Bioenergy logistics chain cost structure and development potential

Report to Enova

Final version, 01. November 2005

by

Energidata AS

Transportøkonomisk institutt (TØI)

and

KEMA Consulting

Preface

This project has been accomplished by a team from Energidata AS, Institute of Transport Economics (TØI) and KEMA Consulting (from The Netherlands), and executed in co-operation with an internal project group from Enova SF and a reference group. Energidata has managed the project with Oddbjørn Fredriksen as the project leader and with Trond Moengen and Bjørnar Otterstad as contributors. Inger Beate Hovi from TØI and Edward Pfeiffer from KEMA has also been members of the project team. Self-employed consultant Gunnar Wilhelmsen and prof. Anders Lunnan (Norwegian Institute of Forest Research) has been acting as discussion partners for the team and given valuable contributions.

Enova SF has been the formal project owner and fonder. Håvar Risnes and Viggo Iversen represented Enova, with Håvar Risnes as the project manager.

A reference group, with the following members, has been actively engaged in the project:

- Knut Mikalsen, Project manager, Viken Fjernvarme
- Erik Nilssen, Project manager, BioVarme
- Knut Lundem Hougsrud, Manager, FK Maskin AB
- Berit Rødseth, Project director, Moelven Timber
- Ellef Grimsrud, Viken Skogeierforening
- Roar Paulsrud, NOR-EST.WOOD
- Knut Hoven, Director, Agder Energi AS

Associated member, EIja Alakangas, VTT Wood Energy Technology, Finland.

The reference group has given valuable contribution to the project.

Bio-energy logistic chains

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Summary

Project

This project was funded by Enova SF and accomplished by a team from Energidata AS, Institute of Transport Economics (TØI) and KEMA Consulting. The overall objective was to investigate the bio-energy logistics chains cost structure. The primary geographical region studied was the central part of south-east Norway, within a transport distance of 150 km from Oslo Airport Gardermoen.

Resources

As a result of environmental advantages, and energy policy supporting the use of renewable resources, bioenergy has the potential for becoming an important energy resource. Norway, and particularly the region in question, has significant bioenergy resources in the forest. Relatively substantial resources are also available in the form of residues from the wood-based industry. It is, however difficult to account for the costs that are attached to the procuring of these resources for energy purposes.

Bio-heat market today

The firewood marked is not included in this project, and is therefore not a part of the bio-heat marked as defined here. Currently, the market for bio-heat in Norway is a niche market. Bio-heat has to compete with electric heating systems in terms of convenience and price. Due to low electricity prices and the immature bio-fuel market, bio-heat is hardly competitive with electric heating today. For bio-energy to be competitive in the heat market the price for other energy carriers, especially for electricity, has to increase, and/or the cost of supplying bio-heat has to decrease. The bio-heat costs includes biomass (raw material)costs, investments and maintenance costs regarding the heating system, as well as costs in relation to the logistics system for the distribution of bioenergy. A variety of alternative logistic chains can be constructed, and the composition of chains will influence the cost for bio-heat.

Logistics Chains

This study comprises logistics chains delivering wood chips and wood pellets to district heating and micro grid systems, and wood pellets to central heating and household applications. The performance of a logistics chain depends on a large number of variables. In order to explore the possibility for improvements and find an efficient logistics chain, the effects of many variables must be calculated. In order to embed the analyses in a context, different scenarios determining the demand for bio-heat and the supply of bioenergy in the actual area has been developed.

Bio-heat market developments

In the so-called ”Bio-Max” scenario, the demand for bioenergy in the area will increase significantly, up to 6.3 TWh in the year 2020, i.e. a tenfold increase in the course of 15 years. In the so-called “Bio-Min” scenario, the increase is relatively low, up to 1.5 TWh in 2020, i.e. a threefold increase in the course of 15 years. A so-called “Bio-admin” scenario is an intermediate scenario yielding an increase in the demand

up to 3 TWh in 2020. Linked to these scenarios are presumed developments of energy prices. A tenfold increase in the market over the course of 15 years, as in the ”Bio-Max” scenario, constitutes a strong development which poses certain demands for market organization and market moves. It is likely that import has to play a role in order to fulfil this growth rate.

