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EVALUATION OF OPTIONS TO ENHANCE THE NORDIC COOPERATION IN THE FIELD OF SOLID BIOMASS FOR ENERGY PURPOSES

Prepared for the Nordic Council of Ministers

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ABSTRACT

The Working Group on Renewable Energy (AGFE), a part of the Nordic Council of Ministers, has the task to strengthen and promote the use of renewable energy in the Nordic region. This is meant to be achieved though exchange of information and experience and by initiating and implementing joint projects. As a part of this initiative, AGFE commissioned an assignment to analyse and explore if there are possibilities to strengthen the Nordic cooperation between Sweden, Finland, Norway and Denmark in the field of solid biomass for energy purposes and if so, to identify key areas and forms of cooperation. Pöyry Management Consulting facilitated the study and analytically supported the work. The starting point was a critical desktop review in the target countries, where topics such as current supply and demand of solid biomass, trade, mobilisation, biomass-to-energy generation, regulatory environment, market and price development were analysed. Interviews with 29 market players along the whole value chain were conducted in order to highlight relevant themes and assess if there are opportunities to enhance the Nordic cooperation. Also, a seminar was conducted in Oslo (March 12, 2012) with the title "*Opportunities for enhanced Nordic cooperation in the field of solid biomass for energy purposes*", inviting the interviewed stakeholders in the target countries and other bioenergy sector experts.

One of the targets included in the climate and energy package, enforced by the European Parliament and Council, is a 20% share of renewable energy in overall EU energy consumption by 2020. Biomass plays a significant role in achieving the 2020 targets. However, according to Pöyry's forecast for 2020, woody and agrobiomass demand will exceed the supply, resulting in a biomass supply gap in Europe of approximately 115 million m^3 or 230 TWh. This indicates that there will be a large biomass deficit and Europe will face a challenge to meet the higher demand pressure from the energy sector. Hence, with regards to the renewable energy targets and a possible biomass deficit year 2020, there could potentially be opportunities to enhance the Nordic cooperation in order to secure the future biomass supply.

The resource assessment in the target countries shows that the theoretical biomass potential is significant in the Nordic countries, particularly for harvesting residues. There is an expected growth in the consumption of biomass in all four countries until 2020 and in order to increase the domestic use of solid biomass from forestry, it is necessary to exploit more of the supply potential. Also, the theoretical potential of agricultural biomass is substantial in the Nordic countries, however only small volumes are currently utilised for energy purposes. Most trade takes place with industrial roundwood used by the forest industry, while the solid biomass trade for energy purposes (mainly pellets and firewood) is relatively low. All Nordic countries, expect Finland, are net importers of biomass assortments for energy purposes.

The interview results show that there exist different forms of cooperation between the Nordic countries, however there is notable potential for improvement to capture much of the inherent biomass potential in the target countries. Exchange of information and research & development, were recognised as the two most established forms of cooperation. However, the cooperation forms are scattered and not organised under any common platform or organisation. Several of the initiatives (e.g. sustainability criteria) have been focusing on finding an EU level solution, rather than a Nordic level consensus. Thus, AGFE can be in a central role to drive the cooperation between the Nordic countries in the field of biomass to energy. Collected ideas and recommendations are summarised under the categories market (improving price transparency/statistics and gain understanding about how biomass to energy trade is expected to develop in the future), technology (mutually beneficial joint research efforts), regulatory (impact of a binding EU sustainability criteria and investigate if additional or alternative financial incentives and support schemes are required to enhance the biomass to energy sector) and other (establish efficient information and meeting platforms and conduct research to understand to what extent it is possible to realize the theoretical biomass potential in the Nordic countries).

SAMMANFATTNING

Arbetsgruppen för Förnybar Energi (AGFE), en del av Nordiska Ministerrådet, har till uppgift att stärka och främja användningen av förnybar energi i Norden. Detta görs genom utväxling av information och erfarenheter samt genom initiering och genomförande av samarbetsprojekt. AGFE har, som en del av detta initiativ, utlyst uppdraget att analysera och undersöka om det finns möjligheter att stärka det nordiska samarbetet mellan Sverige, Finland, Norge och Danmark vad gäller fast biomassa för energiändamål och i så fall identifiera relevanta områden samt former av samarbete. Pöyry Management Consulting har genomfört studien och har bidragit med analytiskt stöd. Studiens utgångspunkt var en kritisk litteraturstudie, där ämnen såsom utbud och efterfrågan på fast biomassa, handel, mobilisering, energiproduktion baserad på biomassa, regelverk, marknad och prisutveckling har analyserats. Intervjuer genomfördes med 29 marknadsaktörer längs hela värdekedjan i syfte att belysa relevanta teman och bedöma om det finns möjligheter att förbättra det nordiska samarbetet. Dessutom hölls ett seminarium i Oslo (12 mars, 2012) med titeln "*Möjligheter att förstärka det nordiska samarbetet vad gäller fast biomassa för energiändamål*". Inbjudna till seminariet var de intervjuade marknadsaktörerna i de nordiska länderna och andra experter inom bioenergisektorn.

Ett av EU-målen som ingår i klimat- och energipaket, är att uppnå 20% förnybar energi av EU:s totala energiförbrukning år 2020. Biomassa spelar en betydande viktig roll för att åstadkomma det uppsatta målet. Enligt Pöyrys prognos för år 2020, kommer efterfrågan på biomassa från skog och lantbruk av vara större än utbudet, vilket resulterar i en brist på biomassa i Europa på omkring 115 miljoner m^3 eller 230 TWh. Detta tyder på ett stort underskott av biomassa och Europa ställs inför en utmaning att möta den ökande efterfrågan från energisektorn. Med hänsyn till EU-målen för förnybar energi och ett eventuellt biomassaunderskott år 2020, kan det potentiellt finnas möjligheter att förstärka det nordiska samarbetet för att säkra den framtida tillgången på biomassa.

Resursanalysen i de Nordiska länderna påvisar att det den teoretiska potentialen för skogsbiomassa är betydande, särskilt för avverkningsrester. Användningen av fast biomassa i Norden förväntas växa fram till 2020 och för att öka den inhemska användningen av skogsbiomassa är det nödvändigt att i högre utsträckning utnyttja utbudspotentialen. Den teoretiska potentialen för biomassa från jordbruket är också betydande i de nordiska länderna, men endast små volymer används för närvarande för energiändamål. Den största delen av handeln sker med industriellt rundvirke som förbrukas av skogsindustrin, medan handel med biomassasortiment för energiändamål (huvudsakligen pellets och ved) är relativt låg. Alla länder förutom Finland är nettoimportörer av fast biomassa för energiändamål.

Intervjuresultaten visar att det finns olika typer av samarbete mellan de nordiska länderna, men det finns en tydlig förbättringspotential för att täcka en stor del av den existerande biomassapotentialen i Norden. Utbyte av information samt forskning och utveckling är de två mest etablerade samarbetsformerna. Trots det är de nuvarande samarbetsformerna utspridda och inte organiserade under någon gemensam plattform eller organisation. Flera av initiativen (t.ex. hållbarhetskriterier) har fokuserat på att finna en EU-nivå lösning snarare än att nå konsensus på en nordisk nivå. Således kan AGFE vara i en central roll för att driva samarbetet mellan de nordiska länderna när det gäller fast biomassa för energiändamål. Samlade idéer och rekommendationer sammanfattas under kategorierna marknad (förbättrad pristransparens/statistik och få förståelse för hur handeln med biomassa för energiändamål förväntas att utvecklas i framtiden), teknik (ömsesidigt fördelaktiga forskningsinsatser), regelverk (effekten av bindande EU hållbarhetskriterier och utreda om det krävs ytterligare eller alternativa ekonomiska incitament och stödsystem för att främja biomassaanvändningen inom energisektorn) och andra rekommendationer (upprätta en effektiv informations- och mötesplattform samt bedriva forskning för att förstå i vilken utsträckning det är möjligt att realisera den teoretiska biomassapotentialen i de nordiska länderna).

EXECUTIVE SUMMARY

Background and objective

The Working Group on Renewable Energy ("AGFE", Arbetsgruppen för Förnybar Energi), a part of the Nordic Council of Ministers, has the task to strengthen and promote the use of renewable energy in the Nordic region. This is meant to be achieved though exchange of information and experience and by initiating and implementing joint projects in order to promote the Nordic countries' technology and know-how to neighbouring countries, Europe and globally. The objective of the study is to analyse if there are possibilities to strengthen the Nordic cooperation between Sweden, Finland, Norway and Denmark in the field of solid biomass for energy purposes and if so, to identify key areas and forms of cooperation. Additionally, strategic issues have been suggested on a Nordic level which can be used by AGFE in the following years work programme.

The solid biomass assortments in the scope of the study include woody biomass (forestry biomass, industrial by-products, pellets and woody energy crops) and agricultural biomass (straw). The study was conducted in three main steps:

1. **Pre-study** – The starting point was a critical desktop review and synthesis of existing publicly available studies on biomass in the target countries, which have been completed or are underway. The main topics analysed include:

    a. **Desktop review** – Current supply and demand of solid biomass from forestry and agriculture, trade, mobilisation, biomass-to-energy generation, regulatory and sector policies, market development until 2020, current and future prices, market mechanisms and best practise supply chains.

    b. **Interviews** – In order to highlight different relevant themes and perspectives regarding solid biomass in the Nordics, interviews were conducted with market players along the whole value chain, from biomass production, market/trade, to final consumption. The focus of the interviews was to assess if there are opportunities to enhance the Nordic cooperation. Pöyry conducted a total of 29 interviews in the target countries.

2. **Seminar** – A seminar (including group discussion sessions) was conducted in Oslo on March 12, 2012 with the title "*Opportunities for enhanced Nordic cooperation in the field of solid biomass for energy purposes*". Pöyry and AGFE acted as facilitators and participants included interviewed stakeholders and other bioenergy sector experts from the target countries.

3. **Analysis and reporting** – Based on the findings in the pre-study and the outcome of the seminar, Pöyry has prepared a report with conclusions and recommendations to AGFE.

Introduction

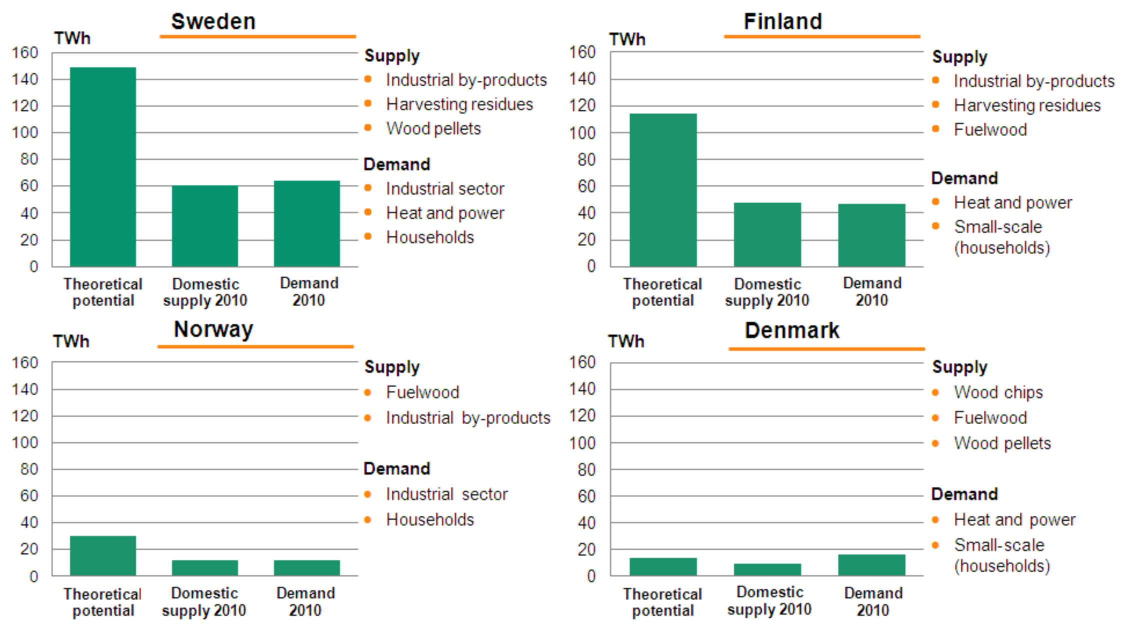
The climate and energy package was enforced by the European Parliament and Council in December 2008 and it became law in June 2009. One of the targets includes a 20% share of renewable energy in overall EU energy consumption by 2020. The Commission has therefore implemented a burden sharing methodology to define the renewable energy targets across member states. Biomass plays a significant role in achieving the 2020 targets. The share of woody biomass of the total biomass consumption in energy production in EU 27 is expected to decrease from 79% in 2010 to 67% in 2020, however it will remain the most important source of biomass in EU 27. Woody biomass supply is expected to increase from 685 TWh in 2010 to 950 in 2020. Supply is likely to grow as a result of higher mobilisation rates of forest biomass and forest industry expansion in Eastern Europe. Agrobiomass demand is projected to increase rapidly from 7% in 2010 to 16% in 2020. The supply is expected to increases from 85 TWh in 2010 to 305 TWh in 2020.

According to Pöyry's forecast for 2020, woody and agrobiomass demand will exceed the supply, resulting in biomass supply gap of approximately 115 million m^3 or 230 TWh. This indicates that there will be a large biomass deficit and Europe will face a challenge to cover the higher demand pressure from the energy sector. The Nordic countries have a large potential to supply woody biomass as a result of their high share of forest coverage. The forest industry and the agricultural sector are well-developed in the Nordics, providing a good biomass base. However, cooperation between the Nordic countries has been relatively limited. Hence, with regards to the renewable energy targets and a possible biomass deficit year 2020, there could potentially be opportunities to enhance the Nordic cooperation in order to secure the future biomass supply.

Evaluation of forest and agricultural biomass resources

As illustrated in Figure 1, the theoretical biomass potential is significant in the Nordic countries, particularly for harvesting residues. In order to increase the domestic use of solid biomass from forestry, it is necessary to exploit more of the supply potential. This is why questions regarding cost efficiency in mobilisation are central. Also, the theoretical potential of agricultural biomass is substantial in the Nordic countries, however only small volumes are currently utilised for energy purposes (Figure 2).

Figure 1 Current supply & demand for solid biomass from forestry



Biomass prices are publically available in all Nordic countries. However, the price information is not fully transparent and price availability gives only an indication of relative price levels between the Nordic countries.

Sweden

Forests and the forest industry play an important role in Sweden and woody biomass is a traditional energy source. Sweden's share of renewable energy in final energy consumption is highest of the EU 27 countries (47.2% in 2010) and bioenergy is the largest energy source accounting for 32% of the final energy consumption. Around 82% of the bioenergy originates from forests and the well-established forest industry, including forest industry liquid by-products, solid by-products and primary forest fuel. A large share of the woody biomass is consumed by the forest industry itself. The use of firewood has been on a relatively constant level during long time, especially in the Swedish countryside (around 9 TWh). The total supply of pellets (incl. imports) reached 10.7 TWh in 2010.

Agricultural land covers around 8% of Sweden's total land area. The production of bioenergy from agriculture accounts for only 1% or approximately 1-1.5 TWh and is mainly based on agricultural products such as straw, cereals, willow and rape. Straw is mainly burned in small farm facilities, however a share is also used as fuel in a number of heating plants in the country. Willow is the only energy crop cultivated on a commercial level in Sweden (around 13 000 ha in 2010), while other energy crops such as reed canary grass and hemp are grown for test purposes. The Federation of Swedish Farmers (LRF) presents a long-term technical potential of straw 7 TWh, willow 4 TWh and other agricultural solid biomass 2 TWh (Figure 2).

Finland

Also in Finland, industrial by-products and harvesting residues play a significant role, accounting for more than half of the domestic biomass supply. In comparison to Sweden, the use of firewood is slightly higher (12 TWh). The two main biomass end-use sectors include heat and power and small scale combustion. Heat and power facilities utilise 31 TWh and the main feedstock is forest chips and industrial by-products. Households consumed 17 TWh of solid biomass. Firewood accounts for 70% and the remaining share consists of forest chips and wood waste. In contrast to Sweden, wood pellets have so far had a minor role in Finland. The total consumption of wood pellets by end-use sector was only about 0.8 TWh.

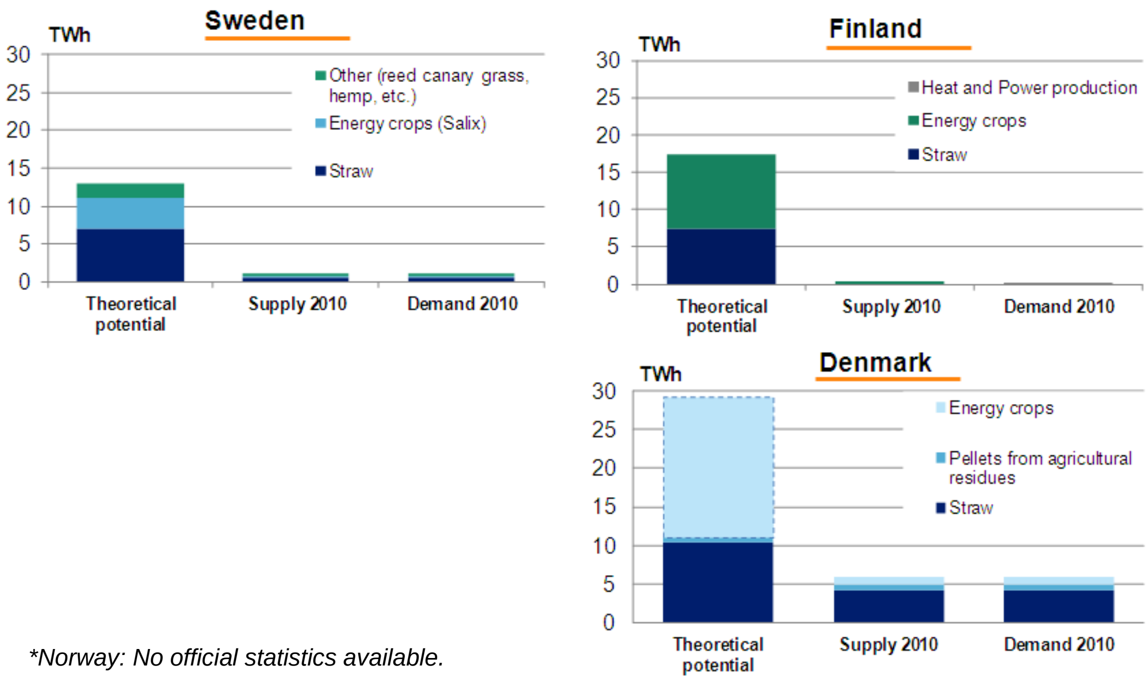
Reed canary grass was cultivated on around 17 000 ha of land in 2010. It is grown on fields and peat lands that previously have been used for peat extraction. Consumption of reed canary grass in Finland for energy purposes has been only marginal, about 100 GWh/a. Nevertheless, the 2020 target for reed canary grass is high; 150 000 ha or 4.5 TWh, however the theoretical potential is even higher, around 10 TWh. Energy crops, mainly willow, are grown on small-scale (10-15 ha) and there is currently no commercial production. Straw is also used only marginally, but the potential is high around 7.5 TWh.

Norway

Norway is richly endowed with forest resources and the annual growth is two times higher compared to the actual harvesting level in 2010. Thus, there exists an extensive potential within biomass production, however Norway lacks end-use markets. Branches and tops are currently left in the forest. However, a rather high share of firewood, around 8 TWh is used for heating purposes in households. A small share of around 3 TWh comes from industrial by-products which are used directly by the forest industry for heat and power. Households are the dominating end-use segment, accounting for 70% of the total woody biomass consumption in the country.

Around 3% of the land area consists of cultivated agricultural land and only a small share of the bioenergy production is based on agricultural solid biomass. Potential exists to exploit resources from the agricultural sector for bioenergy purposes. This includes mainly manure from livestock and residues from food production, such as straw and cereal husks. The total energy potential from straw is estimated to 4.5 TWh, but the sustainable potential is much lower (1-1.5 TWh/a). The Ministry of Agriculture and Food states that straw should be used for energy purposes to a higher extent. There are no official statistics available about the current energy production based on agricultural solid biomass (Figure 2). However, according to Statistics Norway, a small share of straw is utilised internally on farms for heat generation.

Figure 2 Current supply & demand for solid biomass from agriculture*



**Norway: No official statistics available.*

Denmark

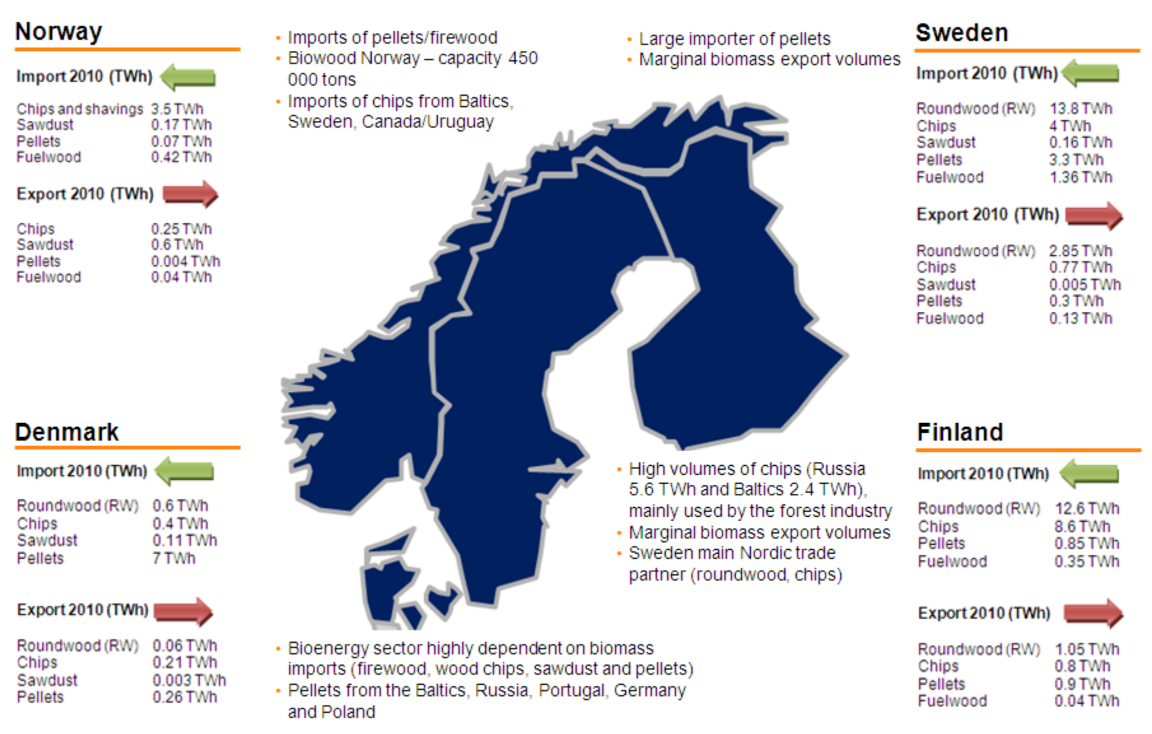
The resource assessment shows that the bioenergy sector in Denmark is heavily dependant on woody biomass. The harvesting levels in Denmark are below the maximum sustainable cut, however increasing wood supply from domestic forests is a subject to mobilisation constraints. Already today, Denmark is a net importer of woody biomass for energy end-use. Firewood is the single largest biomass assortment used with a total domestic demand of 6.9 TWh. It is consumed mainly by private households. The single largest imported biomass assortment is wood pellets. Almost 90% of the pellets in Denmark are currently imported by industrial end-users that consume two thirds of the 5.5 TWh pellet demand in co-firing and heating plants. The only woody biomass assortment that shows potential for future development is wood chips. There are some traded volumes of forest chips, however further potential exists to mobilise a larger share of harvesting residues and stumps for energy use.

Currently, 16% of the bioenergy generation in Denmark originates from agricultural solid biomass, mainly straw. According to Denmark's national renewable energy action plan (NREAP), the theoretical potential is 11 TWh if the whole resource is mobilised. Straw is currently used in two forms, in bales and in pelletised form and the markets is almost exclusively domestic. The greatest potential for agricultural biomass exists from energy crop plantations. Approximately 1 TWh is generated from short rotations woody coppice plantations of mainly willow and poplar. This also includes some experimental volumes of grasses such as reed canary grass, switch grass and miscanthus. The theoretical potential is estimated to 18 TWh, if 15% of the cultivated land area was to be utilised for energy crop production. However, only a part of the potential is seen as realisable.

Solid biomass trade

As illustrated in Figure 3, most of the trade in the Nordic countries takes place with industrial roundwood, which is primarily used by the forest industry for production of sawnwood, pulp and paper and other wood products. Thus, trade with biomass for energy purposes is relatively low. The most significant biomass trade takes place with pellets, where Denmark and Sweden are the main importers. However, most volumes originate from other regions such as the Baltic States and Russia. Chips are primarily used by the pulp and paper industry. All countries expect Finland are net importers of biomass assortments for energy purposes. There were no reported amounts of exported or imported agricultural biomass included in the scope of this study (i.e. energy crops and straw).

Figure 3 Main trade flows of solid biomass, 2010



Interview results – Current status of Nordic cooperation

The chapter presents a summary of the current status of Nordic solid biomass cooperation, based on the desk-top review and stakeholder interviews.

Market assessment – Trade and biomass mobilisation

The interviews conclude that trade will most likely increase in the future in the Nordics and internationally, but cost competitiveness will be the key driver, which currently results in low biomass volumes traded between the Nordic countries. In particular, processed fuels such as pellets, torrefied pellets and liquid biofuels are likely to see an increase in traded volumes the coming years. If sufficient improvements to logistics can be made to improve cost efficiency of the transports, then wood chips trade could potentially increase as well.

The main constraints that the biomass-to-energy sector is facing are very similar across countries. It is profitability of the operation as well as difficulties to trade and price biomass that hinder its mobilisation. In Sweden logistical constraints were named as the third largest constraint. Biomass is a bulky product that does not travel far, thus logistical improvements are required. In the other Nordic countries, constraints related to the consumption/end-use markets were mentioned. The key strengths, as identified by the stakeholders, are similar in Sweden, Finland and Denmark, but differ in Norway. The most important drivers of the market are the political incentives directed to the energy sector in Sweden, Finland and Denmark. Supply chain efficiency is also a strength in these countries, as the delivery capability and cost efficiency is seen as well developed. In Norway, the most important strength for the bioenergy sector development is the alternative fuel price, hence the expected price development of fossil fuels.

Prices and price transparency

There is all across the Nordic countries a relatively low price transparency in the biomass markets. Very little reliable price information is available on monthly basis and there is a lack of country-wise price indices for biomass. This is due to the fact that many supply agreements are bilateral, volume bound and product standardisation is limited, in addition to regional price differences. The markets therefore cannot completely trust the available price information. However, it can provide an indication of relative price levels and capture price fluctuations. Another major challenge that the bioenergy sector is faced with is the use of measurement units. In the forestry sector, the resource has traditionally been priced in tonnes or cubic meters, whereas the energy sector is looking to price biomass in energy content instead. Consequently, the price competitiveness of the energy end-market versus the forest industry end-market is not apparent and the system creates mistrust between players in the supply chain.

Current regulatory and legal framework

In Sweden, the regulatory and legal framework is considered to be sufficient, supported by the fact that Sweden is expected to reach the EU's RED 2020 target already beforehand. However, the framework for the development of 2nd generation liquid biofuels for the transport sector is not sufficient. Stakeholders from Finland, Norway and Denmark think that the regulatory and legal framework is currently inadequate. The main reasons for that are inconsistencies in political will and policies, which creates uncertainty. The market conditions to base long-term investment decision on are seen as unpredictable, unstable and unreliable, impacting energy producers as well as resource owners. Long-term political commitment and consistency is required in order to raise the investment climate in these countries. Also, direct and indirect incentives to biomass production are necessary (e.g. for energy crops, forest chips, stumps extraction, financial incentives for industrial and small-scale biomass utilisation in Denmark and Finland, higher investment support by Enova in Norway).

Opinions and the level of concern regarding sustainability criteria for solid biomass differ between the Nordic countries. In Denmark, sustainability criteria are seen as the single most important area where the legislator can enable a positive future development in the solid biomass to energy field. The country is highly dependent on biomass imports and the content of the sustainability criteria could have a great impact on sourcing strategies. In the other Nordic countries, there is a concern regarding the implementation of sustainability criteria. The existing sustainability guidelines are considered to be good enough and additional criteria is treated with sceptisism and not seen as necessary (sufficient legislation exists and the share of imported biomass is low). If implemented, it will imply bureaucracy and an administrative burden for small-scale forest owners and farmers. Also, a potential implementation of sustainability criteria could possibly create a trade barrier.

Current Nordic cooperation

Interview results conclude that the current Nordic cooperation is moderate and can be improved further. The cooperation forms are scattered and not organised under any common platform or organisation. Few stakeholders are aware of any ongoing initiatives that would aim at improving/promoting the Nordic cooperation. Also, several of the initiatives (e.g. sustainability criteria) have been focused on finding an EU level solution, rather than a Nordic level consensus. Based on the interview results with bioenergy stakeholders in the target countries, the current Nordic cooperation could be identified in the following areas:

	Sweden	Finland	Norway	Denmark
1	Exchange of information	Exchange of information	Exchange of information	R&D
2	R&D	R&D	R&D	Exchange of information
3	Cooperation platforms	Price indices	Trade	Market information
4	Mobilisation	Co-ordination of policies /political decision	Cooperation platforms	Trade

Exchange of information and research & development, were recognised as the two most established forms of cooperation. Exchange of information foremost takes place through networking, seminars/conferences and direct discussions between governments, research communities, companies and on an individual level. Thus, transfer of knowledge/best practices mainly takes place between the same stakeholder groups, rather than across different stakeholder groups. There exist joint research programmes (e.g. VTT in Finland, Skogforsk in Sweden, universities, etc.) between the Nordic countries and also participation in EU-projects. Scandinavian forest researchers, work in cooperation on several issues related to resource assessment, forest inventories, forest chips mobilisation, energy end-use, etc. Other areas include the existing cooperation platforms, i.e. the bioenergy associations (NOBIO, SVEBIO, FINBIO and DANBIO). Among market mechanisms, stakeholders in Norway and Denmark mentioned trade as an established cooperation form. Other areas of cooperation, which have a further improvement potential, include availability of market information and price indices, mobilisation and co-ordination of policies/political decisions.

Future Nordic cooperation – Conclusions and recommendations

During the interviews and the biomass seminar, stakeholders were asked to give their opinion about the most important opportunities to enhance the Nordic cooperation in the future. The main recommendations are presented below.

Market development

- Launch common standards/units. A problem recognised in all Nordic countries is the use of different units (energy content vs. volume) between players in the value chain. This leads to misunderstandings and more accurate measurement procedures are necessary.
- Find a method for calculating country specific biomass potentials by defining a common system.
- Increase price transparency and statistics (market surveillance).
- Necessary to improve existing estimates for biomass projections/price development, including the need for developing a joint Nordic biomass price prognosis.
- Need to increase the understanding of trade patterns for solid biomass between countries in the Baltic Sea region and the rest of the world.

Technology development

- Increase the sharing of knowledge and best practices (more business focused approach).
- Improve biomass logistics, e.g. biomass hubs along the Baltic Sea region.
- Comparison of various biomass supply chains' energy efficiency and economy (from production in the forest/field to end use of electricity/heat/transport). Identify needs for technology and market development.

Regulatory and legal

- Establish a common understanding and consensus among the Nordic countries regarding current topics such as biomass sustainability criteria and renewable energy targets. Many of the questions are today discussed on EU level, thus it would be valuable to have a common base for the political initiatives and a Nordic consensus.
- A common understanding could be beneficial for strengthening the Nordic interests and driving discussion at EU level.
- Enhance the exchange of knowledge and experience regarding support schemes and best practises between countries.

Other common areas

- **R&D and joint Nordic studies**
    - Establish a Nordic project based on market data for wood chips (similar to the European project “Pellet Atlas”, which aims to develop and promote transparency on the European fuel pellet market in order to facilitate pellet trade and to remove market barriers).
    - The Nordic countries could (annually) publish a Nordic biomass outlook – reporting the most important Nordic statistics in a concise manner.
    - Analysis of whether the increased demand for energy wood will increase timber prices in general.
    - Conduct scenario analysis on the effect of solid biomass production as a result of:

  - Changing price relationships between a) solid biomass for energy purposes, b) solid biomass for other purposes (timber, etc.) and c) fossil fuels.
  - Forest and energy policy measures such as increased afforestation, promotion of energy crops, altered production in forestry and agriculture, etc.
  - Binding sustainability criteria for solid biomass within the EU.

- Information regarding on-going biomass projects, coordination of R&D initiatives/programmes and other relevant activities (to avoid repeating work/activities).

➢ **Efficient information and meeting platforms**

- Create a common knowledge sharing point, e.g. an Internet-based platform or a physical knowledge centre ("**Nordic Centre for Bioenergy Information**") for all Nordic countries with focus on solid biomass for energy purposes.
- More cross-stakeholder meeting platforms such as seminars and conferences. A suggestion given is to create a "**Nordic Bioenergy Forum**", for stakeholders involved in bioenergy.

Strategic issues and recommendations to AGFE

Collected ideas and recommendations from the interviews and seminar are summarised under categories market, technology, regulatory and other.

Market development	➢ Support work in improving price transparency and statistics of solid biomass to energy (standards/units, price information, forecasts, indices, etc.) in the Nordic countries. ➢ Gain understanding about how biomass to energy trade is expected to develop in the future (nationally, regionally and globally).
Technology development	➢ Identify areas of cooperation between biomass to energy stakeholders where joint research efforts can be mutually beneficial.
Regulatory	➢ Investigate what impact a binding EU sustainability criteria could have on solid biomass markets in the Nordic countries. ➢ Investigate if an enhancement of the biomass to energy sector requires additional or alternative financial incentives and support schemes.
Other areas	➢ Establish efficient information and meeting platforms, which can enable easy exchange of information and knowledge between biomass to energy stakeholders in the Nordic countries. ➢ Conduct research to understand to what extent it is possible to realise the theoretical biomass potential in the Nordic countries and through which means this can be achieved.

AGFE can be in a central role to drive the cooperation between the Nordic countries in the field of biomass to energy. The study confirms that, while there are different forms of cooperation between the Nordic countries, there is notable potential for improvement to capture much of the inherent biomass potential in the Nordic countries. This biomass potential can, by appropriate policy steering mechanisms, serve both the existing biomass using industry and the emerging bioenergy sector. The biomass-to-energy discussion on a European level is a critical point of time right now – if the Nordic countries have the desire to speak with a common voice in this discussion, then it is timely to act on the recommendations listed above. In facilitating this development, AGFE is the position to act in a catalysing role.

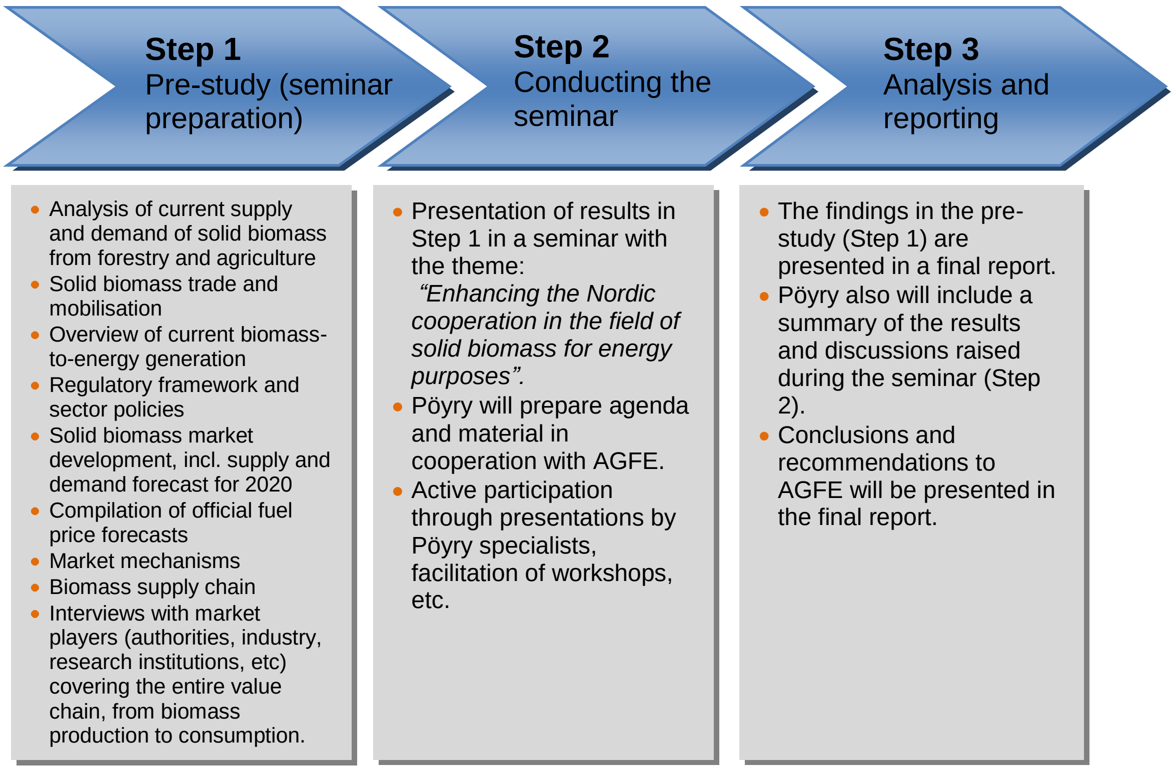
1. BACKGROUND AND INTRODUCTION

The working group on Renewable Energy ("AGFE", Arbetsgruppen för Förnybar Energi), a part of the Nordic Council of Ministers, has the task to strengthen and promote the use of renewable energy in the Nordic region. This is meant to be achieved though exchange of information and experience and by initiating and implementing joint projects in order to promote the Nordic countries' technology and know-how to neighbouring countries, Europe and globally. One of AGFE's challenges has been to, with relatively limited resources, identify possible efforts in the field of bioenergy which can add value to the parties involved.

The objective of the study is to analyse if there are possibilities to strengthen the Nordic cooperation between Sweden, Norway, Denmark and Finland in the field of solid biomass for energy purposes and if so, to identify key areas and forms of cooperation. The analysis has been conducted based on EU's sustainability criteria for solid biomass and cooperation mechanisms in EU's Renewable Energy Directive. Additionally, strategic issues have been suggested on a Nordic level which can be used by AGFE in the following years work programme.

The study conducted by Pöyry Management Consulting is structured in the following three main steps:

Figure 4 Main steps of the study



Source: Pöyry

1.1 Geographical scope

As illustrated in Figure 5, the following four countries – Sweden, Finland, Norway and Denmark – will be included in the geographical scope of the study. Iceland will not be included in the scope due to the country's limited biomass resources and limited biomass consumption.

Figure 5 Geographical scope of the study

1.2 Solid biomass assortments

The following solid biomass assortments will be included in the scope of the study (see definitions in Annex A):

Solid biomass from forestry

- Forest residues/wood chips (e.g. branches, tree tops, stumps and other harvesting residues)
- Small-diameter wood
- Firewood

Industrial by-products from forest industry

- Wood chips
- Sawdust
- Bark

Solid biomass from agriculture

- Straw

Further processed biomass/other biomass

- Pellets
- Woody energy crops

Biomass from waste (organic biodegradable waste) and recycled wood is not included in the study.

1.3 Stakeholder mapping and interviews

In order to highlight different relevant themes and perspectives regarding solid biomass in the Nordics, telephone interviews were conducted with market players along the whole value chain, from biomass production, market/trade, to final consumption. This was done using an interview guide (questionnaire) including predefined as well as open questions to ensure adequate coverage of the topics and a comparable input across the countries. The focus of the interviews was to assess if there are opportunities to enhance the Nordic cooperation regarding solid biomass for energy purposes. The interviews highlight the different regional opinions regarding this issue. Pöyry conducted a total of 29 interviews in the target countries (7 in Sweden, 6 in Finland, 8 in Norway and 8 in Denmark).

Interviewed stakeholders

Pöyry has used a wide range of professional contacts with relevant biomass market players, which has secured easier access to relevant and good information during the interviews. Pöyry has interviewed stakeholders in the following categories:

- Forest owners associations
- Large land owners (forests, agricultural land, energy crops)
- Wood products industry (sawnwood- and pellet producers)
- Pulp, paper and packaging producers
- National bioenergy associations and lobby organisations
- National authorities, ministries and state agencies
- Academies, research institutes and other professional organisations
- Energy companies

Key interview themes

Pöyry has addressed the following themes during the interviews:

Theme A: Company introduction/assessment
- Types and volumes of solid biomass
- Future development

Theme B: Market assessment
- Trade
- Biomass mobilisation – main strengths and constraints
- Supply chain incl. key improvement areas
- Current and future biomass prices

Theme C: Regulatory and legal framework and pricing incentives
- Sustainability criteria
- Market mechanisms

Theme D: Current Nordic cooperation in the field of solid biomass
- Current forms of Nordic cooperation

Theme E: Future outlook (2020) and opportunities to enhance the Nordic cooperation
- Identification of possible future areas of Nordic cooperation
- Recommendations

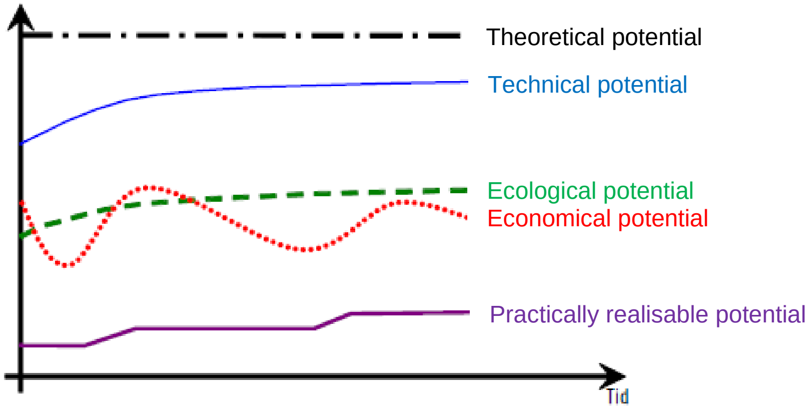
1.4 Definitions and units

Definitions

Theoretical solid biomass potential: The annually growing amount of biomass, taking into account fundamental physical and biological characteristics and climate conditions.

Technical solid biomass potential: The amount of biomass that can be mobilised taking into consideration the logistical and technical limitations, e.g. terrain constraints and soil conditions.

Economical solid biomass potential: The amount of biomass that can be mobilised taking into consideration the economical limitations, e.g. cost competitiveness of the biomass.



Source: "Bioenergi från jordbruket - en växande resurs". SOU 2007:36.

Units

Ha = hectare

m^3 = cubic metre

Mm^3 = million cubic metres

m^{3}s = cubic metre, solid volume

m^{3}sob = cubic meter, solid over bark

m^{3}sub = cubic meter, solid under bark

a= annum/annually

t = tonne

GWh = Gigawatt hour

MWh = Megawatt hour

TWh = Terawatt hour

EUR = Euro

RES = Renewable energy share

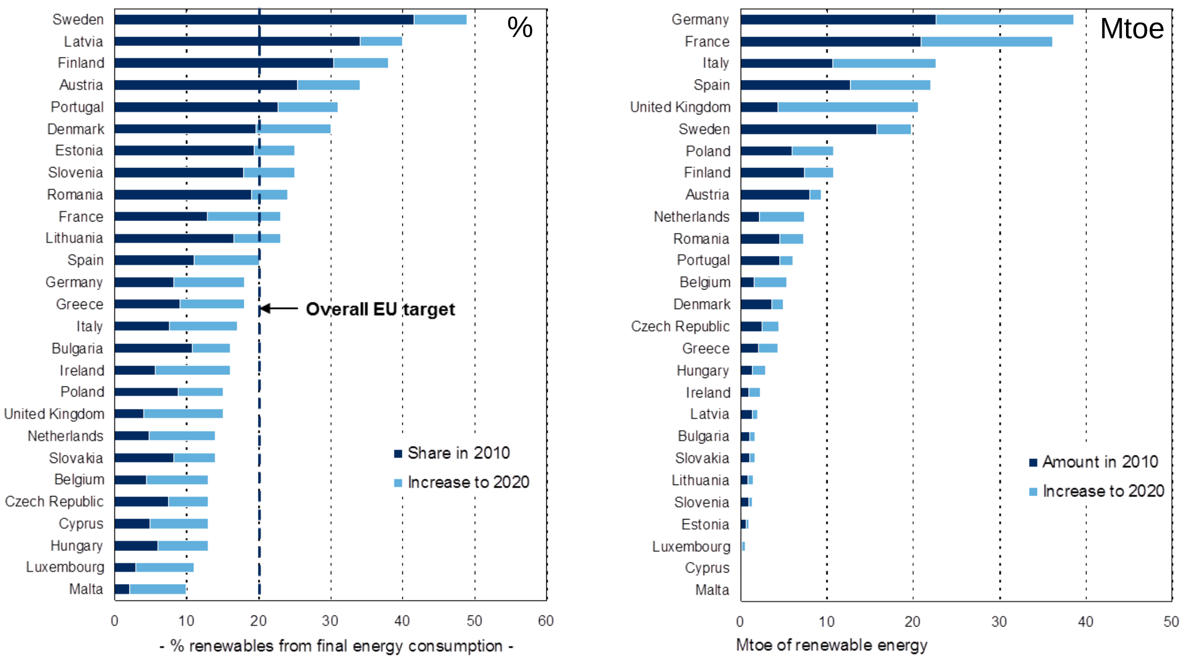
2. ENERGY POLICIES AND SOLID BIOMASS RESOURCES IN EUROPE AND THE NORDICS

The climate and energy package was enforced by the European Parliament and Council in December 2008 and it became law in June 2009. It sets the following targets for the European Union:

- 20% increase in energy efficiency
- 20% reduction in greenhouse gas (GHG) emissions
- 20% share of renewable energy in overall EU energy consumption by 2020
- 10% biofuel component in vehicle fuels by 2020

The Commission has therefore implemented a burden sharing methodology to define the renewable energy targets across member states. Within the framework of the EU Directive 2009/28/EC for the promotion of the use of energy from renewable sources, all member states were required to publish a national renewable energy action plan (NREAP) to detail the measures enabling them to comply with the 2020 targets. The NREAP's provide estimates of final energy consumption and a trajectory of renewable heating and cooling, electricity and transport that the different countries are aiming to achieve by 2020. The NREAP's also illustrate the mix of technologies and sources of renewable energy that the Governments are proposing, in order to comply with binding national targets for the total share of renewable energy sources. Figure 6 illustrates the current status of the consumption of renewable energy in EU member states and country specific 2020 targets.

