Finland

2011

ISBN 978-952-265-202-7 (pdf)
ISSN 1798-1328

PUBLISHERS

Lappeenranta University of Technology (LUT)
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

This publication is available in PDF format on the Internet at www.doria.fi, www.eubionet.net and www.bionergytrade.org

Heinimö, Jussi & Alakangas, Eija: Market of biomass fuels in Finland – an overview 2009, Lappeenranta University of Technology, Institute of Energy Technology, Research Report 19, December 2011, 40 pages + app 2 p.

ISBN 978-952-265-202-7 (pdf)
ISSN 1798-1328

Keywords biomass fuels, international trade, energy policy, Finland

Abstract

This study considered the current situation of solid and liquid biomass fuels in Finland. The fact that the 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 2009. Most of the wood-based energy (56%) 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 met the Kyoto commitment due to the economic recession but the trend of emissions is on the increase. In 2008, the share of renewable energy in the gross final energy consumption was approximately 31%. 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 2009, the total international trading of solid and liquid biomass fuels was approximately 45 PJ, of which import was 23 PJ. The indirect import of wood fuels which takes place within the forest industry's raw wood import grew until 2006 being in that year 61 PJ. In 2009, the import of raw wood collapsed, and correspondingly, the indirect import of wood fuels dropped to 23 PJ. In 2004-2008, wood pellets and tall oil formed the majority of export streams of biomass fuels. During 2007-2009, two large biodiesel production units were established in Porvoo, and palm oil and biodiesel have become the largest import and export streams of energy biomass.

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 2011, the countries participating in Task 40 collaboration were Austria, Belgium, Brazil, Canada, Denmark, Finland, Japan, Italy, Norway, Sweden, the Netherlands, the United Kingdom, and the USA. In addition, several industrial parties and international organizations were involved in the Task, providing a platform for its effective implementation.

The EUBIONET III project boosted sustainable, transparent international biomass fuel trade and investments in best practice technologies and new services on the biomass heat sector, and helped to secure the most cost efficient and value-adding use of biomass for energy and industry. The EUBIONET III project was carried out from September 2008 to August 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, 2008 and 2009. The co-authors of the report are Mr Jussi Heinimö from Lappeenranta University of Technology and Mrs Eija Alakangas from VTT.

Varkaus, December 2011 Jyväskylä, December 2011

Jussi Heinimö Eija Alakangas

TABLE OF CONTENTS

1. INTRODUCTION 6

2. BIOMASS FUELS IN THE FINNISH ENERGY SYSTEM 7
  2.1 Energy demand and energy sources 7
  2.2 Past development of biomass fuels use 9

3. ENERGY POLICY TARGETS AND MEASURES FOR RENEWABLE ENERGY 11
  3.1 Commitments and goals 11
  3.2 Present measures to implement the energy policy 14

4. INDIGENOUS MARKETS OF BIOMASS FUELS 19
  4.1 Users of wood and peat fuels 19
  4.2 Biofuels in the road transport sector 21
  4.3 Potential to produce biomass for energy 23
  4.4 Prices of biomass fuels 24

5. INTERNATIONAL BIOMASS FUELS TRADE IN FINLAND 27
  5.1 Indirect trade of biomass fuels 27
  5.2 Biomass fuels import and export in Finland in 2004–2009 28

6. OVERVIEW OF SELECTED ACTUAL ISSUES OF BIOENERGY MARKETS IN FINLAND 31
  6.1 Wood pellet market 31
  6.2 Liquid biofuel production from forest biomass 33

7. SUMMARY AND CONCLUSIONS 36

APPENDICES

Appendix I A summary of the data used and the assumption made in the calculations of the mass and energy balances in international biomass fuels trade

Appendix II Import and export balance of biomass fuels in Finland in 2004–2009

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 has been 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 has originated from abroad. Finland is also a significant exporter of wood pellets. During the past years, new production capacity for biodiesel has been taken into operation. 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]. Since that, two country reports based on the same methodology have been published (in 2008 and in 2009). In this paper, the previous analysis of the Finnish situation regarding markets and international trade of biomass fuels is updated covering the years 2008 and 2009. 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 selected actual issues on bioenergy markets (wood pellet market and liquid biofuel production from forest biomass) are shortly reviewed in Section 6.

[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 5.4 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). The only significant indigenous energy resources in the country are wood, peat[5], hydropower, and wind energy. In 2008, renewable energy sources accounted for 30.5%, which was the second highest proportion in the EU [5]. In 2009, the economic regression dropped the production of the industry, and thus the total energy consumption was about 6% lower than in the previous year [5].

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

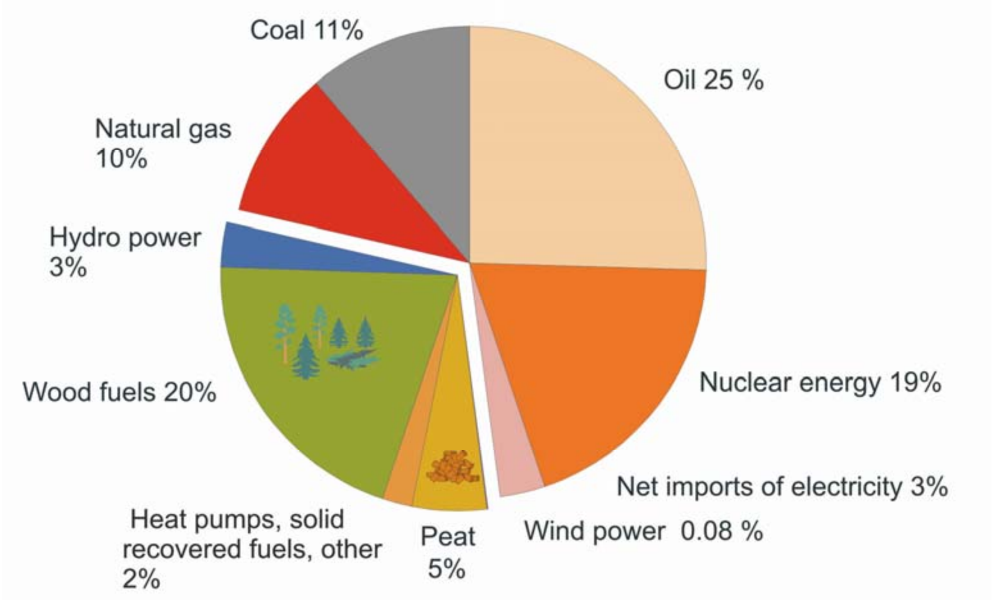

Figure 2. Primary energy sources in Finland in 2009. (The total use of primary energy in 2009 was 1,330 PJ). [5]

In Finland, primary energy consumption per capita is high, 287 MJ/capita in 2008 [5]. For comparison, in the same year the corresponding figure for the EU-27 countries was 151 MJ/capita [5]. 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 [6].

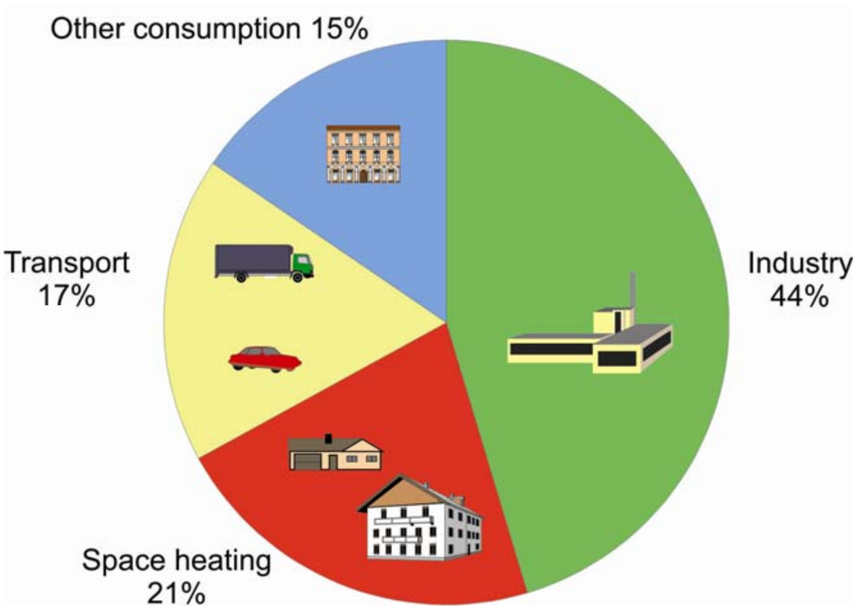

Figure 3. Final energy consumption by sector in Finland in 2009. (Total 1,034 PJ) [5]. Final energy consumption does not include losses of electricity and heat generation and fuel refining.

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) [5].

Table 1. The consumption of biomass fuels in Finland in 2009. Data obtained from[5].

Fuel	**Use in 2009 (PJ)**	**Share**
Wood fuels:		
▪ Black liquor [a]	110.2	31.0%
▪ Solid wood processing industry by-products and residues [b]	56.0	15.7%
▪ Firewood	55.0	15.5%
▪ Forest fuels (forest chips)	43.7	12.3%
▪ Wood pellets	2.6	0.7%
▪ Wood fuels in total	267.5	75.2%
Biogas	1.7	0.5%
Solid recovered fuels (biodegradable fraction)	5.6	1.6%
Other bioenergy [c]	2.1	0.6%
Liquid biofuels in road transport sector and space heating	7.3	2.1%
Fuel peat	71.7	20.1%
In total	355.9	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 [7]. 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.

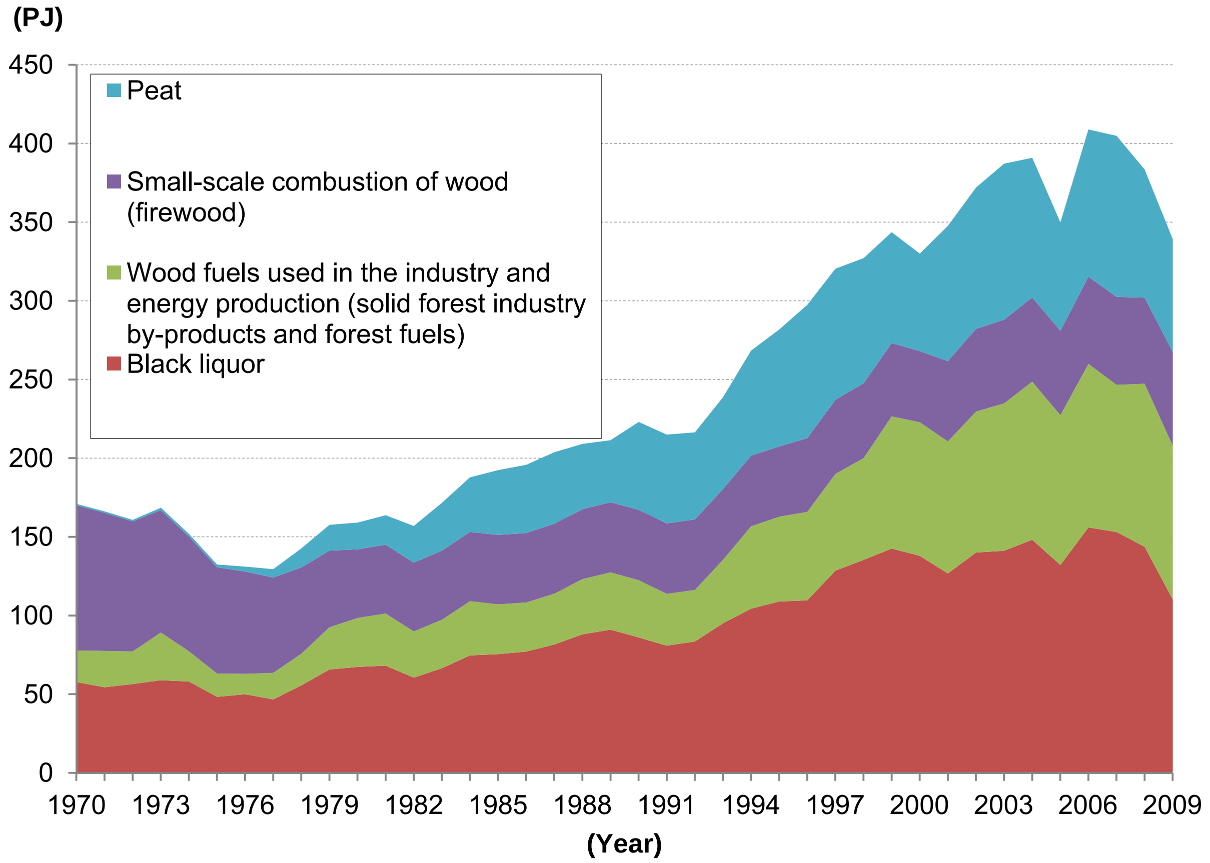

Figure 4. Consumption of wood fuels and peat in Finland in 1970 – 2009 [5].