Logistic Chain analysis

Logistics chains analyses show that there are scale advantages with respect to the production of chips and pellets. These scale effects seem to even out when the production volume reaches 15,000 tons of chips per year and 40,000 tons of pellets per year. Transport costs are highest for raw materials, so production should be situated as close to the raw materials as possible. In the “Bio-Max” scenario the analysis shows that 9 production plants is the optimum between the upfront logistics and the economy of scale of the pellet plants. The plants are distributed over the area with a minimum size of 20-25.000 tons/year, and a middle size of 60.000 tons/a (300 GWh). The logistics costs in 2020 are reduced with 20-35 NOK/MWh compared to 2005.

Market Structure

The organization of the biofuel market is characterized by the fact that there are no central, regional or local marketplaces. Consequently, prices of immediate and future supplies are not transparent. This makes it very complicated for consumers to make choices about the use of bioenergy, and it is difficult to gain a complete overview of every condition relevant to an investment. Hence, it is safe to conclude that the biofuel market relies on an involvement of the authorities or others in order to establish a more functional market, thus initiating the expansion of the market for which the calculations indicate profitability. A natural course in the aftermath of this project would be to further consider the possibilities for a marketplace for bioenergy, and to look at how the organization should be conducted in order to create efficient logistics chains.

Effects

Bioenergy offers an opportunity to use local and regional available renewable energy sources. It can also contribute to the development of local and regional economy and employability. Under certain conditions the bioenergy market can grow rather rapidly. The use of bioenergy can create new opportunities for the Norwegian energy market and contribute to economic development and deployment, but market reordering is required.

1 Project Scope and Limits

1.1 The project

The overall project objective was to investigate the bio-energy logistics chain cost structure, development potential and describe optimum logistics chains to a conceptual design level. The overall scope of work has been defined to:

- Review, consider and describe to conceptual design level highly efficient and environmentally friendly logistics chains for transport of biomass from production sites to central storage facilities
- Evaluate the impact of market volume on logistics chain efficiency and cost structure
- Evaluate the short and long-term impact of potentially increased biomass imports/exports on the Norwegian market
- Recommend the subsequent phases of work that will indicate how the logistics chains should be organized and carried out. Indicate expected schedules and budgets.

The following generic objectives have been defined

- Provide insight in the development of biomass resources and supplies in relation to market demand
- Explore possibilities for starting trajectories towards demonstrating how improved biomass logistics can contribute to stimulate market growth
- Evaluate the competitiveness of Norwegian/international biomass resources for international markets and the local/national Norwegian market.

The following constraints have been defined:

- The project concerns biomass for energy purposes, defined as forest wood, bi-product from traditional forestry industry and wood-based pellets.
- The primary geographical region is defined as being within a transport distance of 150 km from Oslo Airport Gardermoen, see Figure 1.1.
- The marked sectors to be taken into account are district heating, micro-grids, central heating systems and end-use (household).

Figure 1.1. The primary geographical region

1.2 Framework

Figure 1.2 illustrates the framework of the analyses.