Figure 6 Renewable energy shares (%) and absolute volumes (Mtoe) in EU 27

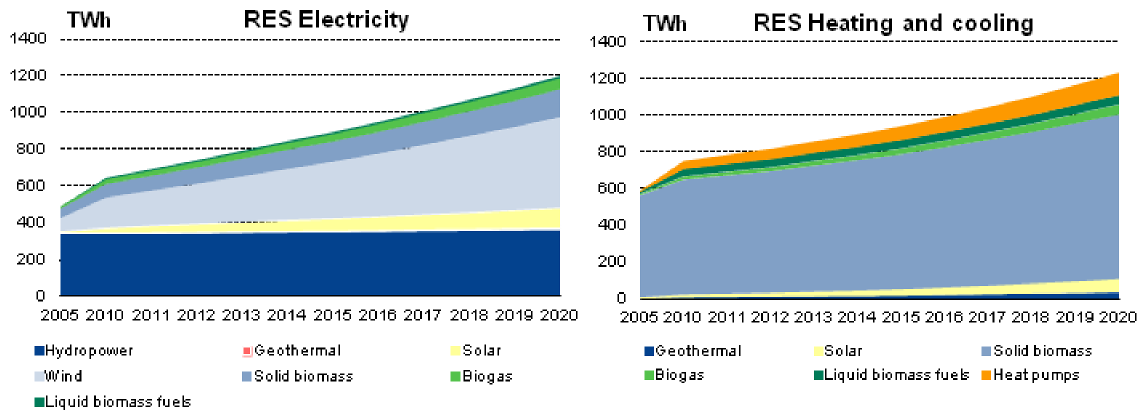


Source: NREAP (National Renewable Energy Action Plan) with base year 2005

As illustrated in Figure 7, renewable electricity consumption in EU 27 is targeted to grow from 493 TWh in 2005 to 1207 TWh in 2020. Solid biomass power is targeted to grow from 55 TWh in 2005 to 154 TWh in 2020 making up 13% of EU 27 RES electricity and 5% of EU 27 total final electricity consumption in 2020. The EU's renewable electricity has traditionally been based mainly on hydropower. Sources of hydropower in EU are however already to a great extent utilised. The increase of solid biomass based electricity is based largely on addition of CHP production in the EU. Biomass sources are limited however and due to the flexible uses of biomass, electricity generation will not be the only end-use and thus growth potential will be limited. Still, the already significant production of biomass power is expected to over double from 2005 to 2020.

Renewable heating and cooling energy consumption is targeted to grow from 594 TWh in 2005 to 1242 TWh in 2020. Solid biomass heating and cooling is targeted to grow from 550 TWh in 2005 to 900 TWh in 2020 accounting for 72% of EU 27 RES heating and cooling and 18% of EU 27 total final energy consumption in heating and cooling in 2020 (Figure 7). Heating and cooling from renewable sources has traditionally been based practically fully on solid biomass. Solid biomass is expected to remain as the main source for renewable heating and cooling for at least the period until 2020.

Figure 7 Renewable energy targets for electricity and heating & cooling in EU 27

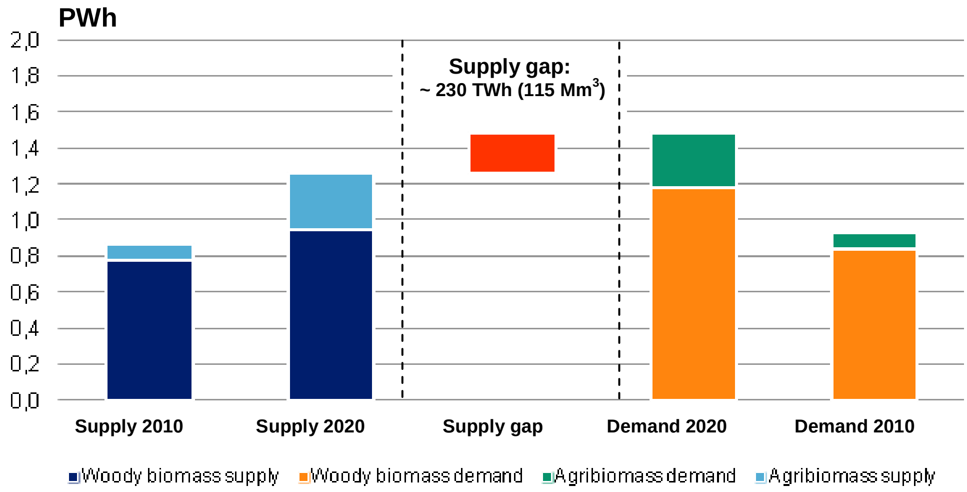


Source: NREAP (National Renewable Energy Action Plan) with base year 2005

The three categories of biomass described in the NREAP's include woody biomass, agricultural biomass and waste biomass (not included in the scope of this study). The share of woody biomass is expected to decrease from 79% in 2010 to 67% in 2020, however it will remain the most important source of biomass in EU 27. Woody biomass supply is expected to increase from 685 TWh in 2010 to 950 in 2020. Supply is likely to grow as a result of higher mobilisation rates of forest biomass and forest industry expansion in Eastern Europe. Agrobiomass demand is projected to increase rapidly from 7% in 2010 to 16% in 2020. The supply is expected to increases from 85 TWh in 2010 to 305 TWh in 2020.

According to Pöyry's forecast for 2020, woody and agrobiomass demand will exceed the supply, resulting in biomass supply gap of approximately 115 million m^3 or 230 TWh (Figure 8). This indicates that there will be a large biomass deficit and Europe will face a challenge to cover the higher demand pressure from the energy sector. The estimated supply gap may potentially be closed with higher direct forest biomass utilisation (e.g. harvesting residues, small-diameter wood and thinnings) and indirect wood supply (recycled wood fibre, landscape care wood). However, imported wood and refined wood fuels are expected to play an important role in achieving the renewable energy targets.

Figure 8 Solid woody and agrobiomass supply for energy purposes in EU 27*



** Estimated EU 27 woody biomass supply and demand for energy production and NREAP based demand assessment.*

Source: NREAP's, Pöyry

The Nordic countries have a large potential to supply woody biomass as a result of their high share of forest coverage. The forest industry and the agricultural sector are well-developed in the Nordics, providing a good biomass base. The forest industry (especially the pulp and paper industry) and the energy sector have been the main biomass demand drivers. Resource mobilisation is relatively good and imbalances in demand and supply have been covered through inter-regional trade. However, cooperation between the Nordic countries has been relatively limited. With regards to the renewable energy targets and a possible biomass deficit year 2020 (Figure 8), there could potentially be opportunities to enhance the Nordic cooperation in order to secure the future biomass supply.

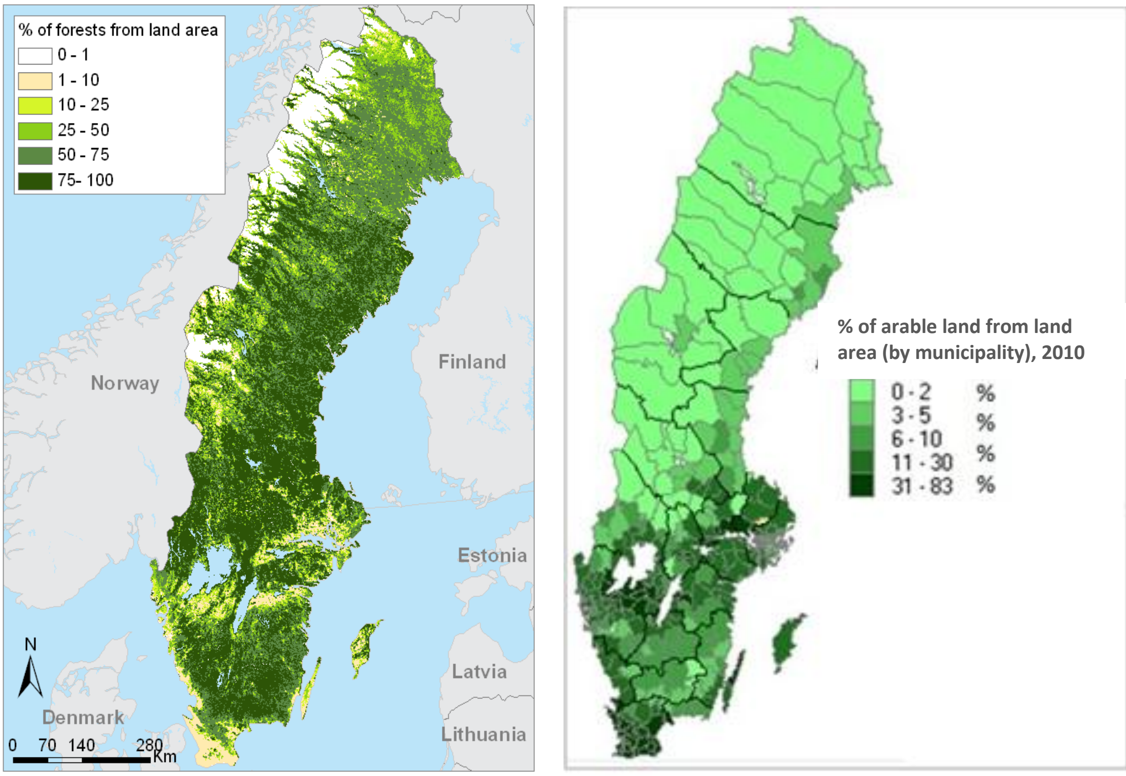
RESOURCE EVALUATION
SWEDEN

3. SWEDEN – EVALUATION OF FOREST AND AGRICULTURAL BIOMASS RESOURCES

3.1 Background

The total forest land area in Sweden is around 28 million ha, corresponding to a forest coverage of 70% (Figure 9). Conifers are very common in Sweden corresponding to 81% of the total growing stock: 42% is Norway spruce and 39% Scots pine. The remaining forests are broadleaved, mainly birch (12%) as well as oak, beech and other broadleaved species (7%). Almost 58% of the productive forest area in Sweden is certified under the FSC or PEFC certification schemes. FSC certified forests amount to 10 million ha and PEFC certified to 7 million ha. The total certified area in Sweden is 13 million ha (Skogssverige).

Figure 9 Distribution and share (%) of forests and arable land in Sweden



Source: European Forest Institute, Swedish Board of Agriculture

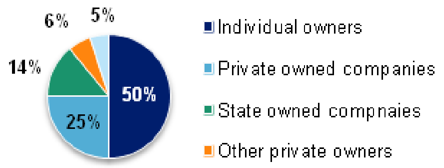
According to the Swedish Forest Agency's gross felling model, the total volume of felled timber was 89.5 million m^3 standing volume in 2010. The net felling volume was 72.8 million m^3sub, of which 35.6 million m^3 sawlogs, 30.6 million m^3 pulpwood, 5.9 million m^3 firewood and other wood accounted for 0.5 million m^3.

Figure 10 Characteristics of forest and agricultural resources in Sweden

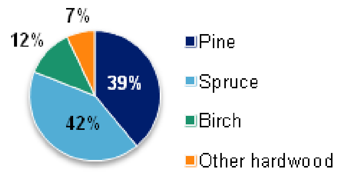
Forest facts	
Total land area	40.8 million ha
Forest area	28.4 million ha
Productive forest area	22.5 million ha
Forest area % of total land area	70%
Sustainable felling level*	78.9 million m^{3}sub
Actual felling (net)	72.8 million m^{3}sub
Growing stock volume	3.358 billion m^{3}sob
Growing stock per hectare	131 m^3/ha
Mean annual increment	4.9 m^{3}sv/ha/year
Agricultural facts	
Agricultural land	3.1 million ha
Share of agricultural land	8%
Main agricultural products	Lay, green fodder and cereals

** According to Swedish Forest Agency (SKA 08, 2010-2019)*

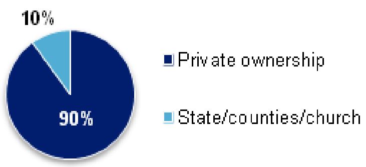
Forest ownership (of productive forest area)



Tree species (in the growing stock)



Ownership of agricultural land



Source: Swedish Forest Agency, Swedish Board of Agriculture, Statistics Sweden

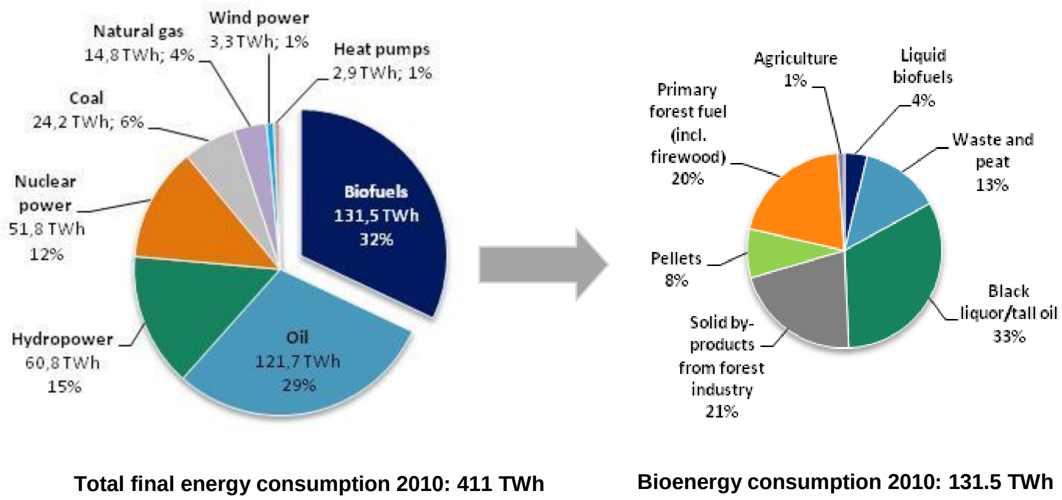
In 2010, the total agricultural land area in Sweden was 3.1 million ha, covering around 8% of the total land area. As illustrated in Figure 9, arable land accounts for 6% (2.6 million ha) and less than 2% (0.5 million ha) is pasture land. The highest proportion of arable land is found in the central (county of Uppsala 24%, Södermanland 21%, Östergötland 19%) and southern parts of Sweden (county of Skåne 47%, Gotland 24%, Halland 20%). Arable land is mainly used for production of lay, green fodder and cereals (wheat, barley and oats). Energy crop were grown on 13 126 ha in 2010, i.e. less than 1% of the arable land. These plantations are mainly found in the counties of Uppsala, Örebro and Skåne. The main type of energy crop cultivated on a commercial level in Sweden is willow, while other energy crops such as reed canary grass and hemp are grown for test purposes.

3.1.1 Introduction to energy market in Sweden

According to the Swedish Energy Agency (Short-term prognosis, ER 2011:15), the total energy consumption in Sweden reached 616 TWh in 2010. The total final energy consumption (excluding losses and use of non-energy purposes) amounted to 411 TWh. The main consumer of energy is the residential/service sector, accounting for 166 TWh (40%) followed by the industry 149 TWh (36%) and the transport sector 96 TWh (24%).

Sweden's share of renewable energy in final energy consumption is highest of the EU 27 countries. According to the Swedish Energy Agency, renewable energy accounted for 47.2% in 2010, indicating that the increase has been faster than the prognosis in the renewable energy action plan (this level was expected to be reached in 2015/2016). As illustrated in Figure 11, bioenergy is the largest energy source accounting for approximately 131 TWh or 32% of the final energy consumption in 2010.

Figure 11 Total final energy consumption incl. share and type of biofuels, 2010

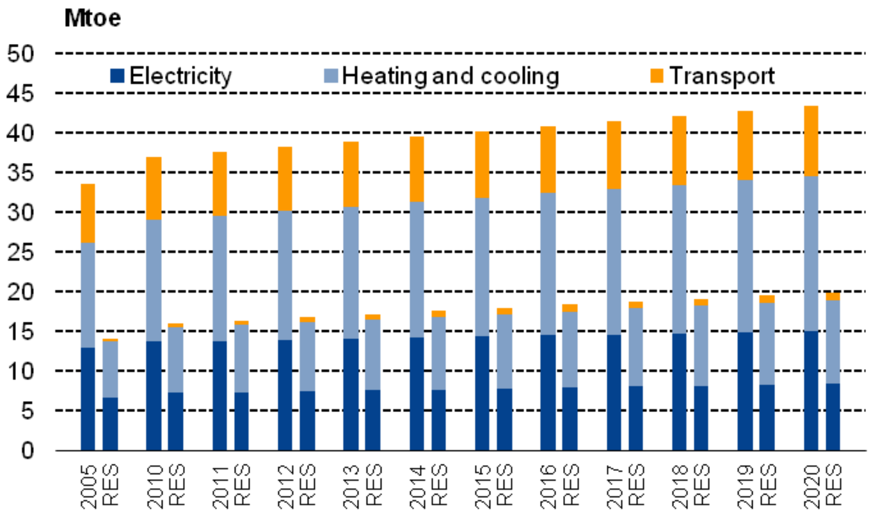


Source: Swedish Energy Agency, Swedish Forest Agency (Forestry Yearbook 2011), Statistics Sweden, Bioenergiportalen, Pöyry

Biofuels consist of forest biomass, waste, peat and agricultural biomass. Around 108 TWh (ca 82%) of the bioenergy in Sweden comes from forests and the well-established forest industry (Figure 11). The most common type of biomass consumed for energy purposes consists of forest industry liquid by-products, approximately 43 TWh (tall oil and black liquor from pulp production) and solid by-products (sawdust, chips and bark) approximately 28 TWh. Primary forest fuel is gaining importance and it the third largest assortment after sawlogs and pulpwood. The main type of primary forest fuel in Sweden is branches and tree tops (GROT), low-quality roundwood and a proportion is harvested as long tops and thin stems. This also includes damaged stemwood (decay or fire-damage). The value of primary forest fuel consumed in 2010 reached approximately 27 TWh. In recent years, the interest to harvest other assortments such as stumps has started to increase (at, present the harvested volumes are marginal). The consumption of waste and peat accounted for 13% in 2010. The production of bioenergy from agriculture accounts for only 1% or approximately 1-1.5 TWh and is mainly based on agricultural products such as straw (0.5 TWh), cereals (0.3 TWh), willow (0.2 TWh) and rape (0.02 TWh).

According to Sweden's National Renewable Energy Action Plan (NREAP), the share of renewable energy in 2020 should reach 49%. Reaching this target means that the total final renewable energy consumption in Sweden should grow from 14 Mtoe in 2005 to 20 Mtoe in 2020 (Figure 12). However, the Swedish Government has decided to increase the target to at least 50%. It is expected that the share of renewable energy in relation to the total final energy consumption will reach 50.2% in 2020. Thus, Sweden predicts a surplus of approximately 1.2% in 2020, corresponding to approximately 5.6 TWh (486 ktoe). Nevertheless, there could be several factors, e.g. possible introduction of sustainability criteria for solid biofuels, energy consumption trends and development of pulp and paper industry, can all have an impact on this prediction.

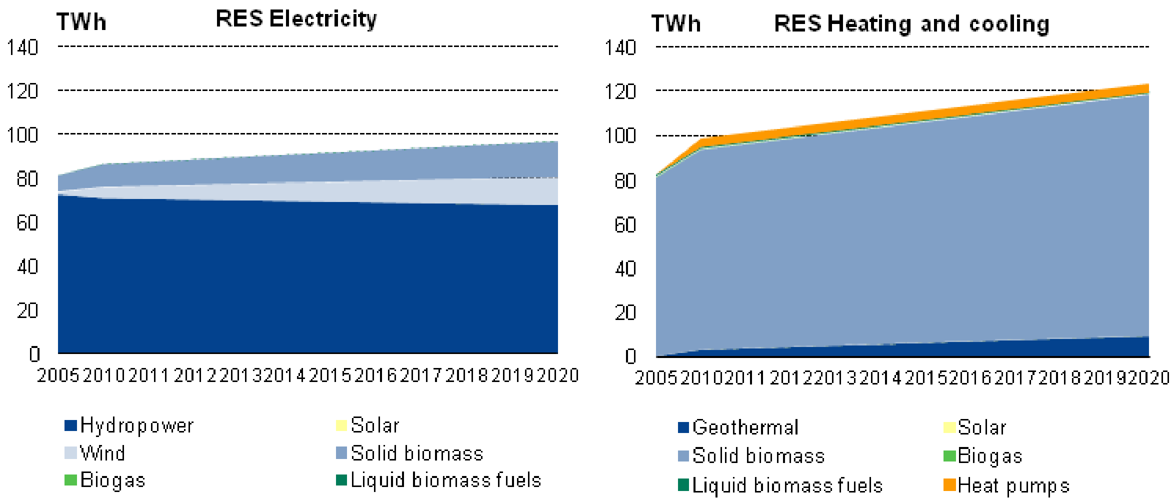
Figure 12 Gross final energy consumption by type – current and future outlook



Source: NREAP (National Renewable Energy Action Plan) with base year 2005

The Swedish Government targets the share of renewable energy consumption in the electricity sector to reach at least 63% (8.4 Mtoe) in 2020, while share in the heating and cooling sector should be at least 62% (10.5 Mtoe) (Figure 13). It is crucial to point out that 90% of the renewable energy in the heating and cooling sector is based on biomass. Further, the share of renewable energy consumption in the transport sector must be at least 14% (1 Mtoe) in 2020.

Figure 13 Renewable energy targets for electricity and heating & cooling



Source: NREAP (National Renewable Energy Action Plan) with base year 2005

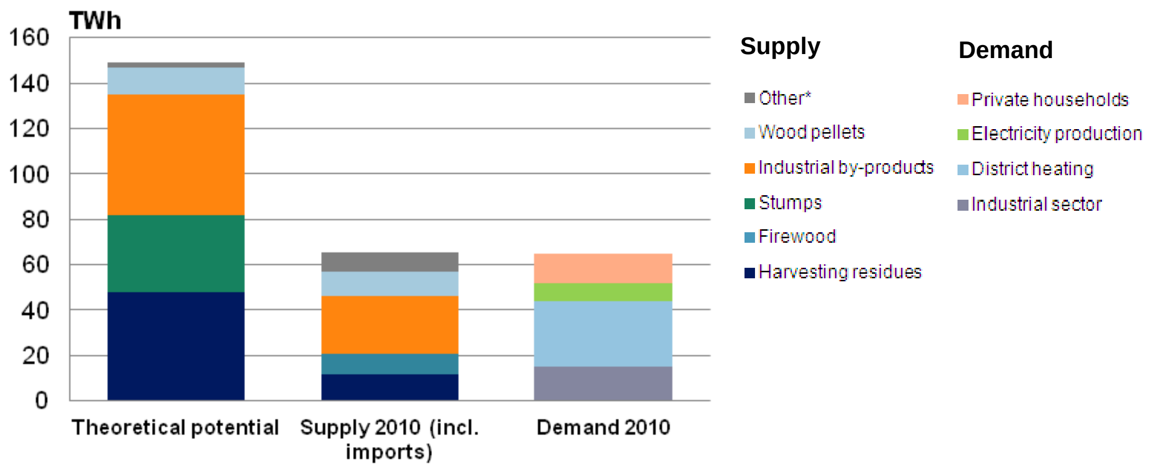
3.2 Resource assessment – Solid biomass from forestry

Primary forest fuel (incl. firewood)

Forests and the forest industry play an important role in Sweden (the sector accounted for 11% of the total export value in 2010) and woody biomass is a traditional energy source. Nevertheless, much of the potential still remains untapped. Most of the biomass used today consists of by-products from the forest industry, however the share of primary forest fuels used for energy purposes is increasing. The primary forest fuel assortments are extracted directly from forest with little or no processing, usually with a moisture content of 40-50%. Through the R&D program "*Efficient Forest Fuel Supply Systems*" (administrated by the research institute Skogforsk), a survey was carried out among the forest fuel producers in Sweden (representing approximately 13 million m³ loose forest fuel, corresponding to 80% of the total production in 2009). Preliminary results show that just over 50% of the forest fuel volume comprised of logging residues (branches and tops), around 40% energy wood (low grade roundwood used as fuel) and 10% small-diameter trees from cleanings and thinnings. Stumps accounted for only 1%. More than 80% of the logging residues were chipped before onward transport to the customer. The supply of primary forest fuel assortments depends on the annual harvesting level in the country.

According to the Swedish Forest Agency, the current extraction and supply of the main forest fuel category, branches and tops (harvesting residues), is approximately 11-12 TWh (Figure 14). The maximum theoretical supply calculated by Pöyry is significantly higher, around 48 TWh, a level which does not take into account practical, environmental and economical restrictions. Including these restrictions, the actual potential is less than 20 TWh. At present, stumps are used only marginally (less than 1 TWh) and harvested mostly on a pilot scale. A study conducted by the research institute Skogforsk (*Skörd av stubbar - nuläge och utvecklingsbehov*) shows that the interest to increase the utilisation of stumps for energy purposes in Sweden has increased during the last 3-4 years, however the knowledge about different technologies and the development is weak. Also, it is currently forbidden to harvest stumps on FSC certified land (harvest can only be carried out on trial basis on maximum 2 500 ha of FSC certified land per year), as it is classified as an untested method (FSC Sweden). However, the stump potential is high and Pöyry's calculations indicate a theoretical potential of 34 TWh.

Figure 14 Current supply & demand for solid biomass from forestry



**Other = chips from roundwood, other by-products and recovered wood*
Source: Pöyry database/calculations, Energy Agency, Swedish Forest Agency

The use of firewood has been on a relatively constant level during long time, especially in the Swedish countryside. However, in recent years the market has grown slightly as a result of the supply of stoves for heating and comfort (*Biobränslemarknaden i Sverige – en nulägesanalys*). According to the Swedish Energy Agency, firewood is the most common fuel used in single family houses. Burning firewood requires a lot of work and storage space, however the energy cost is low. Firewood, chips/sawdust and pellets are the most commonly used energy sources after district heating and electricity in the housing and service sectors in Sweden. The supply of firewood was approximately 9 TWh in 2010 (Figure 14).

The thinning or clearing of young stands (small-dimension trees) has also a large potential in Sweden. According to the R&D program "*Efficient Forest Fuel Supply Systems*", around 2 million tonnes DM could be harvested from young stands, corresponding to 10 TWh/a. At present approximately 1-2 TWh are utilised for energy purposes. The harvesting cost per MWh of small-dimension trees is still around 50% higher than the cost of branches and tree tops. Thus, in order to increase the utilisation level in the future, better technology, improved extraction efficiency and reduction of costs is necessary.

Industrial solid by-products

In Sweden, industrial by-products (chips, bark and sawdust) are mainly produced by the sawmilling industry. Thus, the domestic supply of by-products is depending on the level of activity in the sawmilling sector. However, the maximum volume of sawlogs, and hence by-products, is limited by the sustainable harvesting level in the country. According to SDC (Skogsnäringens IT-företag), information hub for the Swedish forest industry, the consumption of sawmilling by-products in 2010 was as follows:

- **Sawmilling chips:** 10.8 million m^3solid. The majority, 9.7 million m^3solid was sold to producers of pulp (and a marginal volume to wood-based panel producers). Approximately 1 million m^3solid was sold externally (energy purposes) or burned at the mill.
- **Sawmilling sawdust/shavings:** 5 million m^3solid. The majority, 4 million m^3solid was sold externally as fuel or burned at the mill. The remaining share was utilised by producers of pellets and wood-based panels.
- **Bark:** It can be assumed that all bark from the forest industry is burned (sold externally as fuel or burned on site). Thus, according to Pöyry's calculations, this value amounts to approximately 16 TWh.

A significant share (90%) of the sawmilling chips is sold to pulp and paper producers, thus sawdust and bark are the main solid by-products used by the energy sector. The value of industrial by-products used for energy purposes amounts to around 28 TWh (Figure 14).

Processed wood fuel (wood pellets)

Production of wood pellets in Sweden started in the 1980's when the district heating sector converted a number of fossil fuel fired heating plants to solid biomass. The commercial sector emerged with the establishment of a pellet market and in the 1990's the residential sector followed when private households started installing pellet boilers and pellet stoves for heating purposes.

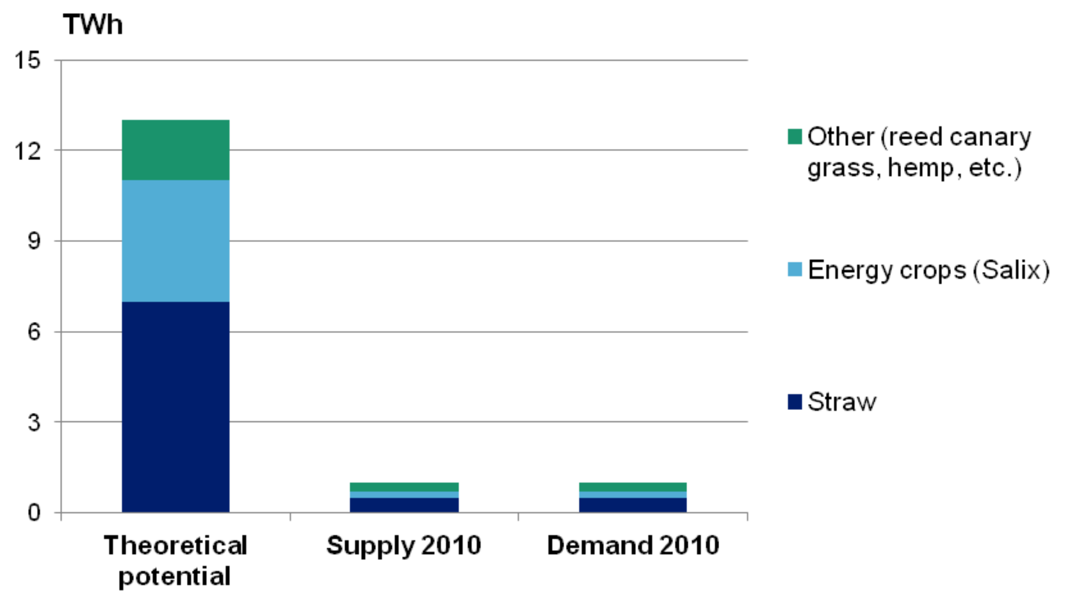
There are currently 81 wood pellet mills in Sweden, of which 77 are operational. The geographical distribution of pellet mills in Sweden generally follows that of the sawmilling industry. The main raw material for wood pellet production in Sweden is sawmilling residues. As illustrated in Figure 14, the total supply of pellets reached 10.7 TWh (incl. imports 3.3 TWh) in 2010. Despite a growing domestic market, the utilisation rate of Swedish pellet production facilities has averaged 70-75%. The main reason behind this has been raw material shortages for producers using sawmilling by-products as raw material. Even so, this rate is higher than the European average.

The residential and industrial sectors are the largest end-use segments for pellets in Sweden. The industrial end-users include large CHP's and district heating plants. Many of the plants source from local or regional pellet producers and some are importing volumes to diversify risk in sourcing operations. The residential pellet markets are more local, though the distribution networks are developing, improving market access and transparency.

3.3 Resource assessment – Agricultural solid biomass

Agricultural solid biomass in Sweden has, so far, been used only in small-scale (1-1.5 TWh) compared to woody biomass. However, a new trend observed in Sweden is that the agricultural sector is becoming an increasingly important supplier of biomass for energy purposes. The biomass comes partly from pure field crops such as cereals and oil plants, but also from an increased utilisation of solid agricultural residues such as straw and manure (for biogas production). In the future, the agricultural sector can become a larger producer of energy compared to the current situation, especially energy crop production has a large potential. The future development is dependent on the political initiatives, food price development and consumer attitudes. The Federation of Swedish Farmers (LRF) present a long-term technical potential of straw 7 TWh, willow 4 TWh and other agricultural solid biomass 2 TWh (Figure 15).

Figure 15 Current supply & demand for agricultural solid biomass



**Potential based on data from "LRFs Energiscenario till år 2020"*

Source: LRF, Swedish University of Agricultural Sciences, SOU 2007:36

Straw

Straw is a by-product from cultivation of cereals and oil plants. Currently, the use of straw has been rather limited in Sweden. According to a report published by the Swedish University of Agricultural Sciences, approximately 0.5 TWh (ca 100 000 tonnes) of straw is used for heating purposes in Sweden (Figure 15). The majority is burned in small farm facilities, however a share is also used as fuel in a number of heating plants in the country. The opinions about the straw potential for energy purposes are different, ranging between 3-10 TWh. The Swedish Board of Agriculture (LRF's Energiscenario till 2020), estimate the theoretical potential of straw at 15-20 TWh. However, the practical potential is lower, only 7 TWh. Other sources estimate the potential to be 10 TWh (Biobränslekommissionen) and 3-4 TWh (Nilsson/Bernesson, SLU, 2009).

The use of straw for energy purposes has a poor reputation in Sweden. During the 70's and '80s, many hazardous fires occurred in the straw-fired boilers. Today this problem is minimised by adapting new technologies. Straw also creates relatively large amounts of ash and requires special heating equipment. At low temperatures, the ash also begins to soften (ash melting point) and increases the risk of clicker formation in the boiler. The availability of straw fluctuates and the volumes depend on the cultivation of cereals, oil plants and its usage as bedding material for animals. Also, the moisture content of straw is critical to its quality as a fuel. Thus, weather conditions in Sweden limit the volumes of straw for energy purposes.

Energy crops

According to Värmeforsk (Thermal Engineering Research Association), energy crops have a good economical potential in Sweden. Currently, energy crops from arable land are considered to be an untapped potential as fuel for heat and electricity generation. However, the growing competition for biomass has started to increase the interest for energy crops. Energy crops from arable land that are suitable for production of energy include willow, straw, hemp, cereal core and reed canary grass. Currently, willow is in the energy crops with the highest yield of biomass (per hectare) and requires minimum energy input for cultivation and harvesting.

There exist many estimates regarding the potential of energy crops in Sweden (see Figure 82 in Annex A). The estimates have been made using different assumptions and during several time periods leading to great variations in the value of the potential. Also, it is not always clear what type of potential is used (physical, technological, ecological, economic, or practical realisable potential). The potential varies between 1 to 59 TWh, however, the majority of the studies state that the potential is in the range of 25-30 TWh by 2020/2025.

The production of energy crops in Sweden has been challenging and only small-scale. A study conducted by Värmeforsk (*"Grödor från åker till energi"*), concludes that the main constraint to increase the production and use of energy crops is that it has been an unprofitable business. To reduce the production cost would require improving the competitive position of energy crops in comparison to alternative biofuels such as forest chips. The study suggests achieving this by developing the logistical supply chain and creating a market-oriented use of energy crops. Another obstacle is the high investment costs required to establish energy crop production.

Summary resource assessment

The resource assessment for Sweden shows that the bioenergy sector in Sweden is dominated by biomass supply from the forest and forest industry. The main solid biomass assortments include branches and tops and industrial by-product from the sawmilling industry. Nevertheless, there is a considerable potential to increase the extraction of primary forest fuels such as branches and tops, stumps, small-diameter wood and other type of wood which is not demanded by the conventional industry.

The consumption of agricultural solid biomass is currently low and most of the volume is burned directly in the farm facilities. Willow is the only the energy crop cultivated on a commercial level and the use of straw for energy purposes is modest. However, the potential is high.

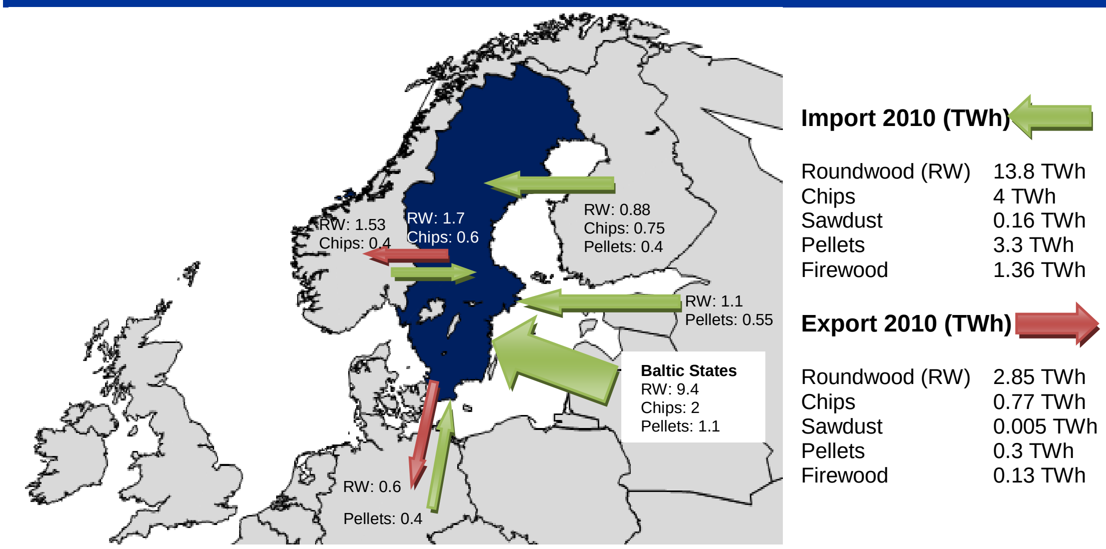
3.4 Solid biomass trade and mobilisation in Sweden

3.4.1 Trade flows

The value of Swedish exports of forest and forest industry products was SEK 128 billion in 2010. The sector accounted for 11% of the total export value (all goods) in the country. However, it is important to point out that the products significant for the Swedish trade include pulp, paper, paperboard and sawnwood. The share of exported solid biomass is marginal and consists of chips, sawdust, wood pellets and firewood.

The majority of the biofuels, peat and waste consumed in Sweden are produced domestically and trade mainly takes place with roundwood for industrial purposes. As illustrated in Figure 16, Sweden mainly imported roundwood (13.8 TWh), chips (4 TWh) and wood pellets (3.3 TWh) in 2010. According to the Swedish Forest Agency (Statistical Yearbook of Forestry 2011), around 58% of the roundwood and by-products are imported from the Baltic States, 30% from Finland, Norway and Russia (roughly one third from each country) and approximately 10% from other EU countries.

Figure 16 Main trade flows of solid biomass 2010 (TWh)



Source: Statistical Yearbook of Forestry 2011

Chips are primarily used by the pulp and paper industry in Sweden and the largest share is imported from Latvia and Finland. Imports of sawdust are marginal. Sweden is a large importer of pellets and the key trade partners include Russia, the Baltics States, Germany and Finland. Compared to the imported volumes, exports of roundwood and by-products from Sweden are relatively small (2.85 TWh of roundwood and around 0.8 TWh of chips/sawdust). The main trade partner is Norway (Figure 16). Regarding the future development of biomass trade, the Swedish NREAP assumes that in 2020 the country will import wood biomass from the same countries as today.

Sweden imports agricultural products and foodstuffs which are either not produced in the country or the current production is small (Agricultural yearbook 2011). With regards to the agricultural products included in the scope of this study (energy crops and straw), there exist no imports/exports.

3.4.2 Solid biomass mobilisation

Solid biomass from forestry

According to the R&D program "*Efficient Forest Fuel Supply Systems*", the extraction of forest fuel in Sweden has emerged due to several factors; some examples include significant forest resources, traditional forestry sector, development of the district heating sector, availability of machinery and skilled labour and implementation of relevant policies supporting bioenergy growth. Sweden has managed to create a functioning market for wood biomass and establish the necessary bioenergy infrastructure.

The traditional utilisation of forests, not taking into account the extraction of forest fuel, has been focused on the production of pulpwood and sawlogs for delivery to the traditional forest industry. This has influenced forest management systems (main focus has been to quickly produce timber of size and nature that can be processed economically). The growing importance of wood fuel has created a necessity to evaluate the forest management system, existing technology and logistics (*Skogsskötselserien 2009*). The main costs associated with extraction of primary forest fuel (branches and tree tops) are comminution and transport. Also, logging residues are very bulky making them difficult to handle compared to other types of biomass (e.g. pulpwood). Thus, comminution at the beginning of the transport chain can reduce the bulk of the material, however it is more expensive compared to centralised processing (EES – Skogforsk).

Stump extraction and mobilisation still requires further research in Sweden. Stumps are bulky and contaminated by soil and stones (one reason why demand on stumps as fuel has been low), which makes handling complicated. It is difficult to reach maximum payload and the hard stump parts can damage the sides of the truck. A methodology which Skogforsk has studied, in order to increase the load and reduce damages and transport of contaminants, is coarse-grinding of stumps at the landing. Results show that costs can be reduced by 15-20% in comparison to transporting whole stump parts. Also, research is being conducted regarding the stump harvest technology and what effects stump extraction has on the soil (nature conservation).

Thinning or cleaning of young stands is an expensive procedure, nevertheless it is possible to reach sufficient volumes of forest fuel which can cover much of the cost. Improved methods and technology is necessary and additional research is required regarding the ecological effects (e.g. loss of nutrients).

Agricultural solid biomass (willow and straw)

According to Värmeforsk (*"Grödor från åker till energi"*) cultivation of energy crops has not been profitable in Sweden. In order to reach profitability, technology developments in all parts of the logistical chain are required to reduce costs of harvesting, storage and transport. An effective supply chain is needed to make energy crops competitive in comparison to forest biomass. There is also no established cooperation between farmers and end-users (utilities), in terms of efforts to improve storage and transportation of the energy crops from the field to energy plant. Another issue is the contractual arrangement. Currently, the contacts are short (up to one year), however in order to make the required investments in the logistical chain, longer contracts (up to five years) might be needed. For the energy companies, it is a matter of securing the delivery. Longer contracts can prevent cash-flow problems for farmers and pricing methods must be adapted so that farmers and energy companies share the risk regarding price developments of agricultural products and fuels.

In order to improve the mobilisation of willow (Salix), it is necessary to upgrade the harvesting technology to secure the supply and create a possibility for more scattered deliveries to energy plants. Willow is, preferably, harvested when the ground is frozen, creating large supply constraints. Another limitation of current harvesting technology is the fact that harvesting machines, tractors and trucks are dependent on each other in the field (unless harvester and tractors are combined). If one process stops, the whole chain is interrupted. This leads to high costs in the entire chain. At present, energy companies use only small amounts of willow in their fuel mix and deliveries are uneven. If the volumes will increase in the future, the security of delivery will be an important issue. In best case scenario, willow is harvested as a whole tree during winter/spring and stored during summer at roadside. Consequently, energy companies know the volumes which will be delivered during autumn, creating a better security of supply. By creating a more even supply, farmers will also have the possibility to get a higher price for their product. An advantage with harvesting willow as a whole tree is that the stems can dry during storage, improving the willow quality and increasing the energy value. Thus, farmers can get a better price and transportation costs can be reduced.

Further, the supply chain of willow can become more efficient by coordination with other fuels in terms of transportation and common terminals. Regarding the market for willow, there is a need to increase competition by attracting more producers. This way, harvesting and transportation costs to energy plants can be reduced. Finally, there is a need to establish a better attitude and reputation among farmers regarding the cultivation of willow.

According to Värmeforsk (*"Grödor från åker till energi"*), straw is seen as a competitive fuel only in the southern part (Skåne) of Sweden, where a couple of energy companies are interested in burning this agricultural by-product. However, in order to attract more farmers and end-users, straw must become more competitive. This implies improving the storage and transport technology. It is also necessary to develop the technology for gathering straw so that it quickly can be transported away from the field without disturbing the farmers work. If consumption of straw and willow would increase significantly, e.g. in Mälardalen where many of the large energy producers are located, it would be possible to establish a large-scale logistical chain. It is also necessary that the pelletizing technology develops and becomes more profitable. This could imply an expansion of the market and even export possibilities. Currently, costs are too high. In recent years, processed fuels have had the highest price development (*see section 3.7.1 – Solid biomass price development*).

3.5 Overview of current "biomass-to-energy" generation

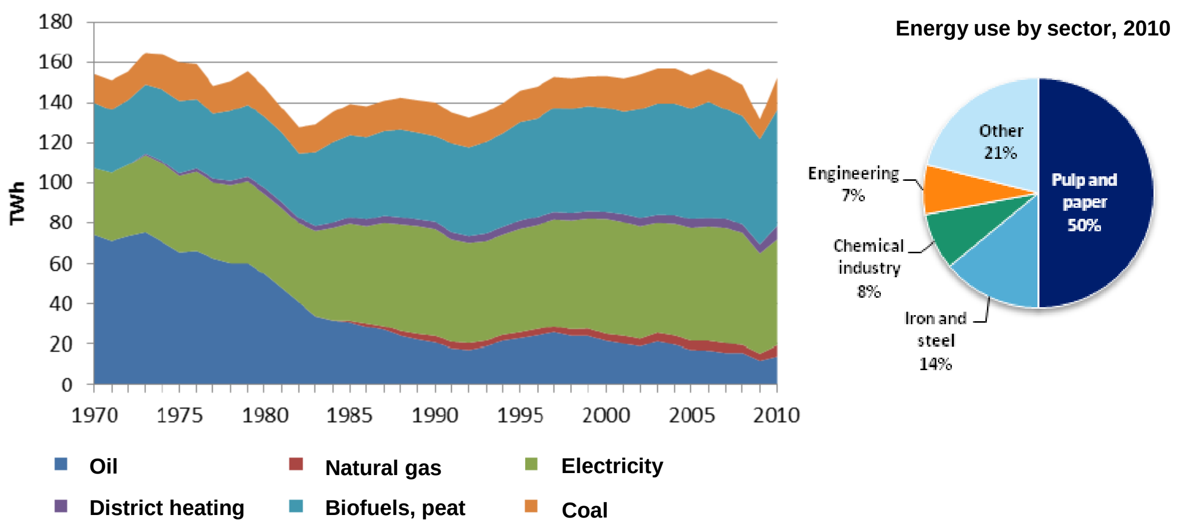
The total energy consumption in Sweden was 411 TWh and the main end-users include residential/service sector (166 TWh), industry (149 TWh) and transport sector (96 TWh). Biofuels, waste and peat are mainly consumed in the forestry industry, for heating and electricity generation and for heating of homes. The largest increase can be found in the industrial and district heating sector. Also the use of biofuels in the residential and transport sectors is increasing. In 2010, the biofuel consumption was 132 TWh (incl. waste, peat and black liquor). Below follows a more detailed presentation of the main energy consumers and their utilisation of solid biomass for energy generation.

3.5.1 Industrial sector

According to the Swedish Energy Agency, the industry accounted for 36% (149 TWh) of Sweden's total energy consumption in 2010. Energy consumption has been rather constant over time, despite an increase in industrial production (Figure 17). The consumption of oil has been constantly decreasing and biofuels have gained more importance and today their share is 54 TWh or 36%.

In Sweden, there are a few key industries that account for the main share of industrial energy consumption (Figure 17). The pulp and paper industry is the largest consumer, accounting for half (75 TWh) of the total industrial energy consumption. A large share of the liquid and solid by-products (e.g. black liquor, bark and sawdust) generated by the forest industry are also utilised by the same industry for energy generation. In 2010, the forest industry consumed 15 TWh of solid by-products for heat production. The iron and steel industry uses mainly coal and electricity and consumption accounts for 21 TWh or 14%. Other industries include the chemical-, engineering, mining-, metal-, and textile industries, with a total energy consumption of 53 TWh.

Figure 17 Energy consumption in the industrial sector (TWh), 1970-2010



Source: Swedish Energy Agency (Energiläget 2011)

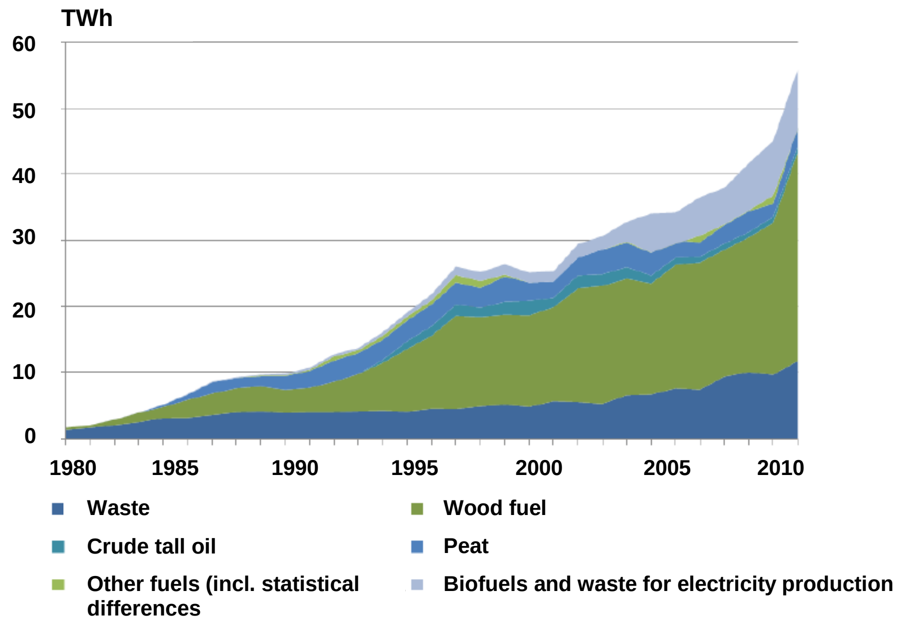
3.5.2 District heating

According to the Swedish Energy Agency, the final consumption of district heating amounted to 60 TWh in 2010 (+16% compared to 2009, due to a cold and long winter period in Sweden). Around 88% was delivered to houses/commercial buildings and 12% to the industry. As described in the Swedish NREAP, district heating is well-developed in Sweden compared to other European countries. The grid is around 20 000 km long across the country. Currently, district heating is the main type of heating in towns and approximately 50% of the national heating requirements are assured by district heating.