3. Energy policy targets and measures for renewable energy

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 [8]. 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 RES Directive has set 38% as a target for the share of renewable energy in final energy consumption in Finland in 2020 [9]. In 2009, the realised share of renewable energy in the final energy consumption was estimated to be nearly 30% [5]. The use of renewable energy in 2009 and Finnish renewable energy targets by energy source for 2020 are presented in Table 2.

Table 2. Renewable energy consumption by energy source in 2009 in Finland and the targets for 2020. 2005 was the reference year for 2020 targets

Source of renewable energy	Year 2005 (PJ)	Year 2009[a] (PJ)	Target level for 2020[b] (PJ)	Increment 2009-2020 (PJ)
Black liquor	132	110	137	27
Solid wood processing industry by-products and residues	70	52	68	16
Hydropower	48	45	50	5
Firewood	51	55	43	-12
Forest fuels (in heat and power generation)	21	*44*	90	46
Recycled fuels	7	8	7	-1
Heat pumps	2	7	29	22
Other renewable energy (includes, e.g., solar energy and agro-biomass)	5	4	1	-3
Biogas	2	2	4	2
Wood pellets	1	3	7	4
Wind power	0.3	1	22	21
Liquid biofuels	0	7	25[c]	18
Total	339	338	483	145

[a] *Data obtained from energy statistics [5].*
[b] *Source: NREAP Finland [10].*
[c] *The figure corresponds to approximately 15% of the projected fuel consumption in the transport sector in 2020.*

Forest biomass is the most important source of renewable energy in Finland, covering approximately 80% of the renewable energy used. Most forest-based bioenergy (over 75%) is generated from by-products of the forest industry (black liquor, bark, and sawdust). The rest of the wood energy is generated from wood biomass that is sourced from forests for energy purposes (firewood and forest chips). The proportion of wood pellets has been negligible. The volumes of the forest industry's energy by-products vary with the production of pulp and paper.

In the current energy policy, [10-12] the target for the use of forest chips (logging residues, stumps, and energy wood[6]) in 2020 has been set at 13.5 million solid cubic metres (equalling approximately 97 PJ). Forest chips will account for most future growth in renewable energy production. Forest chips are expected to become an important raw material in the production of liquid biofuels.

The government is striving for a 20% blending obligation for biofuels in road transport by 2020. Some of the target volume of biofuel is expected to be covered by second-generation biofuels, whose consumption is counted to be twice the volume of other biofuels in the RES Directive [12]. Therefore, the target volume for biofuels in energy terms corresponds to less than 20% of the estimated fuel consumption in road transport in 2020.

In recent years, the actual emissions have met the Kyoto commitment due to the economic recession but the trend of emissions is on the increase (Figure 5). Meeting the 2020 EU targets (-20% for CO_2 emissions compared to the prevailed level in 1990) will need more active climate policy measures in coming years.

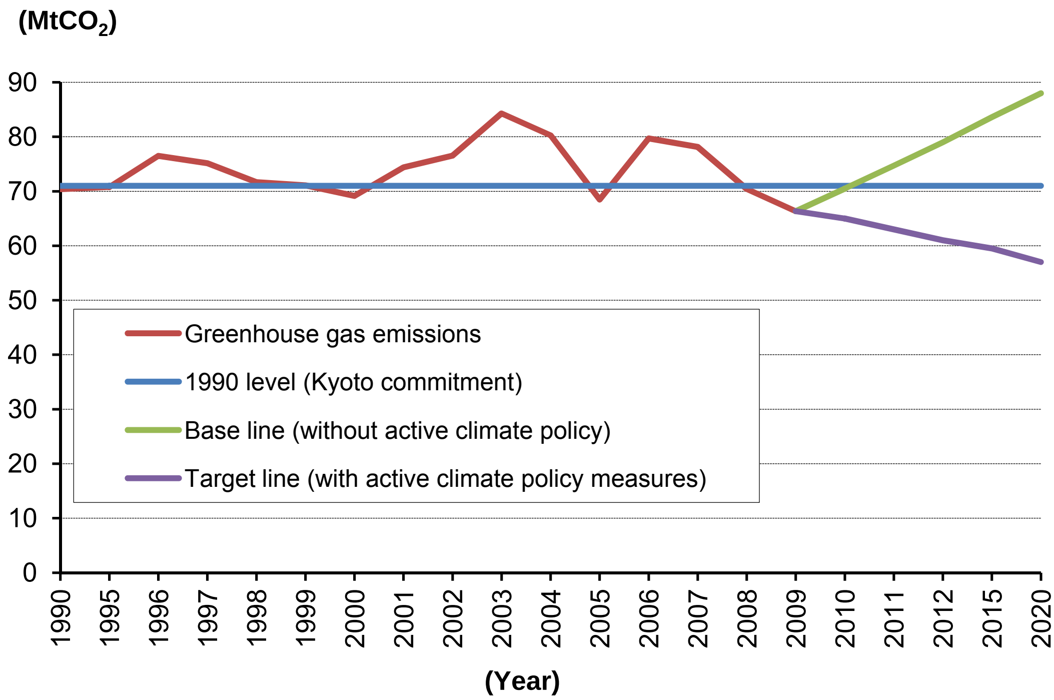

Figure 5. The realised greenhouse gas emissions in Finland and a scenario until the year 2030 compared to the 1990 level. Carbon sinks are not included in the figures. The scenario was compiled in 2008. [13, 14]

[6] In this paper, energy wood refers to trees that are harvested for energy purposes.

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, the 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 the final energy consumption. By 2050, the total consumption of energy will increase further and, without new measures influencing consumption, it will be approximately one quarter higher in that year than at present. Greenhouse gas emissions would increase by as much as 30%. [13]

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, the 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 the final energy consumption by 2050. [13]

According to the strategy, the attainment of the 38% renewable energy target fundamentally depends on having the 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. [13]

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. [13]

The starting point for our electricity sourcing is the 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. [13]

3.2 Present measures to implement the energy policy

Current support system

The Finnish 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. 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. [15]

Support for R&D

The competitiveness of renewable energy sources is promoted through investments 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 (e.g. BioRefine – New products from biomass, Groove – renewable energy – growth from internationalisation) and projects have involved RES technologies, the main focus being on bioenergy. 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. Tekes is also providing funding for Strategic Centres for Science, Technology and Innovation. CLEEN Ltd (energy and environment) and Forestcluster Ltd are operating in biomass and bioenergy sector. Puuska – activating business programme (2010 – 2013) is targeted for wood processing and energy wood sector. Tekes funding for environmentally friendly processes was in 2009 about € 98 million, of which bioenergy accounted for 14%. Tekes funding for energy and climate technologies is shown in Figure 6.

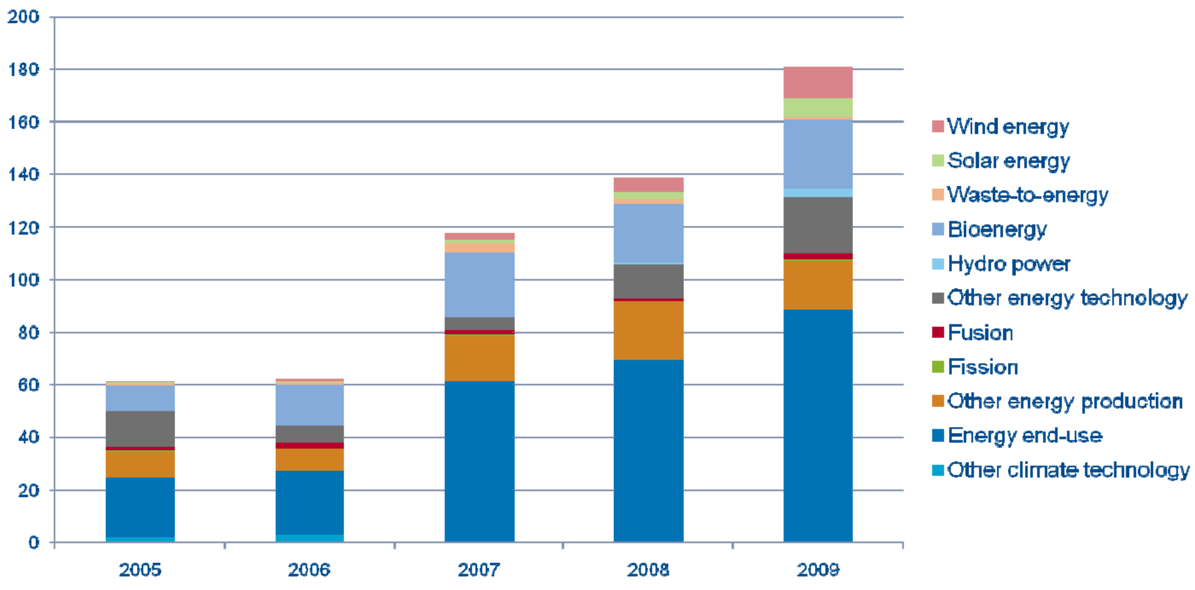

Figure 6. Tekes funding for Energy and Climate Technologies in 2005-2009 [15].

Energy taxation on fuel for heat and power plants

Taxation is one of the main instruments related to climate change and the environmental policy. Energy taxation is the major source of financing for the state. State revenues from excise tax on energy amount to almost € 3 billion. In addition to the fiscal meaning (impact on public financing), energy taxation is a key instrument of energy and environmental policy. As such, it is used to restrain the growth of energy consumption while guiding energy generation and use towards alternatives that cause lower emissions.

The Government changed the structure of energy taxes on fuel for transport and heat and power plants on 1 January 2011. The taxation now takes account of the energy content, carbon dioxide emissions and local/particle emissions that have adverse health effects. [15]

The energy content tax has been adjusted to reflect the volumetric energy content of the fuel. The energy tax component is levied on both fossil fuels and biofuels, based on the same taxation criteria. For the liquid fuels, the energy content is based on the heating values (MJ/litre) used in Directive 2009/28/EC (RES Directive).

The CO_2 tax is based on the CO_2 emissions of the fuel in question. The weight of levies on carbon dioxide has been raised from their 2010 levels. For fossil fuels, the CO_2 emission values (g/MJ) are based on the values used in the national fuel classification of Statistics Finland. The values used in the national fuel classification are based on the values used in the International Energy Agency's and Eurostat's Fuel Classification.

The evaluation of the CO_2 content of biofuels is based on their treatment in the RES Directive. A flat rate tax reduction of 50% is applied to all biofuels that meet the sustainability criteria of the RES Directive. The so-called second-generation biofuels, as defined in the RES Directive (biomass originated from waste and residues), will be totally exempted from the CO_2 tax. The CO_2 tax does not apply to wood and other biomass (solid and gaseous) used in energy production.

In 2011, additional € 730 million will be collected in taxes on fuel for heat and power plants and energy taxes on electricity. Tax on natural gas will be increased gradually until 2015. In addition, peat is now subject to tax. The tax level for peat will be increased gradually: it is 1.9 €/MWh in 2011, 2.9 €/MWh in 2013, and 3.9 €/MWh in 2015.

From the beginning of 2011, CO_2 levies for fossil fuels used in combined electricity and heat production were lowered by 50%. This was done to avoid overlapping carbon dioxide steering and to improve the competitiveness of combined heat and electricity (CHP) production relative to separate heat production.

From the beginning of 2011, the electricity tax for industry (tax class II) has been raised from € 0.263 c/kWh to € 0.703 c/kWh. Together with this, the tax subsidies for renewable electricity production (e.g. electricity produced from forest chips still get subsidies along with wind power, small hydro, biogas, and recycled fuel (REF)) were discontinued.