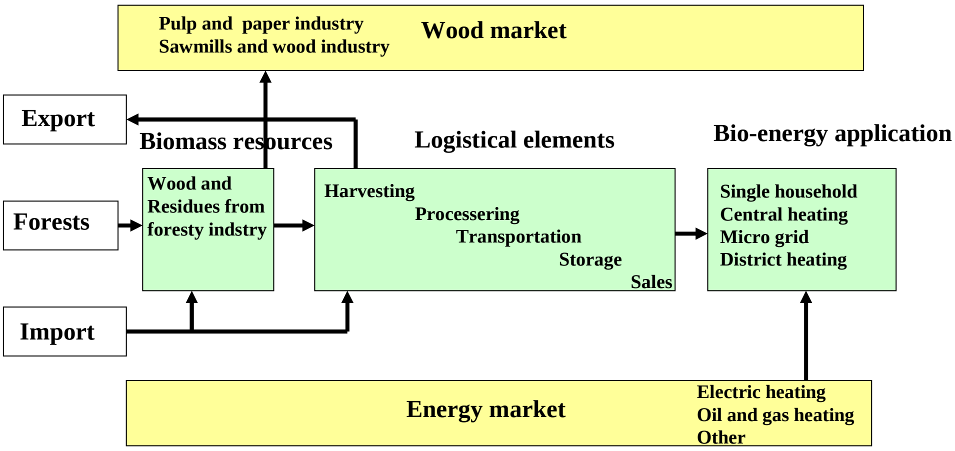

Figure 1.2. Analysis framework

Both circumstances in the wood market and in the traditional energy market affect the bioenergy market. The development of the future price level for competing energy sources (e.g. hydropower, oil and gas) defines a critical framework for a long-term exploitation of bioenergy. The supply of raw materials for bioenergy is strongly interlinked with the pulpwood market. Furthermore, the development of bioenergy is affected by energy policy objectives (e.g. more renewable energy, increased flexibility), but also agriculture policy objectives (e.g. increasing the industrial base in the districts, the overgrowing of arable land), environment policy objectives (climate, tourism) and infrastructure policy objectives (the overgrowing of roads). These objectives are reflected in laws and regulations, e.g. in the form of taxes and subsidies, which in turn affect future production and utilization of bioenergy.

As many interests and incidents clearly affect the future bioenergy market, a foresight process, involving the reference group and other resource persons, has been applied in order to develop an assessment of scenarios. The main analytic structure of the study is illustrated in Figure 1.3. A number of mini-scenarios are developed in the foresightprocess, and used to derive three main scenarios. These scenarios affect the development of both supply and demand for bioenergy. Logistics chains are established to link demand and supply.

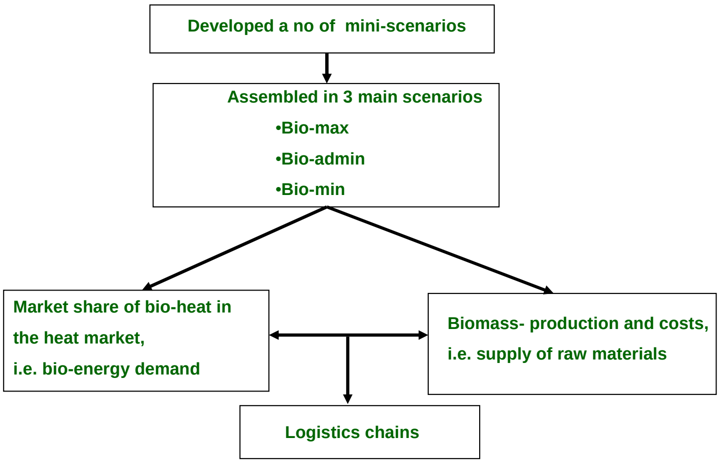

Figure 1.3. Analytic structure of the study

The main focus of the study is the logistic chains, i.e. the system generated for the distribution of bioenergy. The questions dealt with in the study are:

- How big share of bio-heat costs can be linked to logistics?
- To what extent can logistics costs be reduced?
- How can this contribute to improve the bio-heat power to compete with other systems?

Evaluating logistic chains, possible efficiency and synergy effects must be examined. In such evaluations it is appropriate to differentiate between four effects:

- *Scaling effects* exist when the unit cost of supplying a product is reduced when the volume increases. This can be achieved by the increase of volume due to higher demand, centralization of production to larger units, or cooperation/fusion with similar companies.
- *Unit effects* exist when there is a possibility of eliminating functions. This can be achieved through cooperation/fusion between companies, either within the same industry, between different industries or with suppliers or customers.
- *Dispersion effects* exist when the cost of supplying several products together is lower than supplying them separately. This can be achieved through cooperation/fusion between companies producing or supplying different products.
- *Efficiency effects* exist when the unit cost for supplying a product is reduced without volume increase. This can be achieved through increasing the efficiency of the processes in the chains.

In this study the effect of scaling is analysed. Analysing the other possible effects requires business models and efficiency analyses in close cooperation with the market players, which was not a part of this study.

1.3 Resources and Biofuels

Figure 1.4 shows a survey of bioenergy products comprised by the study.