As illustrated in Figure 18, the use of renewable fuels in district heating has increased sharply since the 1980’s. In 2010, 46 TWh of biofuels, peat and waste were used for heat production (excluding electricity production). Wood fuel accounted for around 30 TWh, liquors and tall oil 1 TWh, waste 12 TWh and peat 3 TWh. Wood fuel mainly consists of harvesting residues, low quality roundwood and solid by-products from the forest industry. Also, the use of processed wood products such as pellets and briquettes is increasing in the district heating sector.

The Swedish District Heating Association presented a forecast where it is expected that the length of the district heating grid will increase by almost 25%. Also, the share of renewable fuels will continue increasing by 2015 (Swedish NREAP).

Figure 18 Consumption of biofuels in district heating (TWh), 1980-2010

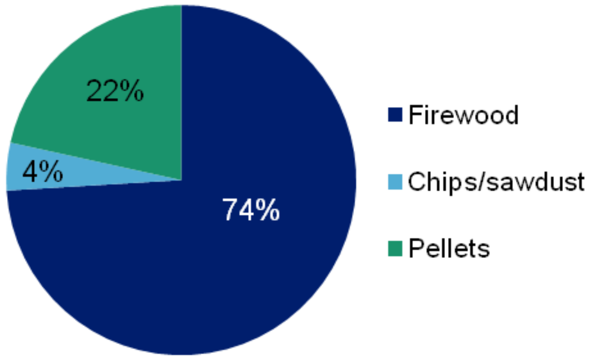


Source: Swedish Energy Agency (Energiläget 2011)

3.5.3 Private households (single-family houses)

The total energy consumption for heating purposes in single-family houses was 35.8 TWh in 2010 (Swedish Energy Agency). Currently, electricity is the most common energy source in single-family houses, accounting for 16.1 TWh in 2010. Approximately 5 TWh came from district heating. However, in recent years the largest increase has been in the use of biofuels (firewood, wood chips, sawdust and pellets). The use of biofuels in single-family houses accounted for around 12.4 TWh in 2010. The largest share consisted of firewood, around 9 TWh, however it has been decreasing over time (Figure 19). The consumption of pellets in single-family houses reached 2.7 TWh in 2010.

Figure 19 Consumption of biofuels in private households, 2010



Total consumption 2010: 12.4 TWh

Source: Swedish Energy Agency (Energistatistik för småhus 2010)

3.5.4 Electricity production

The total electricity production in Sweden was 145 TWh in 2010 and the main sources include hydropower 46%, nuclear power 38% and wind power 2.5%. The remaining share of around 13.5% consisted of fossil fuels and biomass. In 2010 electricity generated from other thermal power (fossil and biomass fuels) amounted to 19.7 TWh. Of this, 12.5 TWh was produced in co-generation district heating plants and 6.4 TWh in industrial CHP (back-pressure) plants (Svensk Energi, Elåret 2010).

According to the Swedish Energy Agency (Elcertifikatsystemet 2011), the electricity production from renewable energy sources (incl. peat) in plants covered by the electricity certificate system reached 18.1 TWh in 2010. Electricity certificates are issued to plants which produce electricity from one or more renewable energy sources and have been approved by the Swedish Energy Authority. According to Statistics Sweden, the value of electricity production based on solid biomass was 7.7 TWh in 2010. The share of forest industry by-products and harvesting residues was around 6.8 TWh, while the remaining 0.9 TWh consisted of further processed biomass (pellets/briquettes).

3.5.5 Transport sector and other end-users

According to the Swedish Energy Agency, the domestic transport sector consumed 96 TWh of energy in 2010. The fuels used are predominantly oil products, such as gasoline and diesel, accounting for 87% of the energy consumption. However, the share of renewable liquid biofuels is increasing reaching 5.7% (5 TWh) in 2010. These fuels include natural gas, biogas, ethanol and FAME (biodiesel).

3.6 Regulatory framework and sector policies relevant for solid biomass supply for energy

The R&D program "Efficient Forest Fuel Supply Systems", describes that an important factor of the well-functioning bioenergy sector is due to "the relative stability of the Swedish policy, and the way that it has been supported through legislation, taxation, certificate systems, fees and subsidies". The designed policy instruments aim at creating a sustainable energy system in Sweden.

Below is a selection of measures to promote renewable energy (relevant for the use of solid biomass) in Sweden.

Figure 20 A selection of measures used to promote the use of renewable energy in Sweden

Name of measure	Type of measure	Expected result	Targeted group and/or activity	Existing or planned	Start and end date of the measure
Energy tax (Act 1994:1776) on energy tax)	Financial	Fiscal and steering tax for more efficient energy consumption and increased share of renewable energy.	Households, enterprises	Existing and planned adjustments.	Petrol 1924, other liquefied petroleum products 1957, LPG 1964 and natural gas1985 -
Carbon dioxide tax (Act 1994:1776) on energy tax)	Financial	Environmental tax	Households, enterprises	Existing and planned adjustments. (1 Jan. 2012)	1991
Exemption from energy and carbon dioxide tax for CO_2-neutral fuels and for vegetable and animal oils and fats and biogas as a heating fuel.	Financial	Promotes the use of bioenergy	All enterprises		1991-
Electricity certificate scheme (Act 2003:113) concerning electricity certificates	Financial / regulatory	25 TWh new renewable electricity generation (previously 17 TWh) for 2020 (previously for 2016) compared with 2002	Quota-bound electricity suppliers/consumers and producers of renewable electricity	Existing and adjustment of quota levels	From 2003 the increase in ambition relates to the period 2013-2035
EU-ETS, (Act 2004:1199) on emissions trading	Financial / regulatory	EU-wide instrument à conversion to the use of renewable energy fuels.	Plants within the trading system	Existing with adjustment	New period from 2013
Support for climate and renewable energy projects, special funds allocated within Swedish Rural Development Programme.	Financial	Increased production and use of renewable energy in rural areas.	Company and project funding	Existing	2010-2013
Investment support for planting energy forests on arable land within the Swedish Rural Development Programme.	Financial	Target regarding multiannual energy crops that an area equivalent to 30,000 hectares is to have been planted during 2007-2013.		Existing	2007-2013
Government public procurement with environmental requirements, (Act on public procurement of water, energy, transport and postal services).	Information / procurement	Promoting the development of new climate-efficient technologies	Governmental authorities	Existing	-
Aid for conversion from direct acting electrical heating (2005:1255)	Financial	Conversion from direct-acting electricity to district heating, bioenergy and heat pumps	Owners of residential buildings or associated premises	Existing	Funding: measures that have been commenced no earlier than 1.1.2006 and completed no later than 31.12.2010.

Source: NREAP (National Renewable Energy Action Plan) with base year 2005

The Swedish government has suggested measures for achieving the targets of at least 50% renewable energy by 2020. In Figure 20, these measures are categorised as financial, regulatory and information/procurement (such as information campaigns). There has been a political interest in securing the domestic energy supply and reducing the dependence on imported fuels.

- Already in the 1970's, sector development took place with the implementation of energy taxation.
- Further, in 1991 the CO_2 tax was introduced and grants were given for converting to bio-based CHP. Biofuels and peat are exempt from CO_2 tax.
- In January 2005 the Swedish government established the emission trading system, which puts a ceiling on CO_2 emissions. The public sector has also played a significant role in initiating, funding and coordinating the required research and demonstration projects.
- The electricity certificate scheme has been the Swedish aid scheme for electricity from renewable energy sources since 1 May 2003. The legal amendments that have been implemented mean that the scheme will continue until 2035. Hydro power, wind power, solar energy, wave energy, geothermal energy, biofuels as well as electricity produced in cogeneration plants using peat are covered by the scheme. The electricity certificate scheme is a technology-neutral and promotes cogeneration production using biofuels.
- Since 1 January 2012, Sweden and Norway have a common market for electricity certificates with the aim to stimulate the expansion of renewable electricity in both countries. The goal is to expand the use of renewable electricity by 26.4 TWh between 2012-2020 (13.2 TWh in each country).

Support for cultivation of energy crops

Sweden's membership in the EU from January 1 1995 implies that the Swedish agricultural support schemes were replaced by EU's. Market regulations are entirely funded by EU while structural, regional and environmental support is financed by the member states. National support can be designed by the individual member states, but must be approved by the Commission. The current Common Agricultural Policy (CAP) in EU is valid until 2013 and after this period it is time for the next major revision of the common agricultural policy.

Currently, there is a possibility to receive the following types of subsidies for cultivation of energy crops for energy purposes in Sweden (Swedish Board of Agriculture and Yearbook of Agricultural Statistics 2011):

- **Aid for cultivation of energy crops** (abolished since 1 January 2010. EU decided that 2009 would be the last year when farmers could receive aid for energy crop production). A brief background; from 2004 a special type of support was given for cultivation of energy crops in Sweden. All agricultural crops could be covered as long as they were approved and used for energy purposes. The support was a maximum of 45 EUR/ha. In 2009, the application for the aid was requested for a land area of 20 498 ha.

- **Single farm payment** (Gårdsstödet) since 1 January 2005 is EU financed. The farmer can receive single farm payment for both arable and pasture land. Farmers must have support rights for every hectare of land which they wish to receive single farm payment for. Also, farmers must have at least 4 ha of agricultural land and support rights for at least 4 ha. Each support right has a certain value depending on the type of land and which region of Sweden (there are 5 regions) the farmer has the agricultural land. Willow must be harvested at least every ten years (poplar and hybrid aspen at least every twenty years) in order to receive single farm payment.

- **Investment support for plantation of energy crops on arable land** (willow, poplar and aspen). In order to receive support for willow, the planted area must be at least 1 ha (for poplar and aspen, the planted area must be at least 0.1 ha). Investment support for new plantations of energy crops through the Rural Development Programme 2009-2013. The support amounts to maximum 5 000 SEK/ha.

- **Project support** for projects related to renewable energy and climate (part of the Rural Development Programme 2009-2013). Renewable energy projects can for example include finding solutions to reduce costs in the production of bioenergy. It may also involve the development of production, processing and distribution of renewable energy.

3.7 Solid biomass market development

Solid biomass from forestry

In general, the development of forest energy has been long-term and stable. From the late 1970's, the use of solid biofuel has increased by around 3 TWh per annum and this development is projected to continue (Skogforsk, Efficient Forest Fuel Supply Systems).

According to the Swedish Forest Agency (Skogsskötselserien - Skogsbränsle), a major share of the by-products from the forest industry are already being utilised. Increasing the volumes of industrial by-products would require energy efficiency and structural changes in the forest industry. Thus, in short-term the Swedish forest can provide the following assortments:

- increasing the harvest intensity through extraction of primary forest fuels such as branches, tops, stumps and small-diameter wood
- re-distribution of stem wood between forest and energy industry
- imports of forest fuels
- expanding the forest industry capacity

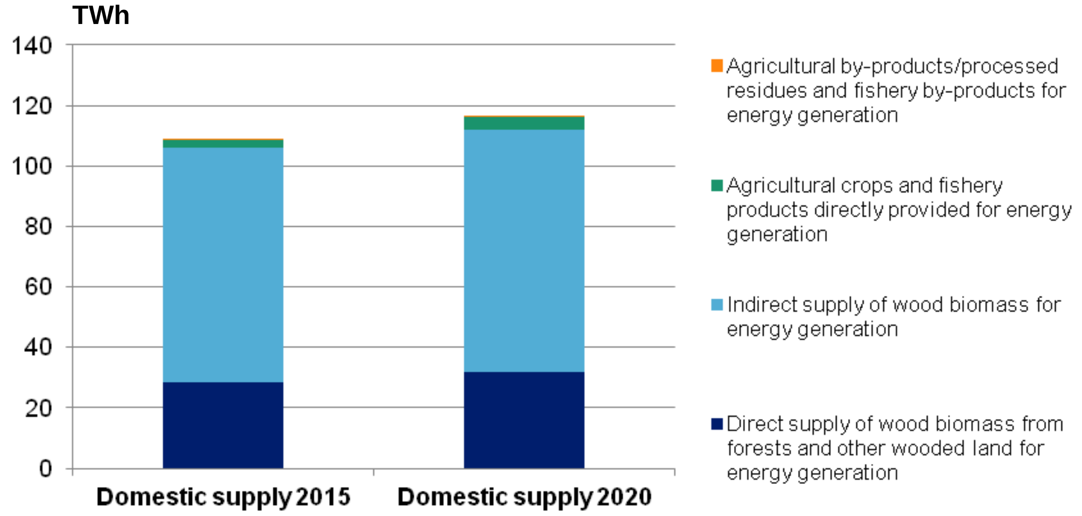
According to the Swedish NREAP, the extraction of forest residues (branches and tops) and stumps can be increased for a short time as the demand for forest fuels increases. A new range that may become interesting if the price of forest fuels rises further is the removal of weak stems or whole trees from clearings and thinnings. Research is being conducted firstly in order to increase the production of biomass in forests and secondly to develop and improve, from a technical/economic perspective, systems for managing forest residues (branches, tops and stumps).

Future supply of forest fuels is estimated to increase as harvesting residues are processed more efficiently and demand from energy sector is forecasted to grow. The Swedish Forest Agency has calculated the potential for branches and tops (GROT) and stumps for the period 2010-2019 (SKA 08). The potential has been calculated according to ecologically sustainable and technologically feasible potential. The potential for extraction of GROT with today's technology is estimated to 15 TWh/a, while the ecologically available potential is about 25 TWh/a. Thus, there is a large potential to improve the technology and working methods. The potential for branches and tops has the highest utilisation in eastern Svealand and north eastern Götaland where the transport distances from source to end-user are short. The ecologically sustainable potential for removal of stumps during 2010-2019 is estimated to be 21-34 TWh/a.

Agricultural solid biomass

The opinions about the future potential of agricultural solid biomass differ a lot. Calculations made by the Government (*SOU 2007:36, Bioenergi från jordbruket – en växande resurs*) indicate that Swedish agricultural sector has an economic realisable potential to produce about 30 TWh of biomass in 2020. Salix, ethanol and RME are biofuels that have the greatest economical potential. In a scenario by the Federation of Swedish Farmers (LRF's Energiscenario 2020), the energy potential from agriculture can reach 20 TWh in the long term (compared to the present 1-1.5 TWh). Approximately half of the increase will be a result of better utilisation of straw and other by-products. According to estimates made by the Swedish University of Agricultural Sciences, at least ten times more straw, i.e. 4 TWh (1 million tonnes), could be utilised in Sweden for production of electricity and heat. On the other hand, the Federation of Swedish Farmers, estimate the potential to 7 TWh/a. A comparison can be made to Denmark, where the use of fuel straw currently amounts to 4 TWh. The other half consists of energy crops such as willow (according to LRF the estimated long-term potential is 4 TWh/a, energy rapeseeds and cereals for production of ethanol. The large increase in energy crops is based on the assumption that energy prices will increase compared to the prices for food commodities.

Figure 21 Future domestic supply of forest and agricultural biomass for energy purposes (according to Swedish NREAP)



NOTE. Biomass from forestry includes black liquor/crude tall oil and recycled wood. Agricultural biomass includes cereals, seed oils, manure and bio oils.

Source: NREAP (National Renewable Energy Action Plan) with base year 2005

According to the Swedish Board of Agriculture, there is approximately 600 000 to 700 000 ha of agricultural land that has been taken out of production and which has not been transferred to other forms of land use. This area consists of land that is not being actively used, including the over-cultivation of pasture. The Swedish Rural Development Programme includes investment aid for energy forests that applies to all arable land. The target regarding energy crops is that an area equivalent to 30 000 hectares is to be planted during the period of the programme, 2007-2013.

3.7.1 Solid biomass price development outlook

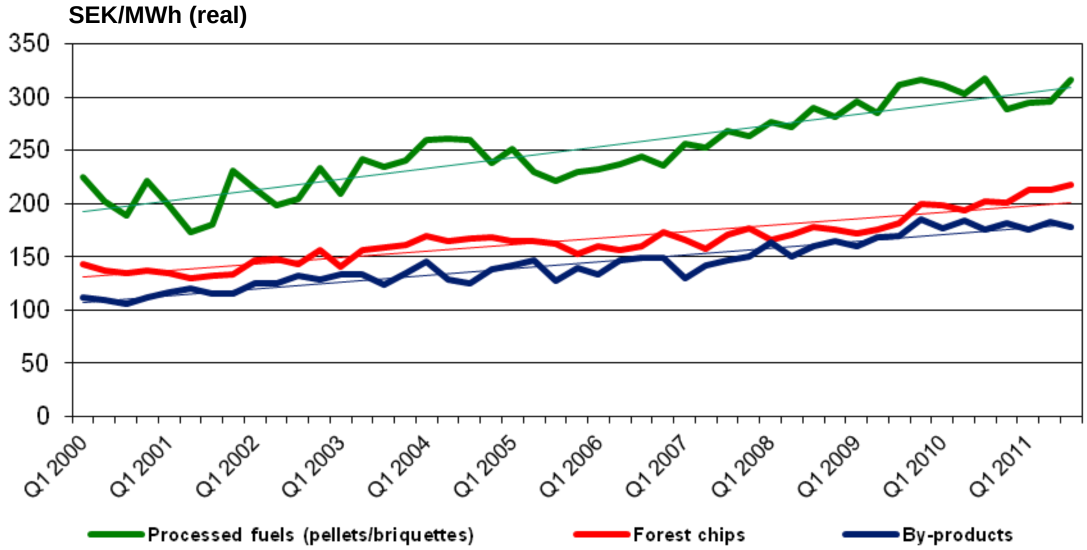
In Sweden, there are two main sources for collection of solid biomass price statistics:

- **The Swedish Energy Agency/ Statistics Sweden (SCB)** presents price statistics for biomass consumed by district heating plants and the industry (in SEK/MWh). The statistics are published every quarter in price sheet for biofuels, peat, etc. ("*Prisblad för biobränsle, torv, mm"*). Prices are presented on an aggregated level for processed wood fuels (pellets/ briquettes), forest chips and industrial by-products. The Swedish Energy Agency also published a long-term price prognosis for these biofuels.
- **The Swedish Association of Pellet Producers (PiR)** publishes a monthly price index on wood pellets, delivered to single-family houses (base month August 006).

Primary forest fuel

The nominal price for primary forest fuel during 1980 to 2005 remained stable at 13 €/MWh. In real terms, the price decreased remarkably. In 2006, the price increased to 15 €/MWh and in 2010 the price was 21 €/MWh. The development depends on the increased demand and local supply shortage. The average cost for primary forest fuels, production and transport to end consumer, was approximately SEK 170/m³loose in 2009.

Figure 22 Historical price development at heating plant (SEK/MWh), Q1 2000 - Q3 2011



** Real prices for wood fuels delivered at mill adjusted with PPI Q3 2011 price level*
Source: Swedish Energy Agency, Statistics Sweden

According to a study (questionnaire answered by large producers of forest fuel in Sweden), the cost for primary forest fuel is increasing. During 2010, the cost increased from 170 to 173 SEK/m^3loose, an increase by around 2%. The cost for branches and tops and small-diameter trees increased, while the cost for firewood and stumps decreased. The study comprises a time series of 2 years, thus it is too early to see any clear trends. For more cost data for primary forest fuels, see Figure 81 in Annex A (Skogforsk, Efficient Forest Fuel Supply Systems).

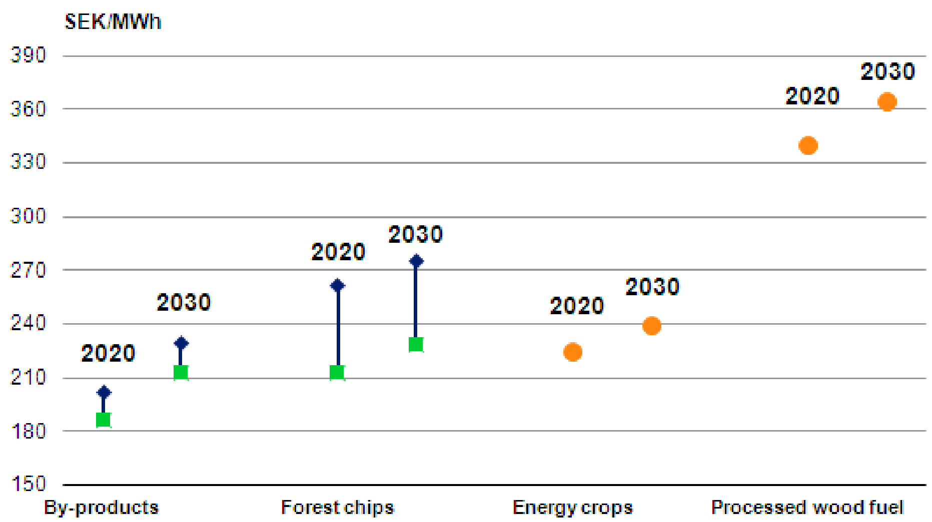
Processed wood fuel (pellets)

The most expensive assortment of woody biomass is processed wood fuel such as pellets, briquettes and wood powder. Pellet prices in Sweden for both industrial and residential pellets (bulk and small bags) show a relatively stable but increasing trend (Figure 22). From Q1 2000 to Q3 2011, prices have increased by 3% annually. With the economic downturn, the capacity utilisation rate declined in sawmills and thereafter in pellet production as raw material became scarcer and prices increased. Pellet imports increased due to price competitiveness and sourcing strategies from larger players in the market. Pellets and briquettes have homogenous quality, are easy to use and have lower moisture content compared to other wood fuels (usually <10%) and hence, are more economic to transport over longer distances. Consequently, wood pellets are a globally traded commodity with prices in European market largely following the market prices in ARA (Amsterdam-Rotterdam-Antwerp). The current price forecasts show a rising trend price for pellets at ARA (Pöyry).

Future solid biofuel price development

According to the Swedish Energy Agency's long-term price prognosis, the price development for biofuels in 2020 is expected to continue in the same level as the average price increase during 2000-2007 (Figure 23). After 2020, prices are expected to continue increasing, however, at a lower pace. Prices are assumed to be slightly higher for processed than unprocessed biofuels.

Figure 23 Future price development for 2020 and 2030 (range low to high)



Source: Swedish Energy Agency's long-term price prognosis

According to the Swedish NREAP, the downturn in the global economy during the course of 2009 led to a reduced demand for roundwood to be used for pulp in conjunction with an increase in the demand for biofuel. This resulted in an equalisation in the price difference between the ranges and the use of comparatively large quantities of roundwood for energy purposes. There are concerns that this shift in ranges could become constant as the demand for biofuels increases as a consequence of the fulfilment of Sweden and the EU's energy targets.

3.7.2 Market mechanisms

The Government has given the Swedish Energy Agency the duty of having complete responsibility for information under the Renewable Directive. The Swedish Energy Agency's responsibility is disseminating information about energy efficiency (and renewable energy) to consumers, domestic households and commercial enterprises.

According to Skogforsk (Efficient Forest Fuel Supply Systems), for a long time there have been insufficiencies in the Swedish statistics on costs, methods, systems and assortments for forest fuel. For example, forest fuel is measured and evaluated in different units across the value chain, from the forest to the end-user. Heating plants uses MWh, hauliers are familiar with tonnes and in the forest the fuel measured in volumes such as m^3solid or m^3loose chips. The usage of different measurement systems often causes misunderstandings. Thus, there are future requirements to improve the statistical information through R&D initiatives. Because the forest fuel business is growing rapidly, it is necessary to establish accurate determinations of fuel volume and quality. Furthermore, forest fuel will fall under the provisions of the Timber Measurement Act and the following measures are required:

- Basic development of measurement technology for both processed and unprocessed fuel assortments.
- Implementation of new measurement procedures and reporting systems in the forest fuel area.
- Information and training initiatives to disseminate knowledge of these procedures and how they are to be used.

RESOURCE EVALUATION FINLAND

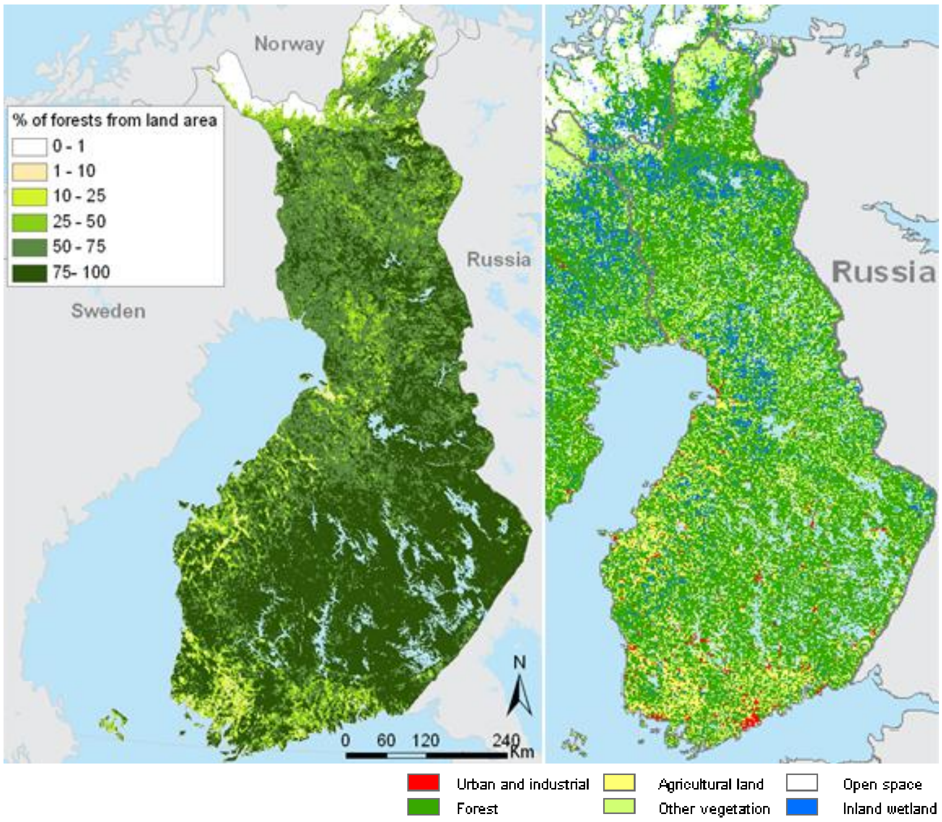
4. FINLAND – EVALUATION OF FOREST AND AGRICULTURAL BIOMASS RESOURCES

4.1 Background

The forest land area of Finland is 26.3 million ha, covering approximately 87% of the country's total land area. The productive forest area, about 20.1 million ha, is one of the largest in Europe. The forests in Finland are quite evenly distributed, as illustrated in Figure 24, only the most northern parts are less forested due to challenging growing conditions. Also the most populated areas of Finland in the southwest have less forest cover. The main tree species are pine and spruce which together account for 80%. The remaining 20% consist of hardwood species, of which birch has the largest share.

According to Finnish Statistical Yearbook of Forestry (2010) private individuals and families own slightly over half of the forest land, the state has a 35% share, private industries 8% and other owners 5%. The forest estate entities owned by private individuals or families are typically quite small and thus the number of private forest owners is large in Finland. In 2008 there were 345 000 (min. 2 ha) forest estate entities with an average size of around 30 ha. About 95% of the Finnish productive forests are certified according to the Finnish national PEFC system. A national FSC system also exists (394 922 ha).

Figure 24 Distribution and share (%) of forests and arable land in Finland



Source: European Forest Institute, European Environment Agency

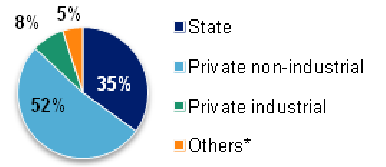
The prevailing forest management practices in Finland provide a stable flow of sawlogs, pulpwood, small diameter roundwood and harvesting residues for the forest industry and power and heat generation. The current management practice of the commercial forests in Finland is based on the even aged management of the forests. Silviculture is organised into rotation periods and a rotation period begins when a new forest stand is established and ends after several decades, when most of the trees are harvested before regeneration of a new forest stand. During the rotation period the forest is usually tended by thinnings, which means that small trees (that can be utilised as pulpwood or biomass for bioenergy generation) are removed. This creates more space for the remaining, more viable trees.

According to the Finnish Forest Research Institute (Metla), the total actual harvesting reached 52 million m^3 in 2010. Around 23 million m^3 of solid wood-based biomass was utilised for bioenergy generation in heat and power facilities and for small-scale use, i.e. in households and other estates.

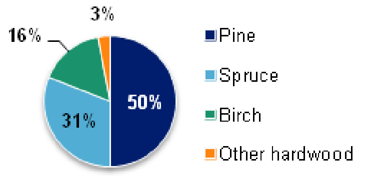
Figure 25 Characteristics of forest and agricultural resources in Finland

Forest facts	
Total land area	30.4 million ha
Forest area	26.3 million ha
Productive forest area	20.1 million ha
Forest area % of total land area	87%
Sustainable felling level	70 million m^3sob
Actual felling	52 million m^3sob
Growing stock volume	2 206 million m^3sob
Growing stock per hectare	107 m^3/ha
Net annual increment	103.7 million m^3sob
Agricultural facts	
Agricultural area	2.7 million ha
Share of agricultural land	9%
Main agricultural products	Barley, oat, wheat, turnip rape and rape, silage, hay

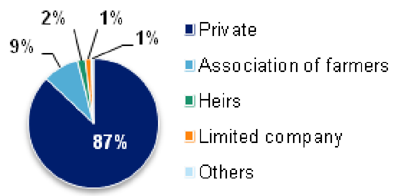
Forest ownership (of total forest area)



Tree species (in the growing stock)



Ownership of agricultural land



** Includes municipalities, parishes, collective forests etc.*

Source: Finnish Statistical Yearbook of Forestry 2010, Tike 2011

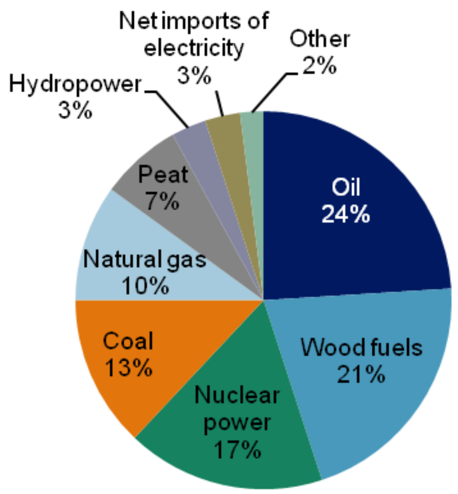
4.1.1 Introduction to energy market in Finland

According to Statistics Finland, in 2010, which was an exceptionally cold year, the total consumption of energy by source in Finland reached about 401 TWh (an increase by 9% from the previous year). Of the single fuels, the highest increase was observed in the total consumption of coal (+22%) and wood based fuels (+15%), whereas the consumption of nuclear power as well as net imports of electricity decreased compared to 2009. In 2010, around 99 TWh or 25% of the total consumption of energy originated from renewable sources (Figure 26).

According to Statistics Finland, the share of renewable energy in the *final* consumption of energy was 30.5% in 2008 (the most recent year of reporting). Final consumption of energy measures the consumption of finished energy products, that is, electricity and heat and fuels used for heating of buildings, transport and industrial processes. The difference between total consumption and final consumption depicts energy conversion and transmission losses.

Fossil fuels, oil, coal and natural gas accounted for the largest share, 47%, of the total energy consumption in 2010 (Figure 26). However, the share of wood fuels was 21% of the total energy mix, which makes it the second largest single fuel type after oil. Also nuclear power has a dominant role in the Finnish energy mix accounting for 17%. It is important to note that currently only about 30% of the energy used in Finland originates from domestic sources (wood fuels, hydropower, wind power, peat, heat pumps) while the remaining part is covered by imports of energy products and net imports of electricity. According to Statistics Finland, the largest amount of energy was imported from Russia, reaching 11.6 TWh in 2010. Nevertheless, Finland is also an exporter of energy. In 2010, the country was a net seller of electricity on the Nordic market, especially to Sweden.

Figure 26 Total energy consumption by energy source in Finland, 2010



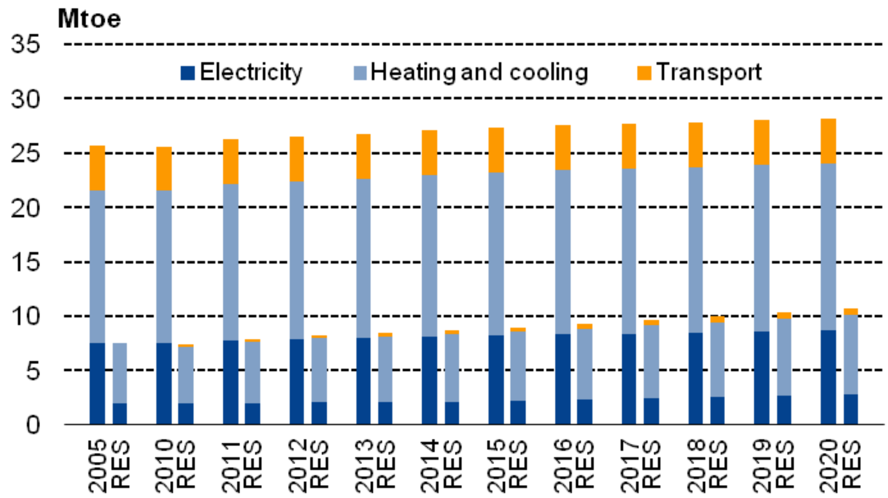
Source: Statistics Finland

According to Statistics Finland, wood fuels (both solid and liquid) accounted for 85 TWh or 87% of the total renewable energy in Finland in 2010. Also hydropower (13 TWh or 13%) has a visible role in the renewable energy generation, while the share if wind power is currently only minor accounting for 0.3% of the renewable energy.

Utilisation of agricultural biomass for energy purposes in Finland has so far been marginal. Thus, wood-based fuels almost fully dominate the bioenergy generation. Currently, the only energy crop cultivated on a commercial level is reed canary grass, which was cultivated on 16 700 ha of land in 2010 (Tike 2011). According to the Finnish Bioenergy Association, the consumption of reed canary grass in power and heating plants has been only about 100 GWh annually. Also, the utilisation of straw for energy has been marginal in Finland and growing willow as short rotation woody energy crop has so far only been tested in small-scale.

To reach EU's 2020 energy target, the Finnish government has established a "renewable energy package". As stated in the Finnish National Renewable Energy Action Plan (NREAP), the aim is to increase the renewable energy production by a total of 38% of the final energy consumption[1] in 2020. This corresponds to 124 TWh gross final energy consumption, which is a 38 TWh growth compared to 2005 (or 134 TWh total energy consumption and increment of 39 TWh from 2005). This target is illustrated in Figure 27. According to the NREAP, renewable electricity generation is estimated to grow 9 TWh by 2020 and will be mainly based on hydropower 14.4 TWh, solid biomass 7.9 TWh and wind 6.1 TWh. The heating and cooling sector is expected to grow by 21 TWh as a whole with solid biomass 45.8 TWh, liquid biomass 30.4 TWh, heat pumps 7.7 TWh and biogas 0.7 TWh as the main sources (Figure 28).

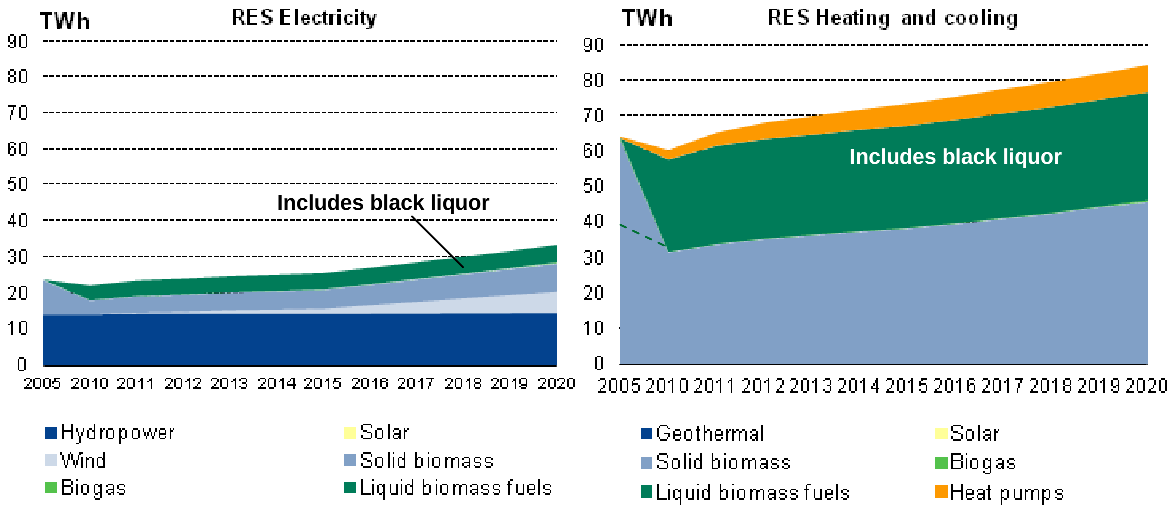
Figure 27 Gross final energy consumption by type – current and future outlook



Source: NREAP (National Renewable Energy Action Plan) with base year 2005

[1] incl. additional energy efficiency

Figure 28 Renewable energy targets for electricity and heating/cooling



Source: NREAP (National Renewable Energy Action Plan) with base year 2005

The amount of solid wood fuels is targeted to grow considerably by 2020 (Figure 28). Forest chips are considered to be the most important single fuel in reaching the Finnish national target whereas the potential for increasing the utilisation of industrial liquid biomass and solid by-products is low since these products are already used to a high extent. The consumption of forest chips in CHP generation and separate heat generation is expected be 25 TWh in 2020 which corresponds to 13.5 million m^3. According to the Finnish Forest Research Institute, the consumption of forest chips in heat and power plants was 12.5 TWh (6.2 million m^3) in 2010, thus considerable efforts need to be made in order to reach the target.

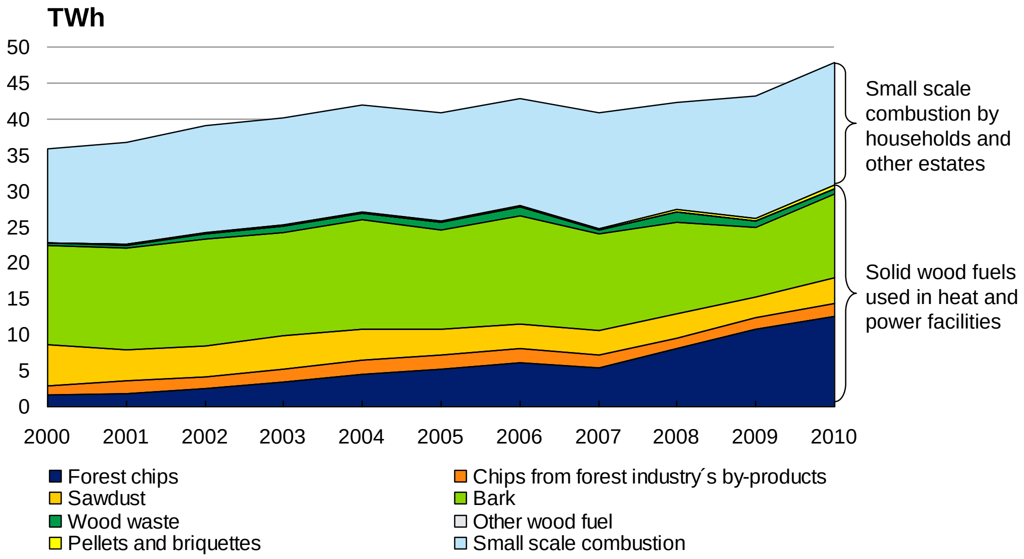
4.2 Resource Assessment – Solid biomass from forestry

Solid biomass from forestry used for energy purposes in Finland largely consists of by-products from forest industry production and harvesting of roundwood. Some wood is also harvested mainly from birch dominated forests, chopped and delivered to households where it is utilised for small-scale heating.

Forest biomass includes logging residues of final harvests, mainly branches, tree tops, stumps and small-diameter wood that is collected from the areas of early thinnings (where no pulpwood available). The forest industry in Finland can be divided into pulp and paper industry and sawmilling industry. Waste liquors, mainly black liquor that remains after the pulping process, are burned for power and heat generation. The energy is mainly used internally by the forest industry itself. The sawmilling industry produces solid by-products, mainly bark, chips and sawdust. Part of by-products are directed either to the pulp industry as a pulping raw material (chips) or to the panel and board mills which especially require chips and sawdust. A share is also burned for energy generation. The amount of industrial by-products is directly dependent on the forest industry's production level. Also, the level of wood procurement relies heavily on the forest industry's demand of roundwood. Thus, the supply of forest residues is also strongly linked to the industry's activity. The forest industry mainly consumes wood fuels internally, however a share is sold to traders, the energy sector and processing industries (pellets). The forest industry uses integrated procurement of roundwood and energy biomass. This means that industrial wood and energy biomass are harvested and transported to the plants using mainly the same equipment.

According to the Finnish Forest Research Institute (Puun energiakäyttö, 2010), industrial liquid by-products accounted for 36 TWh or 42% of the total consumption of wood-based fuels in energy generation (85 TWh) in Finland. Solid biomass accounted for more than half of that share, 49 TWh or 58% (Figure 29). The utilisation of solid biomass in heat and power plants was about 31 TWh, while 17 TWh was used in small-scale in households and commercial buildings, office and other estates. The south eastern region of Finland consumed almost 20% of the total solid biomass in 2010. However, consumption of solid biomass has increased throughout Finland. Of single fuels, the use of forest chips was highest in central Finland. According to Helynen et al. (2007), the highest potential in increasing the utilisation of forest chips is seen in eastern Finland.

Figure 29 Utilisation of solid biomass for energy in Finland, 2000-2010

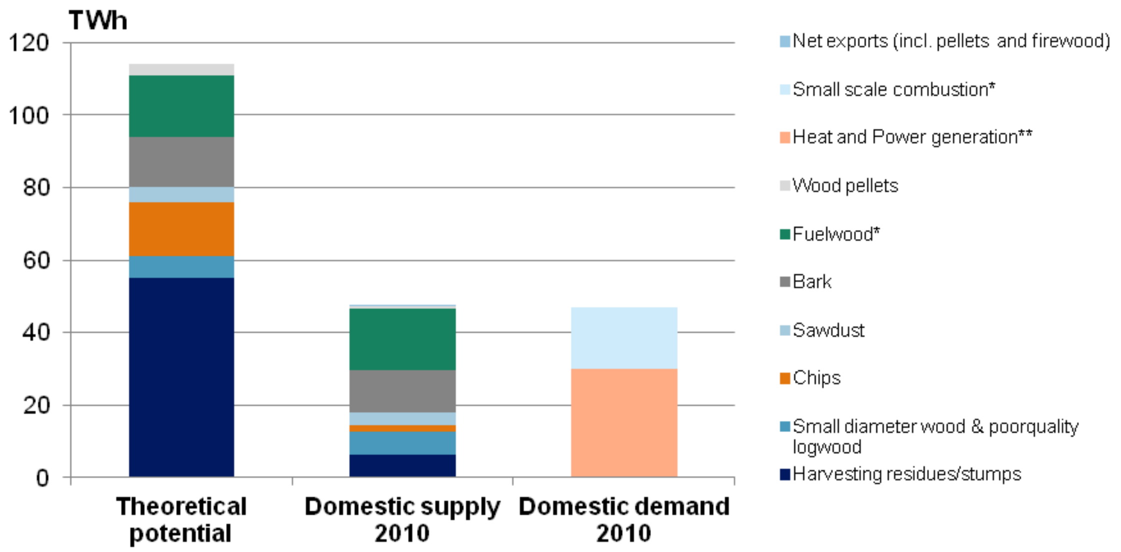


Source: Finnish Forest Research Institute (Puun energiakäyttö 2010)

Solid wood fuels utilised in power and heat facilities

According to the Finnish Forest Research Institute, 31 TWh or 16 million m^3 of solid biomass was utilised by the heat and power facilities in 2010. The increase in utilisation was 2.6 million m^3, an increase by 19% from the previous year. The main feedstock was forest chips (12.5 TWh or 6.2 million m^3, +15 % from previous year) and industrial by-products (17 TWh or 9.2 million m^3, +23 % from previous year). The breakdown of industrial by-products used in heat and power facilities in 2010 was as follows: bark (11.7 TWh or 6.6 mill. m^3), sawdust (3.5 TWh or 1.8 mill. m^3) and chips (1.8 TWh or 0.9 mill. m^3). The main raw material for production of forest chips was small-diameter wood (2.5 mill. m^3), harvesting residues (2.2 mill. m^3) and stumps (1.0 mill. m^3). Also, 0.5 million m^3 of (low quality) logwood was used.

Figure 30 Current supply & demand for solid biomass from forestry



** Household usage: including small-sized- wood, forest chips and waste wood*
*** Excluding waste wood*

Source: Finnish Forest Research Institute (Puun energiakäyttö 2010)

Solid wood fuels utilised in small scale combustion

Households used 17 TWh, corresponding to 6.7 million m^3 of solid biomass in 2010. Around 20% consisted of wood waste, 70% firewood and 10% forest chips. Wood pellets have so far had a minor role in Finland (Figure 30). In 2010, the total consumption of wood pellets by end-use sector was only about 0.8 TWh of which households accounted for 44% and heat and power facilities as well as large scale estates 56% (Finnish Forest Research Institute). Wood pellets production in Finland is export driven. In 2010, the net export of wood pellets was 0.4 TWh (Finnish Forest Research Institute), but pellet demand is expected to increase especially in small and medium scale heating plants and in co-firing (Pöyry). According to a report by the Ministry of Employment and the Economy (Alm 2011), there are 26 pellet mills in Finland and the biggest Finnish pellet producer is Vapo Oy. Vapo produces pellets in Finland, Sweden, Estonia, Denmark, Poland and has in total 15 plants. Recently, Vapo announced that the company will close the plants in the cities of Ilomantsi, Haapavesi and Kaskinen during 2011 due to poor profitability. The world's largest pellet mill with annual capacity of 900 000 tonnes started operating in 2010 in Vyborg, Russia close to the Finnish border (Alm 2011) and this might have an impact on the pellet trade within the Baltic Sea region.

As shown in Figure 30, the theoretical potential for solid biomass is considerably higher than the current supply and demand. This indicates that there is at least a theoretically large potential that remains untapped. However, the amount that could technically be utilised is lower as current practises only support the collection of e.g. stumps from spruce final harvest sites. Also, the willingness of the forest owners to sell biomass, environmental regulations, geographical factors and harvesting methods are limiting factors in biomass mobilisation.