Energy prices are market based, and consumer prices reflect the changes in market prices. The Government does not have any instruments to directly influence the price setting for energy products. However, through energy taxation advantages have been given to industry in the form of a lower electricity tax and a tax refund system for energy intensive industries. In addition, farmers are entitled to excise duty refunds for electricity and oil products used for agricultural purposes, and the energy tax refunds for agriculture have been increased to offset the raise in taxation in agriculture. The new taxes are presented in Table 3.

Table 3. Energy taxes related to traffic and heating fuels and electricity consumption as of 1 January 2011) [16]

Product	Unit	Energy tax	CO_2 tax	Security of supply fee	Total
Motor petrol	EUR c/l	50.36	11.66	0.68	62.70
Bioetanol	EUR c/l	33.05	7.65	0.68	41.38
Bioetanol R	EUR c/l	33.05	3.83	0.68	37.56
Bioetanol T	EUR c/l	33.05	0.00	0.68	33.73
MTBE	EUR c/l	40.91	9.48	0.68	51.07
MTBE R	EUR c/l	40.91	8.43	0.68	50.02
MTBE T	EUR c/l	40.91	7.39	0.68	48.98
TAME	EUR c/l	44.06	10.21	0.68	54.95
TAME R	EUR c/l	44.06	9.29	0.68	54.03
TAME T	EUR c/l	44.06	8.37	0.68	53.11
ETBE	EUR c/l	42.49	9.84	0.68	53.01
ETBE R	EUR c/l	42.49	8.02	0.68	51.19
ETBE T	EUR c/l	42.49	6.20	0.68	49.37
Biogasoline	EUR c/l	50.36	11.66	0.68	62.70
Biogasoline R	EUR c/l	50.36	5.83	0.68	56.87
Biogasoline T	EUR c/l	50.36	0.00	0.68	51.04
Diesel oil	EUR c/l	30.70	13.25	0.35	44.30
Diesel oil para	EUR c/l	24.00	12.51	0.35	36.86
Biodiesel	EUR c/l	28.14	12.14	0.35	40.63
Biodiesel R	EUR c/l	28.14	6.07	0.35	34.56
Biodiesel T	EUR c/l	28.14	0.00	0.35	28.49
Biodiesel P	EUR c/l	24.00	12.51	0.35	36.86
Biodiesel P R	EUR c/l	24.00	6.26	0.35	30.61
Biodiesel P T	EUR c/l	24.00	0.00	0.35	24.35
Light fuel oil	EUR c/l	10.35	8.00	0.35	18.70
Light fuel oil, without sulphur	EUR c/l	7.70	8.00	0.35	16.05
Bio oil	EUR c/l	7.70	8.00	0.35	16.05
Bio oil R	EUR c/l	7.70	4.00	0.35	12.05
Bio oil T	EUR c/l	7.70	0.00	0.35	8.05
Heavy fuel oil	EUR c/kg	54.76	12.74	0.35	67.85
Coal	EUR/t	54.54	72.37	1.18	128.09
Natural gas*	EUR MWh	7.70	5.94	0.084	13.724
Electricity, class I Electricity, class II	c/kWh c/kWh	1.69 0.69		0.013 0.013	1.703 0.703
Tall oil	c/kg	18.79	-	0	18.79
Fuel peat **	€/MWh	3.90		0	3.90

** Energy tax is 3.00 €/MWh during 1.1.2011-31.12.2012, 5.50 €/MWh during 1.1.2013–31.12.2014.*
*** Energy tax for fuel peat is 1.90 €/MWh during 1.1.2011-31.12.2012 and 2.90 €/MWh during 1.1.2013–31.12.2014.*

R = product includes renewable raw material according directive 2001/77/EU
T = product includes renewable raw material according directive 2001/77/EU and it produced from waste or residues which are not suitable for food like lignocelluloses material
P= paraffin diesel oil

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 (e.g. black liquor and other industrial wood waste and by-products) was abolished, except for electricity produced from forest chips. The production subsidies for renewable electricity are subject of revision as a part of the introduction of feed-in-tariff for renewable energy sources.The new law entered into force on 1 January 2011. Also the energy taxation system was updated.

Power plants could be accepted into the subsidy scheme until the objective is met for increasing the utilisation of renewable sources of energy. Wind power plants would be accepted until the total output of generators exceeds 2,500 MVA. The corresponding limit for biogas power plants, utilising biogas as their primary fuel, would be 19 MVA. On the other hand, wood-fuel powered plants would be accepted into the scheme until the total output of generators exceeds 150 MVA and the number of power plants 50.

The 2011 budget proposal for a renewable energy production subsidy proposed a total appropriation of € 55.35 million.

The feed-in tariff scheme’s key purpose is to contribute to meeting the national objective set by the EU for increasing the utilisation of renewable energy sources. This will be done by achieving the target set for wind power of 6 terawatt hours of electricity, as well as going most of the way towards achieving the forest chips objective of 22 terawatt hours.

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. In 2009, a total of € 94.4 million was available for energy supports. The figure includes € 1.3 million in grants from the European Regional Development Fund. The volume of energy support was a record amount, about three times higher than in the previous year. The target of this additional support was to speed up investments on renewable energy and energy efficiency in a way that also promotes economy and employment.

For small scale heating systems of residential buildings, the Government provides investment grants of additional € 30 million. Introduction of primary heating systems based on renewable energy sources is supported by maximum 20% of eligible investment costs. This subsidy came into force on 1 January 2011.

Support for the forestry and agriculture sector

In the Act on the Financing of Sustainable Forestry (544/2007), 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. On 10 December 2010, the Parliament decided on some amendments in the Act. The most important change is separating the financing of sustainable forestry and energy support for small trees. On the other hand, the current fuel timber harvesting and chipping supports will be combined. The Ministry of Agriculture and Forestry will pay support for the harvesting, forestry transport and chipping of timber sold for fuel as part of the management of young plantations. The energy support for fuel wood from small trees will be € 10 per solid m^3 (about 5 €/MWh). The diameter at breast height should be less than 16 cm. The minimum supported amount is 40 solid m^3. The maximum support will be for 45 solid m^3 per hectare, so for stands with higher yield, the actual support will be less than € 10 per solid m^3. The date when these amendments will come into force will be stated in a separate Decree. In 2007, a total of € 5.7 million was spent on fuel timber harvesting and chipping support.

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. [17]

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. [18]

4. Indigenous markets of biomass fuels

4.1 Users of wood and peat fuels

Wood fuels 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 2009 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 [19]. 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 2009, in PJ.

Fuel / End use sector	Forest industry	District heating	Small-scale use (c	Other industry & users	Total
Black liquor	110.2	0	0	0	110.2 [5]
Solid wood processing industry by-products and residues (b	23.4	13.0	0	20.6	57.0
Firewood	0	0	54.0	0	54.0 [5]
Forest fuels (a	14.4 [20]	17.7 [21]	4.7 [5]	6.9	43.7 [5]
Wood pellets (d		0.8	1.0	0.8	2.6
Total wood	148.0 [22]	31.5 [5]	59.7 [5]	28.3	267.5 [5]
Fuel peat	11.0 [22]	35.4 [5]	1.1 [5]	24.2	71.7 [5]

(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 [5]. The consumption of wood pellets between district heating and other users is an estimate by the authors.

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 [23]. 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 71% of the total district heat production in 2009 [5]. The imported fossil fuels natural gas (34%) and coal (24%) are the main fuels in the district heating sector [5]. 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 17% and 15% shares in 2009, respectively [5].

Small diameter energy wood from young forests and logging residues and stumps from final felling 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 location of plants using forest fuels in 1999 and in 2009 is presented in Figure 7.

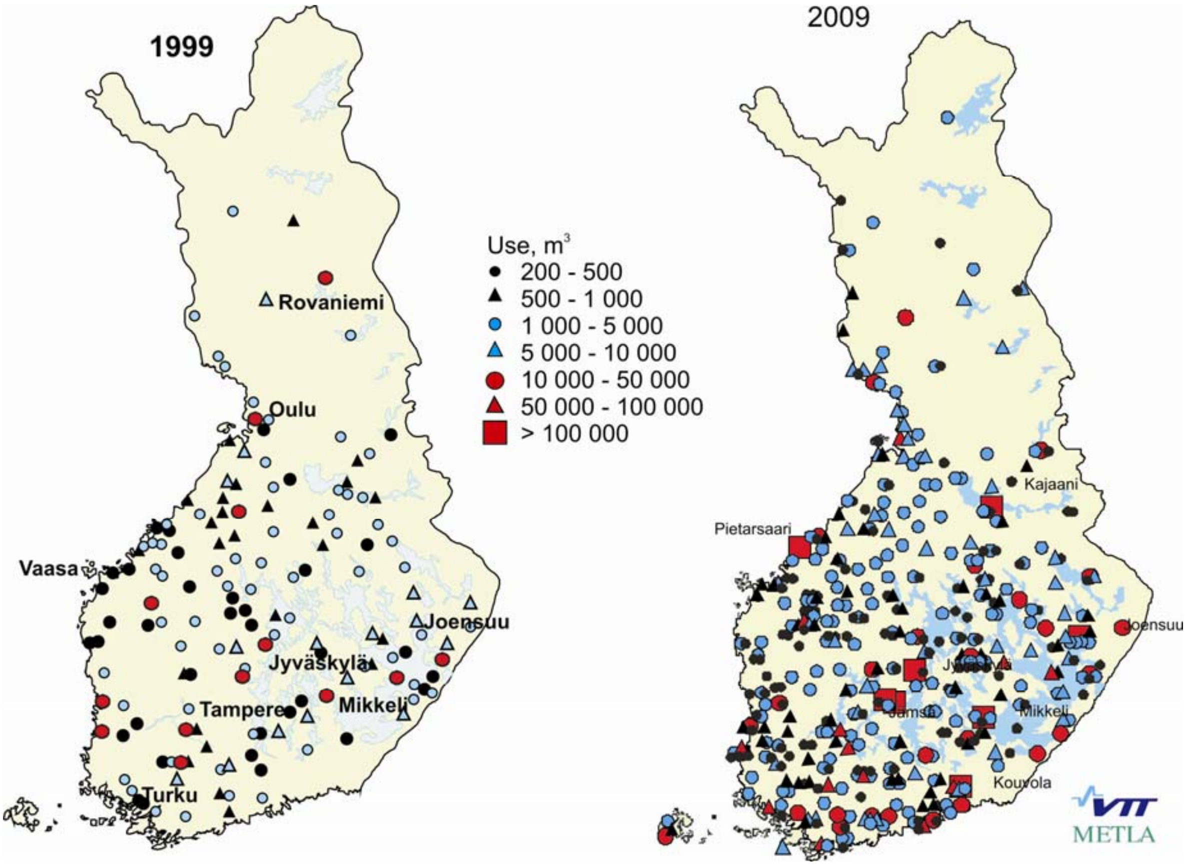

Figure7. The largest users of forest chips in Finland in 1999 and in 2009. Source: Metla and VTT.

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. [24]. 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 [25]. Wood is commonly used as the main fuel in central house heating systems in farms and larger buildings in sparsely populated areas, and according to 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 [26]. The 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 [27].

Table 5 shows the use of solid wood fuels in different size of the plants in Finland in 2009. More than 80% of solid wood fuels are used in boiler plants with boiler output more than 20 MW_{th}.

Table 5. Number and output (boiler output) of different size of plants and domestic use of solid wood fuels in Finland in 2009. Source: VTT

Plant size category	Total output (MW_{th})	Number of plants	Use of solid wood fuels in 2009[b]	
			(PJ)	Share
< 50 kw_{th} (boilers and stoves)	n.a.	n.a.	59.6	40%
< 1 MW_{th}	250	455	3.0	2%
1 – 5 MW_{th}	425	161	3.4	2%
5 – 20 MW_{th}	970	102	9.1	6%
> 20 MW_{th}[a]	8 720	82	73.3	49%
Total	10 365	800	148.5	100%

[a] *Plants are usually multifuel CHP-plants producing heat and power.*
[b] *Wood fuels include forest chips and by-products and residues used for energy production.*

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 6). The consumption of gasoline has remained constant, but instead, the consumption of diesel fuel has increased. The consumption of biofuels has been negligible until 2008. 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 [28]. After these projects, the consumption of biofuels dropped to zero in 2005. In 2009, the share of bio-ethanol in biofuels consumption was 75% and the rest came from biodiesel. Achieving the 5.75% target share set for biofuels in road transport in 2010 will require approximately a 10 PJ annual use of biofuels. 2020 consumption target for transport biofuels was set to 25.2 PJ [12].