Forest biomass				
Wood			Residues from wood based industry	
Forest residues	Stem wood	Whole trees	Dry residues	Wet residues
Pretreatment				
Solid biofuels				
Wood chips			Pellets	Residues
Bioheating systems				
District heating		Micro grids	Central heating	Stove

Figure 1.4. Resources, biofuels and heating systems included in the study

The raw materials or biomass can be divided into two main groups: wood and residues from wood based industries. Through different methods of processing, biomass is transformed into solid biofuels which can be utilized in bioenergy systems. The project covers solid biofuels defined as wood chips and pellets derived from forest wood and residues from wood based industries. Pellets can be produced from residues from sawmill and other wood based industries or from wood chips. The production of pellets is often a combination of size reduction, drying and densification.

Traditional use of firewood and demolition wood is not a part of this study. Firewood is excluded since much of the firewood is treated outside a market, and decentralized small scale use hardly has any impact on logistical costs. Biomass can also be transformed into liquid biofuels, commercial systems exists today for ethanol, but liquid biofuels is not a part of this study. The term “biofuel” in this report means “solid biofuel”

1.4 Bio-heat market

Excluding firewood, the Norwegian bio-heat market is small, diversified and suffering of electric heating competition. At the moment the market for bio-heat in Norway is a niche market. The main application is small scale heating in households and some medium scale district heating or micro-grids applications. Bio-heat has to compete with electric heating systems in terms of convenience and price. Due to low electricity prices and the immature bio-fuel market, bio-heat has problems competing with electric heating today. But even if the market still is small, there has been a large percentage increase in the use of bio-heat over the last years, both as wood chips in district heating or micro-grid systems and as pellets in local systems. It looks like the bio-heat market is growing.

1.5 Methodological approach

Finding optimal logistics chains entails choosing locations for establishing production capacity in relation to the supply of raw materials, and taking into account the market distribution and potentially several levels of processing and transport. In the operational analysis this is classified as a ‘facilities location’ problem. Methods and models used for analyzing this are usually employed to define cost effective strategies for distribution. In cases where detailed models are developed, e.g. within companies where the operation can be mapped out in detail, the models are used in order to establish the optimal logistics with respect to the use of current production facilities, or to consider setting up new ones. A prerequisite in using this kind of model is a good understanding of the cost functions of the different elements in the chains of production and transport, as well as detailed, quantified descriptions of the raw materials supply, together with a thorough description of the market.

The scope of this project comprises logistics chains at a conceptual level, and the method used is a simplified one. It has been necessary to employ presuppositions about raw materials supply and the bio-heat market, and there is a relatively significant uncertainty attached to the cost functions in the logistic chains. Relatively simple models in excel spreadsheet have been developed in order to map the market and the supply of raw materials, and for the study of logistic chains, a parameterised model structure has been developed. This model is simple, but creates the possibilities of constructing a variety of chains, where the influence of different factors can be adjusted and analysed. The model is based on a method described in /14/.

The geographical area, and the scenarios describing different supply and demand situations for bio-energy in that area, is given. Also the geographic distribution of bio-energy resources and bio-heat demand in the area is presumed known. Based on this, analyses are implemented in order to map the cost structure of the logistics chains in different supply situations, and find the situation with the lowest logistic costs.

The logistics chains consist of different elements or components, and can be developed in several ways. Examples of elements constituting a logistics chain for wood chips are shown in Figure 1.5.

Harvesting	Storage	Transport	Chipping	Storage	Transport	Heat conversion

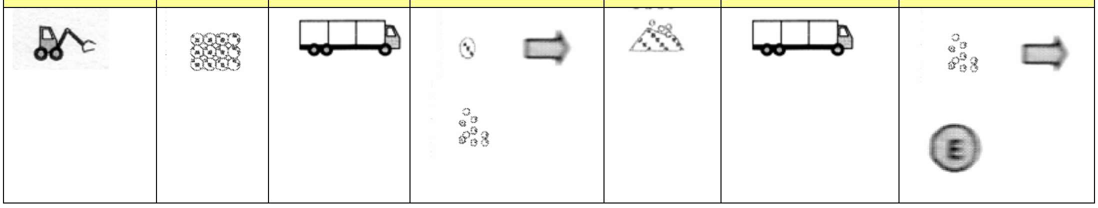

Figure 1.5. Wood chips logistic chain

The logistics chains’ costs are calculated on the basis of the cost structure of the single components and a possible supply strategy. The components cost structure has been collected through questionnaires from market players and from literature. A possible supply strategy is given by the number and locations of production sites, lengths of transport, etc.