4.3 Resource Assessment – Agricultural solid biomass (incl. energy crops)

Reed canary grass

Reed canary grass was cultivated on 16 700 ha of land in Finland in 2010 (Tike 2011). According to Lötjönen & Knuutila (2009), reed canary grass grows in the whole country, even in the north, and as a perennial species can produce biomass for 10 years after one sowing. In Finland, reed canary grass is grown on fields and peat lands that have been previously used for peat extraction. Reed canary grass used as fuel is normally harvested in the spring after the snow has melted when the moisture content is the lowest and thus, the combustion quality most favourable. The average yield of reed canary grass is 4-5 tonnes/ ha and the energy content per ton during springtime (with a moisture content below 25%) can be about 4 MWh (Motiva). According to the Finnish Bioenergy Association (Asplund et al. 2009), the consumption of reed canary grass in Finland for energy purposes has been only marginal, about 100 GWh annually (Figure 31). There are around ten energy facilities that are able to utilise reed canary grass as bales or as a pre-mixed fuel. Currently, only one large-scale plant has invested in a separate feeder for reed canary grass that directly feeds the crushed reed canary grass from the storage to the boiler. The challenges in using reed canary grass as a fuel come from the high ash content and the unfavourable composition of ash in the boilers. Also, there are high variations in the moisture content and the energy content is low compared to other fuel sources (Motiva). With today's boiler technology, reed canary grass needs to be burned together with wood based biomass or peat and the share can be up to 20% of the fuel mix (Lötjönen & Knuutila 2009).

Figure 31 Current supply & demand for solid biomass from agriculture

Source: Finnish Forest Research Institute (Puun energiakäyttö 2010)

The national bioenergy association in Finland (FINBIO) has set a target of 150 000 ha of reed canary grass area in 2020, which could at the maximum level correspond to 4.5 TWh annual energy production (e.g. Asplund et al. 2009). The Finnish Ministry of Agriculture and Forestry has also set a target to increase the cultivation of reed canary grass to 100 000 ha by 2015 (MMM, 2008). In Finland, cultivation of reed canary grass is subsidised financially, however not the energy generation using reed canary grass as a fuel (Lötjönen & Knuutila 2009). In contrast to the targets set by FINBIO and Ministry of Agriculture and Forestry, the cultivated area of reed canary grass has decreased in recent years (2008: 18 700 ha, 2009: 18 000 ha and 2010: 16 700 ha) (Tike 2011). The recent increase in grain prices has reduced the relative profitability of growing reed canary grass, thus also the interest in growing energy crops has fallen (Silvennoinen et al 2008). In the long-term, agricultural commodity prices are expected to rise further due to the increase in global demand and energy crop production (Silvennoinen et al 2008).

Energy crops and straw

Since the 1970's, short rotation woody crops (mainly willow) have been grown on small-scale in Finland, however there is currently no commercial production. Willow is grown on 10-15 ha in research trials carried out by University of Eastern Finland in Siikasalmi in north-eastern Finland. During these trials, a "*Salix schwerinii"* clone was found as the most suitable willow clone in terms of growth and yield. A planting density of 10 000-20 000 cuttings/ha was found as the most cost-effective. During the first 4 year rotation, the annual yield was 6-8 dry tonnes/ha and 8-14 tonnes/ha during the second rotation. The site had been fertilised 2 times during the 20 year trial period and according to the results, 4 years is the optimal harvesting period for achieving maximum yield. Willow cultivation was found marginally profitable and the profitability could be further improved by e.g. improved R&D. In Finland, there has been an increasing interest in testing other short rotation energy crops such as birch, alder and aspen for energy production (Laitila et al, 2010).

The consumption of straw for energy purposes in Finland has also been marginal. However, a potential for a wider utilisation exists. The estimated annual crop yield of straw in Finland is about 2.1 million tonnes which corresponds to about 7.5 TWh (Figure 31). Of this about 20% (0.4 million tonnes) is considered to be a technical and economical potential for energy purposes, corresponding to about 1.5 TWh in energy content (e.g. Asplund et al. 2009).

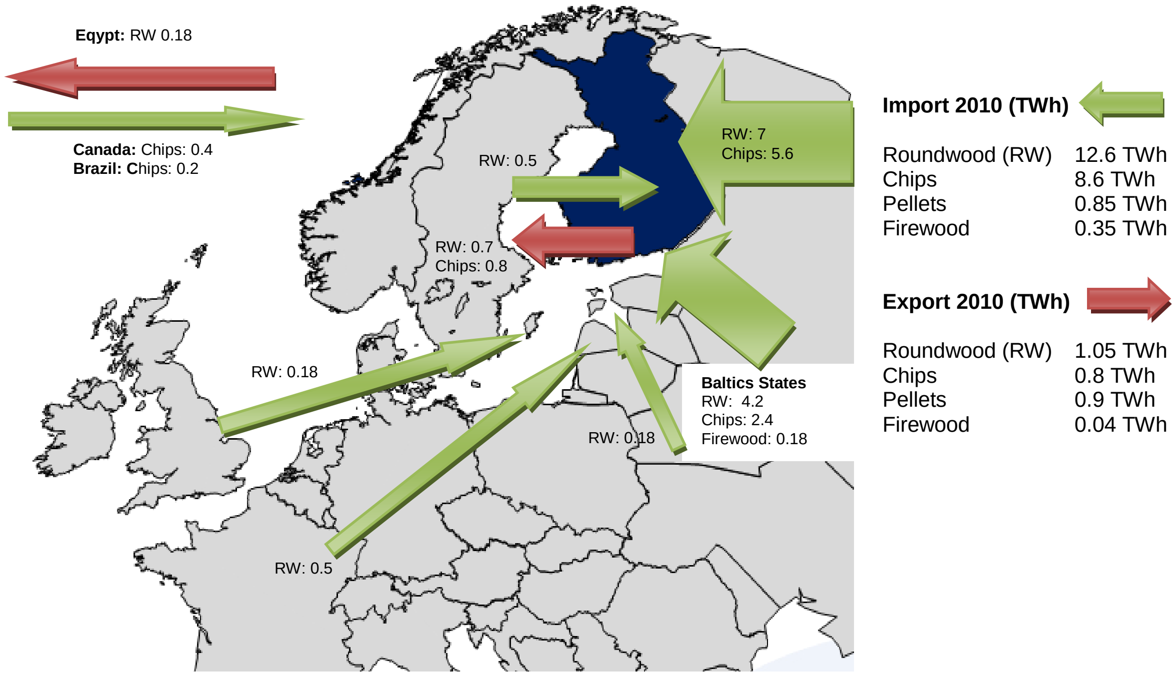
According to the Finnish Bioenergy Association (Asplund et al. 2009) some 1.7 to 1.8 million ha of agricultural crop land is estimated to be sufficient for production of food crops and animal fodder (total agricultural crop land in Finland is 2.3 million ha). The remaining 500 000 could potentially be utilised for energy crop cultivation. If this area was dedicated for e.g. reed canary grass production (with assumed yield of 20 MWh/ha) this would correspond to 10 TWh of theoretical potential (Figure 31).

4.4 Biomass trade and mobilisation in Finland

4.4.1 Trade flows

According to the Finnish Forest Research Institute (Metsäteollisuuden vienti 2010), the value of exports of forest industry products was EUR 10 849 million in 2010. The forest sector's share of exports of goods is slightly less than a quarter and import of foreign timber is a major source of raw material for the Finnish forest industry. In 2010, 4.3 million m^3 (8.6 TWh) of wood chips was imported to Finland which was a record breaking amount (Puun energiakäyttö 2010). The forest industry used in its production about 2.9 million m^3 of imported chips and thus, the remaining 1.5 million m^3 of chips were most likely stored by the pulp industry and consumed in energy generation. Between 2008 and 2010, an average of 1.4 million m^3 of imported chips yearly has not been utilised in forest industry production.

Figure 32 Main trade flows of solid biomass 2010 (TWh)



Source: Finnish Forest Research Institute (2010): Metsäteollisuuden ulkomaankauppa

Currently, the trade flow of solid biomass, i.e. roundwood, chips and firewood, between Finland and the other Nordic countries is rather small compared to Finnish imports of biomass from Russia and the Baltic States (Figure 32). In 2010, Finland imported about 4.1 million m^3 of roundwood and 2.8 million m^3 of chips from Russia. Another 2.4 million m^3 of roundwood and 1.2 million m^3 of chips were imported from the Baltic States. Some roundwood was also imported from Belarus, France and UK and chips from Brazil and Canada. The main trade partner in the Nordic countries is Sweden. In 2010, about 0.3 million m^3 of roundwood was imported from Sweden and 0.4 million m^3 was exported to Sweden. The flow of chips was mainly from Finland to Sweden. The trade between Finland and Norway is marginal and there are no reported trade flows of roundwood, chips or firewood between Finland and Denmark (Metsäteollisuuden vienti 2010). It is likely that the level of solid biomass trade will remain at the current level in the near future. In e.g. Faostat agricultural import-export statistics, for Finland there were no reported amounts of exported or imported agricultural products included in the scope of this study (energy crops and straw).

4.4.2 Solid biomass mobilisation

Solid biomass from forestry

There have been several official programmes in Finland to develop and increase forest fuel collection and use carried out by e.g. Finnish Forest Research Institute, VTT, Metsäteho. Technological development has focused on different harvesting methods, fuel processing (chipping), forest residue bundling, stump lifting and logistics. By integration of roundwood and wood fuel supply chains, the use of wood fuels has increased. Along with the increase in forest based fuel volumes, biomass handling and storage has been developed in recent years. Several wood terminals have been established to improve wood fuel logistics and delivery security. Forest industry's harvesting operations and related transport is almost entirely mechanical in Finland; the mechanisation level is above 99%.

The use of forest chips for energy production is targeted to increase extensively in Finland. Therefore, not only investments in boilers are needed but also the mobilisation of forest chips needs to be improved. For example, more production capacity is required in forest chips supply chains. Based on Pöyry and Metsäteho analysis (Kärhä et al. 2009), more than 1900 machinery units would be necessary (e.g. harvesters, forwarders, stump lifting machines, chippers, crushers, trucks) to supply the targeted 25 TWh of forest chips. This would mean total investments of EUR 530 million. For these 1900 units, the labour demand would be some 3400 machine operators/drivers. Currently, the use of 10 TWh is equal to 750 machine units and 1400 operators/drivers.

According to a study compiled by Technical Research Centre of Finland (VTT) (Laitila et al. 2010), the entire forest biomass supply chain and the supply security should be further developed to make utilisation of forest biomass more profitable. Also, harvesting costs should be reduced and the quality of biomass improved (especially impurities in the chips from stumps is considered as a limiting factor). According to the study, also the current unclear pricing methodology and measuring of biomass can be considered as a weakness in biomass mobilisation. However, an official measurement guideline (Energiapuun mittausopas) for energy wood was introduced in 2008 to clarify the energy wood measurement practices and thus make the energy wood market more transparent. The guideline was compiled in cooperation with key players from the energy and forest industry. A special measurement committee was introduced to formally approve the measurement methods and facilitate the possible cases of conflict (Energiapuun mittaus, 2010). According to Laitila et al. (2010), activation of forest owners to sell enough energy wood is also needed to improve the mobilisation of biomass. Also, improvements in the long distance transport of biomass are needed. The consumption peak of biomass occurs normally during winter time and therefore the need for biomass harvesting machinery and work force is also high. The use of terminals together with rail and boat transport could also improve the biomass supply security and even out the peaks in demand and reduce the need for work force especially in long distance transporting.

According to a study by Pellervo Economic Research Institute (Silvennoinen et al. 2008), one of the obstacles to increase volumes of forest biomass in energy production is that the forest biomass producer prices that are too low. Also, according to the study, forest owners are concerned that roundwood prices would fall if small-diameter wood was increasingly used for energy production instead for pulp and paper production. In the study, also the landowners' own need for energy wood, shortage of forest biomass buyers and concern about nutrient losses in the forest soil after harvesting residue and stumps collection were seen as obstacles in energy wood markets. A large number of small-sized estates that sell only small volumes of wood and consequently, have small earnings from energy wood also cause inefficiency in the market. The study however states that despite the obstacles, there are also signs that a well-functioning energy wood market is gradually developing. As means to improve the market Silvennoinen et al. (2008) emphasises the enhanced dissemination of information. Also, increase in the density of heat and energy plants would enhance the landowners´ willingness to sell energy wood as that would probably offer more equal opportunities for landowners to find buyers close to the biomass source.

The environmental impacts of forest biomass harvesting have been studied in Finland e.g. by Kuusinen & Ilvesniemi (2008) and the research is on-going. In order to take into account the environmental aspects of forest biomass utilisation, a national guideline for energy wood harvesting was introduced in 2005 by Tapio (Äijälä et al, 2010) with contribution from the national bioenergy stakeholders. The guideline makes recommendations about the suitability of forest habitats for forest biomass harvesting as well as provides instructions on suitable harvesting practises of forest biomass. The recommendations in the guideline are followed by all the significant bioenergy market players in Finland and the guideline is updated regularly to keep it in line with the most recent research results. The most recent version is from 2010.

Agricultural solid biomass

Technical Research Centre of Finland (VTT) has carried out studies on the properties of domestic agricultural fuels in Finland (Alakangas, 2000). There are also some studies available about the cultivation of reed canary grass, e.g. by MTT Agrifood Research Finland (Pahkala et al. 2005). According to Laitila et al. (2010), research has been carried out about the harvesting of short rotation willow and profitability of its cultivation in Finland. However, no combustion tests have been carried out so far as the cultivation of willow is still in the trial phase in Finland.

According to a study by Pellervo Economic Research Institute (Silvennoinen et al. 2008), Finnish farmers have a positive attitude and also resources to increase agricultural biomass production. The main motivation for a farm to produce and utilise biomass is that it reduces its dependency on oil both in the heating of farm buildings and in the production process. According to the study, the most popular energy crops among farmers are energy hay and oil crops, but interest towards energy grain is increasing. Energy crop cultivation seems to be especially attractive for farms that already cultivate cereal or other crops and can therefore rather easily shift to energy crop cultivation. In the farmers' opinion, one of the main obstacles in cultivating energy crops is currently low producer prices. However, competitiveness of the bioenergy sector is improving due to rising fossil fuel prices and global binding agreements on biomass consumption. Silvennoinen et al. (2008), states that in order to create more successful operational environment for on-farm biomass and bioenergy production, biomass production should be more profitable. Also, economic conditions should be more stable concerning producer prices. The bioenergy market should geographically cover the whole country as farmers are less interested in biomass production, if there are no end-users or buyers nearby.

4.5 Overview of current "biomass-to-energy" generation

4.5.1 Industrial sector

According to the Finnish Forest Institute and Statistics Finland, from the wood-based biomass used (85 TWh, including waste wood and black liquor) in 2010, 47.7 TWh (56%) was consumed by the industrial sector and 20.3 TWh (24%) by the power and heat suppliers (energy industry). According to the Finnish Forest Research Institute, wood accounts for almost 80% of the fuel consumed by the forest industry and accounts for about one third of the entire energy consumption of the industrial sector.

4.5.2 District heating

According to Statistics Finland solid wood fuel utilisation accounted for approximately 6% (4.6 TWh) of the total domestic electricity generation (approximately 77 TWh) and 17% (6.6 TWh) of the total district heat production (approximately 39 TWh) in 2010. According to Pöyry's database, there are more than 500 wood-fired (>1 MW) boilers in Finland. Solid wood fuels are typically co-fired with peat, which is classified as a slowly renewable fuel. However, in the future the increasing use of forest chips will inevitably decrease the use of peat. In the early 2000's, investments in solid fuel-fired (peat and wood fuels) boilers accelerated in Finland and the level of investments has remained high. Especially the number of small and medium size boilers has increased whereas only a few larger (20-50 MW) investments have been made. In 2007, around 75% of the units using solid wood fuel energy generation were relatively small (<5-20 MW) and generated mainly heat. The larger (>20 MW) units, representing about 25% of all units, consumed the majority of the solid wood fuel available, i.e. 83%. Currently, the largest solid biomass fuel users in Finland are Kaukaan Voima in Lappeenranta, Jyväskylän Energia in Jyväskylä and Alholmens Kraft in Pietarsaari. There are many anticipated investments to large scale (≥ 50 MW) wood fuel firing units, but also to small-scale CHP plants.

In small-scale (<1 MW) heat production, heat entrepreneurship has become a popular operating model. In this model, the entrepreneur, an entrepreneur consortium of 2-4 entrepreneurs or limited company managers operate the biomass-based heating plant and sell heat to end-users. In most cases, the heat entrepreneurs also take part in the raw material sourcing. Currently, there are about 200 heating entrepreneurs supplying heat to 500 locations in Finland based on Pöyry analysis.

According to Pöyry, more than 80 new bioenergy plants (>1 MW) are identified to be operational by 2020. Some of the investments are on a greenfield basis, but most of them are boiler replacements at existing sites. Bioenergy investments will result in more than 1300 MW_e new electricity capacity (includes also other fuels used in multifuel boilers). Investment volumes are roughly estimated to be more than 3 billion EUR by 2020.

4.5.3 Private households and other estates

According to the Finnish Forest Research Institute (Puun energiakäyttö 2010), small-scale consumption of solid wood-based biomass in households, offices, shops etc. was about 17 TWh, corresponding to 6.7 million m^3 in 2010. Around 20% was wood waste, 10% forest chips and 70% firewood. Households consumed about 0.35 TWh of pellets in 2010 (Finnish Forest Research Institute, Puupelletit 2010). The first pellet boilers in Finland were installed already in the 90's but the rate of installations has accelerated during the last ten years (Rouvinen et al. 2010).

4.6 Regulatory framework and sector policies relevant for solid biomass supply for energy

Energy policy in Finland has favoured renewable energy and bioenergy during the past years. Only one significant power plant investment has been made based on the use of fossil fuel[2] while other investments are based on wood fuels and peat. In Pöyry's opinion, current policy and regulatory framework supports this trend also in the future. The

[2] Fortum Power and Heat Suomenoja Combined Cycle Gas Turbine (CCGT) plant in Espoo

following mechanisms were identified that support the use of wood fuels and agricultural biomass in Finland.

Solid wood fuels

As part of the Finnish national goal for increasing the share of renewable energy in the total final consumption of energy to 38% by 2020, a target was set to increase the use of forest chips in CHP production and in separate heat production to 25 TWh (NREAP Finland). This corresponds to 13.5 million m^3sob of forest chips, which is almost double the amount compared to the 2010 consumption level of 6.2 million m^3sob. A significant growth potential is seen in energy wood harvested from young forests and therefore most of the growth should come from the utilisation of small-diameter wood and stumps. The current harvesting cost of small-diameter wood is considered to be too high for the energy utilities, thus support mechanisms are needed to reach the national targets for forest chip consumption. In the Finnish NREAP the following three support mechanisms have been introduced to increase the use of forest biomass:

1) Market based feed-in tariff for new small-scale biomass CHP plants was approved by the European Commission during spring 2011. The feed-in tariff is directed at plants with electricity generation capacity ranging from 100 kW_e to 8 MWe. The feed-in tariff is the difference between the target price (83.5 €/MWh_e) and the actual market price. Additional heat premium of 20 €/MWh_e will be given to electricity production in CHP plants. The feed-in tariff is at maximum 750 000 €/year per production facility. Only new facilities are eligible to receive a feed-in tariff. The support scheme cannot be used simultaneously with other governmental support schemes such as investment grants or feed-in tariff for forest chips. Through the feed-in tariff scheme, electricity producers receive support for a period of twelve years. Wood-fuel powered plants will be accepted into the scheme until the total generator output exceeds 150 MVA and the number of power plants is 50 (HE 152/2010 vp, 2010).

2) Market based feed-in tariff for forest chips that is dependent on the emission allowance prices. With emission allowance price of 10 €/tCO_2 the subsidy is 18 €/MWh_e. With emission allowance price of 23 €/tCO_2 the subsidy is 0 €/MWh_e. Forest chip powered plants will be accepted into the scheme with no restrictions in the generator output or the amount of plants already utilising forest chips. Also, the existing plants can receive a feed-in-tariff based on forest chip utilisation (HE 152/2010 vp, 2010). In November 24^{th} 2011, the Ministry of Economy and Employment stated that the subsidy level will be decreased, but further information is not yet available.

3) Energy wood harvesting is also partly supported. Currently, forest owners can obtain subsidy for the harvesting of energy wood from early thinnings where the majority of the growing stock is below the pulpwood dimensions. The subsidy is available only if the wood directed for bioenergy production is harvested from young stand(s) and the harvested amount is at least 20 m^3. The harvesting subsidy level is 7 €/m^3. Present subsidy mechanism will most likely be replaced with a new one during 2012. This improved energy support scheme is currently waiting for an approval from the European Commission, thus the support scheme is expected to be operational in the Q2 2012 at the earliest. In the new scheme the subsidy will be paid for a maximum amount of 40 m^3 of energy wood per ha and the harvested or delivered amount should be at least 40 m^3 of energy wood at one time. The level of the subsidy is expected be 8 EUR/solid m^3 (MMM 2011 & Laki pienpuun 2011). In Q4 2011, there has been an indication that the level of support will be decreased.

Coal replacement

In the Finnish 2020 national renewable energy target, it is stated that it would be possible to replace approximately 7-8 TWh of coal with renewable biofuels by 2020. The support mechanisms for this are under development. In Finland, coal is mainly used in large CHP plants and condensing power plants near the coast. Based on Pöyry's estimate, approximately 7 TWh of coal could be replaced with wood-based fuels in CHP production, while the same figure in condensing power plants is less than 1 TWh. In CHP, volumes are dependent on heat load whereas in condensing on the competitiveness of electricity production.

Indirect tax support

In 2010, the Ministry of Finance's budget proposal was launched with increased taxes for fossil fuels and peat which indirectly supports the utilisation of wood fuels. The taxes are shown in Figure 33.

Figure 33 Taxes for fossil fuels and peat in Finland

		Taxes from 1.1. 2011					
		Energy content tax	CO2-tax CHP	CO2-tax HP	Supply of security tariff	Total CHP*	Total HP
		€/MWh	€/MWh	€/MWh	€/MWh	€/MWh	€/MWh
Natural gas	2011-2012	3,0				6,1	9,0
	2013-2014	5,5	3,0	5,9	0,08	8,6	11,5
	2015-	7,7				10,8	13,7
Heavy fuel oil		7,7	4,3	8,5	0,25	12,2	16,4
Light fuel oil		10,4	4,0	8,0	0,35	14,7	18,7
Coal		7,7	5,1	10,2	0,17	13,0	18,1
Peat	2011-2012					1,9	
	2013-2014					4,9	
	2015-					5,9	

HP= Heating plant

Source: HE 53/2011 vp

Industrial emission directive

There are also other factors that will encourage the development of the bioenergy sector. The industrial emission directive will be directed towards emissions (SO_2, NO_x, particles) from energy production. This may move some capacity replacement investment earlier than planned, when it is not economical to make additional emission reduction investments in aging capacity (Pöyry analysis on EC directive).

Household consumption of wood fuels

According to the Finnish NREAP, the aim is to keep the small-scale consumption (households) of wood for heating at the target level of about 12 TWh. This is planned to be achieved by the regulations supporting the improvement of energy efficiency of buildings which is likely to reduce the consumption of wood for heating. The introduction of more efficient metering of electricity consumption in households will provide incentives to use wood as a source of additional heat when the market price of electricity is high.

Support for pellets

According to the Finnish NREAP, the use of pellets is expected to increase to 2 TWh by 2020. Currently, at a household level a grant is available for converting from fossil heating methods to renewables including pellets (Decree 1255/2010). This has so far only had a minor impact on the utilisation of pellets in households and, for example, heat pumps are a more commonly chosen alternative. In Finland, the development of household pellet consumption has been very modest compared to Sweden. Other types of support measures for the use of pellets as a renewable energy source are still under discussion.

Support measures for agricultural biomass

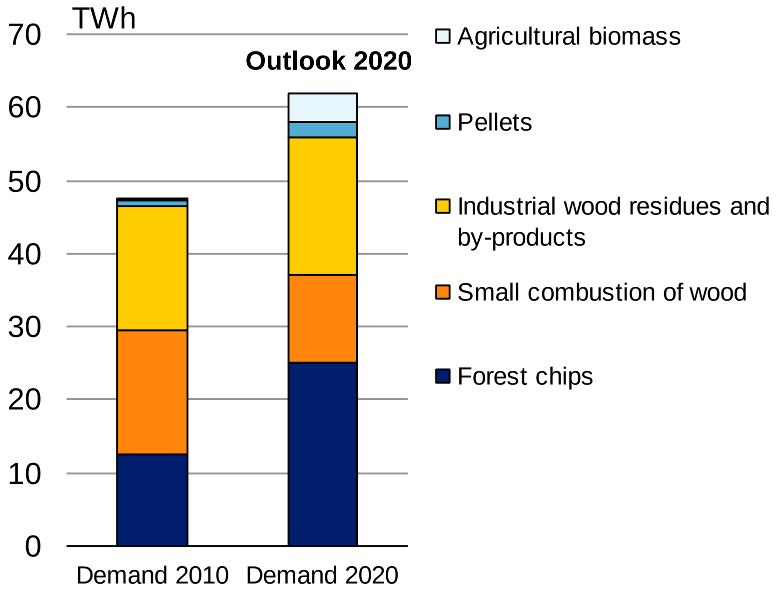
In the Finnish NREAP it is stated that the use of agricultural biomasses for energy generation will be increased by 2020. The potential solid biomass is e.g. straw and reed canary grass. The goal stated in NREAP is to explore opportunities to connect these sources of energy to existing renewable energy support schemes. In Finland, the cultivation of reed canary grass is supported by agricultural subsidies.

4.7 Solid biomass market development

To reach the EU's 20-20-20-10 energy policy national targets the Finnish government has established a "renewable energy package" with the aim of increasing energy production based on renewable forms of energy to a total of 38 % of the final energy consumption by 2020 (124 TWh, increment 38 TWh from 2005). This target is illustrated in Figure 34. To fulfil the national 20-20-20-10 target, the use of forest chips is expected to grow considerably to 25 TWh in 2020 whereas the potential for increasing the utilisation of forest industry's solid by-products is low as they are already effectively used. The small-scale combustion of wood is expected to decrease from the current 17 TWh to 12 TWh by 2020 and the use of pellets is expected to increase from the current 0.8 TWh to 2 TWh. The target set for agricultural biomass energy utilisation is 4 TWh by 2020.

In the future, solid biomass will also be increasingly used in large scale biogas and biomass to liquid production. Three Finnish consortiums are planning to build wood based biomass to liquid (Btl) facilities and have applied for NER300 project funding to be granted by EU. These consortiums are UPM-Kymmene, NSE Biofuels Oy Ltd (consortium by Neste Oil and Stora Enso) and Forest Btl Oy (consortium by Metsäliitto and Vapo). Regarding biogas, the gas company Gasum is cooperating with energy company Helsingin Energia and forest industry company Metsä-Botnia to construct a biorefinery for biogas production in Joutseno, southeastern Finland. The planned production capacity of the refinery is 200 MW. The biorefinery would produce biogas from wood raw material for transmission along the Gasum gas network to usage sites such as Helsinki Energy's Vuosaari power plant. According to the preliminary plan, Metsä-Botnia and its parent company Metsäliitto would be responsible for wood raw material procurement and biorefinery operation. Biogas would be mainly produced from forest chips and bark which are by-products of pulp mill wood procurement. The planned biorefinery would gasify wood chips and refine them into at least 95% methane. The composition of the end product would therefore correspond to natural gas composition. Gasum would take care of biogas injection into the gas network and distribution to gas users. The construction of the refinery will take two to three years from the go-ahead decision which is expected in 2013. Also, Gasum and the Kouvola energy company KSS Energia have signed a letter of intent to build a large-scale biogas facility in the Kouvola region. The biogas produced by the plant could be fed into the gas transmission system and used as a traffic fuel. The biogas facility would use fodder and grazing plants from arable land as raw material. The annual biogas production target is over 100 GWh.

Figure 34 Current and future supply & demand for forest and agricultural solid biomass



Source: TEM 2010

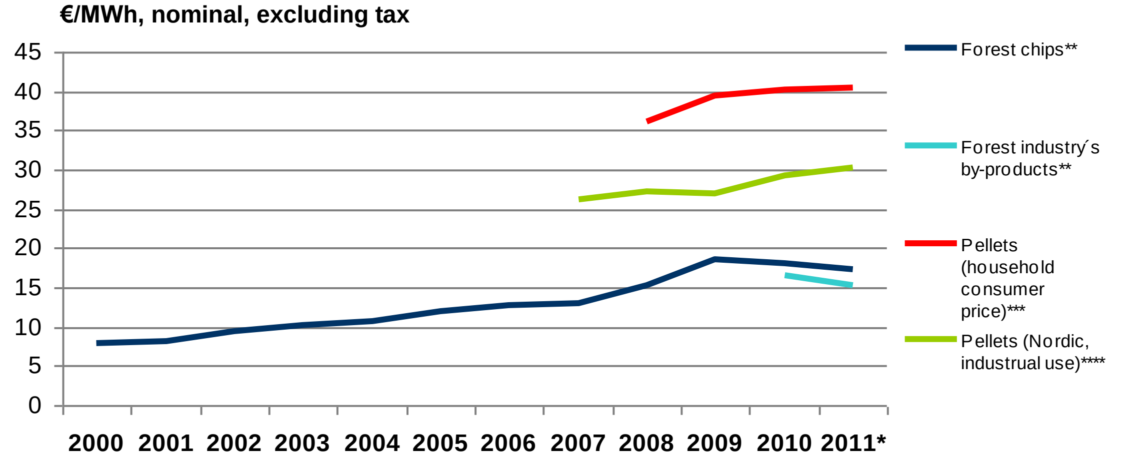
Announced on 13th of December 2011, the current Finnish bioenergy related associations, FINBIO (Suomen Bioenergiayhdistys ry), Finnish Pellet Energy Association (Suomen Pellettienergiayhdistys ry), Wood Energy Association (Puuenergia ry) and Peat Industry Association (Turveteollisuusliitto) will join their forces and merge to create a new Bioenergy Association (Bioenergia ry) which is expected to be operational by June 2012. This will allow improved coordination of efforts and serve the members in a better way as well as facilitating market efficiency.

4.7.1 Solid biomass price development outlook

The current and historical level of biomass prices in Finland is illustrated in Figure 35. The data for forest industry's solid by-product prices have only been collected and reported since 2010 but the prices for forest chips have been available for a longer time. Both price data is available on monthly basis and the data is currently collected and maintained by Pöyry. Also, the consumer prices for pellets are collected by the Finnish Pellet Energy Association (Pellettienergiayhdistys) and reported by Statistics Finland. FOEX Indexes Ltd[3] compiles monthly Nordic pellet price data for wood pellets used for industrial purpose. The most recent price is available on FOEX webpage.

[3] FOEX Indexes Ltd is a private, independent company specialised in operating as a provider of audited, trade-mark registered pulp, paper, recovered paper and wood pellet price indices.

Figure 35 Historical and expected price development 2000-2011



**Latest spot prices for 2011 for forest chips, forest industry´s by-products and pellets*
***Delivered price for biomass. Source: Pöyry*
****Prices exclude VAT 23%. Consumer price for wood pellets utilised for heating. Source: Statistics Finland*
***** Net prices without any taxes. Prices are delivery prices for wood pellets with diameter of 6-10 mm (reported monthly, here as an average of 12 months and for 2011 the most recent spot price). Terms of delivery: CIF Baltic Sea port or North Sea Port (for sea transport) and DDU (for truck or rail transport). Source: FOEX Indexes Ltd*

Source: Pöyry, Statistics Finland (Suomen Pellettienergiayhdistys) and FOEX Indexes Ltd

The price for forest chips, as illustrated in Figure 35, has been slightly decreasing in recent years being currently about EUR 17.40/MWh (September 2011). Also the prices of forest industry's by-products have been decreasing moderately since the start of reporting in 2010 being currently about EUR 15.30/MWh (September 2011). Both the consumer price for household consumed pellets in Finland and the Nordic price for industrial pellets have moderately increased in recent years. The latest price for industrial pellets in the Nordics was EUR 30.15/MWh (15.11.2011) and for pellets consumed in Finnish households EUR 40.50/MWh (July 2011, excluding 23% VAT).

4.7.2 Market mechanisms

In Finland, the energy industry generally uses contracting agreements for biomass procurement and logistics and medium- and large-scale power plants usually have several biomass suppliers. L&T Biowatti, Vapo, Forest Management Associations and forest companies are the main fuel suppliers in Finland that operate countrywide. There are also many regionally acting fuel supplier companies in Finland. The raw wood market transparency has been a somewhat heated issue in Finland during the past couple of years. In 2009, the Finnish Market Court gave a verdict that Metsäliitto, Stora Enso and UPM-Kymmene had an illegal raw wood price cartel during 1997-2004. According to the Market Court, the purpose of the cartel was to restrict the competition between the parties and to regulate the price of raw wood. These forest industry players did not appel the verdict and were imposed on a fine of total 51 million EUR. Currently, the three forest industry companies are facing further court cases as the sellers of wood have summonsed the companies to court.

The main fuel suppliers use sub-contractors to perform the actual harvesting, chipping and transportation of biomass. These sub-contractors are typically locally acting family-owned companies with one or two machines or trucks and less than five employees.

Normally a contract machine operator sells his privately owned machine and working time to one of these large companies. In some regions, local entrepreneurs have established joint ventures and take care of the whole chain independently from forest to energy plant.

Currently, the energy producer pays for fuel per MWh. This energy content of biomass is measured normally by an independent laboratory from the samples taken at the energy plant. Upstream in the supply chain the measurement units normally used are solid m^3 and loose m^3. This usually creates a problem of unpredictable income with the upstream parts of the chain as the end-user pays only for the energy. Therefore a set of best measurement practises is applied throughout the supply chain trying to evaluate as accurately as possible the energy content of different biomass assortments during different times of the year. With these practises the upstream parties are better analysing the energy content and can predict the future incomes from the delivered fuel. For the energy producer this also ensures that the supply chain tries to maximise the energy delivered per m^3 and simultaneously it brings added value to the whole chain. These practises have been approved by all counterparts in the biomass supply chain and the agreement is supervised by a committee which is also committed to develop these practises further.

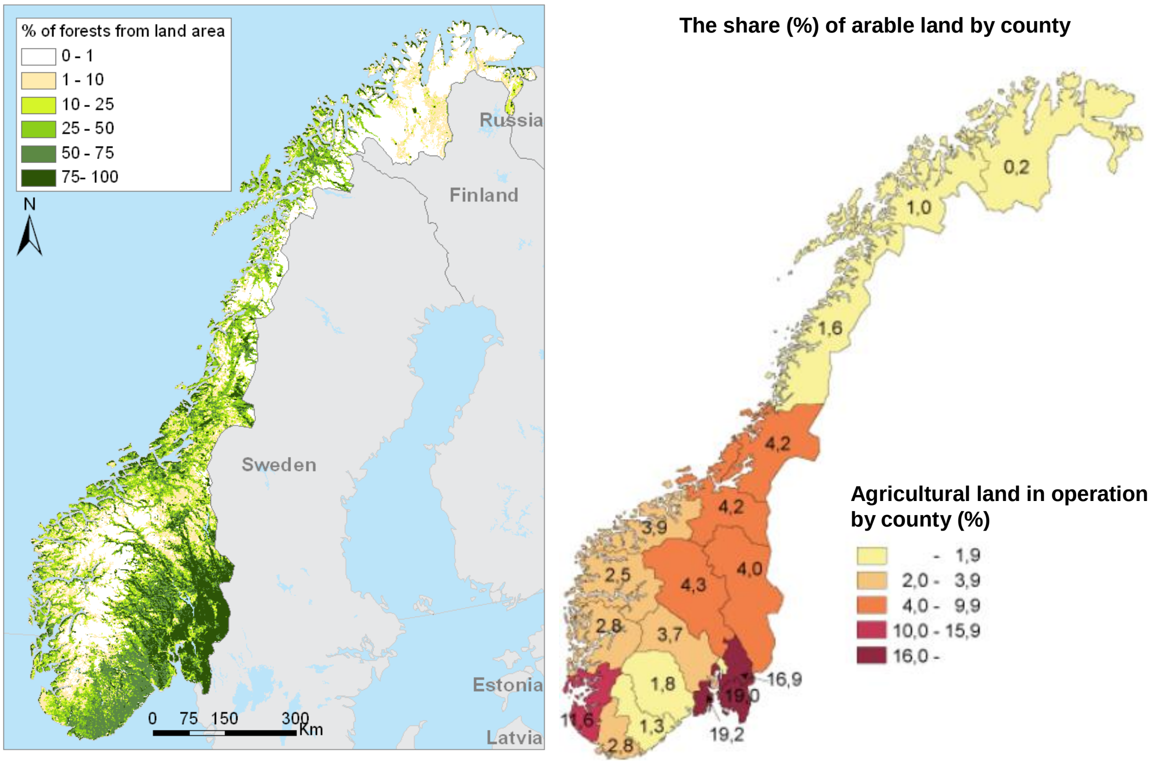
RESOURCE EVALUATION NORWAY

5. NORWAY – EVALUATION OF FOREST AND AGRICULTURAL BIOMASS RESOURCES

5.1 Background

There are more than 12 million ha of forest land in Norway, covering 38% of the total land area. Of this area, 8 million ha are productive forest. As illustrated in the map (Figure 36), most of the forests are found in the eastern part of Norway. This is also were the forest industries are located. The Norwegian forests mainly consist of three types of species: 47% Norway spruce, 33% Scots pine and 18% birch. The remaining 2% are other types of broadleaves such as oak.

Figure 36 Distribution and share (%) of forests and arable land in Norway



Source: European Forest Institute, Norwegian Agricultural Authority

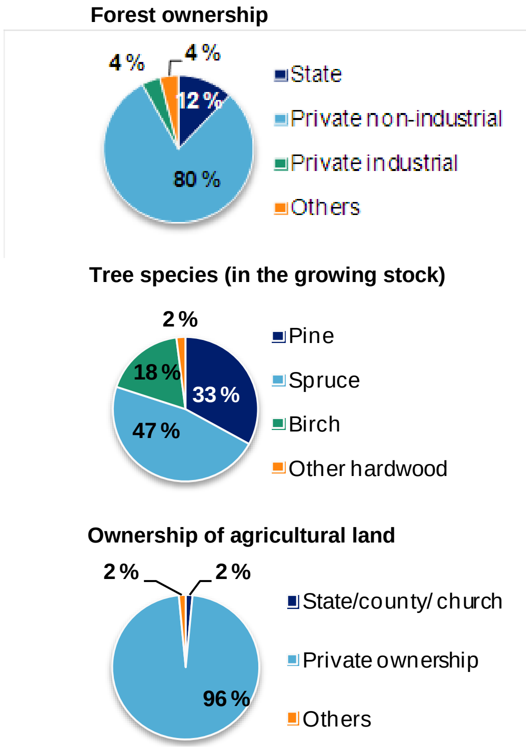
Since the 1930's, the annual increment has been higher than the harvesting level. In 2010 the annual increment was approximately 25 million m^{3}sob, while the harvesting volume was below 10 million m^{3}sob, of which 35% was consumed by the sawmilling and wood-working industry, 25% by the pulp and paper industry, 30% was used as firewood, 2% by the fibre and wood-based panel industry and the rest by other Norwegian or foreign buyers. The annual sustainable harvesting level is approximately 15 million m^{3}sob[4].

[4] Norsk skogeierforbund and Skog og Landskap's prognoses

The Norwegian forestry is represented by many small-scale operators. About 12% of the forest area in Norway is owned by the state and municipalities, while 80% is privately owned. There are more than 120 000 forest holdings. Close to one third of the private forest owners are organised in the Norwegian Forest Association (Norsk Skogeierforbund). The Norwegian Forest Association is divided into 8 district cooperations; Havass Skog BA, Glommen Skog BA, Mjøsen Skog BA, Viken Skog BA, AT Skog BA, Vestskog BA, Sogn og Fjordane Skogeigarlag AB and Allskog AB. These cooperations typically develop forestry planning and carry out logging on behalf of the members.

Figure 37 Characteristics of forest and agricultural resources in Norway

Forest facts	
Total land area	32.4 million ha
Forest area	9.7 million ha
Productive forest area	7.7 million ha
Forest area % of total land area	30%
Permitted felling level[5]	15 million m^3
Actual felling	9.7 million m^3
Growing stock volume	842 million m³sob
Growing stock per hectare	103 m³/ha
Net annual increment	24.8 million m³sob
Agricultural facts	
Agricultural area	1 million ha
Share of agricultural land	3%
Main agricultural products	Dairy, livestock, cereal



Source: Statistics Norway (SSB), NordicForestry.org, FAO Resource Assessment 2010

In 2010, the total agricultural land area in Norway was approximately 1 million ha, covering 3.4% of the total land area. According to Statistics Norway SSB, the majority of the agricultural land is owned by private individual owners. The agricultural land consists of 65% meadow and 31% used for cereal and oil crops. As illustrated in Figure 36, the highest proportion of agricultural land is found in the eastern part (Vestfold 18.5%, Østfold 17.7% and Akershus 15.7%) and Rogaland with 10.7%. The main types of cereal produced are wheat, barley and oats.

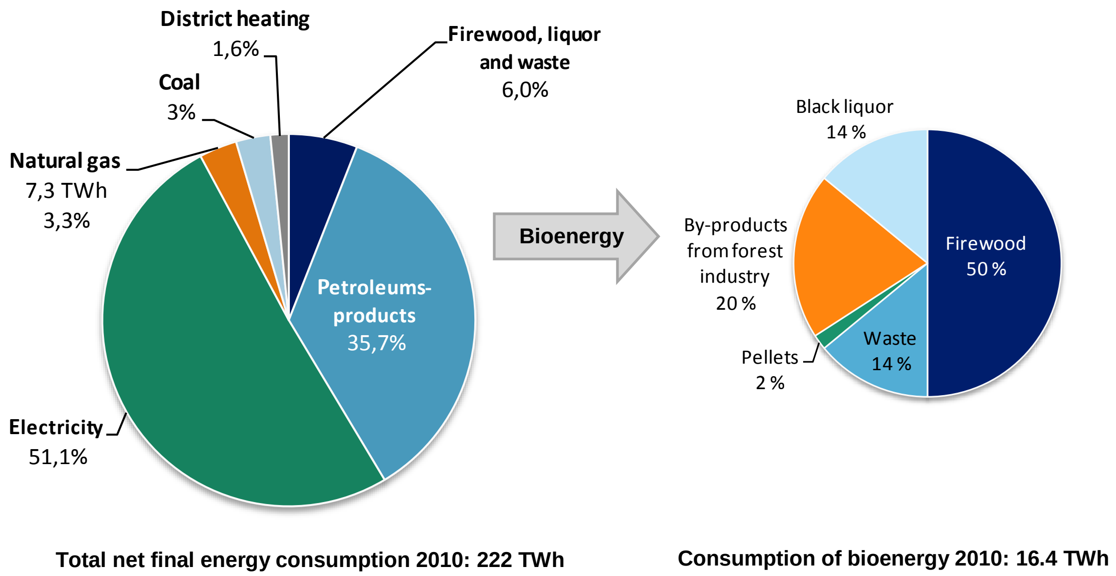
[5] Norsk skogeierforbund and Skog og Landskap's prognosis

5.1.1 Introduction to energy market in Norway

The energy sector constitutes a significant part of the Norwegian economy. The country has large natural resources such as oil, gas and hydropower and is among the largest exporters of oil worldwide. According to Statistics Norway (SSB), the total net final consumption of energy amounted to 222 TWh[6] in 2010. The total net final consumption excludes energy used as raw material and energy consumed in the energy sector. Electricity consumption accounted for more than half of the value (113.4 TWh). This is a large share in international standards and is mainly due to a large power intensive industry, such as the aluminium and ferroalloys industry. Also, electricity is used as the main heating source. Petroleum, natural gas and coal accounted for 42% of total final consumption, while bioenergy, hereunder district heating, wood products and waste accounted for 7%.

According to estimates made by Østlandsforskning, the total bioenergy consumption in 2010 amounted to 16.4 TWh. This includes 2.3 TWh waste utilised in district heating and 2.3 TWh black liquor consumed by the pulp and paper industry. The remaining 11.8 TWh is based on solid biomass of which 8.3 TWh is consumed by households (mainly firewood), 2.1 TWh by the industry (chips), 1.2 TWh in district heating plants (chips) and 0.2 TWh is consumed by the service sector (pellets and chips). In 2008, the Norwegian government created a public governmental bioenergy strategy, hereafter called the Bioenergy strategy (2008). The goal of the strategy is to increase the use of bioenergy by 14 TWh between 2008-2020. In other words, the use of bioenergy has to almost double in comparison to the current level.

Figure 38 Total net final energy consumption incl. consumption and type of biofuels in 2010



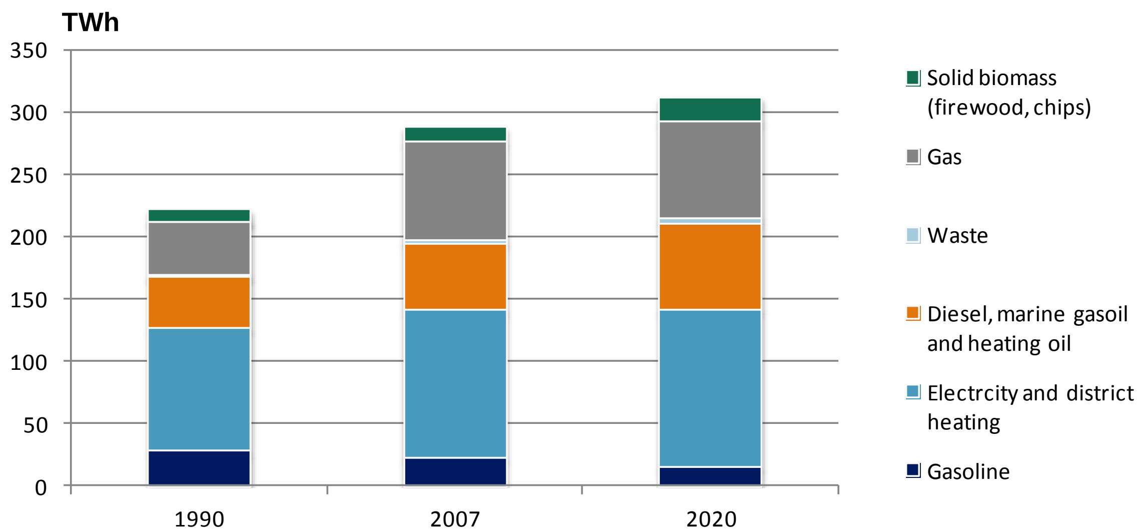
Source: SSB, Langerud, B.; Størdal, S.; Wiig, H.; Ørbeck, M. (2007)

[6] www.ssb.no/emner/01/03/10/energiregn/

If not taking into consideration the oil and gas sector, the Norwegian energy supply is mainly based on renewable energy resources. Hydropower generally accounts for 98-99% of all electricity production in Norway today. The potential is far from utilised, however, due to environmental concerns, there will not be extensive developments in the near future. Statistics Norway (SSB) has calculated that the share of energy from renewable sources was more than 60% in 2010. The goal for 2020 is to increase the share to 67.5%, which is an increase by 7.5% compared to 2009[7]. In addition to the existing renewable energy production, the introduction of a joint certificate market between Norway and Sweden will facilitate investments in more renewable energy. The main objective of the certificate market is that Sweden and Norway together will build new power production based on renewable energy sources. The target is to increase renewable energy production by 26.4 TWh in both countries by 2020. In Norway, the renewable potential is comprised of small-scale hydropower and onshore wind power.