Table 6. Fuels consumption in road transport in 2000–2009 and the proportion of liquid biofuels. [5]

	Fuels in road transportation, total	Gasoline [(a]	Diesel fuel[a]	Liquid biofuels	
(Year)	(PJ)	(PJ)	(PJ)	(PJ)	(%)
2000	148	71	77	0	0
2001	150	72	78	0	0
2002	153	73	80	0.033	0.02
2003	156	74	82	0.176	0.1
2004	161	75	85	0.186	0.1
2005	161	75	86	0	0.0
2006	163	74	89	0.034	0.02
2007	168	74	94	0.076	0.005
2008	164	69	95	3.53	2.2
2009	159	67	92	6.66	4.2

[a] *Includes bio-fractions mixed into liquid fuel*

In recent years, a significant capacity for production of biofuels has been constructed in Finland, covering bio-ETBE,[7] hydro-treated biodiesel (NExBTL), and bio-ethanol (Figure 8). The production of ETBE and NExBTL is based on imported raw materials (bio-ethanol and palm

[7] 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. Bio-ETBE is produced by combining bio-ethanol and fossil isobutylene [29].

oil). Finnish bio-ethanol is produced from non-cellulosic raw materials such as by-products and waste streams of the food industry. Compared to the current use of transport biofuels in Finland, the existing production capacity is large, almost 20 PJ/yr. The existing production capacity will not meet the target level set for biofuels in road transport in 2020, and either more domestic capacity is required or biofuel import has to be increased (Figure 9). On the other hand, most biofuels produced have been exported so far, and, depending on the development of the market, some of the domestic production might be exported in the future as well.

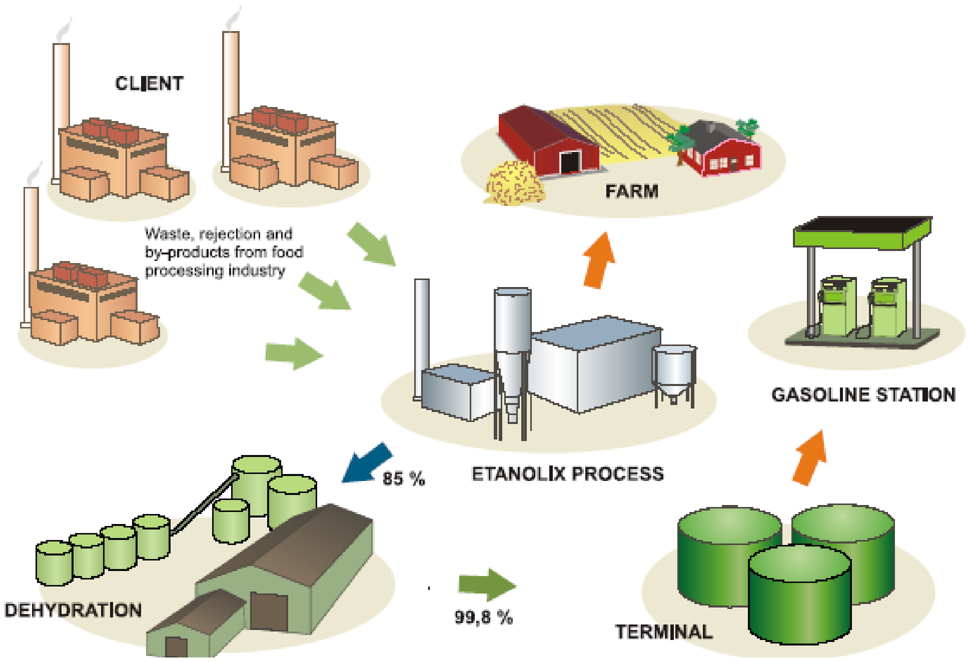

Figure 8. Etanolix concept for food industry side streams and waste. Source: VTT/St 1 [30].

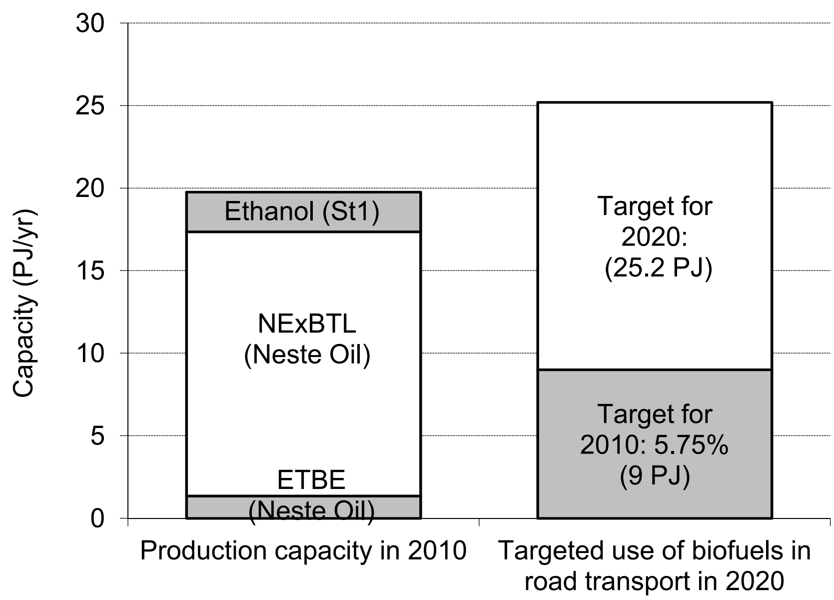

Figure 9. A comparison of existing biofuel production capacity and the 2020 biofuel target set by the government. The projected fuel consumption in road transport in 2020 is approximately 150 PJ.[11] The capacity for production of ETBE includes only the proportion of bio-components (50% of the total calorific value).

4.3 Potential to produce biomass for energy

The current use, production potential and estimated use of major biomass fuels are compared in Table 7. 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 potentials for firewood, agricultural biomass and biofuels in the road transport sector were not available in the literature.

Table 7. The current use, production potential and prospective use of the most important biomass fuels in Finland.

Fuel	Use in 2009 [23] (PJ)	Production potential (PJ/yr)	Targeted use in 2020, (PJ/yr)
Black liquor	110	-	137
Solid processing industry by-products and residues	57	-	68
Forest fuels (forest chips)	44	80-140[a]	90
Firewood	54	50[b]	43
Wood pellets	3	9-27[c]	7
Biogas	2	8-64 [31]	4
Agricultural biomass	2 [(d]	54[e]	1
Biofuels in road transport sector	7	-	25
Fuel peat	102.5	-	n.a.

[(a] The theoretical maximum production potential was evaluated to be 45 million solid-m^3 (324 PJ) [32]. The range is based on studies by Hakkila, 2004, Karjalainen et. al., 2004, and Ranta et al., 2005 [32-34].
[b] Source: VTT / EUBIONET III project.
[c] This equals to 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 [35]. The upper limit was taken from [31] 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.
[d] Includes also animal derived biomass.
[e] The figure is from [31] and is 50% of the theoretical maximum potential.

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. Correspondingly, the volume of the forest industry by-products available for energy purposes would decrease.

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. VTT has estimated that in 2020, the availability of forest biomass will be 72 PJ in total and it will be divided as follows [36, 37]:

- Logging residues from final felling, 3.6 PJ (based on cost level 3.0 – 3.9 €/GJ)
- Stumps and roots, 18.4 PJ (based on cost level 3.9 – 5 €/GJ)
- Forest wood from young stands and first thinning, 50 PJ (based on cost level 5 – 7 €/GJ)

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 to 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 to be 48 EJ and the area suitable for peat production purposes about 1.2 million ha [38]. Approximately 60,000 ha is utilised annually for fuel peat production [39]. 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.

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 higher compared to forest chip. Wood pellets are less expensive than light fuel oil, but are not competitive against heavy fuel oil, natural gas and coal in heat production (Figure 10). 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.

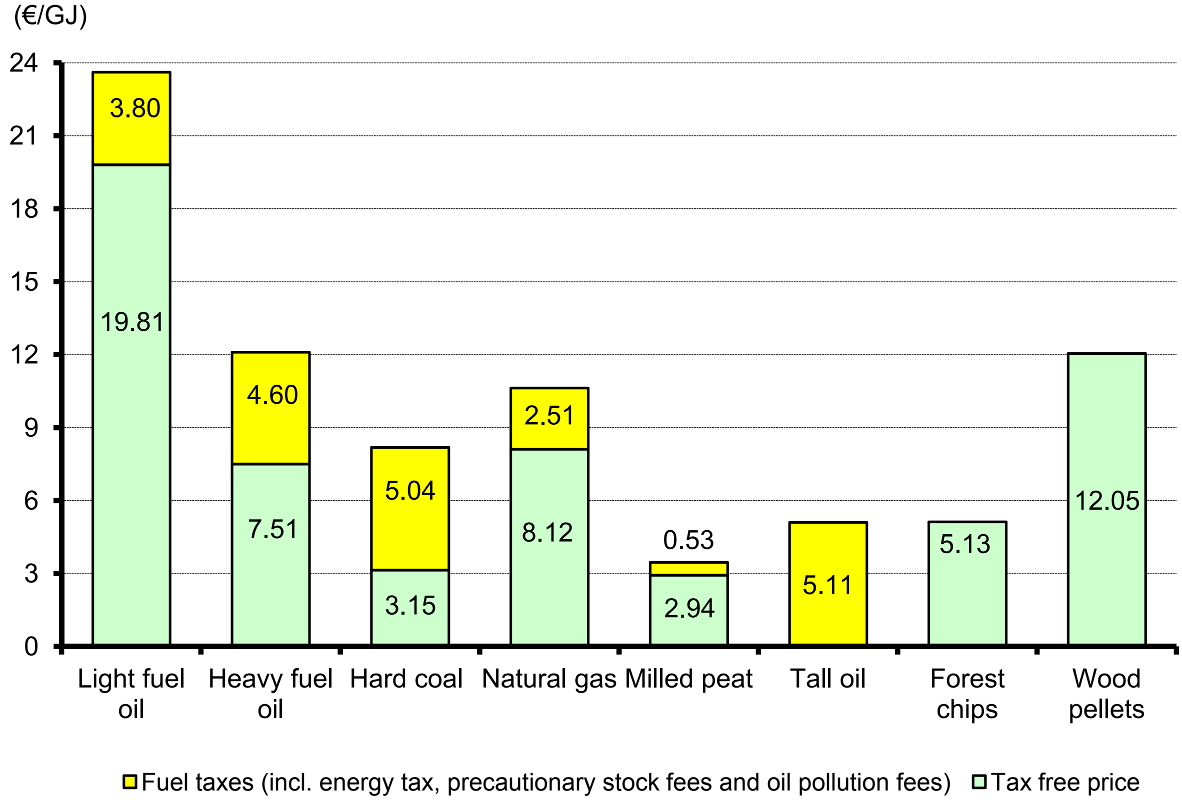

Figure 10. Fuel prices in heat production in January 2011[16, 40, 41]. Value added tax (VAT) 23% excluded. VAT is added for private consumers' prices. The price of tall oil was not available. Tax free price of heavy fuel oil from December 2010.

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 11). 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.