The area in question is divided into a number of smaller areas with raw materials for bioenergy as well as demand for bioenergy, and where production units for solid biofuels can be established. If one of these smaller areas lack balance between raw materials, produced biofuels or demand, raw materials or biofuels must be transported between the areas. Based on this information different supply strategies are developed. There are also possibilities for export from and import to the area.

The analysis process is structured as illustrated in the Figure 1.6 below.

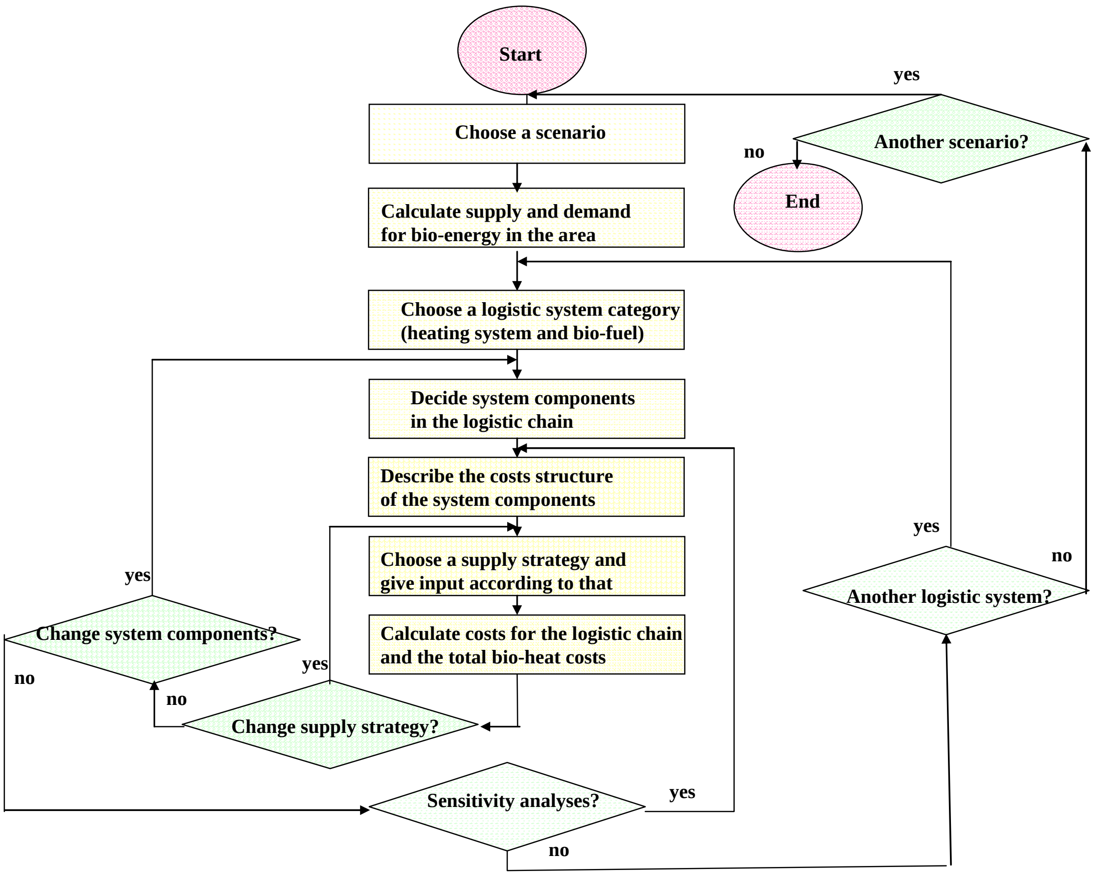

Figure 1.6. Analysis process

Analysis description:

- A scenario is chosen, and the supply and demand of bioenergy is calculated, as described in section 6.3.3.
- Subsequently, a logistics chain is chosen, with the appropriate heating system and biofuel, e.g. district heating based on wood chips.
- Then, a supply strategy is chosen and input data concerning this are decided.