The total final energy consumption for 1990, 2007 and 2020 is illustrated in Figure 39. The numbers also include the energy consumption in the energy sector, i.e. the oil- and gas industry, hydropower stations, etc. As seen in the graph, the total energy consumption is expected to grow. Furthermore, a higher share of the energy will originate from renewable sources such as bioenergy and electricity based on hydropower and wind power.

Figure 39 Total final energy consumption – historical and future outlook (2020)



Source: NVE (2011)

5.2 Resource Assessment – Solid biomass from forestry

In Norway several sectors and industries compete for the same solid biomass resources. The country is richly endowed with forest resources that can be utilised for biomass purposes. The annual roundwood harvesting has been relatively stable the last 80 years, approximately 10 million m^3, whereas the total volume and the annual growth of new

[7] http://www.regjeringen.no/nb/sub/europaportalen/nyheter-europaportalen.html?contentid=651715&id=449646

forests have doubled during this period. According to Statistics Norway (SSB), the annual growth was two times higher compared to the actual harvesting level in 2010. This is facilitating an extensive potential within biomass production. The majority of the forest resources harvested today are used in the pulp and paper industry, for building materials and different wood products. The Bioenergy strategy 2008, states that the long term forest management should facilitate increased utilisation of forest resources and at the same time maintaining a high level of carbon storage in the standing forest. In addition, biodiversity and other environmental values of forest operations must be taken into account. In the sections below the current use and potential of solid biomass assortments is presented[8].

Primary forest fuel and firewood

In Norway, traditionally, branches and tops are left in the forest. The fact that this assortment is not used today leaves a potential to increase bioenergy production further. The potential of exploiting more harvesting residues depends, amongst other things, on the future timber prices. The increased energy potential from harvesting residues is estimated to 3-3.5 TWh at today's harvesting levels. This could be increased by 1.5 TWh if the harvesting increases to the balancing level[9] according to NVE (2010).

In 2010, the estimated use of firewood for heating purposes in households and summerhouses amounted to 1.75 million tonnes, with a theoretical energy value of 8.2 TWh.[10] Firewood is an important reserve in the energy system, particularly during cold winter days. In NVE (2010), the future potential of firewood was estimated to 2-3 TWh additional to today's consumption. However, this depends on the price developments of competing energy carriers, as well as the development of heat pumps.

Industrial by-products

In 2010, industrial by-products accounted for approximately 5.6 TWh, of which the majority was used in the forest industry's own heat production and for district heating. This also includes 2.3 TWh of energy from black liquors. The availability of by-products depends on the market development for the main products in the forest industry, such as the demand for sawnwood. In addition, the demand for competing products such as paper and boards will determine if by-products, such as chips and sawdust, will be used for energy purposes or not. There is a potential to increase the use of industrial by-products for production of bioenergy. Norges vassdrags- og energidirektorat (NVE, 2010), reports a potential to increase the energy production based on by-products by 1-2 TWh. Other studies report an even higher potential. However, it is important to recognise that most of the by-products have alternative uses today.

Processed wood fuel (pellets and briquettes)

According to Norsk Bioenergiforening's (Nobio) sale statistics, the production of pellets amounted to 45 000 tonnes in 2010. There are currently nine pellet mills in Norway located in the southern and central parts of Norway. The capacity utilisation rate in Norwegian pellets mills is very low. Prior to the entry of "Biowood Norway" to the market, the average capacity utilisation rate of the existing mills was approximately 30-35%.

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[8] The figures are based on the Bioenergy strategy (2008), Energi21 (2010), NVE (2010) and Langerud, B. et al (2007)

[9] The annual felling equals the annual increment.

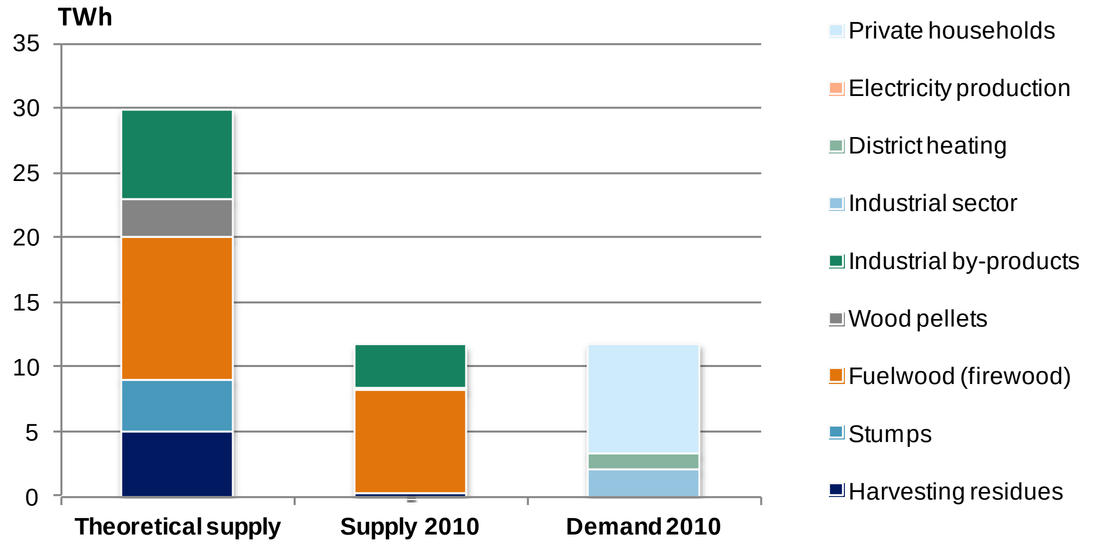
[10] www.ssb.no/vis/magasinet/miljo/art-2011-06-17-01.html

"Biowood Norway" is located in Averøy, on the western coast of Norway and is the largest pellet producer in Norway with a production capacity of 450 000 tonnes wood pellets annually. The raw material will be based on imports and the main markets will be the United Kingdom and Continental Europe. Other producers include Hallingdal Trepellets, Pemco Trepellets AS and Arbaflame AS with production capacities of 50 000 t/a, 30 000 t/ and 25 000 t/a, respectively. Total production capacity is currently 612 000 tonnes.

Total consumption of pellets reached 58 500 tonnes in 2010, indicating that Norway was a net importer of pellets. The residential and industrial sectors are the largest end-user segments in Norway. The industrial end-users include local heating centers and district heating plants. The residential market is relatively small and local. Approximately 18 000 tonnes of pellets are sold in small bags, mainly to private households. Both the industrial and the residential markets are expected to grow in the future. In the industrial sector, the growth is expected to take place in large-scale district heating plants.

According to Nobio's statistics, the total production of briquettes was 31 000 tonnes in 2010. There are currently 14 producers of briquettes in Norway. The total consumption was 48 000 tonnes. Approximately 60% of the briquette volume was consumed in the industrial sector, whereas the rest was sold in small packages to the residential sector.

Figure 40 Current supply & demand (2010) for solid biomass from forestry



Source: St.meld. nr. 39 (2008-2009), NVE (2010)

The technical potential from solid biomass is estimated to 26-35 TWh[11]. In the estimates, it is taken into account that some forest areas are not available because of lack of roads or the terrain being difficult to access. In addition, protected forest areas are also left out of the technical potential.

[11] www.regjeringen.no/nb/dep/lmd/dok/regpubl/stmeld/2008-2009/stmeld-nr-39-2008-2009-/11/3/2.html?id=563774

5.3 Resource Assessment – Agricultural solid biomass (incl. energy crops)

Only a small share of the bioenergy production is based on agricultural solid biomass in Norway. Around 3% of the land area consists of cultivated agricultural land. The limited agricultural land should according to Stortingsmelding nr. 39 (2009)[12], mostly be used for producing food. Nevertheless, a potential exists to exploit resources from the agricultural sector for bioenergy purposes. This includes mainly manure from livestock and waste- and residues from food production, such as straw, cereal husks and offal. According to the report Langerud, B et al (2007), there is a large unused potential of biogas from manure and offal. Currently, 350 000 ha are used for cereal production.

It is estimated that the straw production is approximately 35 kg per hectare, which gives a total of 1.22 million tonnes straw annually. In a report from NVE (2010), the total energy potential from straw is estimated to 4.5 TWh. However, due to agronomic reasons it is recommended that the straw is not removed from the field more than every 3-4 years. This is because straw left in the field works as a natural fertiliser. Thus, the sustainable energy potential from straw is much lower than 4.5 TWh. According to NVE (2010), the potential is estimated to 1-1.5 TWh annually. The cost is estimated to about 10-15 øre/kWh. The Ministry of Agriculture and Food states that straw should be used for energy purposes to a higher extent than today. The production of energy based on straw could be facilitated by developing small-scale heating plants on the farm, in local heating centrals or district heating in areas with abundant cereal production. There are no official statistics available about the current energy production based on agricultural solid biomass. However, according to Statistics Norway, a small share of straw is utilised internally on farms to heat up the farm-buildings.

5.4 Biomass trade and mobilisation in Norway

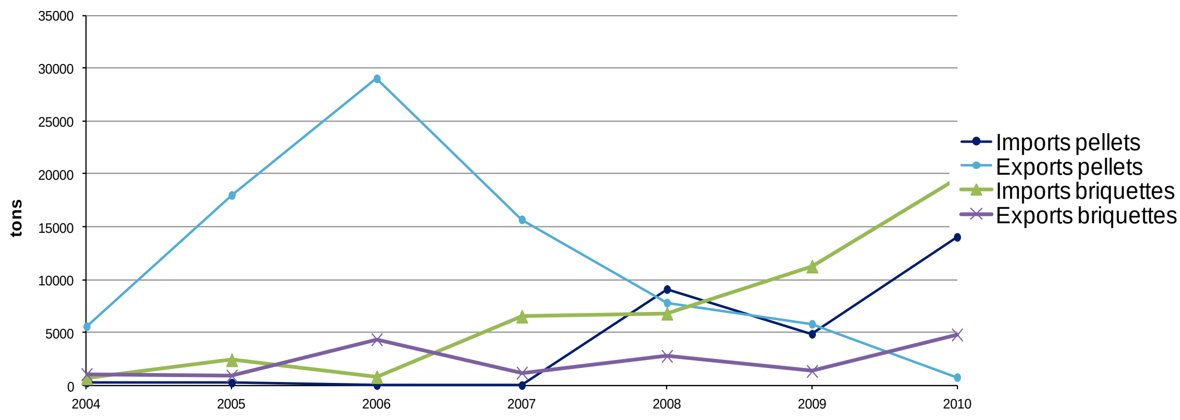
5.4.1 Trade flows

Pellets and briquettes

As illustrated in Figure 41, Norway has historically been a net exporter of pellets, reaching a net export of 29 000 tonnes in 2006. However, in 2010 Norway was a net importer of both pellets and briquettes (mainly due to a cold winter period). Today, the majority of trade with pellets and briquettes is with Sweden. The establishment of “Biowood Norway” could lead to Norway being a large net exporter in the future. The capacity of the company is 450 000 tonnes annually and their main export markets include the United Kingdom and Continental Europe

[12] Stortingsmelding (St.meld) is a report to the Storting (White paper)

Figure 41 Trade of pellets and briquettes



Source: Nobio

Chips and sawdust

According to Statistics Norway (SSB), Norway was a net importer of chips in 2010. Exports reached 108 000 m^3, while the imports were approximately 1.4 million m^3. Figure 42 illustrates that the main trade partners are Sweden, the Baltic States and some volumes from Canada and Uruguay. Chips are mainly exported to Sweden. The imports of chips will most likely increase significantly in the future when "Biowood Norway" is running on full capacity. According to their own website, the plant will require 1.2 million m^3 of chips annually, mainly from USA, Canada, Liberia, Russia and the Baltic States.

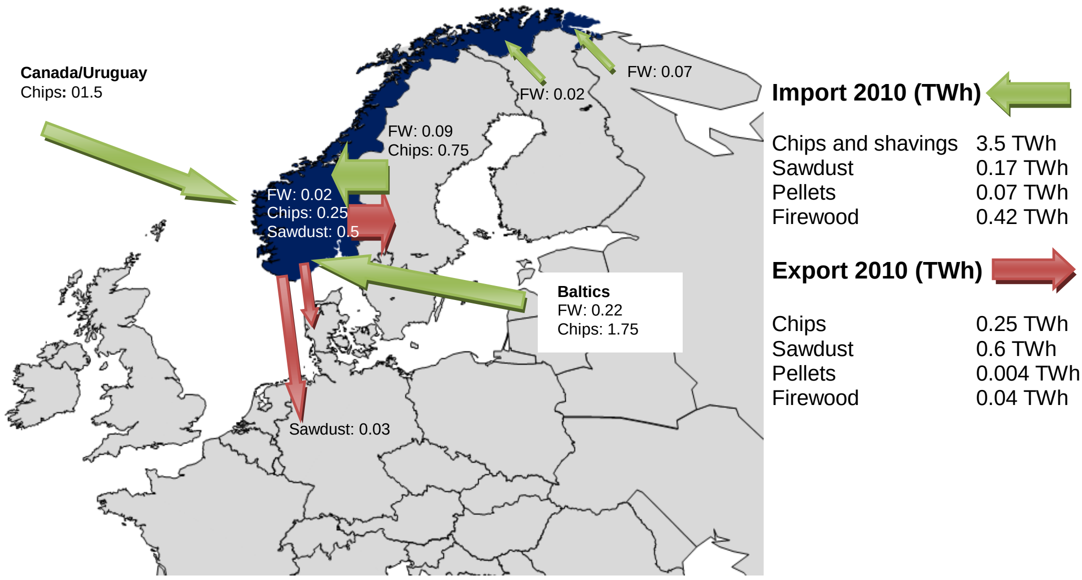
Norway was a net exporter of sawdust[13] in 2010. Exports amounted to 231 000 m^3, while imports were approximately 67 000 m^3. Figure 42 illustrates that most of the trade with sawdust is with Sweden, supplemented with some trade with Germany, imports from Latvia and export to Denmark.

Firewood

According to Statistics Norway (SSB), the total import of firewood was 190 000 m^3 (0.42 TWh) in 2010. As presented in Figure 42, the main trade partners are Sweden, Finland, Russia and the Baltic States. Around 30% of the imports came from Estonia. During the same year, exports of approximately 19 000 m^3 (0.04 TWh) of firewood were reported and almost the entire volume was delivered to Sweden.

[13] Commodity number 44.01.3001: Sagflis

Figure 42 Main trade flows of solid biomass 2010 (TWh)



Source: SSB, Nobio
Definition used from the "Statistikkbanken (SSB): Firewood: commodity number 44.01.1000. Sawdust: 44.01.3001, Chips and shavings: 44.01.2101/44.01.2109/22.01.2200

5.4.2 Solid biomass mobilisation

Solid biomass from forestry

Only a limited share of the forest area in Norway is available for utilisation for bioenergy. First of all, parts of the forest resources are difficult to access and in reality neither practical nor economically exploitable. The fact that most of the forest resources are located far away from the consumers leads to issues regarding transportation. The Norwegian mountainous topography leads to obstacles in harvesting the resources and transportation out to the road network. Furthermore, bioenergy has a relatively low energy density compared to competing energy sources such as oil. This leads to high transportation costs. The geographical conditions in Norway, in addition to poor infrastructure, hamper production and sales of bioenergy. Consequently, this increases the uncertainty regarding access to biomass and makes it less attractive to invest in costly combustion plants. Logistical practicalities are another issue that must be solved to make bioenergy more competitive. Biomass requires large storage space, which leads to high costs for the distributer and the end-user. Moreover, biomass is more demanding in terms of handling and operation compared to using electricity for heating.

In order to lower the costs of transportation and increase efficiency of extraction and improving logistics, a number of measures must be put in place. First, support is needed in order to develop more efficient ways of harvesting in mountainous areas. Improving the technology further could lead to more forest resources becoming economically profitable to harvest. Second, support must be given to the development of infrastructure, in particular forest roads. It is important that all levels of the supply chain are supported simultaneously. However, to be able to sell bioenergy, large investments in for example district heating infrastructure is essential to reach the end-users.

Agricultural solid biomass (straw)

As mentioned in section 5.3, currently only a small share of straw is utilised internally in farms to heat up the farm-buildings. The Norwegian agriculture is characterised by many small-scale farms and the volume of straw on individual farms is usually small. This makes it difficult to establish large scale bioenergy production based on straw.

5.5 Overview of current "biomass-to-energy" generation

The total consumption of energy from solid biomass in Norway amounted to approximately 11.8 TWh in 2010 (excluding bioenergy based on waste and black liquors). The main end-use segments and their respective consumption are presented below.

5.5.1 Industrial sector

According to NVE (2011), the total energy consumption in the industrial sector amounted to 60 TWh in 2009 (excluding the oil industry). Due to abundant cheap hydropower in Norway, almost 70% of the energy consumption in the Norwegian industrial sector was based on electricity. In comparison, only 5.4 TWh (9%) of the energy consumption originated from bioenergy. Approximately 1 TWh of this was based on waste. The remaining 4.4 TWh was thus based on bioenergy (2.3 TWh black liquor and 2.1 TWh chips, bark and other by-products). According to Statistics Norway (SSB), 83% of this value was consumed in the pulp and paper industry and the remaining 17% in sawmills. Most of the bioenergy consumed in the pulp and paper industry was based on black liquor for the production of heat and power for own use. In sawmills, chips and bark are used for drying of timber.

5.5.2 District heating

In 2010, 4.8 TWh of district heating was produced in Norway[14]. District heating is based on a variety of different energy sources, the most important being waste, accounting for about 33% of the energy produced by district heating plants. Solid biomass contributed to 19% (0.9 TWh). The main type of input biomass is chips and pellets. According to Nobio (2011), the total consumption of pellets reached 58 500 tonnes or 280 GWH[15] in 2010 and about 70% was purchased in large volumes for use in district heating plants.

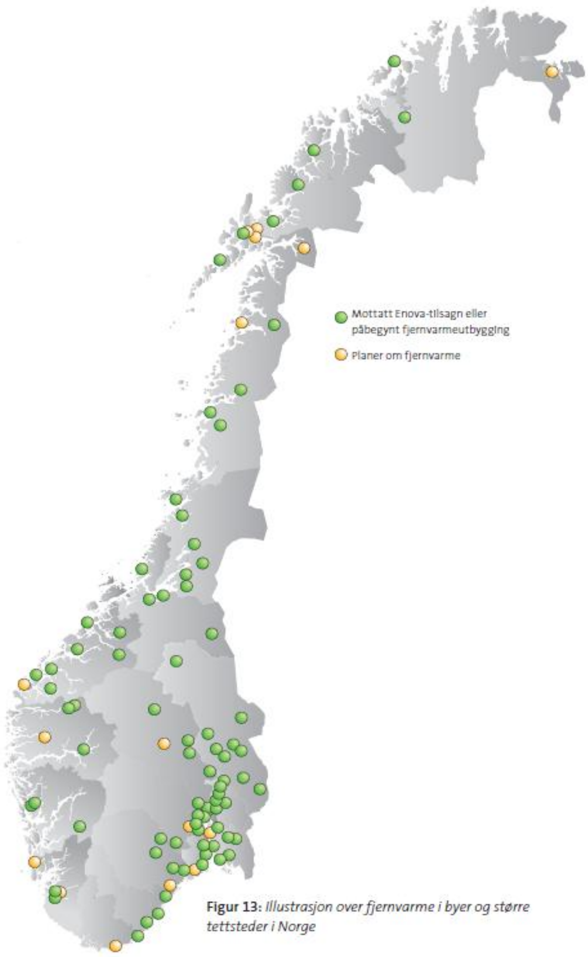
Compared to Sweden, infrastructure for district heating in Norway is underdeveloped and further expansion within this segment requires extensive investments. The fact that district heating competes with cheap electricity, leads to difficulty for the technology to break trough. In addition, the settlement pattern in Norway is less suitable for district heating compared to Sweden. However, market players are optimistic about increasing the share of district heating in overall energy production. Mechanisms to enhance district heating are already put into place. Support from Enova is essential for the development of district heating plants and its infrastructure. Enova is a state-owned enterprise and was established to promote environmentally friendly restructuring of energy consumption and generation in Norway. Enova has already granted investment support for several projects that are under construction. According to Enova's own figures, it is expected that 6.5 TWh bioenergy will be delivered from district heating in 2016. Several plants are under construction, however, the development of district heating infrastructure takes time. In

[14] www.ssb.no/fjernvarme

[15] According to Nobio (2011): 1 ton pellets = 4.8 MWh

general, it takes 3-6 years from a project is granted support before heat production starts. Figure 43 illustrates the district heating development in Norway. The green dots represent district heating plants that have already received commitments from Enova or plants that are under construction. The yellow dots illustrate planed district heating plants. Most of the district heating plants are situated in the eastern part of the country. Some of the main district heating producers today are Eidsiva Bioenergy AS, BKK Varme AS in Bergen, Statkraft Varme AS in Trondheim and Hafslund ASA in Oslo.

Figure 43 District heating development in cities and larger towns in Norway



Source: Enova

5.5.3 Private households

According to Statistics Norway, the consumption of firewood and pellets amounted to 8.3 TWh in private households and summerhouses in 2010. Today firewood is the most common form of bioenergy used in private households and thus constitutes an important reserve in the energy system. According to Nobio's sales statistics, 18 000 tonnes or 86 GWh of pellets were consumed in the household sector in 2010.

5.6 Regulatory framework and sector policies relevant for solid biomass supply for energy

In addition to price and costs of bioenergy, relevant governmental policies will affect what role bioenergy will play in the Norwegian energy market in the future. Policies could be aimed at the supply side, the distribution of or at the end-users. In this section the most important regulatory framework and sector policies discussed in the Bioenergy strategy (2008), are presented.

Traditionally, the Norwegian forest policy has been based on fundamental principles of maintaining the long-term stability and having a flexible resource base. The stated goal has been to meet social, ecological, economic and cultural needs for present and future generations. The Forestry Act, updated in 2005, and the Forest Trust Fund have been central in meeting the goal of the Norwegian forest policies. A number of measures have been implemented to strengthen the access to solid biomass raw material in Norway. The current forest policy includes funding for forestry and bioenergy production; hereunder funding for reforestation, forestry planning, road construction and more specific measures to enhance bioenergy production. In 2006-2007, the policies aimed at bioenergy were considerably strengthened. In 2007 the Trust Fund was opened up for forest owners to invest in production of biomass for bioenergy. Further, farmers and forest owners were given tax benefits from income generated from biofuel sales. The scheme gave clear incentives for farmers and forest owners to increase the generation of biofuel and particularly firewood. These measures resulted in a 12% increase in harvesting in 2007, as well as an increase in planting activity and silviculture work.

The Bioenergy strategy (2008)

The main challenge regarding higher bioenergy production is related to the lack of profitability. A number of political instruments have been put in place to increase the profitability of bioenergy production and to further strengthen the access to raw materials. The strategy plan from the Ministry of Petroleum and Energy outlines necessary measures to meet the bioenergy target. The main focus of the strategy is to increase the use of bioenergy for heating followed by an increase in the supply of firewood and forest based fuels. The strategy will be supported by the following range of measures:

- Compulsory energy and climate planning by all municipalities by January 2010. This is already implemented in 98% of all municipalities, according to Enova.
- Establishment of a bioenergy forum. The aim of the forum is to insure an exchange of information between the authorities and stakeholders. The forum is led by the Minister of the Petroleum and Energy.
- Increased investments support for electricity savings in private households, such as supporting pellet stoves and heat pumps (Enova).
- Investment support for district heating and heating based on renewable energy (Enova).
- Increased budgets for R&D in the field of renewable energy (Government support).
- Prohibition against instalment and replacement of oil boilers in new and existing buildings. Establishment of a support scheme for converting oil boilers to renewable energy sources (Enova).
- Norway and Sweden established a green certificate scheme in January 2012.
- Development of efficient logistics and supply chains related to extraction of raw material for bioenergy purposes from the forest, cultural landscape and roadsides. Part of the project will focus on assessing possible incentive schemes to increase

production of wood chips from logging residues and from the clearing of roadsides and grid lines (Ministry of Agriculture and Food).

The main actors within promoting bioenergy are Enova and Innovation Norway. Innovation Norway is a state owned company that gives support to district heating and other bio-based energy systems. The two main supporting schemes are the bioenergy program and a support program for chip production. The Bioenergy program[16] aims at encouraging farmers and forest owners to produce, use and supply bioenergy. The focus areas of the support scheme are plants for district heating, farm heating, greenhouses and biogas. The projects that are found eligible for support are granted a funding of 35-40% of costs. Pre-studies could be granted a funding up to 50% of the costs. In addition, Innovation Norway supports chip production from woody biomass. The chip production program[17] focuses on developing new products and improving production processes. Support is given to development, competence building and investments. The projects are granted a funding of 25-50% of costs.

The state-owned enterprise Enova has accelerated the growth of bioenergy sector in Norway. According to their own website, "*Enova SF's main mission is to contribute to environmentally sound and rational use and production of energy, relying on financial instruments and incentives to stimulate market actors and mechanisms to achieve national energy policy goals*". One of the main roles for Enova is to reduce the risk of investing in new technology and to enter new markets. Enova has a large range of investment support programs, the most important regarding bioenergy are:

- Support programs for environmentally friendly buildings – The program covers both existing and new commercial and residential buildings.
- Energy consumption in the industry – The program facilitates the conversion from fossil energy to bioenergy and other renewable energy sources in the industry.
- Program for district heating infrastructure – A support scheme aimed at agents who want to develop the district heating infrastructure.
- Program for new district heating – A program that supports players which want to establish new infrastructure for district heating and associated generation of renewable energy.
- Program for small scale heating plants – An important target group for the program are businesses which want to convert from oil based energy supply to bioenergy and other renewable energy sources.
- Support for households – Investment support for more efficient energy use and converting existing heating appliances to be based on renewable energy sources in households; such as pellets stoves and pellets boilers.

In addition, Enova has two projects that target the maturation of new technology:

- Innovative energy solutions – mainly targeting developers and suppliers.
- Introduction of new technology – mainly targeting end users.

[16] www.innovasjonnorge.no/Documents/Landbruk/Retningslinjer%20for%20%20bioenergiprogrammet%202011.pdf?epslanguage=no

[17] www.innovasjonnorge.no/Documents/Landbruk/Retningslinjer%20for%20utvikling%20og%20investering%20i%20flisproduksjon%202011.pdf?epslanguage=no

Environmental and energy taxes

Taxation of fossil fuels has contributed positively to the bioenergy sector development. Norway introduced tax on emissions of CO_2 already in 1991, as one of the first countries in the world. In 2008, the tax was set at 207 NOK per tonne CO_2. In 2010, the CO_2 tax was extended to also include natural gas and liquefied petroleum gas (LPG). A tariff on electricity was introduced in 1951. The tariff includes all electricity consumed in Norway, either produced domestically or imported. The tariff was 11.01 øre/kWh or 14.4 EUR/MWh[18] in 2010. However, compared to Norway's neighbouring Nordic countries, the taxes on oil, gas and electricity are much lower in Norway. The stakeholders in the bioenergy sector in Norway need a predictable regulatory framework and policies. The Government's has a large role in the bioenergy sector development. Lack of support mechanisms and predictability is seen as an obstacle for bioenergy sector growth in Norway. In addition, a further increase in tariffs on electricity and taxes on CO_2 emissions would contribute to bioenergy products becoming more competitive.

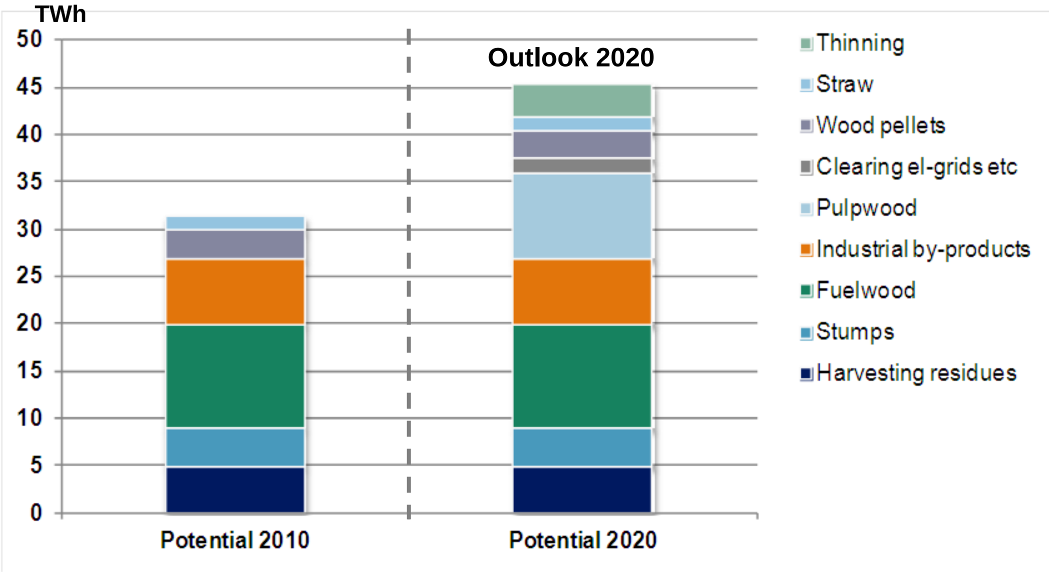
5.7 Solid biomass market development

Most of the forest resources that are harvested today have alternative uses. An increase in the supply of solid biomass must therefore either be in the form of earlier unused growth, unused harvesting residues from existing and potential new logging or timber currently used for other purposes. An increase harvesting is likely to lead to higher operational costs. This is mainly due to the fact that the unused growth is located in terrain that is difficult to access. There are regional differences. However the areas where most of the new growth is expected are presented by relatively steep terrain and remote locations. In other words, more road infrastructure is needed to facilitate a higher extraction of the forest resources. Harvesting residues such as branches and tops and stumps are currently left in the forest. The costs of extracting these resources depend on the operation method, terrain conditions, the transportation distance, volumes, etc. In the report NVE (2010), the costs were estimated to range from 15.8-43.3 EUR/MWh. Most of the potential, about 3.5 TWh, was estimated to have extraction costs of 22.2 EUR/MWh. A market for branches and tops must be established in order to give the forest owners economic incentives to also harvest the residues.

Biomass from clearing areas near electricity lines, roads and railways are seen as a potential source of biomass for bioenergy production. Currently, Norway has 200 000 km of electricity grids, 400 km railways and 93 000 km roads. The estimated biomass potential from these areas is approximately 0.5-1.5 TWh annually (NVE, 2010). The costs of extracting this particular biomass depend on the type of topography, distance and terrain of transportation. Furthermore, in the report, the energy potential from thinnings is estimated to 3.5 TWh. However, the extraction volume is dependent on a number of factors such as the demand from the pulp and paper industry and the prices of pulpwood. Thinnings do not provide much revenue to the forest owners; however, the method can be seen as a measure to increase the future value of the forest. The costs of thinnings are estimated to range between 27.5-39.2 EUR/MWh. In addition, an extensive potential of 9 TWh from pulpwood is reported.

[18] Exchange rate used: NOK/EUR = 7.65. The exchange rate of 2.february 2012.

Figure 44 Current and future potential for forest and agricultural solid biomass



Source: St.meld. nr. 39 (2008-2009), NVE (2010)

Summing up the resource potential from different official reports results in a total potential of approximately 45 TWh in 2020 (Figure 44). However, important measures such as supporting infrastructure investments, both road-network and district heating, must be conducted in order to be able to harvest the resources and distribute it to potential customers.

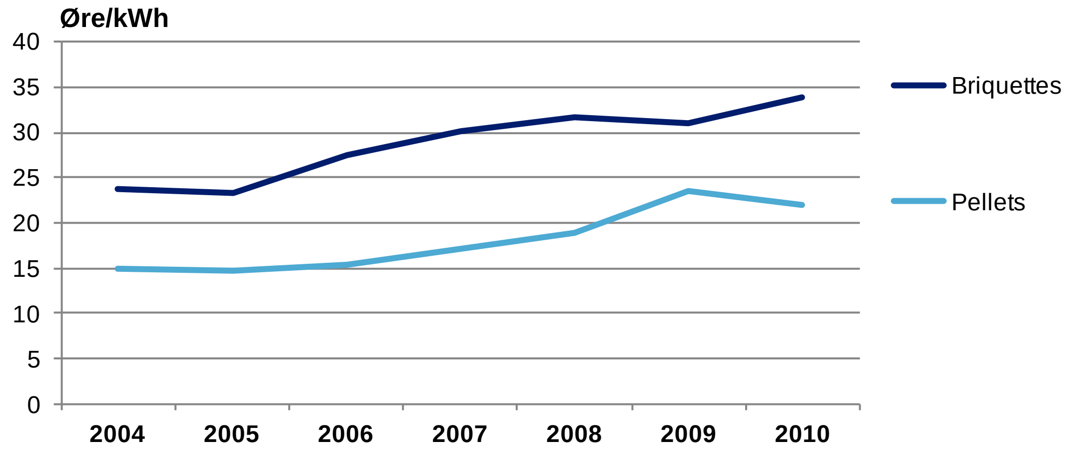
5.7.1 Solid biomass price development outlook

Electricity and oil are the main competitors to bioenergy in the market for heating. Thus, the prices of electricity and oil are important determinants of the demand for biofuels. The price development of biofuels relative to oil, gas and electricity will determine the future competitiveness of biofuels.

In Figure 45, historical pellet and briquette prices from are presented. As seen in the graph, the price of pellets has generally been lower than the price of briquettes. The price of pellets was approximately 44.4 EUR/MWh in 2010, while the price of briquettes was 28.8 EUR/kWh.

Currently there is no official price prognosis for biofuels. However, some of the market players that Pöyry has contacted, believe that the price of chips will stay below 39.2 EUR/MWh until 2020 (in 2010 the price of chips was 30.1 EUR/MWh) and the pellet price will be around 58.8 EUR/MWh in 2020.

Figure 45 Historical pellets and briquettes price, 2004-2010



Source: Nobio

5.7.2 Market mechanisms

At present, the market for bioenergy does not work efficiently in Norway. The most important issue is to increase efficiency in all levels of the value chain. Today, the bioenergy sector is depending on direct and indirect subsidies to be able to compete with other heating sources. Several factors contribute to this, such as easy access to cheap electricity and high costs of investing in district heating infrastructure. Section 5.6 highlighted measures to increase forest biomass mobilisation, accelerate investments in bioenergy production and developing bioenergy markets such as small district heating networks. Enova and Innovation Norway are important institutions that help to achieve this.

Sufficient information about the available bioenergy products and knowledge about alternative heating solutions is essential in order for the bioenergy market to work properly. Enova has in a letter to The Ministry of Petroleum and Energy in 2007 pointed out that there is a general scepticism and a lack of knowledge about alternative heating sources among suppliers and consumers. Furthermore, the limited statistics of bioenergy consumption and the lack of official price prognosis of biomass, show that the bioenergy market is not transparent. Official price prognosis would make investment decisions for market players (consumers and producers) more predictable. Statistics Norway and NVE are planning to increase their competence within the bioenergy market. Improved statistics related to bioenergy sector are expected to improve market transparency.

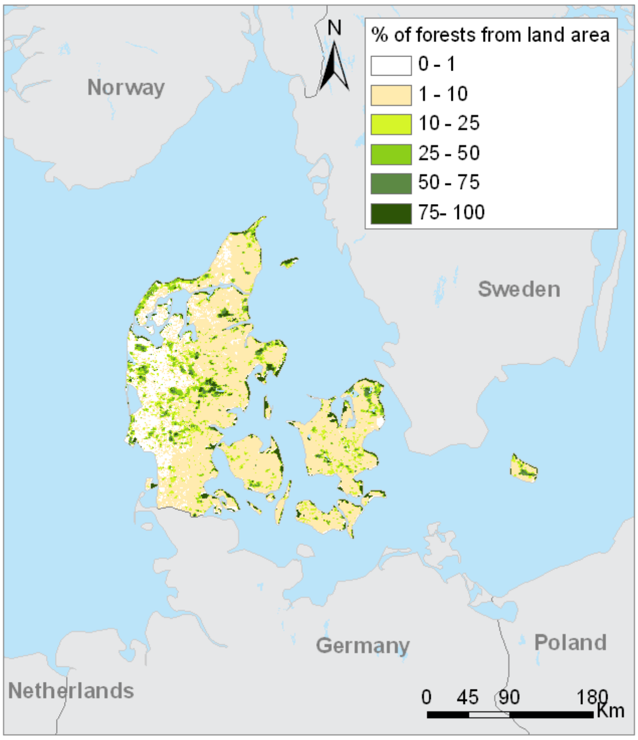
RESOURCE EVALUATION DENMARK

6. DENMARK – EVALUATION OF FOREST AND AGRICULTURAL BIOMASS RESOURCES

6.1 Background

Denmark has a limited land area of 4.24 million ha. Forest coverage is relatively low as only 12.8% of the land area is covered by forests (Figure 46). A much larger share of land, 62%, is arable.

Figure 46 Distribution and share (%) of forests in Denmark

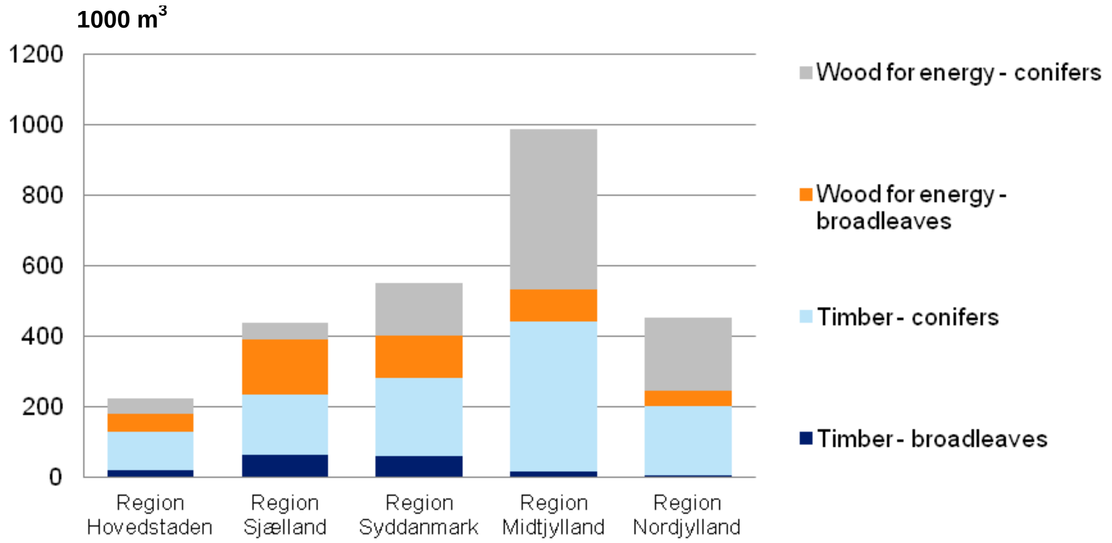


Source: European Forest Institute

The forest harvesting level in Denmark in 2010 was 2.64 million m^3. Timber counted for 1.29 million m^3 and wood for energy 1.36 million m^3 of this, hence the share of wood for energy is high in Denmark. Around 51% of harvested wood volume is for energy purposes. This includes firewood for private households as well as chips and logs for industrial energy use.

There are large regional differences in forest distribution and forest harvesting volumes in the country. Harvesting volumes are the highest in Midtjylland (39%) followed by Nordjylland (20%) and Syddanmark (18%). 15% of the forest harvests take place in Sjælland and the remaining 7% is harvested in Hovedstaden (Figure 47). Figure 47 below also illustrates the high share of conifers in harvests. 77% of harvests are of conifers species and only 23% broadleaves.

Figure 47 Forest harvesting by region (1000 m³), 2010

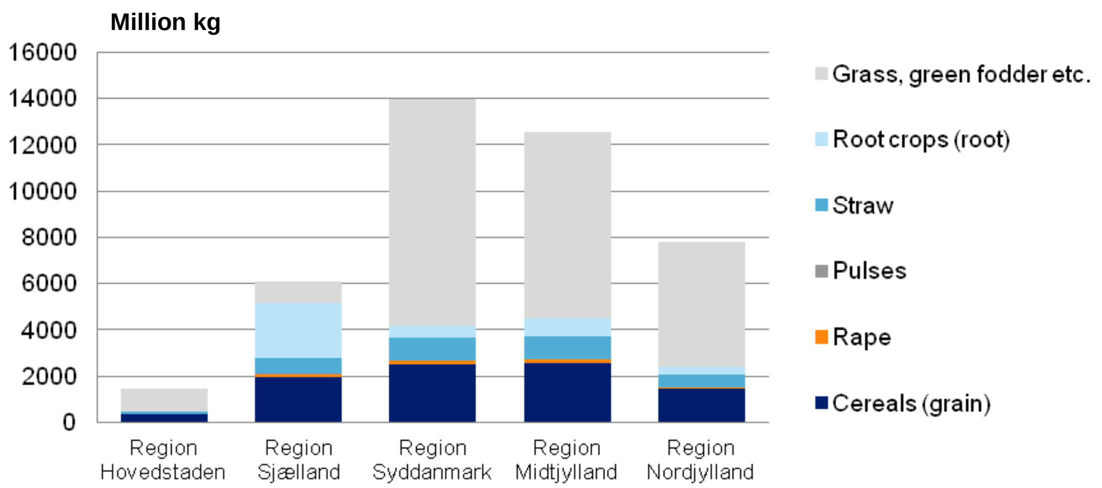


Source: Statistics Denmark, forest statistics

The annual agricultural production volume in 2010 was 41.8 million tonnes. Most of agricultural production is grass and green fodder (60%), followed by cereals (21%), mainly wheat and barley. Root crops consist of potatoes and sugar beets and stand for 10% of total agricultural production and straw has a share of 8% of total. Straw is currently the only agricultural residue used for energy generation.

Similarly for agricultural production, the regional differences are significant. The single most important agricultural region is Syddanmark. One third of the country's agricultural production is located in the area. It is followed by Midtjylland with 30% and Nordjylland with 19% shares. 16% of the agricultural production takes place in Sjælland, and the remaining 3% is located in Hovedstaden (Figure 48).

Figure 48 Agricultural production 2010 (million kg) by region

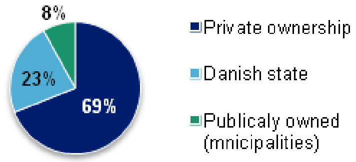


Source: Energy Statistics 2009, Danish Energy Agency

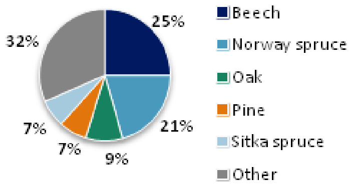
Figure 49 Characteristics of forest and agricultural resources in Denmark

Forest facts	
Total land area	4.24 million ha
Forest area	0.54 million ha
Productive forest area	0.30 million ha
Forest area % of total land area	12.8 %
Permitted felling level	N/A
Actual felling	2.64 million m^3
Growing stock volume	108 million m^3sob
Growing stock per hectare	199 m^3/ha
Mean annual increment	5.45 million m^3sob
Agricultural facts	
Agricultural area	2.65 million ha
Share of agricultural land	62 %
Main agricultural products	Grass / green fodder, cereals and root crops

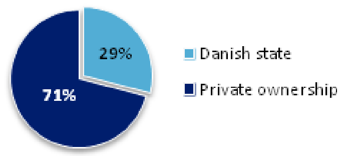
Forest ownership



Tree species (in the growing stock)



Ownership of agricultural land

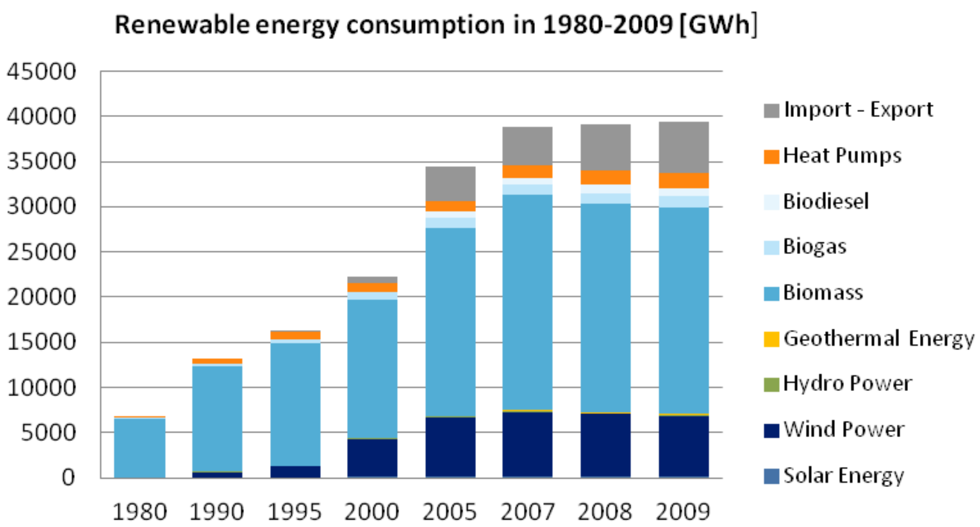


Sources: Statistics Denmark, FAO FRA 2010 Country Report, CIA The World Factbook, Eurostat

6.1.1 Introduction to energy market in Denmark

The renewable energy generation has significantly increased in Denmark during the past 30 years from 6 690 GWh in 1980 to 39 449 GWh in 2009. In the beginning of the period this was almost exclusively solid biomass based. In the 1990's the share of wind power started to increase and other renewable energy technologies started to penetrate the market (Figure 50).

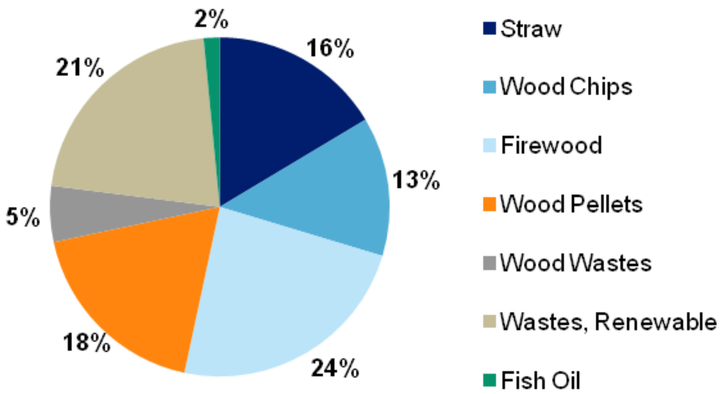
Figure 50 Primary production of renewable energy in Denmark (GWh), 1980-2009



Source: Energy Statistics 2009, Danish Energy Agency

In 2009, biomass from domestic sources represented 58% of the total renewable energy portfolio in Denmark and imported biomass an additional 14%. Woody biomass is the largest source of bioenergy with a total share of 61%. It is followed by waste with a share of 21% and straw with 16%. Fish oil stands for the remaining 2% of the total (Figure 51).