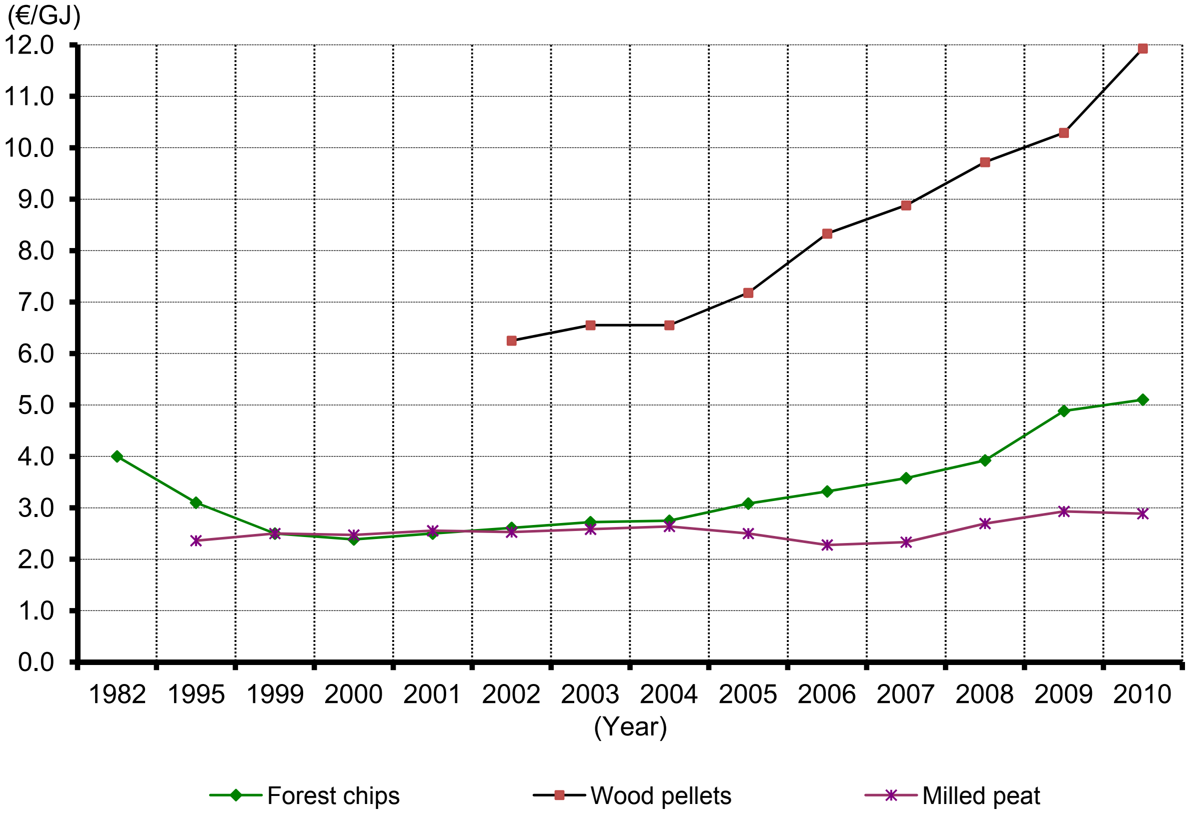

Figure 11. Forest chips, milled peat and wood pellet prices delivered to plants in 1982–2010. Value Added Tax (VAT) excluded. Sources: Forest chips, (years up to 1999 [42], years 2000–2006 [43-49], years since 2007[41]; Peat [5, 41].

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.

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 2004-2009.

The calculations for the major wood streams in the Finnish forest industry in 2009 are presented in Figure 12. 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 currently moist sawdust represents over half of the raw material volume. In 2009, as much as 14% of raw wood used in the forest industry was imported, and in total, 42% of the raw wood volume was converted into black liquor and solid biomass fuels.

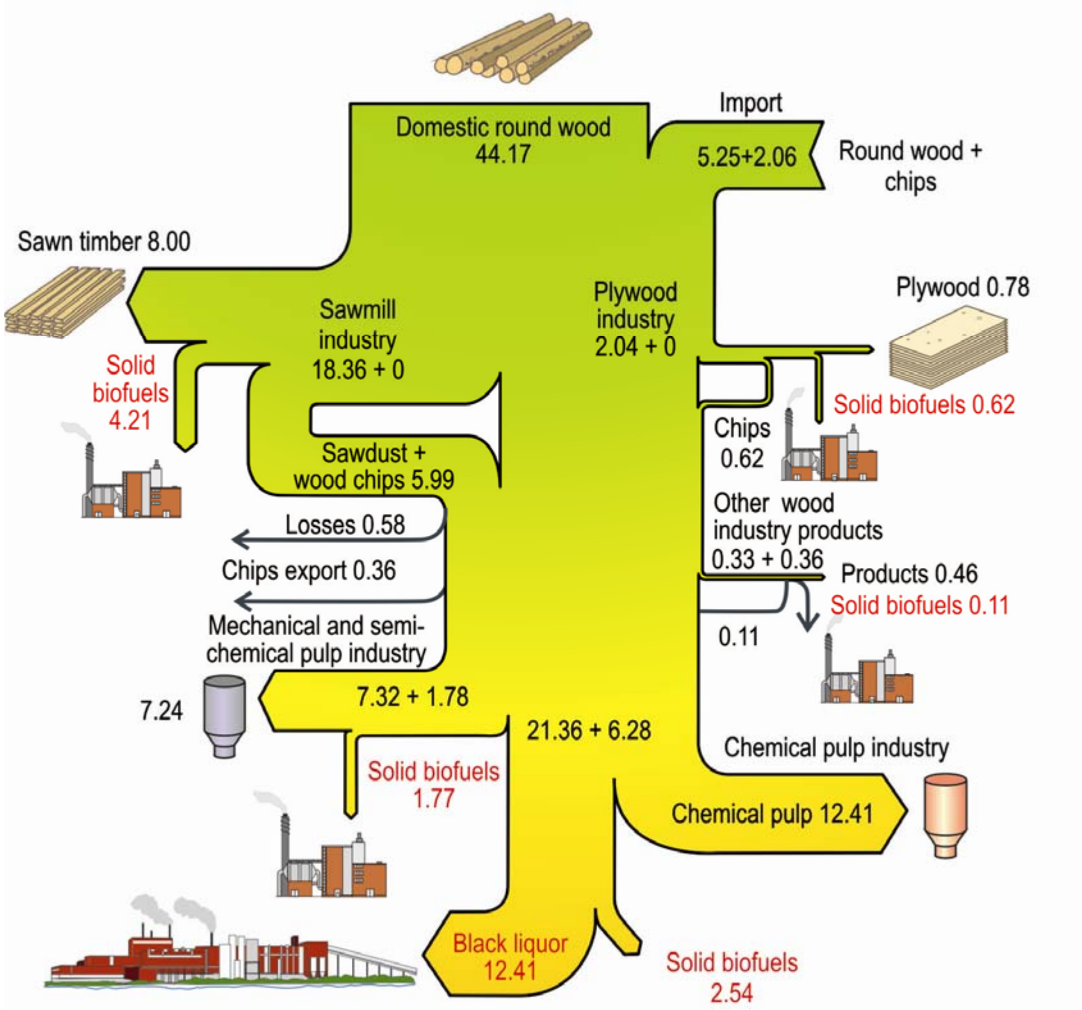

Figure 12. Wood streams in the Finnish forest industry in 2009, in million solid m^3; round wood includes bark. Figure: J. Heinimö (Lappeenranta University of Technology) & E. Alakangas (VTT)

5.2 Biomass fuels import and export in Finland in 2004–2009

Similarly to raw wood, a part of imported and exported forest products, food, and fodder streams ends 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 [50]. The product groups selected in the investigation and their Combined Nomenclature (CN) codes are presented in Table 8.

Table 8. 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 (44013080 since 2009)
Fuel wood (firewood)	44011000
Wood pellets	44013020 (since 2009)
Tall oil	38030010, 38030090, 38070090
Peat	27030000
Ethanol	22071000, 22072000
MTBE, ETBE	29091900 (since 2008; 29091910)
Palm Oil	15111010

[a] *Included solid wood processing industry by-products and residues (and wood pellets until 2008).*

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 2004–2009 are presented in Figure 13 and in detail in Appendix II. 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 development of direct import of biomass fuels in Finland is presented in Figure 14. Especially, the import of palm oil for biodiesel manufacturing has increased considerably during the past years. 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.

Figure 13. Import and export balance of biomass fuels in Finland in 2004–2009. The total calorific values were calculated based on the state of the streams across the border. The positive figures illustrate import and negative figures export.

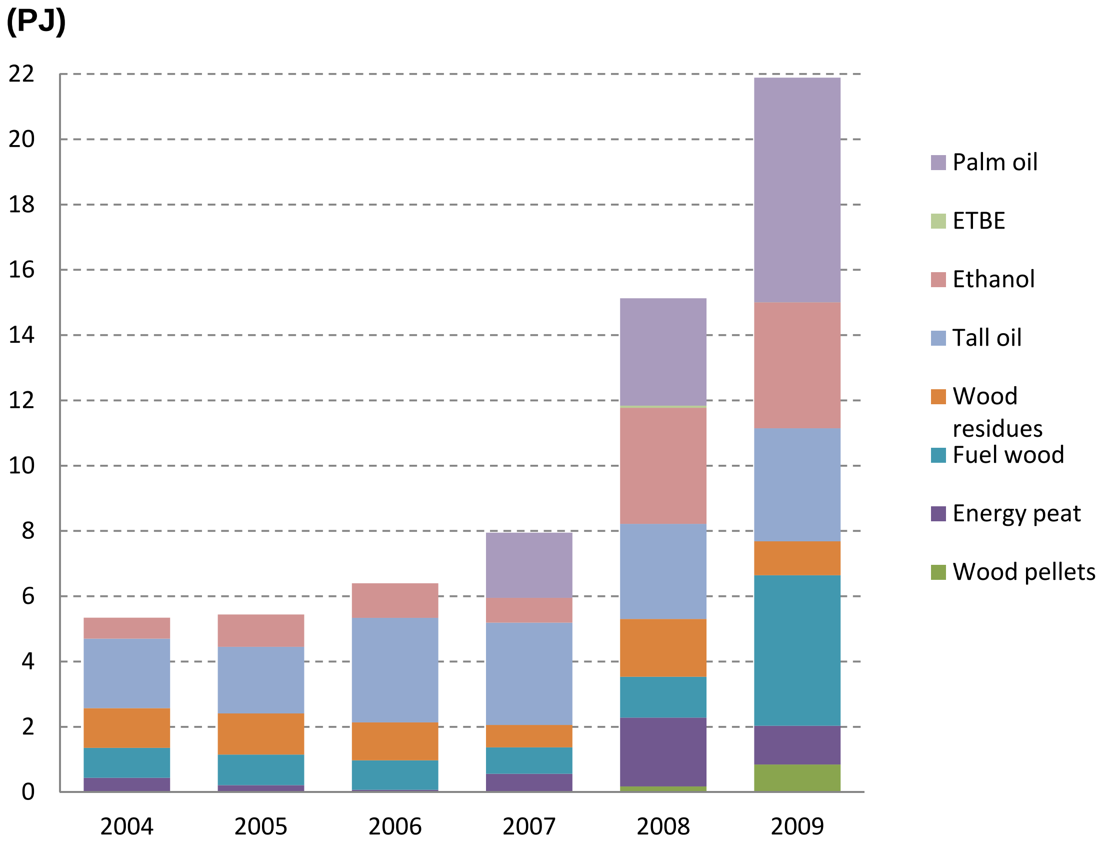

Figure 14. Direct import of biomass fuels in Finland in 2004–2009. The total calorific values were calculated based on the state of the streams across the border.

Foreign-origin wood energy as a proportion of Finnish primary energy consumption in 2004–2009 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 Figure 13. 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 2004–2009

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%
2008	62 PJ	20%
2009	35 PJ	12%

6. Overview of selected actual issues of bioenergy markets in Finland

6.1 Wood pellet market

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 15). 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.