- By means of a simulation model, logistics costs are calculated, as well as corresponding heating costs. If there is reason to change the supply strategy, input data are readjusted and new calculations carried out. If desirable, the elements which are implemented can be changed, and new calculations made. Sensitivity analyses can also be conducted by adjusting the costs of the system components.
- The same calculation process is carried out for other logistics chains.
- Subsequently, a new scenario is chosen and the entire calculation process is repeated.

Due to the limited resources of the project, and because it was time consuming and difficult to establish adequately detailed cost functions for the components, it was not possible to implement all the analyses shown in Figure 1.6. However, an adequate number of analyses were conducted in order to map the cost structure of the most relevant logistics chains, i.e. wood chip chain supplying district heating system and pellets supplying households and district heating systems.

1.6 Data Basis

The basis for estimating cost functions is extracted from a survey carried out amongst a selection of the producers of different kinds of bioenergy in Norway. The survey is supported by cost estimates based on data from Sweden and Finland /14/. The production of bioenergy in Sweden and Finland has a significantly higher volume for all qualities than in Norway. Differences in production volume affects unit costs, as larger production volumes render an improved degree of utilization of invested capital. Despite the limited data basis and the fact that costs given by different producers might be subjectively decided, the derived functions are believed to properly reflect how unit costs vary according to production volume. However, there are considerable variations in the cost of the single components, and it was difficult to establish cost functions for the single components as detailed as desired. The plan was to calculate components cost based on information of capital cost, operation and maintenance cost and energy cost, but this detailed information was hard to obtain, which makes it difficult to map how the logistics cost is influenced by various parameters, such as e.g. interest rate.

The basis for estimating the market and the supply of raw materials is drawn from publicly available statistics and referenced sources. A number of assumptions have been made in order to adapt the data to the methodological approach. Hence, the market descriptions and estimates of raw materials are encumbered with uncertainty.

Methodology, data and results from different analyses that are carried out, can be found in separate notes, see the reference list.

2 The Wood Market

2.1 Wood Mass Flow

The supply of raw materials is an important premise for the development of bioenergy. The development of different market players competing for biomass is central to the problem at hand. Figure 2.1 shows the wood mass flow in Norway today. (Bioenergy used internally in the industries is not shown). The figures are converted to TWh and based on statistics from SSB (Central Bureau of Statistics) and NVE-report no. 7/2003 “Bioenergy Resources in Norway”/9/. (NVE: Norwegian Water Resources and Energy Directorate).