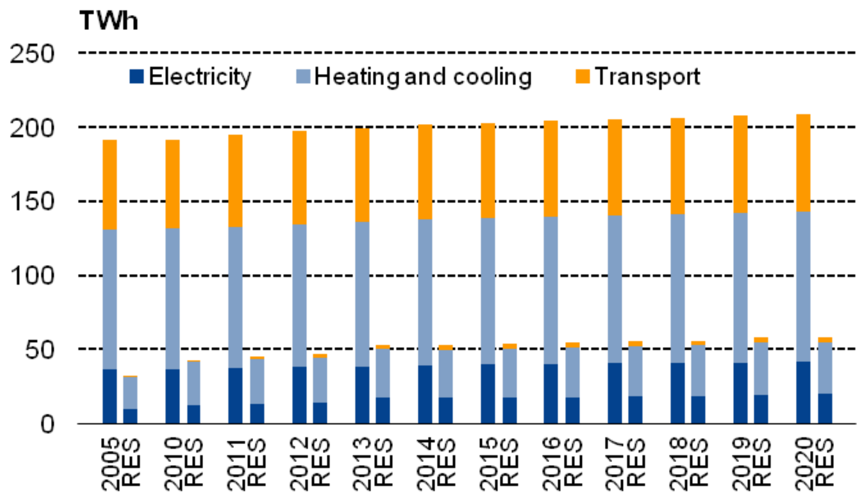
Figure 51 Biomass-to-energy assortments in 2009



Source: Energy Statistics 2009, Danish Energy Agency

The binding renewable energy target for Denmark imposed by Directive 2009/28/EC is to have 30% of its gross final energy consumption generated from renewable sources by 2020. According to the National Renewable Energy Action Plan (NREAP), this goal will be reached both by increasing renewable energy generation as well as implementing energy efficiency measures. Reaching this target means that the total final renewable energy consumption in Denmark should grow from 3 Mtoe level in 2005 to 5 Mtoe level by 2020 (Figure 52).

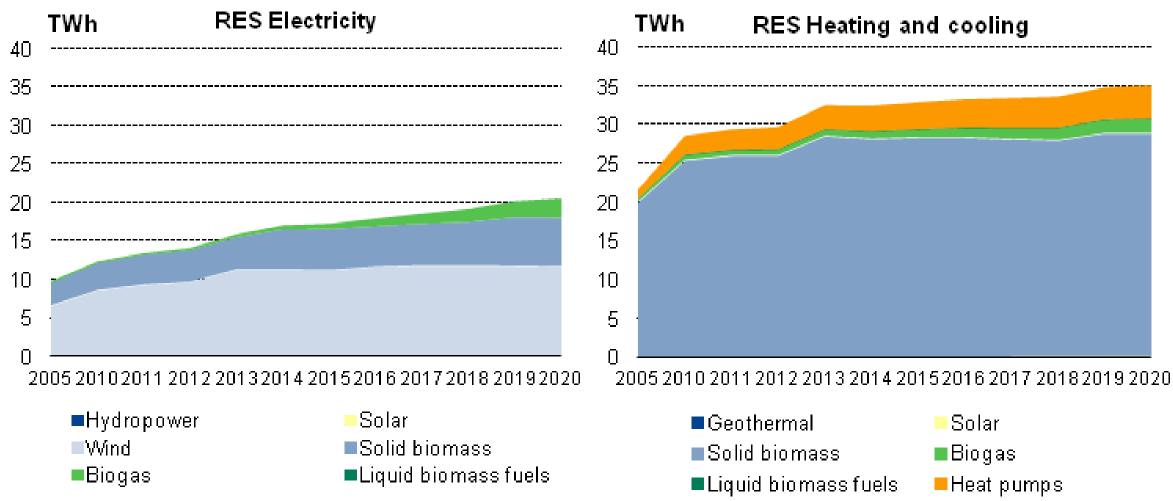
Figure 52 Gross final energy consumption by type – current and future outlook



Source: National action plan for the promotion of renewable energy 2009-2020, Denmark

Renewable electricity generation is estimated to double from the 2005 level by 2020, and will be mainly based on wind (12 TWh), solid biomass (6 TWh) and biogas (2 TWh) also in the future. Heating and cooling sector is to grow by 60% as a whole with solid biomass (29 TWh), heat pumps (4 TWh) and biogas (0.2 TWh) based technologies (Figure 53).

Figure 53 Renewable energy targets for electricity and heating/cooling



Source: National action plan for the promotion of renewable energy 2009-2020, Denmark

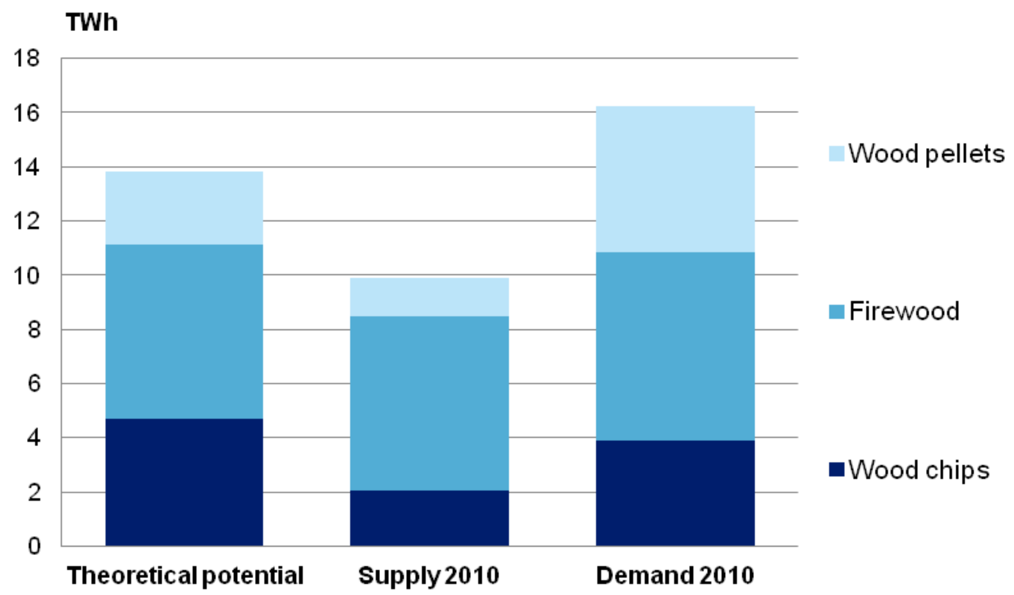
6.2 Resource Assessment – Solid biomass from forestry

The harvesting levels in Denmark are below the maximum sustainable cut, however increasing wood supply from domestic forests is a subject to mobilisation constraints. Already today, Denmark is a net importer of woody biomass for energy end-use. Firewood is the single largest biomass assortment used with a total domestic demand of 6.9 TWh. It is consumed mainly by private households. Most of the firewood volumes are domestically sourced, but approximately 0.5 TWh are imported. Hence, the firewood potential is in practice utilised.

The single largest imported biomass assortment is wood pellets. Almost 90% of the pellets in Denmark are currently imported by industrial end-users that consume two thirds of the 5.5 TWh pellet demand in co-firing and heating plants. Despite the growing domestic market, the utilisation rate of the Danish pellet production facilities has been low, ranging from 30% to 60% on average. The main reason behind this has been raw material shortages of wood processing by-products. Domestic wood pellet production capacity is not expected to grow further. Imports come mainly from the Baltics, Russia, Poland, Portugal and Germany in addition to the Nordic countries and North America.

The only woody biomass assortment that shows potential for future development is wood chips. Wood chips that are currently sold in the market are mostly wood industry by-products. There are some traded volumes of forest chips, however further potential exists to mobilise a larger share of harvesting residues and stumps for energy use. Despite this, Denmark will need to rely on biomass imports to satisfy its energy wood demand (Figure 54).

Figure 54 Estimated supply & demand for solid biomass from forestry (TWh)



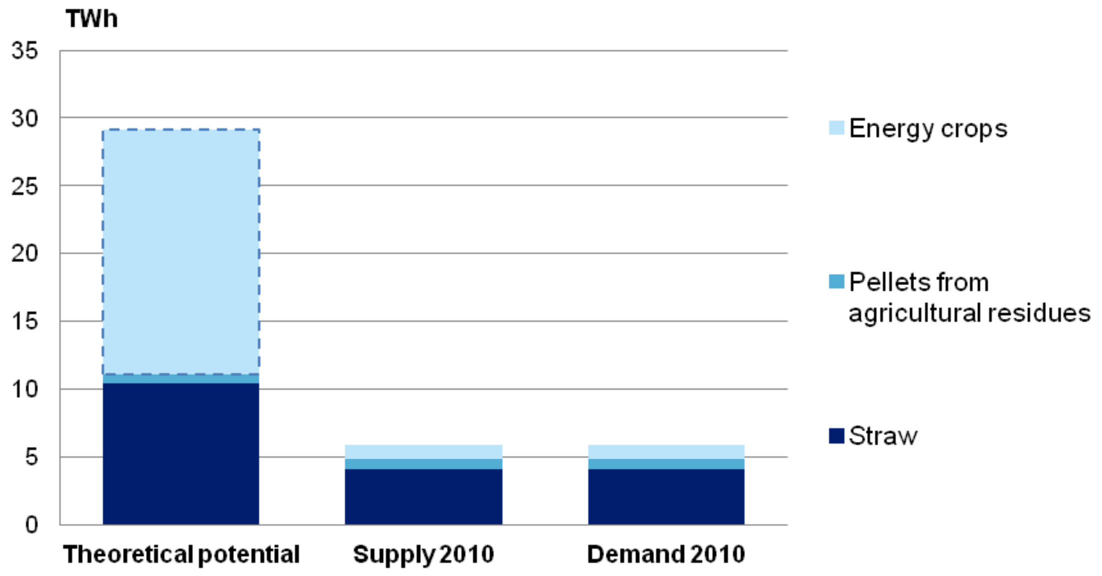
Source: Pöyry database, energy statistics Denmark, Statistics Denmark

6.3 Resource Assessment – Agricultural solid biomass (incl. energy crops)

Currently 16% of the bioenergy generation in Denmark is from agricultural solid biomass, mainly straw. According to NREAP, the theoretical potential is 11 TWh if the whole resource was mobilised. Straw is currently used in two forms, in bales and in pelletised form and the markets is almost exclusively domestic (hence, the supply and demand balance.

The greatest potential for agricultural biomass exists from energy crop plantations. Approximately 1 TWh is generated from short rotations woody coppice plantations of mainly willow and poplar. This also includes some experimental volumes of grasses such as reed canary grass, switch grass and miscanthus. The theoretical potential is estimated to 18 TWh, if 15% of cultivated land area was to be utilised for energy crops production. However, only a part of the potential is seen as realisable. Still the role of energy crops is expected to increase in the future (Figure 55).

Figure 55 Estimated supply & demand for agricultural biomass (TWh)

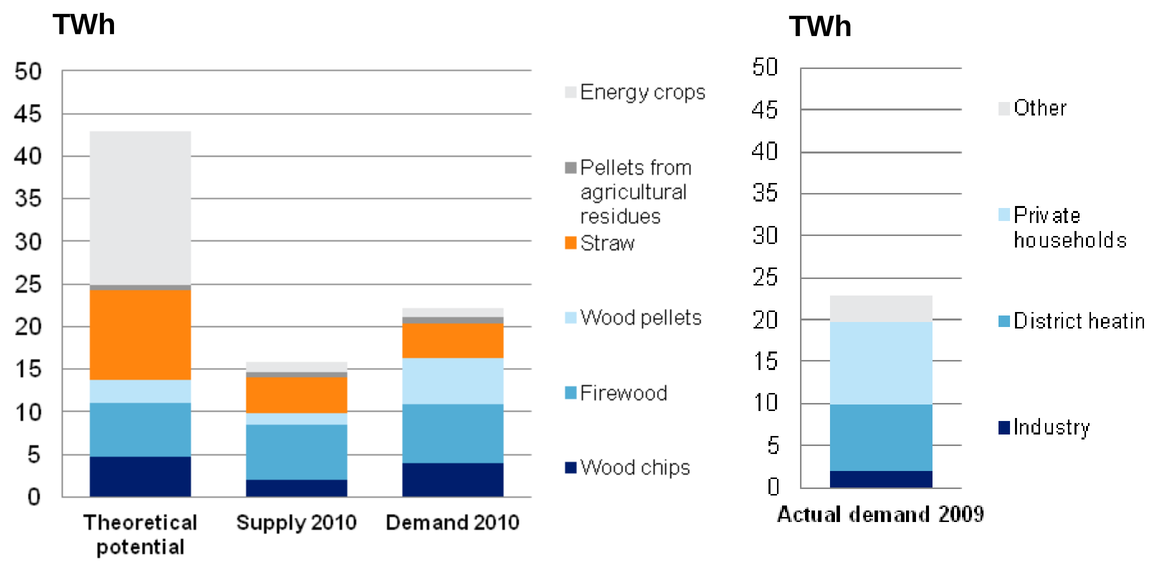


Source: National action plan for the promotion of renewable energy 2009-2020, Denmark, energy statistics Denmark

6.3.1 Resource Assessment – Supply & demand balance 2010

The resource assessment shows that the bioenergy sector in Denmark is heavily relying on woody biomass. Woody biomass resources are effectively utilised and only stumps and harvesting residues mobilisation can offer additional volumes of woody biomass for bioenergy production. Agricultural biomass has the largest potential in Denmark. Significant volume of straw is utilised in bioenergy production and some energy crops plantations have been established. However to reach the potential, straw mobilisation would need to double and plantations area cover 15% of the cultivated land in Denmark. Only a part of this potential can be realised (see Figure 55).

Figure 56 Estimated supply & demand balance for forest and agricultural solid biomass in 2010 and actual demand in 2009 by sector (TWh)



Source: National action plan for the promotion of renewable energy 2009-2020, Denmark, energy statistics Denmark, Statistics Denmark, Pöyry database

6.4 Biomass trade and mobilisation in Denmark

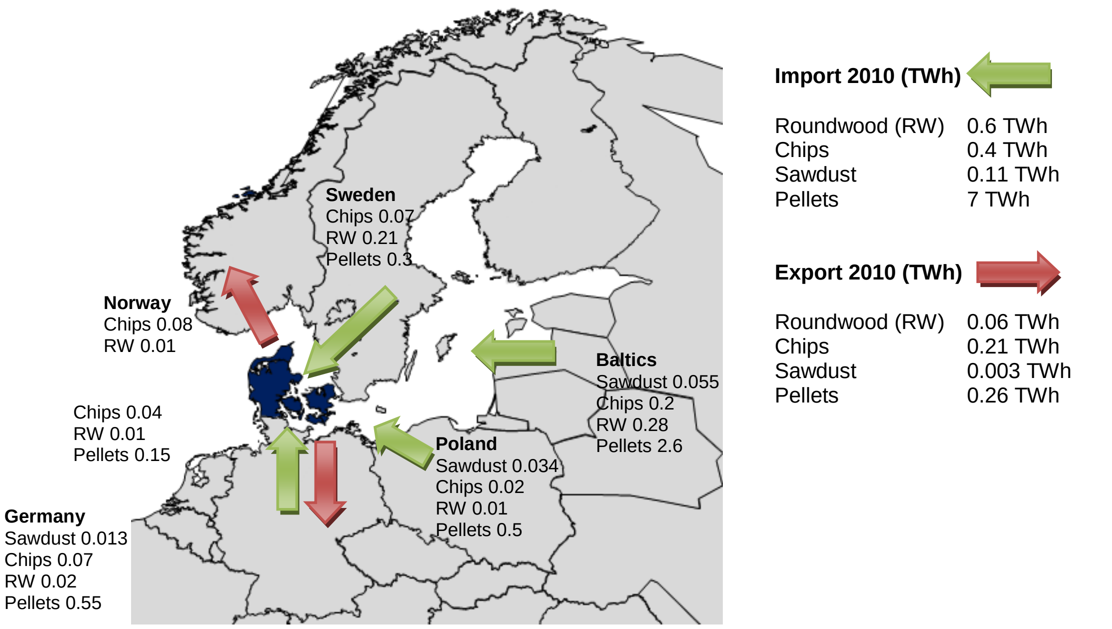
6.4.1 Trade flows

The bioenergy sector in Denmark is currently dependent on biomass imports. Denmark imports several biomass assortments for energy use; roundwood (including firewood), woodchips, sawdust and pellets.

1.5 million tonnes of pellets were imported to Denmark in 2010. The largest importers were the Baltic States, Russia, Portugal, Germany and Poland. Also the Nordic countries and North-America delivered large volumes of pellets to Denmark (Table 1).

The main trade flows of roundwood, woodchips and sawdust are with countries in proximity to Denmark. The Baltic States, Poland, Sweden and Germany stand out as the largest importers for these assortments (Figure 57). There were also some biomass exports, mainly to Germany and Norway, however these are interregional trade flows and not driven by any particular market driver.

Figure 57 Main trade flows of solid biomass to energy 2010 (TWh)



Source: Eurostat

6.4.2 Solid biomass mobilisation

There are studies on Danish biomass resource base concluding that it is possible to raise production levels significantly from the current, without compromising the environment or the production of animal feed and foods. It would, however, require production of perennial energy crops. This means that not only mobilisation, but development and realisation of cost competitive delivery chains is required.

Harvesting volumes in Danish forests have increased during the past 10 years, particularly for coniferous species. Even if the resource base is not utilised, without targeted measures, the wood supply from domestic sources is not likely to significantly increase in the future. Currently, there are no specific plans from the government's side to improve forest management in order to encourage more growth or recovery of biomass from forests.

It is estimated that approximately a half of the straw potential is currently utilised. There is potential to increase utilisation of straw for energy purpose. Straw is a challenging fuel due to its chemical content and its availability is dependent on exogenous elements, such as weather conditions. Whether the energy sector is willing to increase the utilisation of straw is not obvious. Also, as for forestry biomass, the economies of scale are usually limited and the marginal cost of mobilisation increases for the last fragments of resource. Already at current mobilisation rates, the cost competitiveness of straw is limited to a short inland transportation distance.

The cost competitiveness of forestry biomass, mainly forest chips from harvesting residues, is limited by transportation distance. There are also harvesting techniques and equipment that could improve the efficiency of forest operations in Denmark. Still today, the price of forest chips falls behind the price of imported pellets. It is the alternative cost that remains the most important hinder for larger scale mobilisation.

6.5 Overview of current "biomass-to-energy" generation

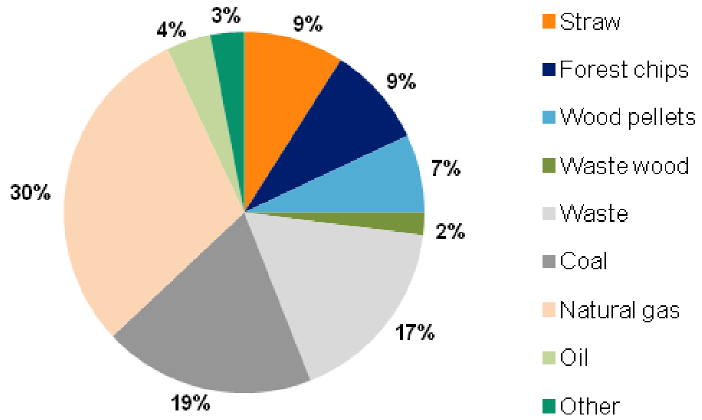
6.5.1 Industrial sector

The agriculture, mining and manufacturing industries consumed in total 63.6 TWh of energy in 2009. Only approximately 5% of this was from biomass. In the agricultural sector 0.5 TWh straw was consumed, and the manufacturing industries, mainly forest industry, consumed wood industry by-products and waste wood for an energy value of 1.4 TWh. In addition, the sectors represent a minor share of the district heating market.

6.5.2 District heating

District heating is a large end-user of biomass in Denmark. In 2009, 46% of the fuel mix was biomass, mainly woody biomass (20%), waste (17%) and straw (9%). As the district heating sector had a gross energy consumption of 27.9 TWh, the wood and agricultural biomass share corresponds to 8 TWh. Around 80% of district heating is produced in CHP plants and 20% in heating plants (Figure 58).

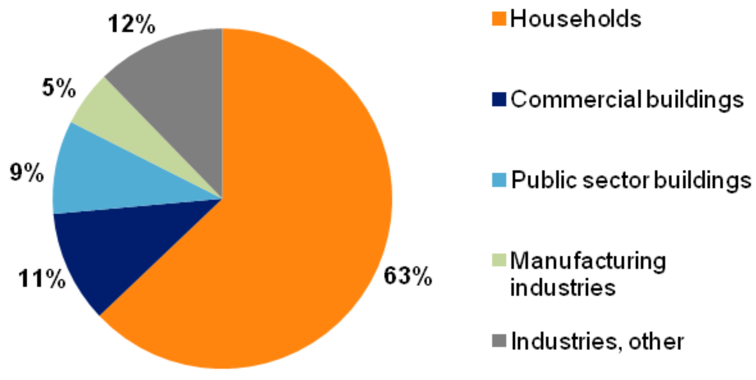
Figure 58 Solid biomass consumed by district heating 2010



Source: Annual statistics 2010, Dansk Fjernvarme

Of the district heating produced in Denmark, 63% is consumed by private households, 20% by commercial and public sector buildings and remaining by manufacturing and other industries.

Figure 59 District heating – End-use segments



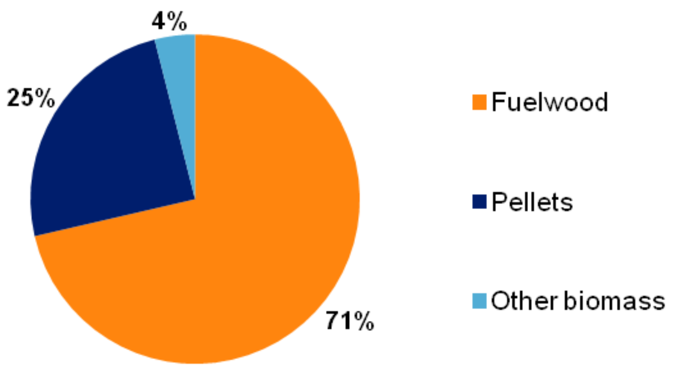
Source: Energy Statistics 2009, Danish Energy Agency

6.5.3 Private households

The gross energy consumption of households in Denmark was 83.1 TWh in 2009. Just over 20% or 18 TWh of this originated from biomass, either in direct combustion or in district heating.

In direct combustion, households consumed 9.8 TWh of biomass in 2009. This can be roughly split into three main categories; firewood, pellets and other. Firewood is the assortment with the highest share of total, 71%, corresponding to 7.0 TWh. Also pellets are an important fuel for households with a 25% share of total (2.4 TWh). The remaining 4% consists of some volumes of wood waste and straw (Figure 60).

Figure 60 Solid biomass consumed by households



Source: Energy Statistics 2009, Danish Energy Agency

6.6 Regulatory framework and sector policies relevant for solid biomass supply for energy

There are several policies and regulatory measures in place in Denmark to incentivise biomass-to-energy sector development. Currently, there are negotiations ongoing to reach a new Danish energy agreement following the national renewable energy action plan.

Biopower production is subsidised in order to increase the use of biomass for electricity generation. The support scheme is optional and based on energy policy agreement that can be adjusted in accordance with new agreements. The subsidy was amended by the RE Act in 2009 and has no fixed end date at current time.

The feed-in tariff for biopower producers is 0.15 DKK/kWh, regardless if the electricity is produced in installation that solely use biomass or installation that use a combination of biomass and other fuels. All sizes of installations are eligible for the support and there are no specific requirements for e.g. compliance with energy efficiency criteria.

To ensure that the electricity grid will not constraint the incentive, it is also stated that electricity generation from decentralised co-generation plants and electricity generation installations that produce electricity from renewable energy sources, have priority access to the grid.

In the coming years, a considerable contribution to the renewable energy sector is expected to come from district heating and combined heat and power production based on biomass. A number of conditions promote the use of renewable energy in district heating, e.g. biomass is non-taxable. However, the regulations in their current form incentivise electricity generation and not heat generation where prices are regulated and all additional surplus from tax exemption is directly transferred from the producer to the consumer.

A topic that is currently being negotiated as a part of the new Danish energy agreement is to provide an increased incentive for heat producers to convert from fossil fuels to biomass. This could be achieved by making it possible for heat producers and heat consumers to share the economic benefit from tax incentives, that have so far been directed only to consumers. If approved, this incentive could have a significant impact for heat supply.

There are some regulations related to biomass resources as well. The Green Growth agreement from 2009 focuses on breaking down the non-economic barriers for expansion of the biomass resource base. For a period of time, it is also meant to open up for subsidies for biomass installations. The Planning Act will be amended to allow local authorities to include biomass installations in their planning.

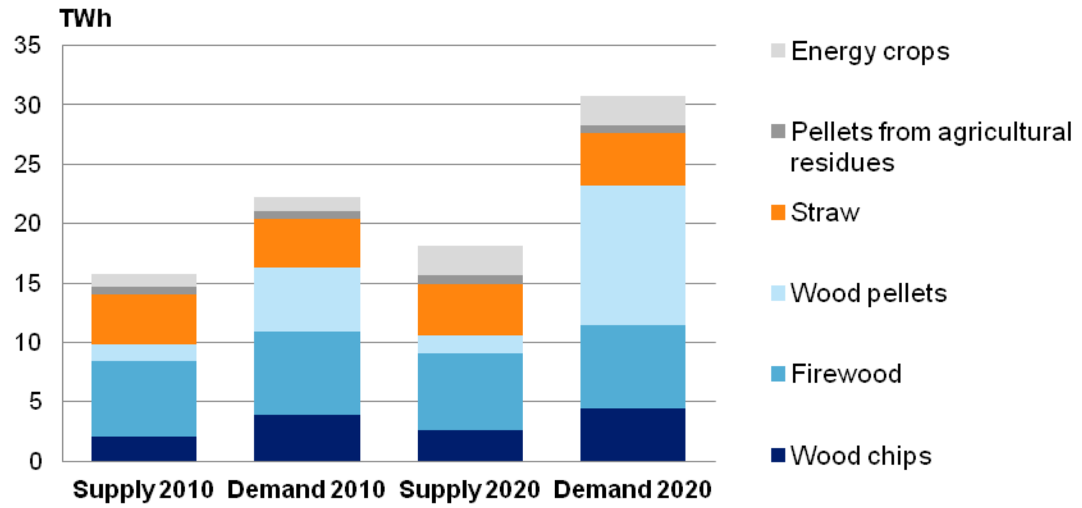
The Green Growth agreement also sets some specific goals for increasing the biomass resource base by subsidizing planting of perennial energy crops. The goal is to reach 30 000 ha of energy crops plantations by 2020. The Ministry of Food, Agriculture and Fisheries has set aside DKK 96 million for the establishment of plantations. There are also tax reliefs related to the operation. Planting costs of willow and other perennial energy crops are considered as an operational cost and are therefore tax deductable.

6.7 Solid biomass market development

According to the NREAP, the solid biomass utilisation for energy generation is expected to grow by 8.9 TWh by 2020. This is the single largest increase for the renewable energy sources, meaning that solid biomass will remain the most important renewable energy source in Denmark the coming years.

The 8.9 TWh is largely expected to be covered by imported wood pellets and only 2 PJ (0.56 TWh) is estimated to be produced in Denmark by increasing wood chips production. The ambition is also to increase the production energy crops by expanding the plantation resource base to 30 000 ha by 2020. Further growth in biomass generation from other sources, such as straw, is expected to remain domestic, with generation and consumption running parallel (Figure 61).

Figure 61 Current supply & demand balance for forest and agricultural solid biomass (TWh)



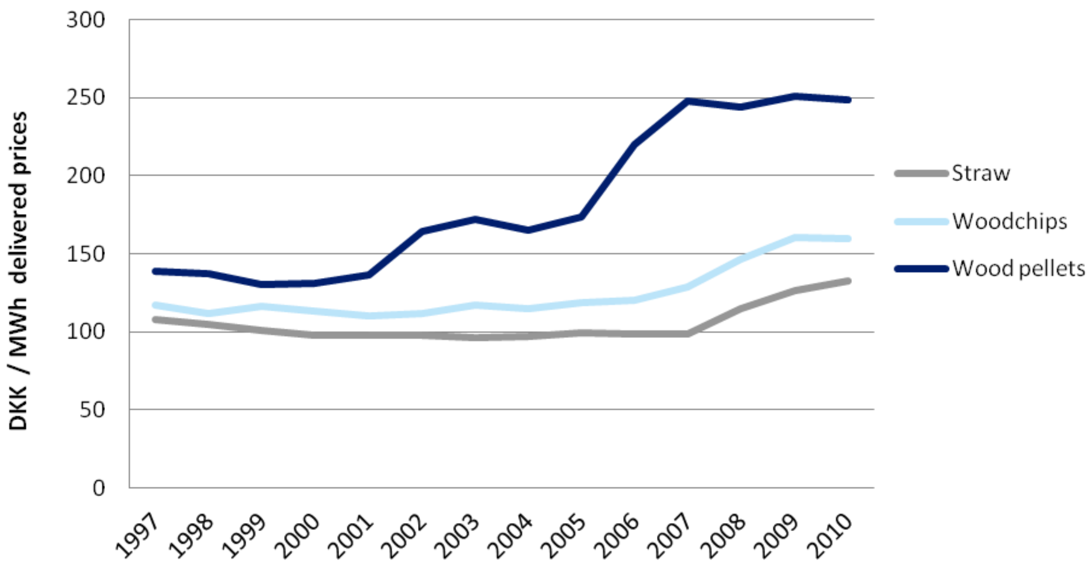
Source: National action plan for the promotion of renewable energy 2009-2020, Denmark, energy statistics Denmark

Denmark's strategy for renewable energy sector development therefore relies on imports of solid biomass. Even if the theoretical potential is significant, the increase in domestic resource base will only represent a fraction of the biomass need. It is the large scale CHP and heating plants that are expected to replace fossil fuels with pellets and drive this development.

6.7.1 Solid biomass price development outlook

The prices for wood pellets have increased significantly during the 1997-2010 period. This development has been driven by the increase in wood prices but also in demand. Prices for straw and woodchips have been more stable, but even them showing an increasing trend in the same period. It can also be noted that woodchip prices have consistently been above straw prices (Figure 62).

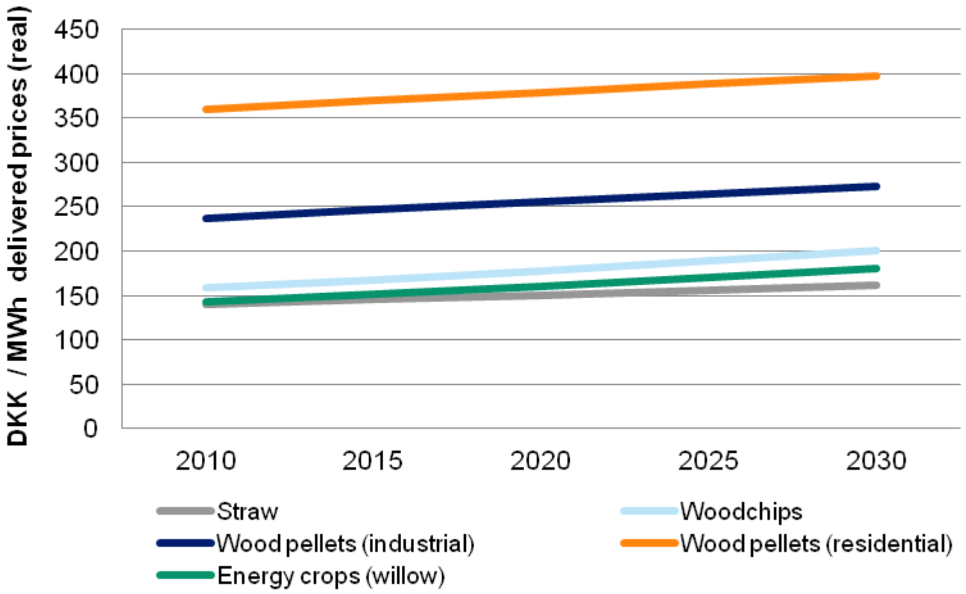
Figure 62 Historical biomass prices, 1997-2010



Source: Dansk Fjernvarme

The price trends for the different biomass assortments are expected to be similar in the coming 20 year period (Figure 63).

Figure 63 Biomass price prognosis, 2010-2030



Source: Opdatering af samfundsøkonomiske brændselspriser Biomasse

6.7.2 Market mechanisms

Wood markets are established and well-functioning in Denmark for logs and pulpwood, however the energy assortment markets are less structured and transparent. The energy wood markets in Denmark operate to large extent through intermediaries. The private forest ownership is small-scale which leaves room for harvesting companies and traders as volume aggregators. There are two large trading companies in particular that dominate the markets of private forestry. There is also some direct sales from forests to end-use. Consequently, the market transparency for the forest owner is reduced, as it is the trader that contracts deliveries with the end-user. Traders also act as risk mitigators by taking on the short and medium term supply contracts, whereas the wood markets are still very much spot market based.

Since the market is relatively young, there have been particular challenges related to the measurement systems in place. The energy sector is looking to procure MWh, whereas the forest sector has traditionally been selling in volumes measures, mainly m^3. For the forest owners to compare values between the different assortments and make sales decision thereafter can be difficult.

The district heating association "*Dansk Fjernvarme*" collects and publishes price information on the different biomass assortments regularly and is the main source for price information.

7. BIOMASS SUPPLY CHAINS – COMMON PRACTISES AND LESSONS TO BE LEARNED

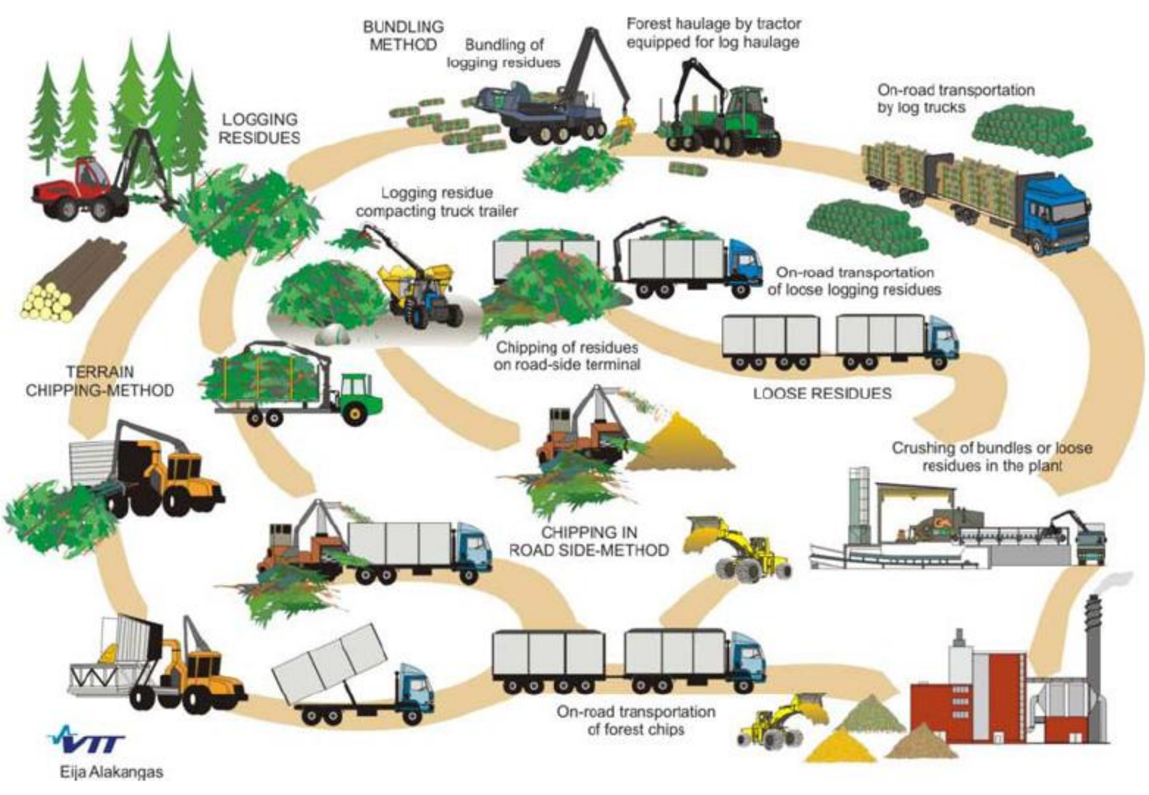
7.1 Solid biomass from forestry

Harvesting residues - tops and branches

Harvesting residues, also referred to as forest chips, consist of branches and tree tops, which are usually left behind in the forest after timber harvesting operations. Harvesting residues are normally not collected in traditional harvesting, however the assortment can technically be used in bioenergy applications. For all four countries in the Nordics, harvesting residues are extracted for industrial end-use. There exist several methodologies for collection and harvesting of forest residues (Figure 64):

- Collection of harvesting residues from the forest by forwarder, chipping at forest roadside and haulage of wood chips to market
- Collection in forest by bundling machine, formation of bundles in the forest, forwarding to roadside of bundles and transportation to market
- Extraction of whole trees to roadside by skidder, processing and chipping at roadside and transportation to market

Figure 64 Illustrative supply chain for harvesting residues (typical in the Nordic countries)



Source: Alakangas, E.& Virkkunen, M. Biomass supply chains for solid biofuels – from small to large scale. December 2007.

Despite the method used, the integration of large scale collection of harvesting residues required coordination between land owners and harvesting companies to assure that there are enough residues in the area to make the operations economically viable. Additionally, specialised equipment is also required (i.e. additional chippers/grinders and/or bundlers).

Harvesting residues – stumps

Stump represents about 20% of total tree biomass (Skogforsk). Stumps have lower moisture content compare to other tree biomass and hence, are generally high in energy content but also high in contaminants such as alkalis and silica present in sediment which needs to be taken into account during the selection of boiler technologies. Spruce is considered to be the most appropriate tree species for stump harvesting due to its root system (EUBIONET II). In forestry it can be advantageous to remove stumps to facilitate replanting. This is often done by allowing the stump to decompose naturally. Removal of stumps is a fairly new practice as there is no use for stumps except for bioenergy. The cost range is often high due to challenging productivity and low material bulk density. Also, there is a need to assess the environmental impact of stump removals.

Sweden and Finland are the only countries in the Nordics which have small-scale stump extraction for industrial end-use. There exist several technologies to eliminate stumps from the ground, however further knowledge and development is still required in order to make the methods more rational. At present, mainly Finnish technology from the 1970-1980’s is used (when attempts were made to use stumps as raw material for pulp production). An excavator with 3-5 long fingers is used to extract the stump from the ground. Then the stump is split using a cutting unit and shaken in order to remove the soil. Finally, the stumps are stacked in a pile for drying and further transport (Figure 65). Similar to the collection of other harvesting residues, the collection of stumps requires coordination between landowners and harvesting companies to ensure sufficient quantities to make operations economically feasible (Pöyry, Skörd av stubbar – nuläge och utvecklingsbehov).

Figure 65 Illustrative supply chain for stump biomass delivery

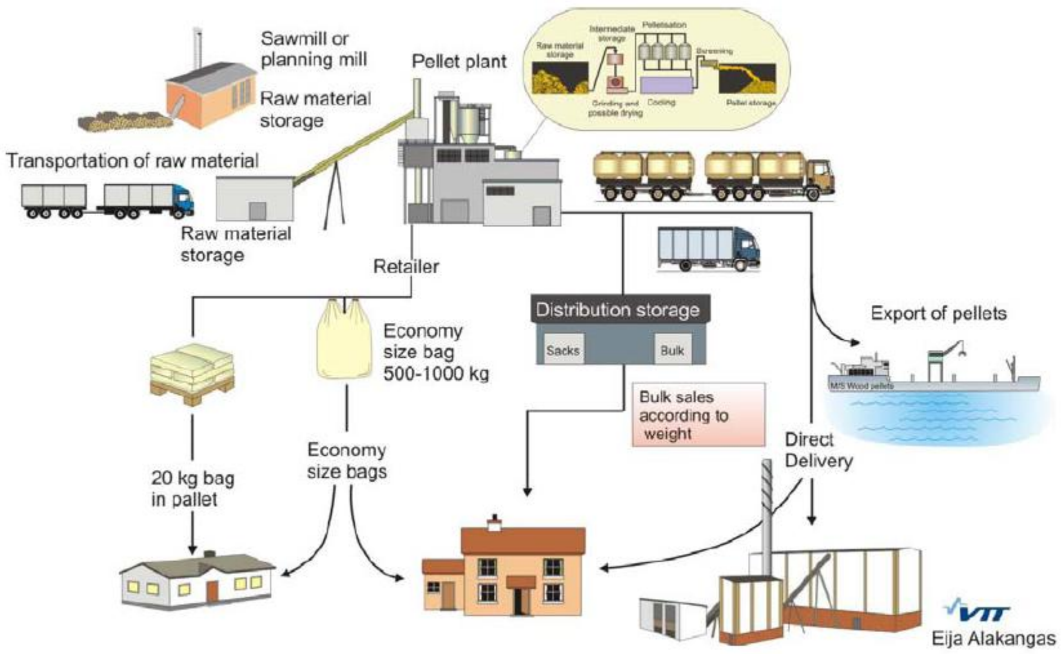
Source: Alakangas, E.& Virkkunen, M. Biomass supply chains for solid biofuels – from small to large scale. December 2007.

Wood pellets

Wood pellets are a densified form of biomass typically produced from forest industry residues (mainly of sawdust, woodchips or wood shavings). Pellets represent a uniform fuel that can be handled and stored easily. The idea of transforming sawdust and wood shavings into pellets was born in the US during the 1970s energy crisis. Wood pellets were first produced on a large-scale in Europe in the 1980s, initially for use in large power plants in Sweden (Pöyry).

Wood pellets are produced using woody biomass through a relatively simple process of milling, drying and compacting (Figure 66). In some larger pellet manufacturing facilities roundwood is taken in as a raw feedstock and must be debarked and chipped before entering the drying process. This requires a log yard, wood handling facilities, and chipping and debarking equipment; adding to the capital cost but allowing a larger and more flexible supply of material (Pöyry).

Figure 66 Illustrative supply chain for pellets



Source: Alakangas, E.& Virkkunen, M. Biomass supply chains for solid biofuels – from small to large scale. December 2007.

In the milling process, raw material is ground to small particles. The next step is drying, which is (besides raw material cost) the single largest cost component in the production of wood pellets when using wet materials. When the material is dried, the fine particles are forced under extremely high pressure, 210-400 MPa (30.5 - 58 thousand psi), through a die. The high temperatures reached as a result of the pressure and friction softens the lignin, a component of the wood, which then acts as a binding agent. After that, pellets must be cooled to harden their lignin coating.

Pellets destined for the bagged residential market should be packaged immediately. If stored in bulk, it is essential that pellets be kept in a cool and dry environment. Pellets in bulk are stored in silos or flat bottom warehouses. The residential and small industrial pellet market is increasingly being supplied using dedicated tank trucks with pneumatic blower pipe systems. Volumes to domestic distributors or residential customers may also be delivered in bags on pallets. The cost associated with distribution to households is one of the key drivers of the price development of residential pellets. Rail transport is frequently used to deliver wood pellets from inland production sites to an export facility. Further transport in the receiving country is, however, mainly done by truck and barges (Pöyry).

The industrial and residential sectors are the largest end-use segments for pellets in Sweden, accounting for 40% and 35%, respectively. The remaining 25% is for commercial end-use. The industrial end-users include large CHPs and district heating plants. There are a few integrated players such as Skellefteå Kraft producing pellets for their own use, however many of the plants source from local or regional pellet producers and some are importing volumes to diversify risk in sourcing operations. In Finland, the pellet boiler market is still small, where the residential and small-scale commercial heating sectors are the main end-users, accounting for 44% and 41% of the total consumption, respectively. In Denmark, on the other hand, the industrial sector is the largest end-use market for pellets, with a market share of 65%. This is due to the large number of co-firing plants in Denmark using pellets. Industrial users mainly manage their own supply chains and import pellets directly from foreign producers. Also in Norway, the industrial sector is the leading end-user (69%). The industrial end-users include local heating centres and district heating plants.They source pellets from local or regional pellet producers.

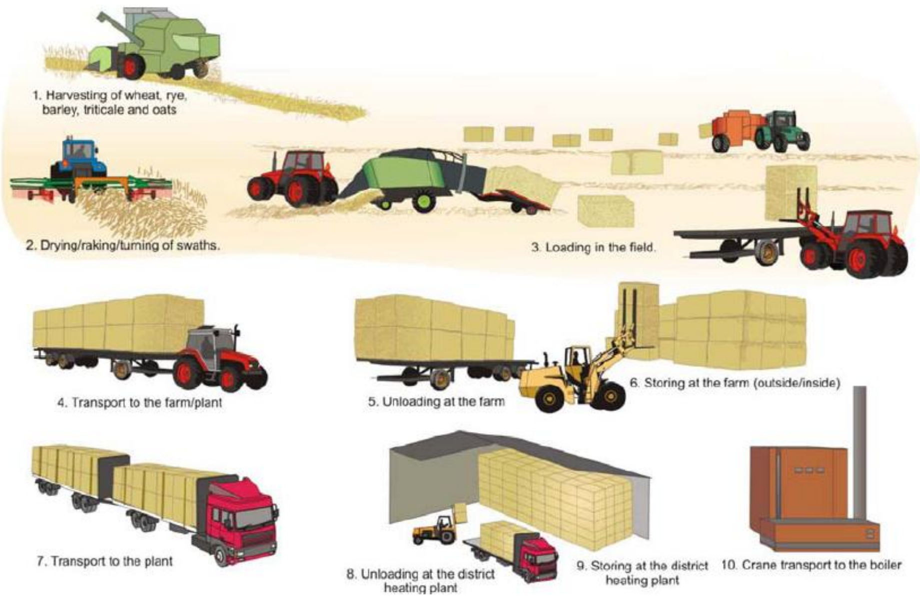
7.2 Solid biomass from agriculture

Straw supply chain for the energy sector in Denmark

In comparison to the other Nordic countries, straw is used for commercial purposes mainly in Denmark, where the industrial sector is the main end-use market. Straw is an important source of energy in Denmark and a few decades ago straw was considered to be a waste product and was mainly burned directly on the fields after harvest. The utilisation of straw for energy purposes began in 1991, when field burning became illegal in the country due to environmental reasons. Currently, straw handling is an independent discipline and there have been significant investments in baling machines, wagons and stores.

The next step after straw is harvested is the baling process (Figure 67). Straw for the energy sector is almost always delivered as big bales (about 125 x 240 x 240 cm, weight over half a ton), also known as Hesston bales. Farmers prefer to remove the straw for the field as soon as possible in order to start planting next year’s crops. On the other hand, if straw is left on the field for some time and can dry after one or more rain showers, it will have better fuel qualities (substances such as Chlorine and Alkaline are washed away). However, the price for straw is based on weight and moisture content, thus very few framers apply this methodology in practice. A typical straw yield is around 3 tonnes/ha. The disadvantage with big bales is that transport is not utilised effectively. A lorry can carry 24 big bales, which is about 12 tonnes of straw and only about half of the weight of what a lorry can carry. This results in higher transportation costs.

Figure 67 Illustrative supply chain for straw bales (district heating plant)



Source: Danish Technological Institute / Alakangas, E.& Virkkunen, M. Biomass supply chains for solid biofuels – from small to large scale. December 2007.

Further, straw is loaded in the field with a front loader, excavator, tractor shovel, telescope loader or a mini loader. The first three have a front installed loading system, while telescope loaders are able to lift the straw bales higher, thus straw can be stacked high and storage costs can be reduced. The bales are transported to the energy plant and a portable crane is used for unloading. The bales are weighted and analysed for water content while hanging in the crane. At last, the straw bales are transported to a storeroom where they are placed on a conveyor leading to the combustion plant. Smaller heating plants use forklift trucks for unloading 1-2 bales at the time (INBIOM 2011).

Straw bales can also be converted to pellets before delivery to energy plant. This process increases the production cost, however transportation cost is reduced especially if transported longer distances. Also, the handling procedure can be easier and stocks can be reduced.