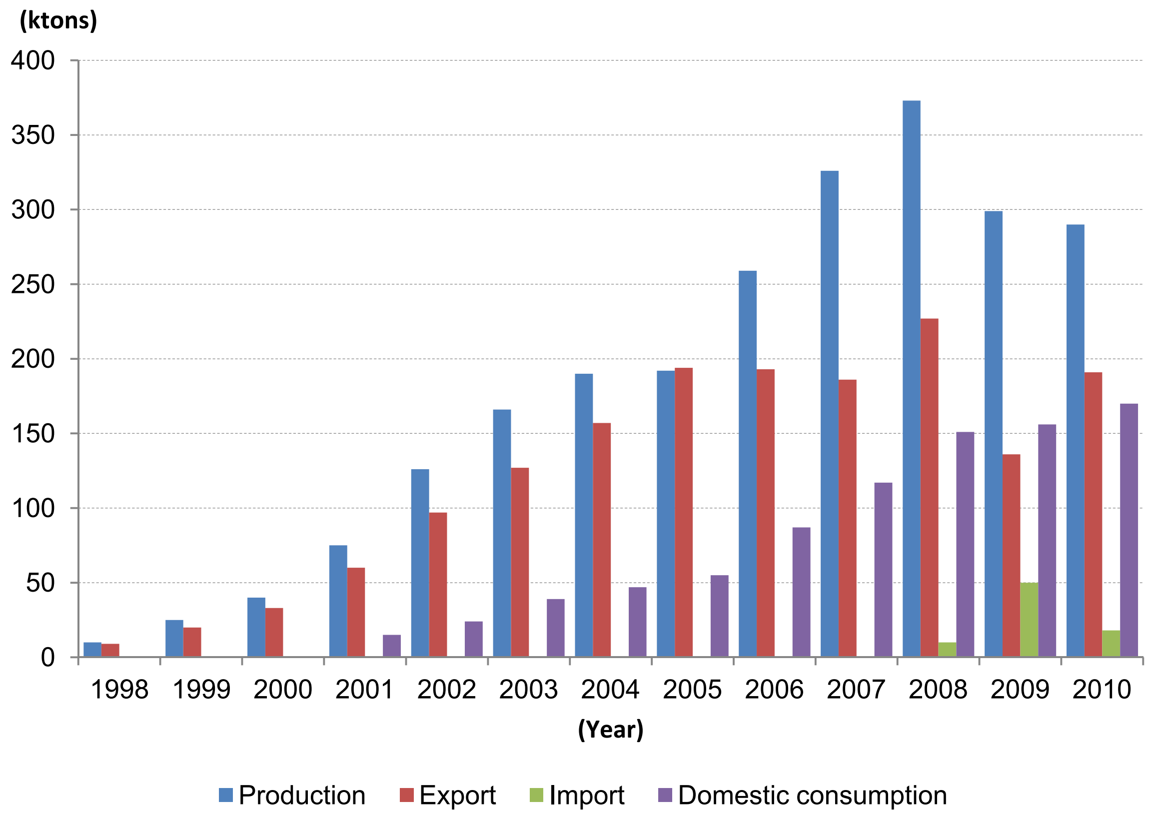

Figure 15. Wood pellet production, domestic consumption, and export in Finland in 1998–2010. In 2005, the export surpassed production resulting from a change in stocks. [51-53]

At the beginning of 2011, there were 28 wood pellet mills in operation (Figure 16). The total production capacity of the pellet mills is approximately 700 000 t/yr.

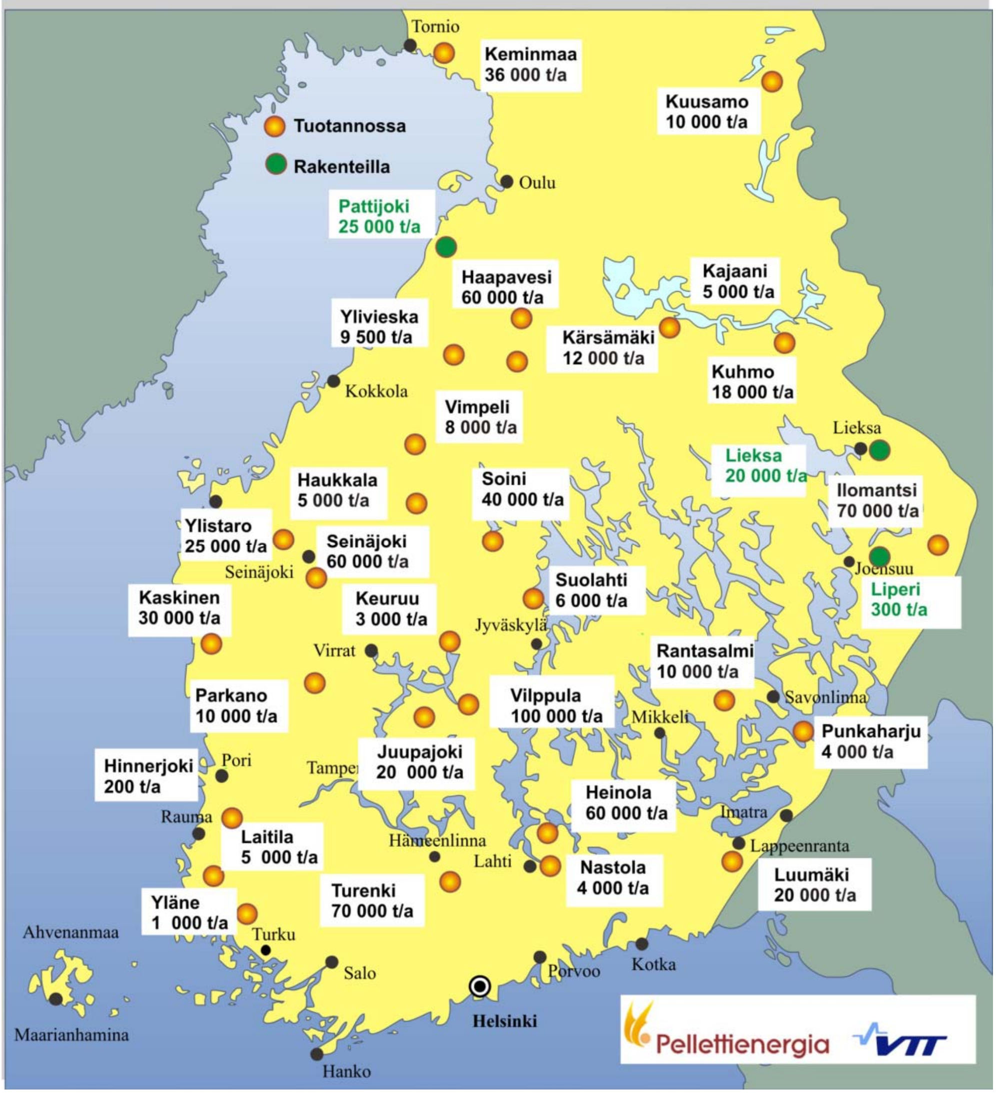

Figure 16. The locations and production capacities of Finnish wood pellet mills at the beginning of 2011. Green dots = under construction. Source: Pellettienergia association and VTT.

In 2010, the export of wood pellets was 191 000 tons. Sweden (49%), Denmark (45%) and Germany (3%) were the main countries of export for wood pellets[54]. 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 2009, the total pellet export form Finland was 146 ktons and the major export countries were:

- Sweden 80 ktons
- Denmark 51 ktons
- The United Kingdom 5 ktons

In 2010, the total pellet export from Finland was 167 ktons and the major export countries were [54]:

- Sweden 82 ktons
- Denmark 72 ktons
- Germany 5 ktons

The domestic consumption of wood pellets has increased continuously in Finland and represented more than half of the pellet production in 2010. The number of private small-scale pellet users in 2008 was estimated at 20 000 [26]. 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 [52]. 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. The newest pellet mills are equipped with a drying process, and they utilise moist raw materials. During the past year, the pellet production in Finland has suffered from the increasing price of raw material and competition in European pellet markets, and the continuous growth of the industry has come to an end. For example, the largest Finnish pellet manufacturer Vapo has announced that it will close three pellet mills during 2011.

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 [23]. 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 [31]. 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 [23]. 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 Liquid biofuel production from forest biomass

The forest-industry cluster has several interesting opportunities for the production of second-generation biofuels, such as options for process integration and utilisation of existing raw material sourcing organisations and facilities [55-57]. Synthetic diesel production with gasification and Fischer-Tropsch (F-T) synthesis, dimethylether (DME) production at pulp mills, and bio-oil production with integrated fast pyrolysis (ITP) are regarded as most promising technologies for producing liquid fuels from woody biomass within the forest industry [55, 57]. The price developments for energy and forest products have increased the forest industry's interest in the production of second-generation biofuels. The price of energy is increasing whereas the prices of paper and paperboard have been declining [58]. For example, in Finland in 2000–2007, the price index for energy increased by 53% [59]. In the same period, the unit price of exported paper products fell by 20% [59].

As an EU member state, Finland has committed itself to the 10% biofuel target. However, its cold climate has given Finland unfavourable conditions for cultivation of the oil and sugar crops used for the production of conventional biofuels. Production of second-generation biofuels from forest biomass by 2020 is defined as one target in the Finnish Climate and Energy strategy [11].

A separate (standalone) biomass-to-liquid (BTL) plant, such as an F-T plant, can convert approximately half of the raw material's calorific energy into fuel and electricity [60, 61]. The rest of the raw material's calorific value is converted into heat. Integrating a BTL plant with a pulp and paper mill offers high overall efficiency, as the excess heat from the BTL process can be utilised for power generation and process heat on-site. Efficient integration of the processes allows even greater than 80% efficiency in conversion from feedstock energy into biofuel [55, 56]. In addition, forest-industry mills' raw wood procurement organisation and wood-handling facilities can be utilised for the raw material sourcing of BTL production.

Options for the integration of BTL plants with pulp and paper mills have been studied intensively in recent years; see, e.g., [55-57, 62]. The emphasis in the design of the integration of a BTL plant with a pulp and paper mill can be on the minimising of either additional biomass demand or external electricity purchasing [56]. Figure 17 depicts the changes in raw material and energy balance of a typical pulp and paper mill that result from the integration of a BTL plant for both of the above cases. When the demand for external electricity is minimised, the total conversion efficiency of approximately 75% can be achieved. A BTL plant in a forest-industry environment can convert roughly one million solid cubic metres of forest biomass into 120,000 t (5.4 PJ)[8] of products, such as synthetic biodiesel.

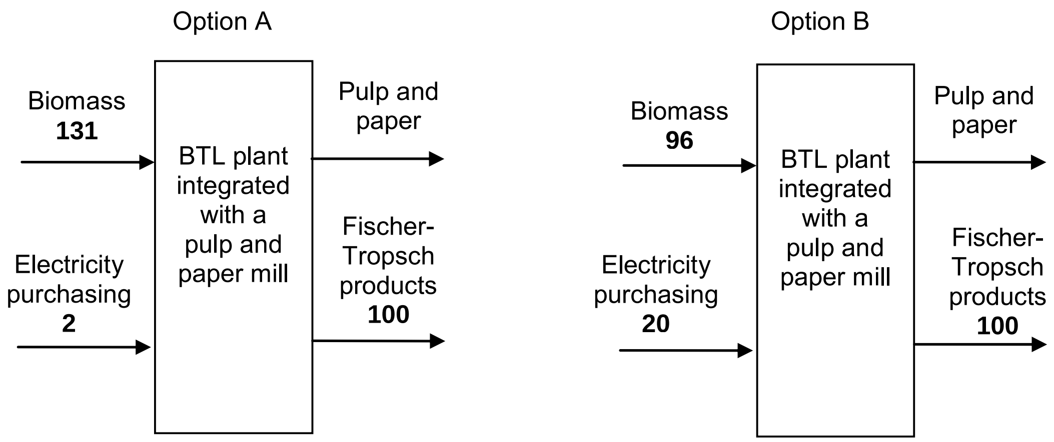

Figure 17. Examples of integration options for F-T products with a pulp and paper mill and the changes in energy balance. The numbers in the figure are energy-based. Option A minimises purchasing of external electricity, and option B minimises that of biomass. Data obtained from sources [56, 62].

In a recent study, the Technical Research Centre of Finland (VTT) and Pöyry evaluated the market potential of liquid biomass fuel technologies in the European forest industry by 2020 [57]. In the analysis, mill-level information on existing power and recovery boilers, including data on boiler size and age, was utilised. The idea was to replace old boiler capacity that is coming to the end of its technical service life with new bioenergy technologies while taking technological limitations such as boiler size and the heat demand of the mill into account. The liquid biofuel production technologies included in the study were ITP, F-T diesel, and black

[8] Conversion efficiency: 75% and calorific value of F-T products: 44 GJ/t.

liquor DME. According to the study, the greatest country-specific potential for liquid biofuel production within the forest industry lies in Finland, at approximately 60 PJ/yr, equalling 1,400,000 tons of biofuels per year [57].

All of the large Finnish forest-industry companies have been involved in the development and commercialisation of BTL processes with their technology partners. A summary of the present state of liquid biofuel production and projects involving BTL production in Finland is presented in Table 10. In addition, the forest industry companies have several alternative locations for BTL plants abroad. The capacities given for planned F-T biodiesel projects are the maximum production capacities used in the environment impact assessment (EIA) plans. Investment decisions on BTL plants are expected during the second half of the year 2012 [63].