Supply chain for willow in Sweden

In comparison to the other Nordic countries, willow is used for commercial purposes mainly in Sweden, where the industrial sector is the main end-use market. There are approximately 300 species of willow in the northern hemisphere, of which 30 can be found in Europe. However, only a few of these suitable as short rotation energy plantations. In Sweden, cultivation of willow mainly takes place in the southern and central parts of Sweden (Bioenergiportalen).

Willow cuttings (approximately 13 000-15 000 willow cuttings/ha) are planted during spring and early summer and the soil should be ploughed and prepared in the same way as for planting grain. Planting is performed by professionals (contractors) using special planting machinery. The willow can be harvested approximately 4 years after planting and the best harvesting period is during winter. After the first harvest, it is possible to harvest every 3-4 years, however this depends of how the plantation is managed and how rapidly the willow grows. The first harvest will yield around 20-25 tonnes of dry substance chips/ha, while the next harvest will yield around 30-35 tonnes dry substance chips/ha. The next step in the process is chipping the willow directly in the field (harvesting and chipping is usually done simultaneously in one step) and the willow chips is then transported to the nearest energy producer. Willow chips have similar combustion properties as wood chips. However, willow easily absorbs heavy metals from water and soil, thus willow chips often contains higher levels of heavy metals compared to other forest fuels, especially cadmium (Bioenergiportalen, SalixEnergi).

7.3 Lessons to be learned and key improvement areas (based on interview results)

During the telephone interview with main stakeholders in the bioenergy sector, Pöyry asked about the key improvement areas in order to bring efficiency to supply chains. The interview results for each country are summarised below.

Sweden and Finland

The interviewed stakeholders share the same opinion that the level of the solid biomass supply chain development in Sweden in relatively high, with an average score of 4.6. (scale from 1=low to 6=high). Despite the difficulty among the stakeholders to mention any specific best practice supply chains, several examples were given including the forest chips supply chain, by-products from the forest industry, pellets supply chain and also the supply chain for small-diameter wood from thinnings is under development.

The main key improvement areas in order to bring efficiency to current supply chains include:

- Technical and logistical improvements, especially for agrobiomass
- Improving and developing the forest technology. The current technology is developed for harvesting of roundwood (with a relatively large diameter), thus there are large potentials in technical development of harvest systems for the “third assortment”, i.e. primary forest fuels.
- Refining, densification and torrefaction of biomass are becoming increasingly important issues in the future. Reducing the bulkiness of biomass, compacting it more and developing new products. Easier to transport and store (also creates incentives fro trade).
- Improving the choice of raw material, continued optimisation of the logistical chain and portfolio management.
- Review the efficiency regarding reloading of biomass for train transport. Reduce cost for thinnings in forest clearing operations.
- Better use if the train system.
- For agrobiomass, cut costs by reducing the transportation distance. This can be achieved by adapting the combustion technology (boilers) in the heating plant according to the type of biomass which can be found in the vicinity of the plant.

- If the solid agrobiomass volumes will increase in the future, it is worth evaluating how to coordinate the handling of these volumes with the ones coming from the forest

According to a biomass producer, the level of supply chain development is high in Finland and the sub-contractor led supply chain model works very well as there is very good cooperation between the sub-contractors and the wood buyers. In contrast to that, a representative of energy industry stated that the level of biomass supply chain development is rather low as there are too many operators in the chain. To bring efficiency to current supply chains more open market platforms and places would be needed. Also, according to a representative from bioenergy related company more free trading, competition and price transparency would be needed to bring more efficiency to current supply chain(s).

During a wood energy technology programme carried out in Finland the development of supply chains for forest biomass was carried out according to a research institute representative. However, after the end of the programme there has been very little public funding for development work of supply chains available. To improve the supply chains, there should be demonstrations of the whole chains and improvement made also in specific parts of the chains. Also, development of new business models and networks should be carried out.

Norway and Denmark

Stakeholders in Norway assessed the level of solid biomass supply chain development to be modest with an average grade of 3.2 (scale from 1=low to 6=high). Many different issues were raised and below the most frequent points are presented:

- Need to improve the infrastructure. This is critical in several levels of the supply chain, starting from harvesting operations to delivery to end-users.
- Need of a larger critical mass, i.e. necessary to achieve large-scale production and consumption.
- Reduce uncertainty. Players in all levels of the supply chain experience uncertainty, e.g. agents planning to invest in chips combustion plants are dependent on a secure delivery of chips. On the other hand, chips producers need to prove that they are capable of delivering high quality chips at all times. Before the combustion plant is built the investor is not aware of this and requires a risk premium. This reduces the profitability.
- Products must be standardised. This will improve the value of the fuel and also reduce the risks for biomass consumers.
- Increase the cooperation between the forest industries and consumers. They need to combine their supply chains.
- An authority pointed out that the commercial side of the supply chain needs to be improved. The willingness to pay and the prices of bioenergy products have to increase. Profitability in all the levels of the supply chain must increase. If this is achieved, the technical and logistical obstacles will be solved.

In Denmark, the supply chains are suffering from inefficiencies, partly due to the fragmented ownership and low volume aggregation, partly due to the know-how and available technologies. In some forest regions there are equipment coordination in state forests, however this does not extent to the whole resource base. Also limited demand for domestic biomass has limited the development of supply chains. In the quantitative assessment, the stakeholders ranked the supply chain development at 2.9/6, hence low.

8. STAKEHOLDER MAPPING AND INTERVIEW RESULTS

In order to highlight different relevant themes and perspectives regarding solid biomass in the Nordics, telephone interviews were conducted with market players along the whole value chain, from biomass production, market/trade, to final consumption. This was done using an interview guide (questionnaire) including predefined as well as open questions to ensure adequate coverage of the topics and a comparable input across the countries. The focus of the interviews was to assess if there are opportunities to enhance the Nordic cooperation regarding solid biomass for energy purposes. The interviews highlight the different regional opinions regarding this issue. Pöyry conducted a total of 29 interviews in the target countries (7 in Sweden, 6 in Finland, 8 in Norway and 8 in Denmark).

8.1 Sweden

8.1.1 Market assessment

The general opinion of all the interviewed stakeholders is that the future consumption of wood biomass in Sweden will rely foremost on the removal of primary forest fuels. There is a significant potential to increase the extraction of branches and tops, however new assortments such as stumps and small-diameter wood from thinnings will gain more importance. The two latter assortments require improvements in harvesting technology and stumps are associated to environmental issues. This will also imply improving the forest management techniques and increasing the harvesting levels. The participants in the study have different opinions about agricultural biomass; all of them share the opinion that there is a considerable potential to utilise more agricultural biomass for energy purposes, however there is scepticism concerning the role of the agricultural sector as a supplier of raw material for energy purposes. Lack of incentives, high competition from the dominating forest sector and previous failed attempts to stimulate the sector development, are some topics raised by a leading research institute. Thus, the volumes of agrobiomass supply are predicted to be small even in the future. A national authority also mentioned the competition between the alternative uses of land, i.e. food vs. energy.

Trade

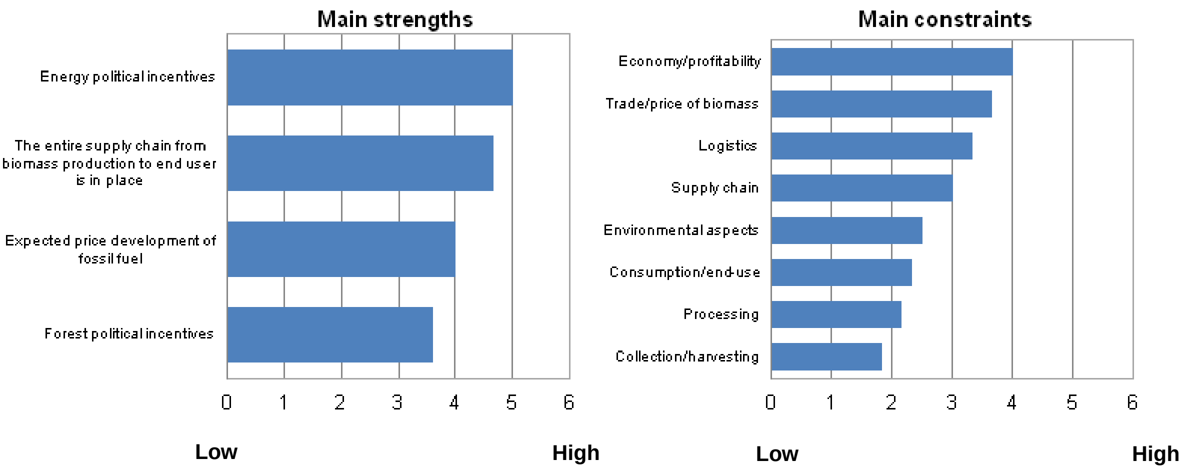
The participants in the study share the opinion that trade will most likely increase in the future as a result of increasing domestic and international biomass demand. Nevertheless, primary focus will be on the domestic market where most of the biomass will be consumed, similar to today's situation. Assortments for trade include densified/processed fuels, such as pellets, torrefied wood, etc. A large biomass producer states that the company does not export biomass in order to keep up the price level on the local Swedish market. The district heating plants in the country have a high paying capability and also transport costs, associated with trade over longer distances, create a barrier. From a Nordic dimension, there is a lack of logistical infrastructure from northern Sweden to Norway. The same stakeholder mentions that future trade will primarily be intra-Nordic and possibly some volumes will be delivered to Western Europe. Several of the stakeholders think that there will be trade from southern Sweden to Denmark. Poor quality pulp pulpwood (e.g. decayed spruce), harvesting residues, chips and pellets are the main assortments of interest. The opinion of a research institute is that Danish customers will probably become more significant and will demand biofuels to compensate their energy need during windless days. A large consumer of solid biomass in Sweden states that Russia plays a key role regarding the future trade development (the level of export duties on roundwood). Also, a new supply pattern including train solutions will open up the market. A stakeholder within the energy crop (willow) business stated that the foreign demand for willow is low, thus focus is on the domestic market and striving to reduce the transportation costs.

According to the interviewed stakeholders, the typical national solid biomass transport distance ranges between 50-80 km for woody biomass and around 30-50 km for agricultural biomass.

Biomass mobilisation – strengths and constraints

As illustrated in Figure 68, the main strength regarding biomass mobilisation is the energy political incentive scheme in Sweden. However, the three main constraints connected to solid biomass mobilisation include economy/profitability, trade/price of biomass and logistics. The profitability is the most crucial parameter and biofuel assortments are less profitable (profit per unit is much lower) compared to sawlogs and pulpwood. One stakeholder states that the profitability of using the agricultural land for biomass production (for energy purposes) is worse in comparison to alternative land uses. Also, the agricultural policies change every 3rd year, creating future insecurity among farmers and high investment risks. Also, the price of biomass is an important driver. A large biomass producer mentioned that the lack of trade is due to low competitiveness (e.g. pellets). The logistical constraint that needs to be addressed is that biomass is a bulky product that does not travel far. Logistical costs must go down or biomass prices need to increase, otherwise biomass will be left in the forest. It is also a question of finding compacting methods in order to get higher energy value per volume unit. A research institute mentions that many logistical improvements are left to be done. Despite good cooperation between players along the entire logistical chain, there is a need to review several issues, i.e. reduce the amount of empty trucks, find the optimal loading and unloading volumes, etc.

Figure 68 Biomass mobilisation – Main strengths and constraints



Source: Pöyry interviews (average grade on a scale from 1=low to 6=high)

Prices

A biomass producer states that, despite possible future price increases, the price development which has been observed the last ten years will not continue in the same pace in the future. The ceiling for how much energy plants are willing to pay has been reached and also the market is not growing as fast as before. A representative from a research institute thinks that prices for primary forest fuels (green chips) and industrial by-products will increase in the future. The sawmilling industry in Sweden is under pressure and sawnwood production will drop, thus the volume of industrial by-products will decrease. The price of willow (chips) follows the price of forest chips. The price for straw is 25% lower compared to willow. The price for straw is expected to increase for animal bedding purposes, however not for energy purposes.

Price transparency is regarded to be modestly sufficient, with an average score of 3.2. (scale from 1=low to 6=high). The pricing of biomass is currently a problem due to differences in the units used by the foresters/forest industry (volumes) and the energy companies (energy value). This is not an adequate system because it creates mistrust between players in the supply chain.

8.1.2 Regulatory and legal framework and pricing incentives

The majority of the stakeholders share the opinion that the regulatory and legal framework is able to support the bioenergy sector development in Sweden. A representative from a national authority confirms this statement and stresses that Sweden is expected to fulfil the RED 2020 target of 49% already beforehand (the share is now 48%). This illustrates that the existing support schemes are well-functioning and their structure does not need to be changed much. Other stakeholders mention the CO_2 tax as a stable and sustainable tool. A representative from a research institute also mentioned that there are many countries that have the same base fundamentals, however the framework and the incentives have not been good enough. A market mechanism mentioned that enhances a well-functioning biomass market is the pellet standard. There is trustworthy information available about pellets, prices and the delivery standards.

Some of the measures mentioned that can stimulate further sector development include:

- For short rotation energy crops, reduce the hesitation and the restrictive opinions regarding this type of plantations. A more liberal view will lead to increased cultivation in the future.
- Biomass for energy is a low priced commodity, therefore technical development in primary production may need more support in the future (so far a lot has been done on the market side, instead finances should be provided to develop the supply side/technological development).
- Research is required regarding environmental issues that today yet lack clear answers/solutions and may lock up otherwise available biomass (e.g. extraction of stumps).
- Market mechanism that hinders the biomass market from functioning well are the communication problems caused by the use of different unit between the energy industry (MWh) and the foresters/forest industry (m^3). There is a need to review this system in order to create a better flow.

Another important issue raised by a large biomass producer and a national organisation, is that the regulatory and legal framework is not sufficient for the development of 2nd generation liquid biofuels for the transport sector. Currently, heat and electricity are not the main challenges. Electricity is 90% renewable and heat 80-90%, while the transport sector is still dominated by fossil fuels and renewables account for only 5%. A question that arises is how should we utilise the forests in order to increase the use of biomass in the transport sector?

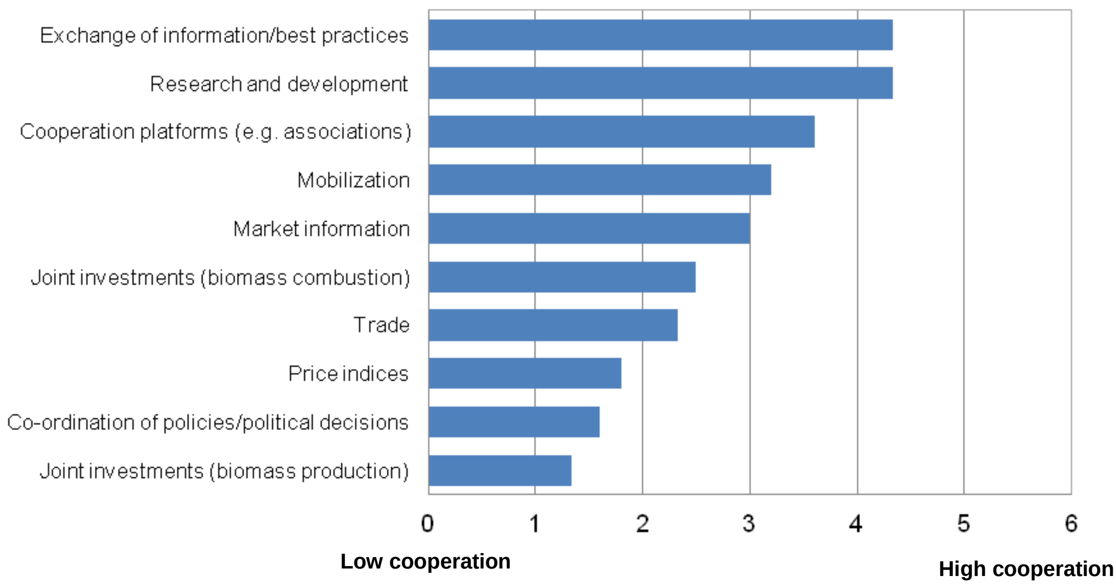
Sustainability criteria

The general opinion shared by the stakeholders is that the discussion about sustainability criteria for solid biomass does not currently appear as a problem in Sweden. A national authority underlined that there is already sufficient legislation that regulates this type of issues (e.g. certification rules). If sustainability criteria on solid biomass are introduced in Sweden it will imply bureaucracy and a more administrative burden for small forest owners and farmers delivering biomass for energy purposes (will not be able to deliver the same biomass volumes to the market). A possible implementation can also create a trade barrier. A question raised by the representative, if the delivery of industrial roundwood is not subject to the sustainability criteria, why should there be restriction for solid biomass?

8.1.3 Current Nordic cooperation in the field of solid biomass

As illustrated in Figure 69, the main types of Nordic cooperation include exchange of information/best practices, research and development and the existing cooperation platforms (e.g. Nordic bioenergy associations).

Figure 69 Current Nordic cooperation in the field of solid biomass



Source: Pöyry interviews (average grade on a scale from 1=low to 6=high)

Some of the examples mentioned related to these topics include:

- Joint research programmes between the Nordic countries (e.g. Skogforsk in Sweden). Participation in EU projects such as CA-RES (www.ca-res.eu, the Swedish Energy Agency is a part of working group nr. 9 “Biomass mobilisation”), REFUREC (www.refurec.org), etc.
- Nordic conferences (e.g. World Bioenergy), networking, lobbying, study visits, etc.

- Exchange of information/best practices, knowledge and discussion take place on several levels; governmental, research community, companies and on an individual level.
- Nordic bioenergy associations: FINBIO, NOBIO, SVEBIO and DANBIO. Also a European Biomass Association (AEBIOM) and other organisations such as the European Energy Council (ERC).
- Financing or co-financing of energy related projects, e.g. Nordic Energy Perspectives (NEP)

8.1.4 Future outlook and opportunities to enhance the Nordic cooperation

The general opinion shared by the stakeholders is that there exists some cooperation between the Nordic countries, however it can be improved.

Stakeholder	Type of cooperation / Recommendation	Description
National authority	Cooperation between authorities	➢ Increased cooperation between the energy agencies in each country in the Nordics. Have regular forms and channels of communication regarding relevant issues and questions (e.g. sustainability criteria on solid biomass). Currently many of the topics are discussed on EU-level, but it would be useful to have something similar on a Nordic level.
	Statistics and price information	➢ Increase the availability of statistics and price information (expert knowledge needed). ➢ Find a common method for calculating biomass potentials by defining a united system (based on certain assumptions). Currently, many ways are used for calculating potentials, making it difficult to compare data between countries.
Several stakeholders	Coordination of support measures	➢ Coordination of support measures in the future. (e.g. bilateral agreements such as joint electricity certificate system between Sweden and Norway). Learn from the political systems in each country → what works well? ➢ Harmonisation of the support system/rules necessary to create better prerequisites for trade/cooperation.
	Information platforms/communication channels	➢ Establishment of a common Internet-based platform for all Nordic countries in the field of solid biomass. The aim would be to inform and promote biomass for energy purposes. ➢ Inform about the current projects in the fields of biomass, etc.
Research institute	Technology development	➢ Find solutions for development of technology (stumps, branches and tops, etc.).
	Meeting platforms	➢ Organisation of more events where stakeholders can meet ➢ Conferences
	R&D	➢ Coordination of research → which are the current activities? Avoiding repeating activities. ➢ Promote more synthesis work among senior researches
Biomass producer	Biomass processing	➢ Possibility to increase the cooperation regarding further processing of biomass between the Nordic countries. ➢ Possibility to build gasification plants in e.g. Sweden? Combine raw material, capital and end-use. E.g. how can Norway and Sweden cooperate in the field of liquid biofuels from the forest (not just technology, but also financial cooperation)?
	Knowledge sharing	➢ How to utilise agricultural resources? How can we increase the use of straw? → learn from Denmark ➢ State and forest industry in much more close cooperation in Finland. What can we learn from it?

8.2 Finland

8.2.1 Market assessment

During the last decade investments were made in 300 biomass boilers and 53 CHP plants in Finland and the same investment speed will continue according to energy industry stakeholder interviewed. Also other stakeholders shared the opinion that the bioenergy and biomass market will keep growing in Finland. Currently, wood-based biomass dominates the market. Use of agricultural biomass in Finland is marginal, and according to interviewed research institute representative also difficult to increase. According to the stakeholders, the typical national solid biomass transport distance ranges between 10-120 km for woody biomass, and on average, a ~50 km distance was stated. For agricultural biomass transport distance, “about 80 km” and “10-40 km” were mentioned.

Some moderate changes are likely to happen in the consumption of different wood based solid biomass assortments in the future according to most of the stakeholders interviewed. Many stakeholders commented that the biomass directly from forests will remain the largest biomass assortment and grow further due to e.g. need to fulfil the 20-20-20 targets and abundant forest resources. This development is however affected by e.g. the development of forestry industry harvesting volumes, energy prices, support schemes and investment possibilities. Of the forest biomass assortments, stumps and logging residues were seen to have most growth potential. According to energy company stakeholder, especially the share of stumps may grow if quality can be improved, utilisation becomes more competitive and sustainability will be assured. The amount of forest industry’s by-products changes annually due to market cycles of sawmill industry. An energy industry representative stated that the total amount is decreasing gradually due to the improved technology and wood utilisation. The same stakeholder stated that an increasing part of the sawdust may be utilised in pellet production in the future. Also, the amount of torrefied wood fuels utilised may grow according to energy company stakeholder and imported torrefied wood might become competitive in the long run.

The major reason that hinders the wider utilisation of agricultural biomass in Finland according to the interviews is the barriers in the current combustion technology. Most of the current energy plants and boilers in Finland are not designed for agricultural biomass. There is also a need for further R&D to develop the usability of agricultural biomass in large-scale according to representative of leading research organisation. Despite the barriers, consumption of all biomass assortments is potentially under consideration by the energy industry and an energy company stakeholder stated that the consumed amount of agricultural biomasses may grow in the future. However, according to the stakeholder, availability and competitiveness of agricultural biomass depend heavily on agricultural support schemes and land availability.

Trade

Most of the other stakeholders interviewed stated that the foreign trade of biomass is likely to increase between Finland and counterparts and also internationally. Regarding the current situation, an energy industry stakeholder stated that currently the energy assortments, mainly woodchips, are exported to Finland only from Russia, Estonia and Latvia and not from Nordic countries due to the high price level. In the future, trade will be both intra-Nordic and with other countries and will grow due to improved logistics, diverse subsidies and incentives, and promotional campaigns according to bioenergy related company. Also, the reduction in pulp production is likely to affect positively on the traded amounts of energy biomass. According to a biomass producer the trade is likely to increase especially between Russia, Sweden and Finland as there is a lot of unutilised biomass potential in Russia. Especially the ship transport of wood between Russia and Sweden is likely to increase or at least remain stable because Swedish end-users are able to pay good price for wood. The growth of biomass flow from Russia to Finland may be hindered, however, by the high logistics costs in Russia. According to energy company stakeholder, international wood fuel trade will grow and mainly processed fuels will be traded but also raw materials such as roundwood, but there will be a local lack of competitive fuels in some locations. It was also stated that trade will grow due to subsidises on biomass utilisation and logistics as biomass can transported e.g. on barges easily, and it is likely that continental ships will import increasing amounts of wood chips from e.g. Canada to Europe in the future.

Despite the mainly positive overall growth prospects given to biomass trade, some stakeholders also indicated that there may also be barriers that reduce biomass trade in the future. One stakeholder stated that the pellet exports from Finland to Denmark and Sweden might decrease in the future if new incentives to utilise wood pellets in large scale will come in force in Finland, and another stakeholder continued saying that Finnish pellet industry is not able to supply to Nordic countries due to high logistical costs and high raw material cost. According to biomass producer, importing of biomass, at least to Finland, from the Baltic States is likely to decrease in the future due to the intensifying utilisation within the Baltic States themselves. Also, according to representative of bioenergy related company, Baltic Sea shipping costs will increase due to CO2 fees that will be higher than in EU level generally, which is likely to affect the biomass trade in the region.

Biomass mobilisation – strengths and constraints

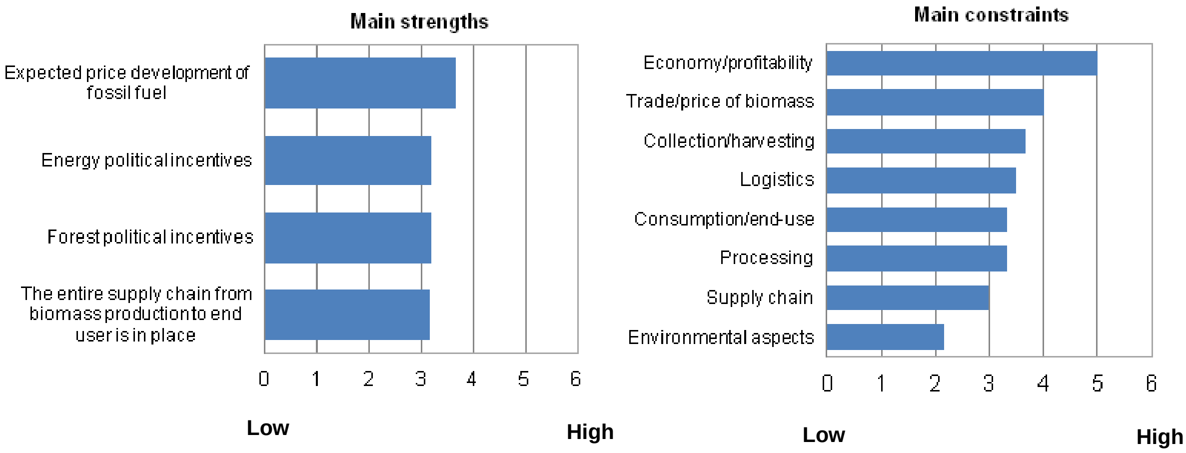
According to the stakeholder interviews the economy and profitability of biomass as well as trade and price of biomass were the highest constraints related to biomass mobilisation for energy purposes in Finland (Figure 70). A research organisation representative stated that biomass is too expensive fuel compared to coal and much more biomass would be used if price was 20% lower. Many stakeholders mentioned that the profitability and availability of biomass trade vary between regions. Especially the high price of biomass in Eastern Finland is a high constraint for biomass mobilisation according to biomass producer. The stakeholder also mentioned that procurement of small diameter wood is and will be a big challenge due to the bad economic profitability. In addition, export duties from Russia were mentioned as economic constraint in biomass mobilisation.

Constraints in biomass mobilisation in supply chain, processing and logistics of biomass mentioned by the interviewed stakeholders were e.g. 1) collection and harvesting of small diameter wood as well as logistics for large scale users of biomass, 2) pelletizing and baling which are too expensive biomass processing methods, 3) biomass storing which may have room for improvement, 4) biomass is not easy to combust which is a constraint in its utilisation, 5) unclear sorting of biomass between energy and pulp industry end users, 6) bad road infrastructure and climatic problems which can lead to practical difficulties and regional variations in biomass trading, 7) insecurity in bioenergy business which lowers willingness to investment in biomass logistics, 8) collection and harvesting of biomass is very dependent on consumption needs of forestry industry. It was also mentioned that further technical development would also be needed in processing of biomass.

Too many and constantly happening changes in the energy political incentives and feed-in-tariffs as well as co-existing subsidies and emission taxes were also seen as constraints in biomass mobilisation by some stakeholders. According to biomass producer there should be firm long term political decisions made on the subsidies, and regulatory mobilisation of wood markets should be improved to stimulate the sector development as there is a lot of under-utilised wood potential in Finland. Energy industry representative stated that the subsidies should be directed towards the end users of biomass so that the biomass would remain available for domestic use and not be exported. Also, district heating fuelled by biomass should be eligible to receive feed-in-tariff and not only electricity. The stakeholder further stated that bureaucratic bioenergy investment pre approval system is a market mechanism that hinders the biomass market from functioning well in Finland.

Competition from biomass between pulp and paper and energy use was also mentioned as constraint in biomass mobilisation by some stakeholders. Some stakeholders also mentioned that it may be hard to find enough skilled staff to work in forests or fields in the future, which may affect on biomass mobilisation. Also, the forest ownership structure in Finland was seen as a hindering factor in biomass mobilisation by one stakeholder. In general, the environmental aspects of biomass utilisation were seen as rather low constraint in biomass mobilisation (Figure 70) and expected price development of fossil fuels was seen as the biggest strength in the biomass mobilisation according to the stakeholder interviews (Figure 70). Energy prices in general are likely to increase and fossil fuels will be left without subsidies in the future which will enhance the biomass mobilisation, summarised a representative of bioenergy related company. The stakeholder also stated that strengths in biomass mobilisation are incentives to increase biomass supply such as support for forest growth and forest thinnings, existing energy political incentives to support biomass mobilisation (however there is less support than in many other countries) and national heritage of using wood in Finland.

Figure 70 Biomass mobilisation – Main strengths and constraints



Source: Pöyry interviews (average grade on a scale from 1=low to 6=high)

Prices

The biomass price transparency is neither low nor high (average score of 3 out of 6) in Finland according to the stakeholders. However, the stakeholder comments indicated that price transparency has room for improvement. According to one stakeholder, there is very little reliable price information available on monthly basis and there is a total lack of reliable country-wise price indices for biomass. According to the stakeholder, better price information and information on traded volumes would not only enhance the biomass mobilisation but also allow the use of various price risk management tools. A representative of an energy company stated that biomass should be offered to market with product specifications and an open market place with standardised products and contracts should be available. A research institute representative commented that specific prices for different types of forest chips (chips made of logging residues, whole trees, stumps, small diameter wood) are missing in Finland as in the current price data for forest chip all assortments are aggregated. According to the stakeholder, e.g. small plants using higher quality forest chips (chipped from e.g. small diameter wood) need to pay more than officially reported forest chip prices indicate. Also, the data on the end user of chips is not sufficient enough according to the stakeholder. However, according to some stakeholders, a change for better in price transparency is expected as e.g. FOEX is developing biomass price indices which enhance market transparency, and there are also other upcoming changes expected for better price reporting in Finland.

The stakeholders that shared their views on future development of biomass prices seemed to think that at least the prices for forest chips and firewood will increase. According to one stakeholder, the price for forest chips is likely to increase because forest chips cannot be subsidised forever. Another stakeholder stated that the price will increase as more taxes on peat are expected. The expected increasing share of small diameter wood in the forest chips is likely to increase price of forest chips according to one stakeholder. The prices for forest chips and firewood are expected to increase because demand for both is already high and increasing, and the prices for both assortments follow other energy prices and thus are likely to increase. According to the stakeholders, prices for forest industry’s by-products will either remain stable or increase in the future due to e.g. decreasing amount of forest industry’s by-products available in the future, rising costs and increasing consumption. Views of stakeholders differed regarding the future pulpwood prices. One stakeholder commented that the both hardwood and softwood pulpwood prices will remain stable because since Russia has joined the WTO there will be less export taxes, and also more growth in Finnish forests will provide chance for safe supply of wood. One stakeholder predicted that the softwood and hardwood pulpwood prices will decrease due to low pulpwood demand in the future. Two stakeholders commented only the price development of softwood pulpwood, one stating that price will increase and the other, in contrast to that, commented that the price will decrease due to decreasing consumption. Only one stakeholder gave price prognosis for pellets stating that the price is likely remain stable, and no comments on the price development of the agricultural biomass were made by the stakeholders probably due to the very limited production amounts of those assortments in Finland.

8.2.2 Regulatory and legal framework and pricing incentives

According to two thirds of stakeholders the current regulatory and legal framework in Finland is not able to support the bioenergy sector development in terms of increased supply, distribution and use. The stakeholders interviewed representing energy and biomass producers all stated that unpredicted and frequently happening changes in subsidy policies, thus unstable political decisions, cause a great deal of trouble for the sector as it is hard to make long term (investment) decisions in unstable policy environment. To stimulate the sector development, less support models and longer perspectives are required according to energy industry stakeholder. There were varying comments about whether the support should be directed to the biomass suppliers or to the consuming end. According to two stakeholders the domestic biomass should be promoted by giving incentives to biomass sources, while one stakeholder stated that that support should be directed towards the end users of biomass so that the biomass would remain available for domestic use and not be exported. According to a research organisation representative, there is not very much support for use of biomass in small-scale e.g. use of pellets in heating is not increasing in Finland. Another representative of research community stated that global unpredictable carbon policy is the most serious threat for forest fuels in Nordic countries.

Sustainability criteria

The stakeholders interviewed had rather positive views about the current biomass sustainability level in Finland and e.g. the sustainability guideline for biomass that exists in Finland was mentioned as a good tool. Also, forest certification including criteria for energy wood was mentioned as a good instrument. Two stakeholders brought up that the EU level sustainability policies for bioenergy may affect the sustainability criteria in Finland in the future. Despite the overall positive views about the level of bioenergy sustainability in Finland, stakeholders also raised some concerns regarding it:

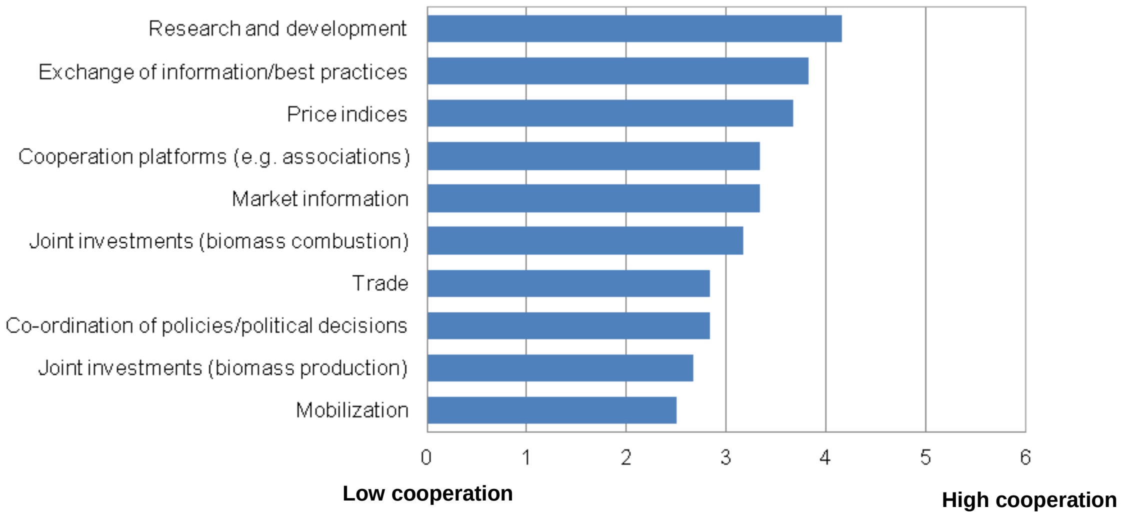
- If more small-diameter wood will be harvested in the future there is a risk that harvesting damages caused to the remaining trees and soil will increase.
- Finland should not be penalised but rewarded in the EU level for the early development of the bioenergy production by the forest products industry.
- Question of how much biomass should be left into the forest is still open and this may cause changes in future biomass mobilisation.
- Economic sustainability of biomass can be poor especially from forest owners' and machine entrepreneurs' points of views.
- There are too heavy systems to prove the biomass sustainability, e.g. small operators are not in the same category with big operators.
- Sustainability of imported wood is always a question.
- There is no need for overlapping sustainability schemes in forest management and agriculture.

8.2.3 Current Nordic cooperation in the field of solid biomass

According to the stakeholder interviews there is rather high Nordic cooperation in the fields of solid biomass research and development as well as in exchange of solid biomass related information and best practices (Figure 71). According to the interviews, the level of Nordic cooperation was lowest in the fields of solid biomass mobilisation and trade as well as in joint biomass production investments (Figure 71). Many stakeholders were not aware of any ongoing initiatives that aim at promoting Nordic bioenergy cooperation. However some forms of on-going cooperation were mentioned. According to research organisation there is Nordic cooperation in trade of solid biomass through EUBIONET III project and the Nordic countries are also active in EU level in energy technology platforms for biomass. According to bioenergy related company there is Nordic cooperation in the trade of pellets which works well, and there is also some R&D cooperation between research institutes and between universities. Many stakeholders were aware of and had participated bioenergy related conferences held in Nordic countries. However, one stakeholder stated that conference programs have not seemed very interesting which does not encourage participation. Many stakeholders also mentioned that they cooperate or have strategic partnership with Nordic sister-organisations in e.g. bioenergy research and trade information related fields. E.g. the energy industry stakeholder has had cooperation with sister-organisations in Denmark and Sweden regarding district heating, but these have been mainly separate projects with no upper level coordination.

The stakeholders seemed to have rather varied attitudes towards Nordic cooperation platforms. According to bioenergy related company cooperation platforms such as Nordic bioenergy association are nice ideas but it is difficult to come up with strong but homogeneous action items as national targets and potential tools are very different. A biomass producer stated that Nordic cooperation originating from political forums is very likely not to succeed and cooperation that is based on the market mechanisms is more likely to succeed. However the stakeholder mentioned that maybe the planned merging of bioenergy associations in Finland will enable the more coordinated cooperation also at Nordic level.

Figure 71 Current Nordic cooperation in the field of solid biomass



Source: Pöyry interviews (average grade on a scale from 1=low to 6=high)

When the stakeholders were asked what are the most critical success factors/barriers to achieve the targets to increase use of biomass in EU countries by 2020 the following issues were mentioned as threats or barriers in achieving the 2020 targets:

- Low coal price
- Uneven division of initiatives which may make pulp and paper industry and energy industry enemies fighting for raw material
- Lack of price transparency
- Not enough raw material available in Europe
- Targets to increase the use of solid biomass for energy purposes by 2020 are set too high

Factors or solutions that would enhance the possibility to reach the targets by 2020 were also mentioned, including:

- Political decisions in Finland on support mechanisms should be more long term based and stable, not overlapping and changing constantly.
- Harmonisation of taxes, subsidy schemes and regulations should be carried out.
- Enhanced cooperation between forest and energy industries and good availability of raw material.

Types of Nordic cooperation and/or recommendations to enhance the cooperation that were mentioned in the stakeholder interviews are summarised below:

Stakeholder	Type of cooperation / Recommendation	Description
Several stakeholders	More cooperation in enhancing the trade and price transparency on Nordic level.	➢ Market rules, e.g. definitions of bio-energy, subsidies, taxes, market information availability, should be as equal as possible in all Nordic countries.
	There should be more research carried out regarding the bioenergy sector in Nordic level.	➢ There has already been research regarding the climate (change) in Nordic countries.
Research Institute	Actions to promote Nordic biomass cooperation should be taken after common 2020 targets for all Nordic countries are clear.	➢ Most effective Nordic cooperation takes into account the Nordic conditions and common EU policy.
Biomass producer	More info on the status of reaching the 20-20-20 targets should be available.	➢ There is in general need to increase the information on the energy sector development in Nordic and European level.
	Availability of energy wood in the future is unclear and more precise predictions would be needed in that field.	
Energy industry	Role of researcher exchange could be increased.	➢ There has been a project coordinated by the Nordic Council of Ministers that has included trainee and researcher exchange between the Nordic countries.
Bioenergy related company	Nordic countries could work more together to jointly bring their common views on bioenergy issues forward at EU level.	➢ There are potentially harmful methodologies proposed on the EU level penalizing those who have promoted sustainability in an early stage. Nordic countries could work together to remove such threats on EU level.
	More seminars and conferences.	➢ Seminars and conferences are most effective forms of Nordic cooperation. However, energy industry and forest industry representatives do not currently typically attend the same conferences.
Research organisation	Nordic funding for the supply chain development should be available.	➢ Technology development and transfer in wood supply are the most effective forms of Nordic cooperation.

8.3 Norway

8.3.1 Market assessment

Trade

Today, most of the trade occurs in the eastern and central parts of Norway. Due to high transport costs, trade mainly takes place in the local and regional markets. The typical national solid biomass transport distance reported by the stakeholders ranges from 5-80 km. Transport distances in the eastern part of Norway, Oppland and Hedmark, are typically shorter. This is also where the volumes are highest and many transactions take place. Moreover, the type of biomass assortment also influences the transport distance. Assortments with high energy content, such as pellets, are typically transported over longer distances than chips.

About half of the commercial stakeholders stated that they did not undertake cross-border trading. The main reason for this is the high transportation costs. Furthermore, one of the producers claimed that the net-grants for harvesting forest residues are low when taking into account transportation costs. Other commercial stakeholders pointed out that the main trade partner is Sweden and the main assortments include forest residues and industrial by-products. Most stakeholders believe that the intra-Nordic trade volumes will increase in the future and main trade flows going from Norway to Sweden. Increased use of co-firing in coal plants will lead to increased demand of pellets and chips in continental Europe. This could facilitate export potential for Norwegian biomass producers in the near future.

Several stakeholders expect that the introduction of “Biowood Norway” could affect the cross-border trade. “Biowood Norway” states, on their own website, that the company will focus on chips imports from USA, Canada, Liberia, Russia and the Baltics, whereas the final product (pellets) will be sold mainly to the UK and the continental Europe.

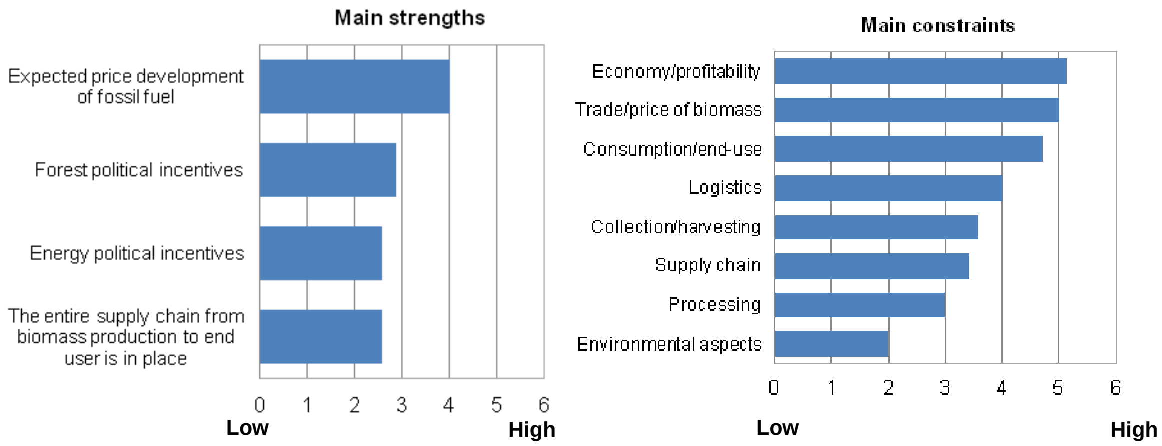
Biomass mobilisation – strengths and constraints

As illustrated in Figure 72, only the expected price development of fossil fuels is considered to be beneficial for the bioenergy sector in Norway. Expectation of increasing fossil fuel prices, will lead to increased competitiveness of bioenergy in the future.

The opinions regarding the energy and forest political incentives differ between the stakeholders. Two players think that the energy and forest political incentives are strong and mentioned the Enova programs (energy political), the bioenergy and chips production programs (forest political). Other stakeholders claim that the political incentives are in general weak. The main opinion is that policies must become more predictable and stable over several years. In addition, it was pointed out that the coordination between forest and energy policy makers must be improved.

Regarding the main strengths, most of the themes are awarded an above average grade (which means that they are considered as constraints). The only exception is environmental aspects, considered rather to be a strength of bioenergy. In contrast, economy/profitability, consumption/end-use and trade/price of biomass are all regarded as constraints for the mobilisation of biomass. One of the issues raised is that electricity has traditionally been the main heating source in Norway, thus most of the residential houses do not have waterborne heat systems. The infrastructure for district heating is not in place either. This makes it both difficult and expensive to develop more heating systems based on biomass. In addition, several of the stakeholders pointed out that the settlement pattern scattered, which is another obstacle for the bioenergy market development. Another issue is the fact that Norway is expected to have a high energy surplus in the coming years. This is mainly a result of the green certificate scheme between Norway and Sweden which will facilitate 26.4 TWh by 2020. In Norway, it is expected that wind power and hydropower will make up the increased renewable production. The high energy surplus could result in lower electricity prices. Low electricity prices could make it less attractive to install heating systems based on bioenergy, and thus lead to lower demand for bioenergy in the future.

Figure 72 Biomass mobilisation – Main strengths and constraints



Source: Pöyry interviews (average grade on a scale from 1=low to 6=high)

Prices

The stakeholders assessed price transparency of solid biomass for energy purposes to be average (grade 3). The interviewed consumers of biomass were in general satisfied with the price transparency and believe that the prices they are paying are competitive. One of the producers pointed out that biomass is not a product “off the shelf” and that it is difficult to standardise prices when the products differ. On the other hand, most of the stakeholders recognised that more price transparency is needed. The statistics today is based only on a few sources, thus it is difficult to know if it reflects the actual prices in the market. In addition, the volumes are low and there are only few biomass suppliers in Norway today. This could lead to variations in prices between suppliers and regions.

One of the stakeholders pointed out that the relative price of biomass must decrease over time in order to become more competitive compared to other energy sources. The bioenergy sector is a young in Norway, this explains the high prices. However, growing markets and increasing volumes could lead to cost efficiency and lower prices in the future.

8.3.2 Regulatory and legal framework and pricing incentives

Only two stakeholders think that the current regulatory and legal framework in Norway is able to support the bioenergy sector development in terms of increased supply, distribution and use. The green certificate scheme and the role of Enova were mentioned as important instruments to achieve growth in the bioenergy sector. However, the majority of the stakeholders think that the current regulatory and legal framework in Norway is not sufficient. Low electricity price is the most prominent obstacle. The electricity tariffs are lower compared to other Nordic countries. Increasing the tariffs on a “Nordic” level could make bioenergy competitive in Norway. However, the stakeholders recognise that increasing the tariffs would be an unpopular political decision. On the other hand, electricity prices could increase in the future for other reasons. A policy that promotes building more electricity interconnectors to the European continent could lead to higher electricity prices in Norway. This combined with higher CO_2 prices in Europe could lead to bioenergy becoming more competitive. Another important issue pointed out is the need for higher investment support from Enova. In addition, it was emphasised that the regulatory and legal framework must become predictable and stable. This will reduce the risks for the potential market players who want to invest in e.g. district heating plants based on bioenergy.

A respondent mentioned that the most important obstacle for increasing bioenergy consumption is related to the structure of the supply side. Today, most of the Norwegian forests are owned by small-scale farmers which do not receive their main income from forestry. As the stakeholder stated; “harvesting of forest resources is done when they need some money and not to manage their forests”. This is not a problem in itself. The problem, according to the stakeholder, is that “The Act of 28 November 2003 no. 98 relating to Concession in the Acquisition of Real Property” hinders the turnover of forest properties, and furthermore, hinders large scale forest management. Larger forest owners could lead to a more efficient forest management and thus higher harvest of for example forest residues.

Sustainability criteria

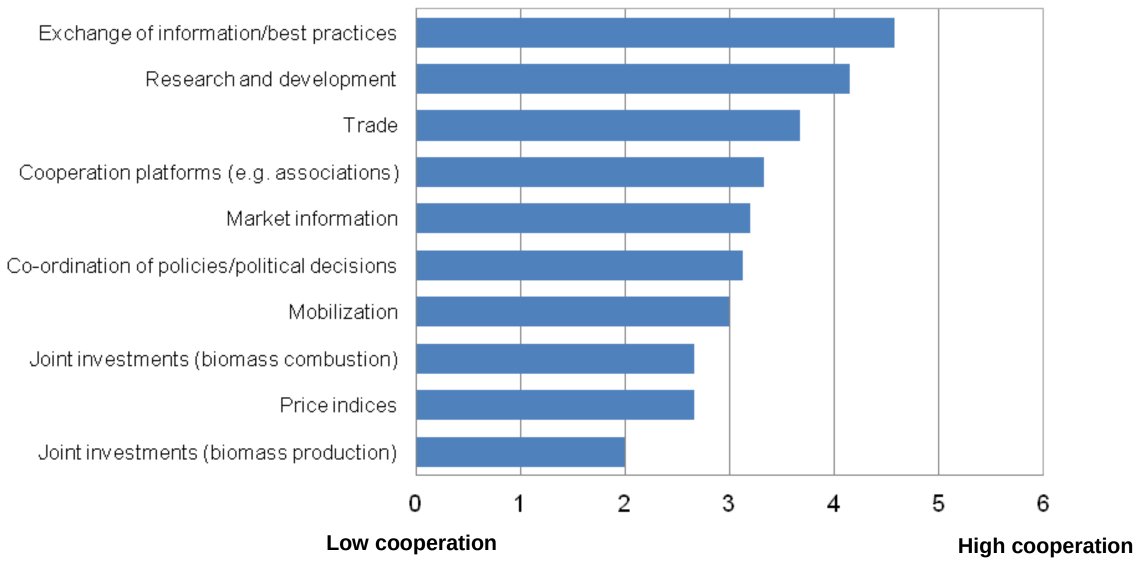
All the stakeholders agree on that there is no sustainability issues related to the current harvest of the Norwegian forest resources. The annual harvest is far below the annual increment and there is, in fact, a large potential to increase the annual harvest. Furthermore, it is claimed that the existing schemes for sustainable forest management are sufficient tools to ensure sustainability.

8.3.3 Current Nordic cooperation in the field of solid biomass

Regarding “Current Nordic cooperation in the field of solid biomass”, about half of the themes have been awarded above average grades. The stakeholders pointed out the themes “Exchange of information/Best practices” and “Research and development” to have a high degree of Nordic cooperation. Several of the stakeholders emphasised that exchange of experience form the other Nordic countries is an important tool in the process of developing the bioenergy sector in Norway. The Nordic neighbours provide with practical experience with regard to operation of and investments in plants in Norway. For instance, Norwegian companies conduct site visits and meetings in the process of developing new combustion plants. In addition, the participants in the study pointed out that there is currently a high level of cooperation between universities and research institutions in the Nordic countries.

In the case of “Co-ordination of policies/political decisions”, the stakeholders differed in their views. Two of the authorities and one of the producers awarded grade 5 while the rest of the stakeholders (mainly consumers and producers) awarded grade 2. On the positive side, the agreement on a Green Certificate scheme between Norway and Sweden was mentioned. In addition, one of the authorities pointed out that the existence of the Nord Pool Spot power exchange is a proof of high degree of Nordic policy co-ordination. On the negative side, it was pointed out that the big differences in tax on electricity consumption among the Nordic countries, is a proof of a low degree of co-ordination regarding policies/political decisions.

Figure 73 Current Nordic cooperation in the field of solid biomass



Source: Pöyry interviews (average grade on a scale from 1=low to 6=high)

8.3.4 Future outlook and opportunities to enhance the Nordic cooperation

In general, nearly all the stakeholders pointed out that Norway must adopt the Nordic attitude towards bioenergy. It must be stated clearly that bioenergy is a renewable energy source, and bioenergy must be given the same support as hydropower and wind power. According to the respondents, one of the most important measures to improve the competitiveness of bioenergy is to increase the Norwegian taxes on electricity consumption.

Regarding the opportunities to enhance the Nordic cooperation, the respondents had various opinions on what could be done to improve the conditions of bioenergy in Norway. Several of the stakeholders pointed out that the Nordic countries should cooperate on and facilitate investments in more interconnectors of electricity to Central Europe. More electricity interconnectors from the Nordic countries to Central Europe could increase the prices of electricity. As mentioned earlier in the report, the EU-countries will increase their demand for bioenergy in order to meet the renewable energy targets by 2020. A number of the producers and consumers pointed out that this could facilitate an opportunity for the Nordic countries to become exporters of energy to Central Europe. In this context, one of the national organisations proposed an opportunity for Nordic cooperation. His proposal was that commercial actors in the Nordic countries should join together on a large scale investment that could serve Central Europe with bioenergy. This could for example be investment in an industry producing liquid biofuels, biogas or pellets, or other types of bioenergy products with high energy content. The Nordic countries are richly endowed with forest resources that could be utilised for this purpose. In addition, one of the Norwegian pulp and paper factories is closing down (Follum). This will free up forest resources that could be used for bioenergy purposes. The stakeholder stated that it should not matter in which country the industry is placed, however, it should be close to where the resources are located. This will free up forest resources that could be used for bioenergy purposes.

Furthermore, one of the producers stated that it is important to establish common environmental standards for bioenergy in the Nordic countries. Firstly, it was recommended that common quality standards for the different biomass assortments should be established in the Nordic countries. This would reduce the uncertainty for the market participants. Secondly, it was recommended that a common certificate scheme for forest residues should be established. This common certificate scheme should, amongst other things, define how the forest residues should be harvested and how much is sustainable to harvest. This is useful to forest landowners and managers as tools to help them ensure sustainable stewardship of their land.

In general, the stakeholders stressed that it is important to continue the Nordic cooperation within research and development projects. The research and development projects should result in a common knowledge platform available for all stakeholders within the bioenergy sector.

A couple of respondents also underlined that, because the development of the bioenergy sector in the Nordics countries are at different levels then the appropriate political instruments also differs. In Norway, there is a need of developing most of the levels of the supply chain, whereas in Sweden, the supply chain is already working efficiently and the volumes are big. This large difference in the level of development of the bioenergy sector makes it less applicable to coordinate political instruments targeting the bioenergy sector. Different types of cooperation forms recommended by the stakeholders are presented below.

Stakeholder	Type of cooperation / Recommendation	Description
Biomass producer	Common certificate scheme on forest residue harvesting	Establishment of a common certificate scheme for forest residues. It must be made a common certificate scheme on how the forest residues should be harvested. This is useful to forest landowners and managers as tools to help them ensure sustainable stewardship of their land.
	Standardisation of products	Establishing common quality standards for the different biomass assortments in the Nordic countries.
Several stakeholders	Knowledge platform	The result of continued cooperation within research and developments.
National organisation	Joint investment in bioenergy industry	Commercial joint investment in a Nordic industry focusing on biofuel, biogas or pellets that could be exported to the Continent.

8.4 Denmark

8.4.1 Market assessment

According to the stakeholders, the bioenergy sector development in the short and medium term can be divided into three key segments – the growth in biomass use at the large co-firing plants, local district heating plants and small scale end use. The business case has been the best one so far for producers replacing coal with wood pellets in large scale CHP plants. There are however voices raised for the improvement of the bioenergy sector incentive schemes for the heat generation in particular in large scale CHP plants and district heating plants in order to achieve the aspired renewable energy goals across the country. This is a topic that is currently being negotiated in connection to the new Danish energy agreement.

The biomass assortments currently used for energy generation are mainly wood pellets, straw, forest chips and some small volumes of other wood chips (from industry by-products and energy crops). Private households use firewood, which is often from small diameter pulpwood. To what extent the domestic resource can be extended and cost effectively serve energy production is subject to debate. There is potential to increase both forest chips and straw supply, but whether the energy producers will find these assortments attractive and competitive to imported biomass is unclear.

The Danish renewable energy policies for the use of biomass have focused on incentivising energy generation by means of feed-in tariff and fuel tax exemptions, and thus very limited support mechanisms have been directed for biomass production. So far the Danish state has only incentivised energy crops production in agricultural land, but no direct incentives have been directed to forest chips or straw production. The discussion on sustainability criteria for biomass is high on the agenda at current time and the resource owners see the implementation of such criteria to potentially improve the competitiveness of domestic and Nordic biomass.

In the long-term there is a common understanding among stakeholders that biomass should be mobilised for the highest value added sectors, even in the context of energy, such as biogas or liquid biofuels production, and not necessarily serve the energy sector in direct combustion for heat and power only.

Trade

Denmark differs from the other Nordic countries in that its domestic resource base is rather limited. Bioenergy sector is therefore largely dependent on trade and price development of imported biomass assortments. Most of the imported biomass for energy use is wood pellets through intra-European and intercontinental trade. As the renewable energy plan states, the stakeholders are expecting the sector to develop mostly on imported biomass also in the future.

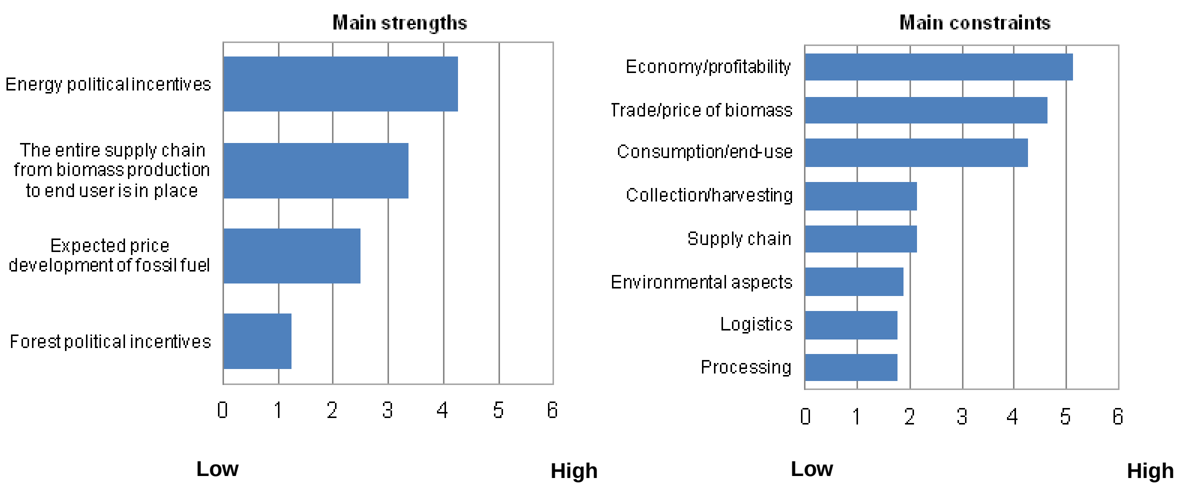
Biomass trade flows are currently suffering from the lack of product standardisation as well as from inefficient logistics operation in the Baltic Sea region. Since there are mostly bilateral agreements and direct deliveries between suppliers and end-users, both volume aggregation and logistics can be inefficient. In addition, the incoherent quality of biomass is reducing market transparency and possibilities for volume aggregation and trading.

Biomass mobilisation – strengths and constraints

There are no direct incentives for forest or agricultural biomass production or mobilisation. The only existing direct incentive is for the establishment of energy crop plantations on agricultural land. The stakeholders emphasise that the political incentives are to the energy generators, not to domestic biomass mobilisation, as the bioenergy sector relies heavily on imports.

The key constraints related to the mobilisation of domestic biomass, as expressed by the interviewees, are the assortment specifications (straw and forest chips), cost competitiveness and volume restrictions. Straw and forest chips are also used to some extent, but many end users prefer wood pellets as a more homogeneous fuel which is well suited for converted biomass or co-firing plants. At least n the recent past, the economics of fuelling by imported pellets has been better for these plants. The costs of biomass (resource, processing and transportation costs) are the main limiting factor of domestic biomass use. If cost competitiveness could be improved and as more dedicated biomass plants are operated, the stakeholders expect that the resource base as such could be expanded. The most ambitions visions indicate that the straw collection could be doubled and 100,000 ha of land could be planted by forests, without impacting the agricultural production or compromising sustainability criteria in any way.

Figure 74 Biomass mobilisation – Main strengths and constraints



Source: Pöyry interviews (average grade on a scale from 1=low to 6=high)

According to stakeholders, improvement opportunities exist. One such in particular is the mobilisation of biomass for local small scale district heating plants. In the regions of Denmark where natural gas grid currently exists, district heating companies are not allowed to change from natural gas based co-generation to biomass based heat generation. The impacts of this to biomass demand are difficult to estimate, however it is the view of some of the stakeholders that was this allowed, it could improve the competitiveness and therefore mobilisation of biomass-to-energy in these areas. Currently the cost effective transportation distance for domestic biomass is estimated to 50km.

Prices

There is low transparency in pricing due to the high number of bilateral contracts. The district heating association collects price information from biomass consuming plants at a monthly basis, however due to the structure of the market, the price transparency remains low. In the quantitative assessment, the stakeholders ranked the price transparency at 1.7/6, hence very low.

Within the forest industry, there have been well-established pricing practices in place, however the energy sector is pricing woody biomass differently. It is looking at buying energy content, which can be difficult for many of the forest owners to transfer into a comparative volume value, as they are looking into selling the biomass to different end uses. Another aspect impacting this is the strong role trading companies are playing in the Danish wood markets as an intermediary. They can have a positive impact for volume aggregation from fragmented forest ownership as they can mitigate some of the risk related to security of supply, however this market structure reduces price transparency. It was suggested by a stakeholder that if the end-users, like district heating companies, would work in cooperation with the forest owners directly, then standards and measurement systems could be developed to improve market transparency.

It is a common view among stakeholders that price transparency improves the functioning of markets and is desirable also in the case of Danish biomass markets. Price indexation is one way to achieving better visibility to market. The other concrete measure that was mentioned is biomass standardisation. This would contain quality specifications as well as sustainability criteria requirements and make the assortments more comparable to one another in the market place.

8.4.2 Regulatory and legal framework and pricing incentives

It is a common view among the stakeholders that the sustainability criteria is the single most important area where the legislator can enable a positive future development in the solid biomass to energy field. For the energy companies this would reduce some of the uncertainty related to biomass sourcing and use, particularly when importing biomass over longer distances or from regions where there is limited transparency in the chain of custody. Also, if the view on biomass would shift, this could influence the investment plans in the energy sector. Therefore, across stakeholders, bringing clarity to sustainability criteria is of key importance. It is also expressed that the preference is towards a common view on sustainability criteria on a European level, so that different national frameworks would not be implemented. Therefore stakeholders express concerns for delays in the process, as common understanding across the EU can be difficult to achieve in the short-term.

Currently, the government is preparing a new energy agreement for Denmark, which is also creating some uncertainty among biomass producers. It is unclear how the government views the domestic resource base and its role in the bioenergy sector development in the future, and as no clear targets are stated, long-term investments either in forestry or agricultural sector are unlikely to take place. If the policy view was clear and supporting the domestic resource use, then it could be pared with an increased support for forestation and allowing high yield species.

Stakeholders also expressed views that there is room to improve the financial incentives towards heating sector on an industrial scale or even for small-scale use.

8.4.3 Current Nordic cooperation in the field of solid biomass

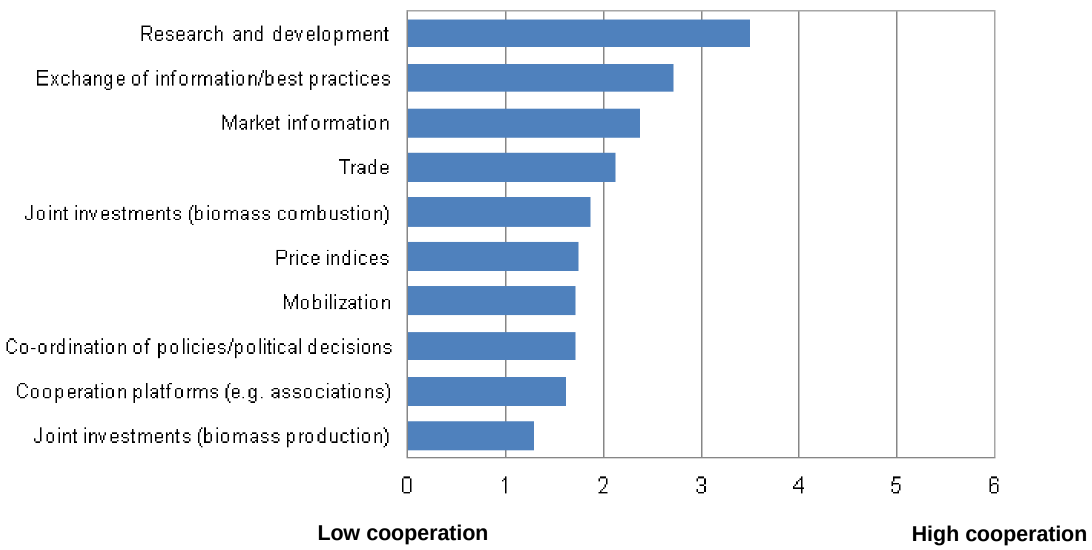
There are several on-going cooperation forms in the Nordic bioenergy sector, however they are scattered and not organised under any umbrella initiative or organisation.

The most established cooperation is in the field of research and development. Scandinavian forest researches work in cooperation on several issues related to resource assessment, forest inventories, forest chips mobilisation, energy end-use etc. Some includes some exchange of information and best practices, however less systematically that could be aspired.

The work towards common biomass standards, particularly for wood pellets, has been an on-going initiative led by the Nordic energy companies. Also measurement systems for biomass specifications have been discussed in cross-country forums. The focus has however been on finding an EU level solution, and not a Nordic level consensus.

Among market mechanisms, trade is the most common one, but limited due to the cost competitiveness of biomass originated from other regions. Due to the limited trade flows, also exchange of market information and price indexation is not developed to the point that could be expected by the stakeholders. Still, many of the stakeholders regard themselves to have knowledge of the current state as well as trends in the Nordic market development.

Figure 75 Current Nordic cooperation in the field of solid biomass



Source: Pöyry interviews (average grade on a scale from 1=low to 6=high)

8.4.4 Future outlook and opportunities to enhance the Nordic cooperation

In general, the Nordic countries have much in common in terms of how they view forestry and its management for the benefit of the related industries. This could form a common base also for the political initiatives at the EU level, however only a few such initiatives have so far been taken. Many stakeholders believe that using this common understanding for co-ordination of policies could be beneficial for driving discussions also at the EU level.

One concrete topic related to this is the sustainability where many stakeholders found that establishing a common view in the Nordic countries about the criteria requirements, could be important in the EU level discussions. Still, the Danish stakeholders were not ready to compromise on their views to reach a common Nordic understanding, which as such is somewhat contradictory.

Trade within the Baltic Sea region is recognised as an area where the Finland, Sweden and Denmark are all present and where (in)efficiencies bring benefits or looses to market players in all countries. This is therefore also seen as an area where cooperation could be improved. One concrete idea that came about in the interviews was the establishment of biomass hubs (1-2) along the Baltic Sea region, where volumes could be aggregated and traded, and logistics optimisation improved.

There could also be more exchange of information and best practices across the countries. At the moment most of this takes place through research initiatives, but in the future a wider and more business focused approach could be taken. Denmark could contribute by its knowledge of agricultural biomass and learn from Finland and Sweden in particular of the forest biomass mobilisation.

Stakeholder	Type of cooperation / Recommendation	Description
Several stakeholders	Political consensus on sustainability criteria	Establishment of a common understanding on sustainability criteria to coordinate effort at EU level.
Biomass consumers and their representatives	Optimisation of trade flows	Establishment of hubs or cooperation platforms to bring aggregation and logistical efficiency to biomass trading
Several stakeholders	Sharing of best practices	Wide and business focused collaboration to learn from best practices, with focus on forestry and agricultural biomass

9. CURRENT STATUS OF NORDIC COOPERATION

Chapter 9 gives a description and analysis of the current status of Nordics solid biomass cooperation, based on the desk-top review and stakeholder interviews.

9.1.1 Market assessment

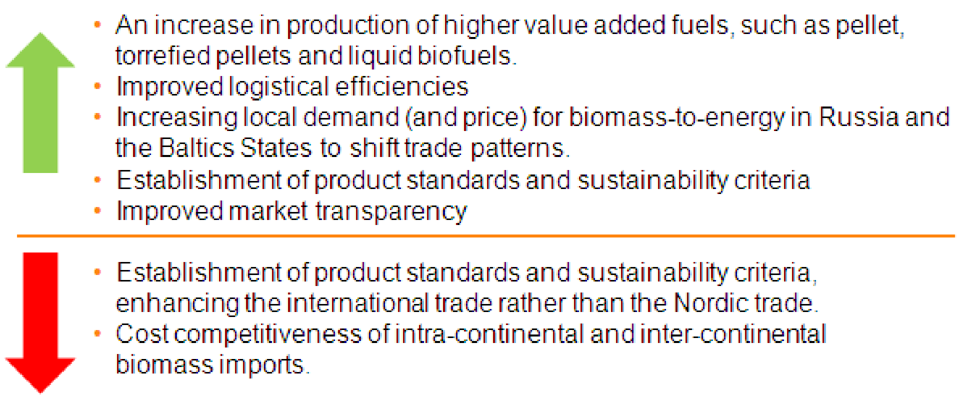
Trade

Trade of biomass is common, particularly in the forest industry sector, but also important volumes of biomass for energy have been imported to the Nordic countries, e.g. pellet imports to Denmark. There are, however relatively low volumes of biomass assortments traded between the Nordic countries, mostly due to the high local biomass prices that are not competitive to imports from other regions, such as Russia or the Baltics.

Biomass trade to the Nordics is expected to increase in the future as a result of increasing demand. In particular, processed fuels such as pellets, torrefied pellets and liquid biofuels are likely to see an increase in traded volumes the coming years. If sufficient improvements to logistics can be made to improve cost efficiency of the transports, then wood chips trade could potentially increase as well. One such example is wood chips trade between Norway and Sweden that could under improved infrastructural conditions increase.

Since much of currently traded unprocessed biomass originates from Russia, the country's position on export duties will be an important factor in the development. As Russia is entering the WTO, the highest proposed duties are not likely to be implemented, and biomass export opportunities are therefore expected to improve.

Figure 76 Factors driving trade of biomass between the Nordic countries



Source: Pöyry interviews

Solid biomass mobilisation

In biomass mobilisation, there are clearly identifiable strengths and constraints in the Nordic countries. The main constraints that the biomass-to-energy sector is facing are very similar across countries. It is the profitability of the operation as well as the difficulties to trade and price biomass that hinder its mobilisation. In Sweden logistical constraints were named as the third largest factor, whereas in the other countries constraints related to the consumption/end-use markets were mentioned. This is not surprising considering that Sweden is the only one of the energy markets where biomass has reached an important share of the fuel markets if excluding the firewood use by private households. In Finland the end-use of peat is restricting the market growth, in Norway the use of electricity for heating and lack of district heating networks and in Denmark, the regional use of natural gas as the primary fuel are all constraining the potential market growth.

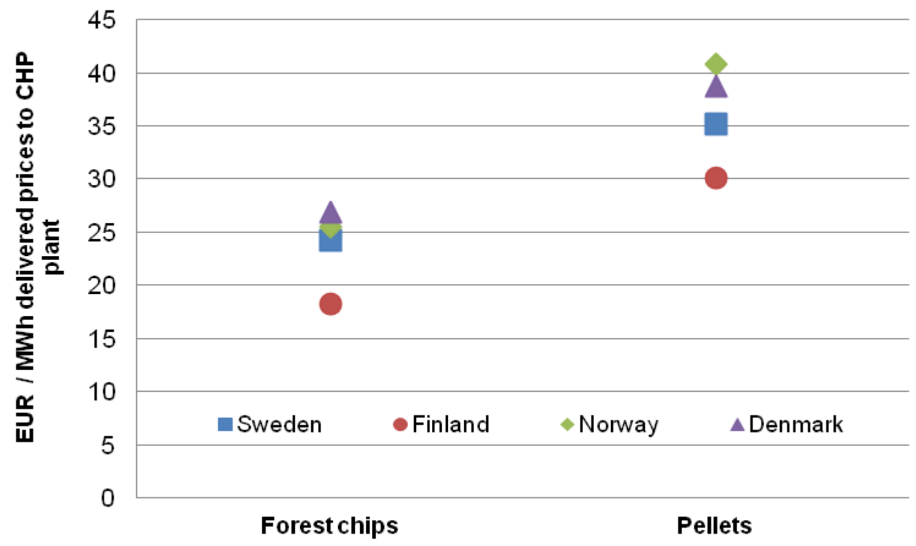
The key strengths, as identified by the stakeholders, are similar in Sweden, Finland and Denmark, but differ in Norway. The most important driver of the market is the political incentives directed to the energy sector in Sweden, Finland and Denmark. Supply chain capabilities are also a strength in these countries, as the delivery capability and cost efficiency is seen as well developed. In Norway, the picture is somewhat different. The most important strength for the bioenergy sector development is seen the alternative fuel price, hence the expected price development of fossil fuels. The second strength is the political incentives offered to the forestry sector.

Prices and price transparency

There is all across the Nordic countries a relatively low price transparency in the biomass markets. In the case of Norway, prices for all biomass assortments are not publicly available and in the case of the other Nordic countries, the existing price information is not fully transparent. This is due to the fact that many supply agreements are bilateral, volume bound and product standardisation is limited, in addition to regional price differences. The markets therefore cannot completely trust the available price information even when it is frequently reported. Still, it does provide some important price information, e.g. give an indication of relative price levels and capture price fluctuations.

Regarding the price levels, many stakeholders believe that price ceilings have already been reached in terms of paying capability, and there is little expectation for the biomass prices to significantly increase from current levels. The import prices provide a ceiling for domestic price development as well.

Figure 77 Comparative price levels in the Nordics in 2011



Source: Pöyry interviews

A major challenge that the bioenergy sector is faced with is the use of measurement units. In the forestry sector, the resource has traditionally been priced in tonnes or cubic meters, whereas the energy sector is looking to price biomass in energy content instead. The energy content is dependent mainly on the species and its moisture content, which the resource owner can find difficult to estimate. Consequently, the price competitiveness of the energy end-market versus the forest industry end-market is not apparent.

9.1.2 Regulatory and legal framework and pricing incentives

Stakeholders were asked to answer if the current regulatory and legal framework is able to support the bioenergy sector development in terms of increased supply, distribution and use. The majority of the interviewed players in Sweden share the opinion that the regulatory and legal framework is sufficient, mainly supported by the fact that Sweden is expected to reach the RED 2020 target already beforehand. However, the framework for the development of 2nd generation liquid biofuels for the transport sector is not sufficient (and still dominated by fossil fuels). On the other hand, representatives from Finland, Norway and Denmark think it the regulatory and legal framework is currently inadequate. The main reasons for that and suggestions on how to further stimulate the sector development are as follows:

- Inconsistencies in political will and policies creates uncertainty
  - Unpredictable, unstable and unreliable market conditions to base long-term investment decision on (longer perspectives are required).
  - Impacting energy producers as well as resource owners. Long-term political commitment and consistency is required in order to raise the investment climate in these countries.

- Direct and indirect incentives to biomass production
  - Energy crops / forest chips / stumps extraction
  - Higher investment support (e.g. Enova in Norway)

- Finland: lack of biomass supply incentives, creating unnecessary competition between the energy and conventional forest industry.
- Finland/Denmark: lack of support and need to improve the financial incentives for industrial and small-scale biomass utilisation (e.g. share of pellets for heating purposes is not increasing in Finland).

➢ Norway: the low taxes on electricity consumption (currently lower compared to the other Nordic countries) regarded as the most prominent obstacle for bioenergy sector development.

➢ Sweden: the hesitation and restrictive opinions regarding energy crop plantations must be reduced. Also, technical development in primary production/supply side requires more support in the future (so far a lot has been done on the market side).

Sustainability criteria

Stakeholders were asked to answer if they see any problems related to sustainability today and in the future. The opinions between the Nordic countries differ and the main results are presented in the table below.

Sweden	Finland	Norway	Denmark
• Does not currently appear to be a problem in Sweden. • Already sufficient legislation (e.g. Forestry Act, certification rules, etc.) that regulates this type of issues. • Only a small share of imported biomass for energy purposes. • Scepticism if mandatory sustainability criteria are necessary. • If implemented, will imply bureaucracy and an administrative burden for small-scale forest owners and farmers. Thus important to consider the practicalities with a potential introduction. • Unnecessary barriers to the use of biofuels may be created. Could possibly create a trade barrier.	• EU criteria is regarded as a good measure, but not needed for Finland's conditions. • Good sustainability criteria and recommended practices for solid biomass procurement already in place. • Small operators will suffer compared to large operators.	• Is not seen it as an issue in Norway. • Existing schemes for sustainable forest management are sufficient to ensure sustainability.	• Important and very much needed. • Regarded as the single most important area where the legislation can enable a positive future development in the solid biomass to energy field. • For energy companies this would reduce some of the uncertainty regarding biomass sourcing and use, particularly when importing biomass over longer distances. • The preference is towards a common view on sustainability criteria on a European level, so that different national frameworks would not be implemented. • Stakeholders express concerns for delays in the process.

9.1.3 Current Nordic cooperation

Based on the interview results with bioenergy stakeholders in Sweden, Finland, Norway and Denmark, the current Nordic cooperation could be identified in the following areas:

	Sweden	Finland	Norway	Denmark
1	Exchange of information	Exchange of information	Exchange of information	R&D
2	R&D	R&D	R&D	Exchange of information
3	Cooperation platforms	Price indices	Trade	Market information
4	Mobilisation	Co-ordination of policies /political decision	Cooperation platforms	Trade

Exchange of information and research & development, were recognised as the two most established forms of cooperation. Exchange of information foremost takes place through networking, seminars/conferences and direct discussions between governments, research communities, companies and on an individual level. Thus, transfer of knowledge/best practices mainly takes place between the same stakeholder groups, rather than across different stakeholder groups. There exist joint research programmes (e.g. VTT in Finland, Skogforsk in Sweden, universities, etc.) between the Nordic countries and also participation in EU-projects. Scandinavian forest researchers, work in cooperation on several issues related to resource assessment, forest inventories, forest chips mobilisation, energy end-use, etc.

Other areas include the existing cooperation platforms, i.e. the bioenergy associations (NOBIO, SVEBIO, FINBIO and DANBIO). Among market mechanisms, stakeholders in Norway and Denmark mentioned trade as an established cooperation form, however limited due to cost competitiveness. Other areas of cooperation include availability of market information and price indices, mobilisation and co-ordination of policies/political decisions.

A general analysis is that the current Nordic cooperation is moderate and can be improved further. The cooperation forms are scattered and not organised under any common platform or organisation. Also, several of the initiatives (e.g. sustainability criteria) have been focused on finding an EU level solution, rather than a Nordic level consensus.

10. FUTURE NORDIC COOPERATION AND RECOMMENDATIONS TO AGFE

With regards to enhancing the Nordic cooperation, the Nordic Council of Ministers has introduced the concept "*Nordic advantage*", which indicates that all areas of activity should contribute to a common objective. The overall objective is that joint Nordic activities must:

1) Strengthen the Nordic community. This may, for example, be achieved by creating a common Nordic profile that can provide the residents of the Nordic countries a sense of belonging.
2) Improve the Nordic influence internationally. This may, for example, be achieved by increasing the Nordic influence in the work within the EU and international forums.
3) Be cost-effective compared to if the same activity was conducted on a national level.

Recommendations regarding future Nordic cooperation

The interviewed stakeholders were asked to give their opinion about the most important opportunities to enhance the Nordic cooperation in the future. Also, during the biomass seminar held on 12 March in Oslo, participants were encouraged to provide further recommendations, which AGFE can use in the coming years work programme. The main results of the interviews and seminar are presented below.

- **Establish a Nordic understanding and consensus**
    - Establish a common understanding and achieve consensus among the Nordic countries regarding current topics such as biomass sustainability criteria and renewable energy targets. Many of the questions are today discussed on EU level, thus it would be valuable to have a common base for the political initiatives and a Nordic consensus.
    - A common understanding could be beneficial for strengthening the Nordic interests and driving discussion at EU level.
    - Enhance the exchange of knowledge and experience regarding support schemes and best practises between countries.

- **Launch common standards/units**
    - A problem recognised in all Nordic countries is the use of different units (energy content vs. volume) between players in the value chain. This leads to misunderstandings and a more accurate measurement procedures are necessary.
    - Establishment of common biomass standards in the Nordic countries.
    - Biomass potentials are calculated based on many different assumptions, creating lack of comparability between countries. A request is to find a method for calculating country specific biomass potentials by defining a common system.

- **Increase price transparency and statistics (market surveillance)**
    - Increase the availability of statistics and solid biomass price information.
    - Necessary to improve existing estimates for biomass projections/price development, including the need for developing a joint Nordic biomass price prognosis.

- Is there a possibility for the Nordic countries to influence the International Energy Agency (IEA) to start making biomass price prognosis?
- In order to enhance price transparency (e.g. create price indices), a large enough physical biomass volume is required in order to have reliable benchmarks. Necessary to increase the number of players that report biomass prices on a Nordic level.
- Need for increasing the understanding of trade patterns for solid biomass between countries in the Baltic Sea region and the rest of the world.

➢ **R&D and joint Nordic studies**

- Establish a Nordic project based on market data for wood chips (similar to the European project “Pellet Atlas”, which aims to develop and promote transparency on the European fuel pellet market in order to facilitate pellet trade and to remove market barriers. Market data provided for wood pellets, including players, prices, consumption, etc).
- The Nordic countries could (annually) publish a Nordic biomass outlook – reporting the most important Nordic statistics in a concise manner.
- Analysis of whether the increased demand for energy wood will increase timber prices in general.
- Scenario analysis on the effect of solid biomass production as a result of:

    - changing price relationships between a) solid biomass for energy purposes, b) solid biomass for other purposes (timber, etc.) and c) fossil fuels
    - forest and energy policy measures such as increased afforestation, promotion of energy crops, altered production in forestry and agriculture, etc.
    - binding sustainability criteria for solid biomass within the EU

- Comparison of various biomass supply chains’ energy efficiency and economy (from production in the forest/field to end use of electricity/heat/transport). Is it possibly to identify some particularly promising supply chains where there is a need for technology - or market development?
- Information regarding on-going biomass projects, coordination of R&D initiatives/programmes and other relevant activities (to avoid repeating work/activities).
- R&D regarding small-scale CHP, cheaper boilers and future buildings.
- Focus on the biological potential - not just “same procedure as last year”
- Silvicultural and agricultural crops and production
- Focus on stronger multi-disciplinary/thematic approaches:

    - ecological and technical
    - economical and carbon balances
    - social sciences and forest/industry owners
    - biomass and end usages

- **Efficient information and meeting platforms**
  - Create a common knowledge sharing point, e.g. an Internet-based platform or a physical knowledge centre ("**Nordic Center for Bioenergy Information**") for all Nordic countries with focus on solid biomass for energy purposes. The idea is to provide information (e.g. supply chains) and promote the utilisation of wood, straw and other biofuels for energy purposes as alternatives to coal, oil and gas. Examples of outputs:
    - Hot line help (phone or mail)
    - Start up assistance to district heating plants, smaller heating plants and groups of citizens interested in converting to biomass
    - Factsheets
    - How-to-do reports on straw and wood for energy
    - Articles and calculation tools
  - The "Nordic Centre for Bioenergy Information" should be continuous and developed by individuals with professional background and scientific staff being experts on biomass mobilisation, biomass utilisation, combustion, gasification, engineering, economy, fuel types, etc. Also collaboration between institutes, at least one in each Nordic country, is required.
  - Avoid duplicating already existing platforms. A suggestion given is that the bioenergy associations in the Nordic countries establish one common platform.
  - Increase exchange of information and best practices through a more business focused approach (currently this is mainly done through research initiatives), with focus on forestry and agricultural biomass.
  - More cross-stakeholder meeting platforms such as seminars and conferences. A suggestion given is to create a "**Nordic Bioenergy Forum**", for stakeholders involved in bioenergy. The forum should include topics, which can attract minister level attention (and possibly participation). The forum could be held for the purpose of creating clear Nordic action plans for enhancing biomass utilisation, which can be presented to the ministers.
  - Nordic Bioenergy Forum: Commitment is required from high political ranks in order to bring forward common Nordic opinions and to improve the Nordic influence internationally.

Strategic issues and recommendations to AGFE

Collected ideas and recommendations from the interviews and seminar are summarised under categories market, technology, regulatory and other.

Market development	➢ Support work in improving price transparency and statistics of solid biomass to energy (standards/units, price information, forecasts, indices, etc.) in the Nordic countries. ➢ Gain understanding about how biomass to energy trade is expected to develop in the future (nationally, regionally and globally).
Technology development	➢ Identify areas of cooperation between biomass to energy stakeholders where joint research efforts can be mutually beneficial.

Regulatory	➢ Investigate what impact a binding EU sustainability criteria could have on solid biomass markets in the Nordic countries. ➢ Investigate if an enhancement of the biomass to energy sector requires additional or alternative financial incentives and support schemes.
Other areas	➢ Establish efficient information and meeting platforms, which can enable easy exchange of information and knowledge between biomass to energy stakeholders in the Nordic countries. ➢ Conduct research to understand to what extent it is possible to realize the theoretical biomass potential in the Nordic countries and through which means this can be achieved.

AGFE can be in a central role to drive the cooperation between the Nordic countries in the field of biomass to energy. The study confirms that, while there are different forms of cooperation between the Nordic countries, there is notable potential for improvement to capture much of the inherent biomass potential in the Nordic countries. This biomass potential can, by appropriate policy steering mechanisms, serve both the existing biomass using industry and the emerging bioenergy sector. The biomass-to-energy discussion on a European level is a critical point of time right now – if the Nordic countries have the desire to speak with a common voice in this discussion, then it is timely to act on the recommendations listed above. In facilitating this development, AGFE is the position to act in catalysing role.

ANNEX A – DEFINITIONS AND TERMINOLOGY

A.1 Definitions

Industrial roundwood: sawlogs, veneer logs and pulpwood**.** Logs are used for production of e.g. sawnwood, plywood and wood-based panels. Pulpwood consists of small diameter (6-9 mm), low quality logs suitable for production of pulp and to some degree used by the wood-based panel sector. However, energy companies have a high wood-paying capability and are competing directly with these industries for raw material.

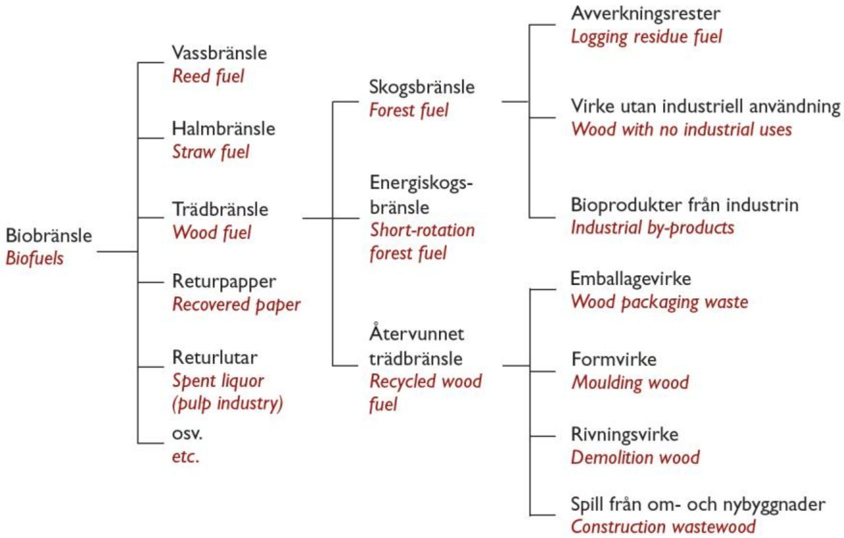
Sawdust: main sawmilling by-product. Sawdust is composed of fine wood particles and can be used as fuel or for production of particleboard. Important raw material for the pulp & paper and wood-based panel industry. Also in strong demand by wood pellet and energy producers.

Chips: main sawmilling by-product consisting of small, solid pieces of wood. Chips can be used for production of pulp & paper and wood-based panels.

Bark: has high ash content and is therefore not favoured by the bioenergy industry. It is a major by-product of the softwood sawmilling industry and often burned at sawmills to provide heat (for drying kilns) and energy.

Pellets: produced of dried (10-12%) wood residues such as sawdust, chips and shavings. The diameter is 6-12 mm and length 10-30 mm. The consumption of raw material is approximately 2.4 m^3/t. The best species for pellets production is pine and spruce (softwoods).

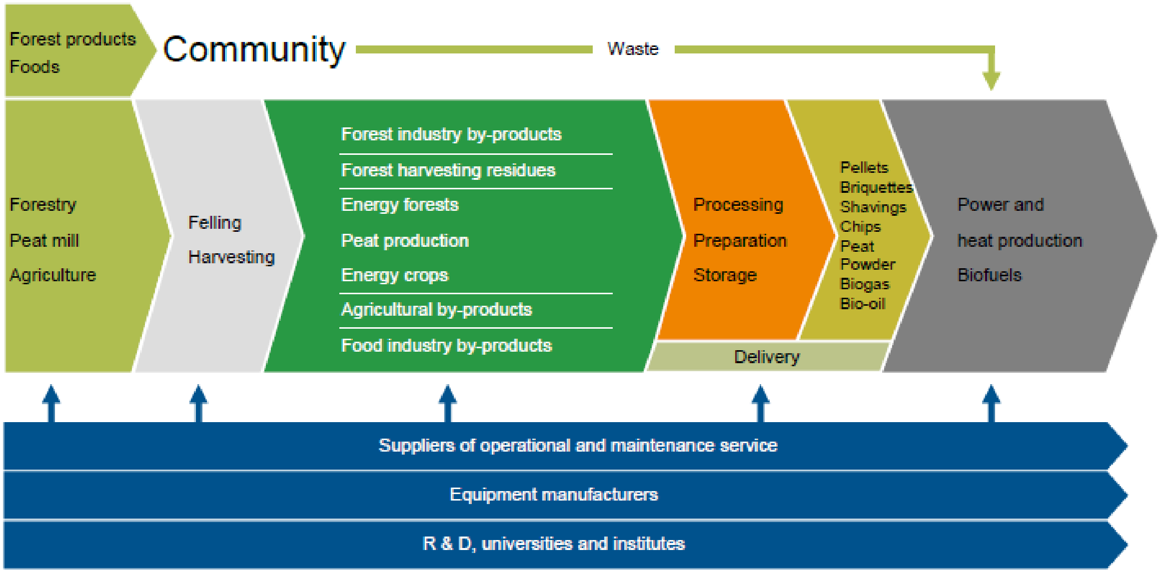
Figure 78 The fundamental division of biofuels according to Swedish standards



Source: *Swedish Standards Institute, SS 18 71 06*

A.2 Bioenergy stakeholders

Figure 79 Bioenergy fields and stakeholders

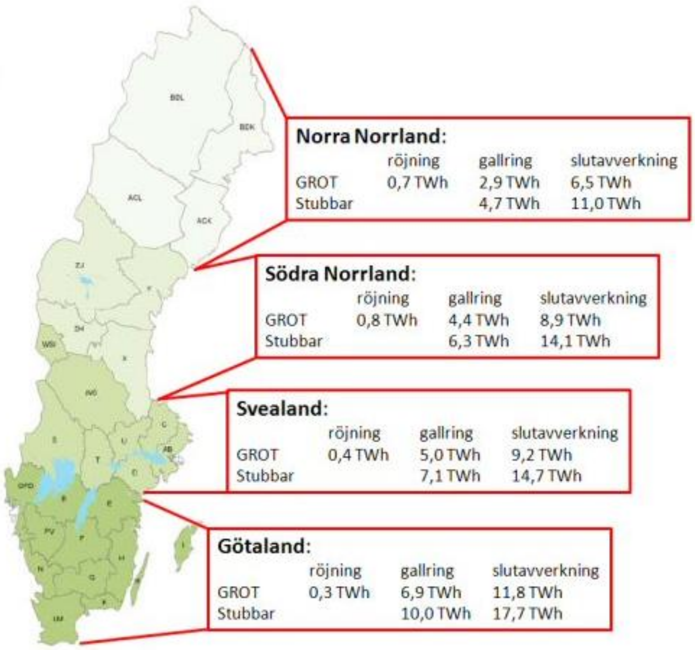


Source: SWENTEC

ANNEX B – COUNTRY SPECIFIC TABLES

B.1 Sweden

Figure 80 GROT and stump potential in Sweden (TWh) without ecological and technological restrictions



Source: Kunskap Direkt (Skogforsk), based on data from Swedish National Board of Forestry (SKA 08)

Figure 81 Cost (SEK/m^{3}loose) for primary forest fuels in Sweden, 2010

Kostnader för skogsbränsle, 2010				
	Grot från slutavverkningar	Klenträd från gallringar	Energived	Stubbar från slutavverkningar
		kr/m³s		
Ersättning till markägaren	40	8	53	3
Avverkning/upptagning	0	45	23	44
Terrängtransport	32	28	17	27
Omkostnad	8	7	5	5
Summa fritt bilväg	**80**	**88**	**98**	**79**
Sönderdelning	44	39	21	38
Terminalkostnader	6	5	12	5
Vidaretransport	37	34	25	33
Administration	10	9	9	6
Summa fritt slutkund 2010	**177**	**175**	**165**	**161**
Summa fritt slutkund 2009	**172**	**165**	**167**	**174**

Terrain transport distance was for respective assortment is 358, 370, 343 and 365 meters. The average transport distance by road is 73, 77, 61 and 71 km.

Source: Skogforsk (Kunskap Direkt)

Figure 82 Potential of energy crops (according to different studies)

Utförare	Potential energi (TWh)	Areal hektar	År	Anm.
Biobränslekommissionen (1992)	Totalt 51–59 varav halm 11	800 000[1]	2002–2007	Praktisk potential bedömdes till 10–15 TWh
Naturvårdsverket (1997)	28	Varierar	2021	28 TWh var ett beting som skulle uppnås i studien
Klimatkommittén *a) med tekniska, ekonomiska och ekologiska restriktioner* *b) utan restriktioner* (2000)	1–2 20–30	800 000	2010	Jo-politik avgörande. Anläggningsstödet bör enligt Jordbruksverket höjas för att nå 1–2 TWH
Svebio (2004)	23	500 000–600 000		Baseras på LRF:s bedömningar
LRF:s energiscenario (2006	5 23	500 000–600 000	2010 2020	Scenariet underlag för näringspolitisk grundsyn och handlingsplaner
Lantmännen (2006)	29,5–36,5	Upp till 1 milj. ha	2020	Lantmännens affärsvision
Lars Jonasson (2005)	25	ca 900 000	Lång sikt	Utgår från oljepris på $ 100
Kommissionen mot oljeberoende (2006)	10 32	300 000–500 000	2020 2025	Oklart på vilka grunder arealerna bestämts

Source: SOU 2007:36 (Bioenergi från jordbruket – en växande resurs)

Figure 83 Production cost (SEK/MWh) for energy crops in Sweden

Produktionsområde	Salix	Hampa	Rörflen	Halm
Götalands södra slättbygder	130	318	222	150
Götalands mellanbygder	160	318	225	150
Götalands norra slättbygder	140	325	228	150
Svealands Slättbygder	153	330	232	150
Götalands skogsbygder	168	345	236	-
Mellersta Sveriges skogsbygder	168	351	239	-
Nedre Norrland	-	362	239	-
Övre Norrland	-	362	239	-

** The figures should be regarded as approximate rather than exact costs.*

Source: Report by Värmeforsk ("Förstudie - sammanställning och syntes av kunskap och erfarenheter om grödor från åker till energiproduktion", juni 2007)

B.2 Denmark

Table 1 Largest importers of wood pellets 2010 (tonnes of pellets)

Nr	Importer	Imported volume
1	Estonia	248,163
2	Latvia	209,527
3	Russia	163,142
4	Portugal	125,027
5	Germany	114,163
6	Poland	108,066
7	Finland	99,219
8	Lithuania	87,749
9	USA	80,005
10	Sweden	65,131
11	Great Britain	41,866
12	Canada	37,496
13	Belarus	23,613
14	Netherlands	18,525
15	Ukraine	13,571

Source: Eurostat

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