Table 10. Summary of biofuel production and planned projects in Finland [64-71]

Company	Location	Product or technology	Raw material	Production capacity (t/yr)	Status / Other
Neste Oil	Porvoo	ETBE	Ethanol	100,000	Production started in 2004
Neste Oil	Porvoo	Hydrogenated biodiesel, NExBTL process	Tri-glycerides (mainly palm oil)	380,000	Two production plants, production started in 2008
St1 Biofuels	Hamina (dehydration plant), with ethanol production units in Lappeenranta, Närpiö, Hamina, Vantaa, Lahti, and Hämeenlinna	Ethanol, Etanolix technology	Food-industry waste, scraps, and by-products	88,000 (dehydration capacity)	Production started in 2008
Realised plants↑		Status in late 2010			Planned plants↓
UPM	Rauma	Second-generation biofuels (biodiesel), with gasification and Fischer-Tropsch synthesis	Lignocellulosic biomass (wood)	300,000 (per plant)	Environmental impact assessment (EIA) completed in December 2009.
UPM	Several alternative locations	Pyrolysis oil, fast pyrolysis / ITP process (process integrated with a fluidised bed boiler)	Lignocellulosic biomass (wood)	n.a.	Joint development project with UPM, Metso, Fortum, and VTT.
Vapo and Metsäliitto	Kemi or Äänekoski	Second-generation biofuels (biodiesel), with gasification and Fischer-Tropsch synthesis	Lignocellulosic biomass (wood, field biomass, and peat)	200,000 (per plant)	EIA completed in December 2009.
NSE Biofuels[a]	Imatra or Porvoo	Second-generation biofuels (biodiesel), with gasification and Fischer-Tropsch synthesis	Lignocellulosic biomass (wood)	200,000	EIA will be completed in April 2011. Products of BTL process can be used as raw material in the NExBTL process.

[a] *A joint venture of Neste Oil and Stora Enso.*

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 21% of the total energy consumption in 2009. 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.

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 met the Kyoto commitment due to the economic recession but the trend of emissions is on the increase. In 2008, the share of renewable energy in the gross final energy consumption was approximately 31%. 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 trade of biomass fuels has a substantial importance for the utilisation of bioenergy in Finland. In 2009, the total international trading of solid and liquid biomass fuels was approximately 45 PJ, of which import was 23 PJ. The indirect import of wood fuels which takes place within the forest industry's raw wood import grew until 2006, being 61 PJ in that year. In 2009, the import of raw wood collapsed, and correspondingly, the indirect import of wood fuels dropped to 23 PJ. In 2004-2008, wood pellets and tall oil formed the majority of export streams of biomass fuels. During 2007-2009, two large biodiesel production units, with the capacity of 380 000 t/yr in total, were established in Porvoo, and palm oil and biodiesel have become the largest import and export streams of energy biomass.

REFERENCES

[1] IEA. 2007. Key World Energy Statistics. Paris. 78 p. Available at: http://www.iea.org/textbase/nppdf/free/2007/key_stats_2007.pdf.

[2] Heinimö, J. 2008. Methodological aspects on international biofuels trade: international streams and trade of solid and liquid biofuels in Finland. Biomass and Bioenergy. Volume 32. Issue 8. pp. 702-716.

[3] Heinimö, J. & Alakangas, E. 2006. Solid and Liquid Biofuels Markets in Finland - a study on international biofuels trade. Department of Energy and Environmental Technology. Lappeenranta University of Technology. ISBN 952-214-199-2. 92 p. Available at: http://www.doria.fi/lutpub.

[4] Ministry of Employment and the Economy of Finland. 2009. "Uusiutuvat energialähteet ja turve". Last accessed 17 June from: http://www.tem.fi/index.phtml?s=2481.

[5] Statistics Finland. 2011. Energy Statistics. Yearbook 2010. Official statistics of Finland. Helsinki.

[6] IEA. 2004. Energy Policies of IEA Countries. Special 30th anniversary edition. 2004 Review. 539 p.

[7] Paappanen, T., Leinonen, A. & Hillebrand, K. 2006. Fuel peat industry in EU. Summary report. Technical Research Centre of Finland (VTT). VTT-R-00545-06. Jyväskylä. 20 p.

[8] Promotion the use of renewable energy sources. 2008. "Text adopted by the European Commission". Last accessed 4 June 2009 from: http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//TEXT+TA+P6-TA-2008-0609+0+DOC+XML+V0//EN&language=EN#BKMD-2.

[9] European Commission. 2009. Directive2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the Promotion of the Use of Energy from Renewable Sources and Amending and Subsequently Repealing Directives 2001/77/EC and 2003/30/EC. 23 January. Brussels, Belgium. 47 p.

[10] Pekkarinen, M. 2010. Kohti vähäpäästöistä Suomea - Uusiutuvan energian velvoitepaketti. Power Point presentation. 20 April. Ministry of Employment and the Economy. Helsinki. Available at: http://www.tem.fi/files/26643/UE_lo_velvoitepaketti_Kesaranta_200410.pdf.

[11] Ministry of Employment and the Economy. 2008. Pitkän aikavälin ilmasto- ja energiastrategia [´Long-term Climate and Energy Strategy´]. Helsinki. 130 p. Available at: http://www.tem.fi/index.phtml?s=2542.

[12] Ministry of Employment and the Economy. 2010. Suomen kansallinen toimintasuunnitlema uusiutuvista lähteistä peräisin olevan ennergian edistämisestä direktiivin 2009/28/EY mukaisesti (NREAP Finland). 19 p.

[13] Government's Ministerial Working Group on Climate and Energy Policy. 2008. Long-term Climate and Energy Strategy. Government Report to Parliament. (In Finnish). 6 November. 130 p. Available at: http://www.tem.fi/files/20585/Selontekoehdotus_311008.pdf.

[14] Statistics Finland. 2011. Suomen kasvihuonekaasupäästöt 1990-2009. (Finnish green house gas emissions in 1990-2009). Katsauksia 2011/1. Helsinki. 55 p. Available at: http://www.stat.fi/tup/khkinv/suominir_2011.pdf.

[15] Alakangas, E., Vesterinen, P. & Martikainen, A. 2011. The legal and technical requirements of biomass and bioenergy in 18 EU-countries - National reports - D4.2.2. August. 202 p.

[16] Finnish Government. 2010. Laki nestemäisten polttoaineiden valmisteverosta 29.12.1994/1472. 30 December. Available at: http://www.finlex.fi/fi/laki/ajantasa/1994/19941472.

[17] Ministry of Employment and the Economy. 2008. 2008 report as provided for in directive 2003/30/EC on the promotion of the use of biofuels or other renewable fuels for transport in Finland. 2 December. 5 p. Available at: http://ec.europa.eu/energy/renewables/biofuels/ms_reports_dir_2003_30_en.htm.

[18] Ministry of Trade and Industry. 2007. 2007 report as provided for in directive 2003/30/EC on the promotion of the use of biofuels or other renewable fuels for transport in Finland. 5 April. 6 p. Available at: http://ec.europa.eu/energy/res/legislation/doc/biofuels/member_states/2007_rapports/finland_en.pdf.

[19] Peltola, A. (ed.). 2008. Metsätilastollinen vuosikirja 2008 [´The Finnish Statistical Yearbook of Forestry 2008´]. Finnish Forest Research Institute. ISBN 978-951-40-2131-9. 456 p.

[20] Ylitalo, E. 2011. Finnish Forest Research Institute. Personal communication. E-mail. 10 October.

[21] Association of Finnish Energy Industries. 2010. Kaukolämpötilasto 2009. 59 p. Available at: http://www.energia.fi/fi/tilastot/kaukolampotilastot/kaukolammitys.

[22] Ylitalo, E. (ed.). 2009. Metsätilastollinen vuosikirja 2010 [´The Finnish Statistical Yearbook of Forestry 2010´]. Finnish Forest Research Institute. ISBN 978-951-40-2266-1 (PDF). 470 p.

[23] Statistics Finland. 2009. Energy Statistics. Yearbook 2008. Official statistics of Finland. Helsinki. ISBN 978-952-467-996-1.

[24] Tekes. 2008. Growing Power. Bioenergy Solutions from Finland. 1st edition. The Finnish Funding Agency for Technology and Innovation (Tekes). Available at: http://www.tekes.fi/julkaisut/GrowingPower_2009.pdf.

[25] Alakangas, E., Erkkilä, A. & Oravainen, H. 2008. Tehokas ja ympäristöä säästävä tulisijalämmitys - Polttopuun tuotanto ja käyttö 'Efficient and environmentally friendly biomass heating - firewood production and use'. VTT-R-10553-08. 67 p. Available at: www.biohousing.eu.com/stoveheating.

[26] Finnish Pellet Energy Association. 2009. "Lausunto ilmasto- ja energiastrategiaan 19.5.2009". Last accessed 4 June from: http://www.pellettienergia.fi.

[27] Torvelainen, J. 2009. Pientalojen polttopuun käyttö 2007/2008 ['Use of firewood in single-family houses']. Finnish Forest Research Institute. Metsätilastotiedote 26/2009. 4 p.

[28] Ministry of Trade and Industry. 2005. 2005 report as provided for in directive 2003/30/EC on the promotion of the use of biofuels or other renewable fuels for transport in Finland. 21.12.2005. 4 p. Available at: http://europa.eu.int/comm/energy/res/legislation/doc/biofuels/member_states/rapports_2005/2003_30_fi_report_en.pdf.

[29] Enguidanos, M., Soria, A., Kavalov, B. & Jensen, P. 2002. Techno-economic analysis of bio-alcohol production in the EU: a short summary for decision-makers. European Commission. Joint Research Centre (DG JRC). Institute for Prospective Technological Studies. Report EUR 20280 EN. 28 p. Available at: http://www.senternovem.nl/mmfiles/26432_tcm24-124153.pdf.

[30] Vesterinen, P., Alakangas, E., Veijonen, K. & Junginger, M. 2010. Prospects of bioenergy in new industrial sectors - D2.3, EUBIONET III Report VTT-R-01749-10. February. 24 p.

[31] Asplund, D., Korppi-Tommola, J. & Helynen, S. 2005. Uusiutuvan energian lisäkäyttömahdollisuudet vuoteen 2015. 10.5.2005. Jyväskylän Teknologiakeskus Oy. Jyväskylä. 57 p. Available at: http://julkaisurekisteri.ktm.fi/ktm_jur/ktmjur.nsf/all/E5063805F1B754D5C22570190028414D/$file/34642005.pdf.

[32] Hakkila, P. 2004. Developing technology for large-scale production of forest chips. Wood Energy Technology Programme 1999 - 2003. Final report. Technology Report 5/2004. Tekes. 44 p. Available at: http://www.tekes.fi/english/programm/woodenergy.

[33] Karjalainen, T., Asikainen, A., Ilavsky, J., Zamboni, R., Hotari, K.-E., et al. 2004. Estimation of Energy Wood Potential in Europe. Working Papers of the Finnish Forest Research Institute 6. 43 p. Available at: www.metla.fi/julkaisut/workingpapers/200x/mwp006.htm.

[34] Ranta, T., Lahtinen, P., Elo, J. & Laitila, J. 2005. The regional balance of wood fuel demand and supply in Finland. FINBIO - the Bioenergy Association of Finland. Bioenergy2005. International Bioenergy in Wood Industry Conference and Exhibition. 12-15 September 2005. Jyväskylä. pp. 39-45.

[35] Finnish Pellet Energy Association. 2009. "Pellettien tuotantotavoitteet (Statistics/targets for the production of pellets)". Last accessed 27 May 2009 from: http://www.pellettienergia.fi/?lang=1&pv=50&av=30&pg=teksti&id=110.

[36] Alakangas, E., Veijonen, K. & Flyktman, M. 2009. Bioenergy barriers and solutions - WP2. Country report: Finland, EUBIONET III. 25 p.

[37] Asplund, D., Flyktman, M. & Uusi-Penttilä, P. 2009. Arvio mahdollisuuksista saavuttaa uusiutuvien energialähteiden käytön tavoitteet vuonna 2020 Suomessa. FINBIOn julkaisu 42. ISBN 978-952-5135-41-1. 56 p.

[38] Virtanen, K., Hänninen, P., Kallinen, R.-L., Vartiainen, S., Herranen, T., et al. 2003. Suomen turvevarat 2000 (The peat reserves of Finland in 2000). Geological Survey of Finland. Geological Survey of Finland, Report of Investigation 156. Espoo. 101 p.

[39] Flyktman, M. 2005. Energia- ja ympäristöturpeen kysyntä ja tarjonta vuoteen 2020 mennessä (Demand and supply of fuel peat in Finland 2020). Research report PRO2/2085/05. VTT Processes. 28.12.2005. 34 p. Available at: http://www.turveteollisuusliitto.fi/user_files/files/energia-ymparistoturpeen_kysynta_2020.pdf.

[40] Finnish Government. 2010. Laki sähkön ja eräiden polttoaineiden valmisteverosta 30.12.1996/1260. 30 December. Available at: http://www.finlex.fi/fi/laki/ajantasa/1996/19961260.

[41] Statistics Finland. 2011. "Energy prices". Last accessed 10 November from: http://pxweb2.stat.fi/database/statfin/ene/ehi/ehi_en.asp.

[42] Hakkila, P., Kalaja, H. & Nousiainen, I. 2000. Use and prices of forest chips in Finland in 1999. AFB-net V Task - export and import possibilities and fuel prices. Technical Research Centre (VTT). Jyväskylä. 35 p.

[43] Ylitalo, E. (ed.). 2001. Puupolttoaineen käyttö energiantuotannossa vuonna 2000. Metsäntutkimuslaitos. Metsätilastotiedote 574. 4.5.2001. Official Statistics of Finland. Helsinki. 5 p.

[44] Ylitalo, E. (ed.). 2002. Puupolttoaineen käyttö energiantuotannossa vuonna 2001. Metsäntutkimuslaitos. Metsätilastotiedote 620. 22.4.2002. Official Statistics of Finland. Helsinki. 5 p.

[45] Ylitalo, E. (ed.). 2003. Puupolttoaineen käyttö energiantuotannossa vuonna 2002. Metsäntutkimuslaitos. Metsätilastotiedote 670. 25.4.2003. Official Statistics of Finland. 25.4.2003. Helsinki. 5 p.

[46] Ylitalo, E. (ed.). 2004. Puupolttoaineiden käyttö energiantuotannossa 2003. Metsäntutkimuslaitos. Metsätilastotiedote 719. 6.5.2004. Official Statistics of Finland. 6.5.2004. Helsinki. 7 p.

[47] Ylitalo, E. (ed.). 2005. Puupolttoaineiden käyttö energiantuotannossa 2004. Metsäntutkimuslaitos. Metsätilastotiedote 770. Official Statistics of Finland. 11.5.2005. Helsinki. 7 p.

[48] Ylitalo, E. (ed.). 2006. Puupolttoaineiden käyttö energiantuotannossa 2005. Metsätilastotiedote 820. 4.5.2006. Official Statistics of Finland. Helsinki. 7 p.

[49] Ylitalo, E. 2007. Finnish Forest Research Institute. Personal communication. E-mail. 31 May.

[50] Eurostat. 2009. "EU trade since 1995 by CN8." Last accessed 4 June 2009 from: http://epp.eurostat.ec.europa.eu.

[51] Alakangas, E. & Paju, P. 2002. Wood pellets in Finland - technology, economy, and market. OPET report 5. OPET Finland. Technical Research Centre of Finland (VTT). 64 p.

[52] Finnish Forest Research Institute. 2009. "METINFO -database". Last accessed 4 June 2009 from: http://www.metla.fi/metinfo.

[53] Heinimö, J. & Orava, H. 2002. Pellettien markkinat ja pellettiliiketoiminta Suomessa, Ruotsissa ja Tanskassa. Mikkelin ammattikorkeakoulu. Tutkimuksia A 6. ISBN 951-588-087-4. 55 p.

[54] Eurostat. 2009. "EU trade since 1995 by CN8." Last accessed 18 March 2011 from: http://epp.eurostat.ec.europa.eu.

[55] Joelsson, J., Gustavsson, L., Pingoud, K. & Soimakallio, S. 2009. CO_2 balance and oil use reduction of syngas-derived motor fuels co-produced in pulp and paper mills. In 17th European Biomass Conference and Exhibition. Hamburg, Germany. pp. 2252–2260.

[56] Mäkinen, T., Soimakallio, S., Paappanen, T., Pahkala, K. & Mikkola, H. 2006. Liikenteen biopolttoaineiden ja peltoenergian kasvihuonekaasutaseet ja uudet liiketoimintakonseptit. VTT Research Notes 2357. ISBN 951-38-6826-5. 134 p.

[57] Sipilä, E., Jokinen, J., Sipilä, K. & Helynen, S. 2009. Bioenergy market potential in European forest industry to 2G biofuels and CHP power production by 2020. In 17th European Biomass Conference and Exhibition. Hamburg, Germany. pp. 2084–2092.

[58] Sipilä, E., Vehlow, J., Vainikka, P., Wilén, C. & Sipilä, K. 2009. Market potential of high efficiency CHP and waste based ethanol in European pulp and paper industry. VTT Research Notes 2500. ISBN 978-951-38-7320-2. 73 p. Available at: http://www.vtt.fi/publications/index.jsp.

[59] Hetemäki, L. 2009. Puu paperiksi vai energiaksi? Presentation at ´Kevätpäivä´ seminar of FINBIO. 22 May. Available at: http://www.metla.fi/hanke/50168/pdf/lauri_hetemaki_FINBIO_220409.pdf.

[60] Rudolf, M. 2005. Biomass-to-liquid Fuels (BtL) - Made by CHOREN - Process, Environmental Impact and Latest Developments. Presentation at Automobile & Environment at Belgrade EAEC Congress, May. 10 p.

[61] Tijmensen, M., Faaij, A., Hamelinck, C. & van Hardeveld, M. 2002. Exploration of the possibilities for production of Fischer Tropsch liquids and power via biomass gasification. Biomass and Bionergy. Volume 23. Issue 2. pp. 129–152.

[62] McKeough, P. & Kurkela, E. 2008. Process evaluations and design studies in the UCG project 2004 - 2007. VTT Research Notes 2434. ISBN 978-951-38-7210-6. 45 p.

[63] Talouselämä. 2011. "Biodieselin tukikilvassa on vain yksi onnekas". Last accessed 5 February from: http://www.talouselama.fi/uutiset/article573544.ece.

[64] Jokela, P. 2010. Biopolttoaineiden kehitystyö UPM:ssä. Presentation at Itä-Suomen Bioenergiapäivät seminar on 22 March.

[65] Neste Oil. 2011. "Releases". Last accessed 4 February from: http://www.nesteoil.com.

[66] Reini, K. & Törmä, H. 2010. Suomen metsäteollisuuden uusien mahdollisuuksien aluetaloudelliset vaikutukset. Helsingin yliopisto (University of Helsinki). Ruralia instituutti. Raportteja 55. ISBN 978-952-10-5419-8. 37 p.

[67] St1. 2010. "Etanolin tuotanto ja hankkeet". Last accessed 29 December from: http://st1.fi/.

[68] UPM. 2011. "Releases". Last accessed 4 February from: http://www.upm.com/en/about_upm/media/.

[69] UPM-Kymmene Oyj. 2009. Toisen sukupolven biojalostamon ympäristövaikutusten arviointiohjelma [´Environmental impact assessment for second-generation biofuel production plant´]. 67 p.

[70] Vapo. 2010. "Vapoil -project". Last accessed 29 December from: http://www.vapoil.fi.

[71] WSP Environmental Oy. 2009. Metsäliiton ja Vapon biodieselhanke YVA Ohjelma [´Environment impact assessment for Vapo's BTL project´]. 3 December. 79 p.

[72] Nikkonen, J. (Neste Oil Oyj). 2006. Personal communication. E-mail. 26 January.

[73] Nikkonen, J. (Neste Oil Oyj). 2007. Personal communication. E-mail. 20 December.

[74] Aarne, M. & Peltola, A. (ed). 2005. Metsätilastollinen vuosikirja 2005 (The Finnish Statistical Yearbook of Forestry). Finnish Forest Research Institute. 396 p.

[75] Eurostat. 2005. "EU trade since 1995 by CN8." Last accessed October 2005 from: http://epp.eurostat.cec.eu.int.

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 [23] ▪ Wood pellets were assumed to be manufactured from indigenous wood.
Energy peat, including peat pellets	▪ The import and export volumes of peat (in PJ) were from Foreign Trade Statistics [5].
Fuel wood (Firewood)	▪ Import and export volumes were obtained from Foreign Trade Statistics information [50]. ▪ 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 [50] ▪ Until 2009 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 zero ton in 2007-2008, which was the total export under CN code 44013090, with the export of wood pellets subtracted. Since 2009 wood residues have been recorded under a new CN code 44013080 that excludes wood pellets. ▪ 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 [72, 73]. For the years 2007-2009, the import volume of ethanol was obtained from trade statistics [50] ▪ 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 [72]. ▪ According to the manufacturer, exports of ETBE were 29 100 t in 2005 and 23 100 t in 2006 [73]. ▪ 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). Since 2008 export and import of ETBE was recorded under a new CN code 29091910 ▪ The bio-component percentage of exported ETBE was assumed to be 50% (concerning years 2005-2009). ▪ The calorific value of the bio-based component of ETBE was assumed to be similar to that of ethanol.
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), (€ 56 million in 2008) and (€ 93 M in 2009). ▪ 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, in 2008 (€ 630/t) at 89 000 t and in 2009 (€ 500/t) at 186 000 t. ▪ The calorific value used for palm oil was 37 MJ/kg.
Bio-diesel	▪ Until 2007, 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. ▪ In 2008-2009, the export of biodiesel was evaluated to equal palm oil import subtracted with domestic consumption of biodiesel.
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 [74, 75]. 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.

Import and export balance of biomass fuels in Finland in 2004–2009 . 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**	**2008**	**2009**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Direct trade	**5.34**	**5.44**	**6.40**	**7.95**	**15.13**	**21.89**	**8.15**	**8.39**	**8.38**	**10.94**	**10.62**	**10.94**
▪ Wood pellets	0.00	0.00	0.00	0.00	0.17	0.84	2.65	3.27	3.26	3.14	3.83	2.31
▪ Energy peat	0.44	0.21	0.07	0.56	2.11	1.19	0.29	0.60	0.26	0.54	0.18	0.46
▪ Fuel wood	0.92	0.94	0.90	0.81	1.25	4.61	0.06	0.04	0.08	0.08	0.01	0.05
▪ Wood residues	1.21	1.26	1.16	0.69	1.77	1.04	0.06	0.21	0.02	0.00	0.00	0.05
▪ Tall oil	2.13	2.04	3.20	3.13	2.91	3.46	4.45	3.88	4.45	4.89	3.68	3.48
▪ Ethanol	0.64	0.99	1.06	0.76	3.55	3.86	0.00	0.00	0.00	0.00	0.00	0.00
▪ ETBE[a]	0.00	0.00	0.00	0.00	0.07	0.00	0.64	0.39	0.31	0.28	0.00	0.18
▪ Palm oil	0.00	0.00	0.00	2.00	3.29	6.88	0.00	0.00	0.00	0.00	0.00	0.00
▪ Biodiesel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	2.92	4.42
Indirect trade	**56.01**	**57.58**	**61.16**	**56.34**	**64.74**	**23.10**	**2.40**	**3.02**	**3.08**	**3.08**	**3.29**	**2.92**
▪ Round wood	50.71	52.08	55.52	50.35	54.91	15.12	2.00	2.56	2.61	2.38	2.65	1.98
▪ Chips	5.16	5.25	5.26	5.54	9.25	7.46	0.39	0.45	0.35	0.37	0.54	0.89
▪ Sawdust	0.14	0.25	0.37	0.45	0.59	0.52	0.00	0.00	0.12	0.33	0.09	0.05
Total	**61.35**	**63.02**	**67.55**	**64.28**	**79.87**	**44.99**	**10.55**	**11.41**	**11.46**	**14.01**	**13.91**	**13.86**

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

ISBN 978-952-265-202-7 (PDF)
ISSN 1798-1328
Lappeenranta 2011