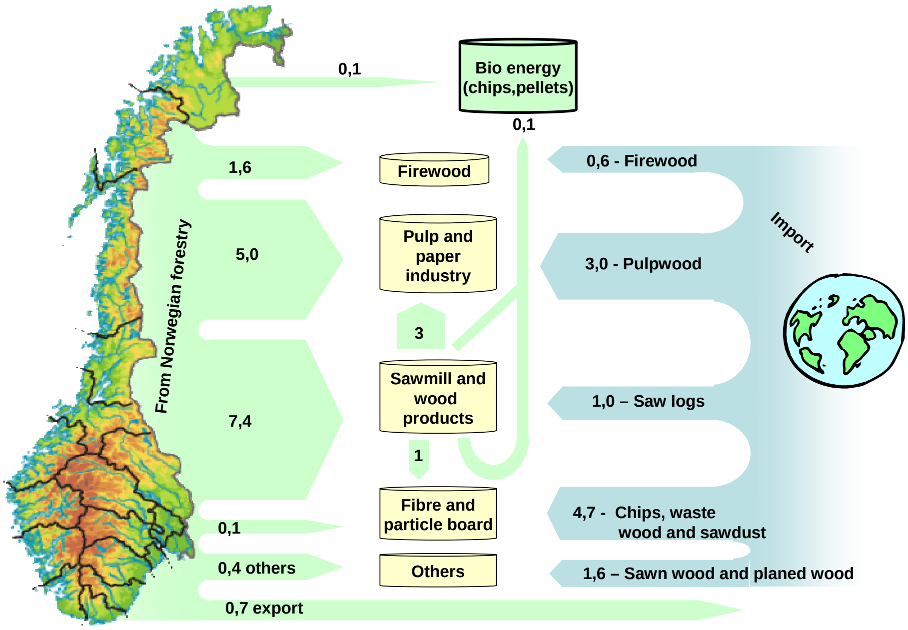

Figure 2.1. Wood mass flow in Norway today in TWh/year (1TWh = 0,5 millioner fast m^3)

Structural changes within the businesses will affect the availability of wood based resources at a competitive price for bioenergy applications, and the logistics that follow from it. In the three scenarios that have been developed, presuppositions about such changes have been made to the extent which is important in the usage of biomass for energy purposes. Such assessments depend on acquiring an overview of how biomass flows between the different industries today, and to what price. Most players are however, hesitant to imply how structural changes affect their industry and the supply of biomass for different purposes. This is partly due to strategic considerations, but also indicates a real uncertainty with respect to this. Structural changes affect not only the part of the market involved, it may have general implications as well.

The pulpwood market is small, with few players, and is not very transparent. This makes it difficult to gain a complete overview of costs and price structure, and to estimate how the prices of the raw material might develop in other markets.

Table 2.1 shows some heating values and conversion factors.

Table 2.1. Bulk weight and heating values

	Bulk weight, fresh matter. ton/m^3	Bulk weight, dry matter. ton/m^3	Heating value MWh/ton dry matter.
Pellets	0,7	0,7	4,8
Wood chips	0,63	0,45	4,7
Forest residues	0,73	0,4	4,4
Stem wood	0,63	0,45	4,4
Sawdust	0,55	0,40	3,0
Shavings	0,3	0,25	4,4

2.2 Fuel quality

The fuel quality is important for the development of bioenergy plants, costs and waste. According to the European Committee of Standardization (CEN), who are currently working on new standards for fuels, there are three main categories: *Pure biomass*, which comprises pure wood and other biomass; *Contaminated biomass*, which is fuel that cannot be burnt without meeting the demands of waste combustion set by the EU or the Norwegian Government; and *Hazardous biomass*, e.g. CCA impregnated wood, which can only be burnt using a special combustion- and cleansing technology. This project covers pure biomass only.

The substantial differences in the quality of the solid biofuels between different suppliers and within different supplies, represents a significant barrier. Confidence in solid biofuels must be built upon the application of systems for quality insurance being based on well defined standards. International / European standards for solid biofuel are regarded as especially important.

2.3 Biomass for wood chips

Chips are a collective term denoting wooden chippings from different types of wood, such as forest residues, stem wood or whole trees. Currently wood from forestry is mostly used in the form of firewood, and only a small portion (0.1 TWh), is used as chips. It is presumed that there is a big potential for increasing exploitation of chips for energy purposes. For the country as a whole, a possible increase of usage is presumed to reach 12-16 TWh /9/, 70-80 % of this is assumed to exist in the project's "primary geographical region" (the central part of the eastern area of Norway). The supply far exceeds an estimated maximum demand for bioenergy in this area over a 15-year time perspective.

The supply consists of different types of wood, of which exploitation might differentiate with respect to costs. Chips from whole trees, i.e. from thinning, clearing (e.g. of broadleaved trees) and forest residues, can be taken from a forest with no other demands on the forest owner, that it should yield a small profit margin. The forest owner will probably benefit from the fact that the residues are cleared away, as this facilitates the preparation for planting. However, experience from Sweden and Finland indicates that not all forest owners will be interested in providing residues. Certain restrictions due to the nutrient balance must be expected. Sweden, Finland and Denmark have guidelines for forest residue utilisation; this is expected to come in Norway too. Furthermore, agricultural interests and the tourist industry want to stop the overgrowing of pasture, field boundaries and so forth. The Public Roads Administration wishes to keep roadsides clear, Electricity Companies want to keep power lines from overgrowing, and they are willing to supply at a low price, or in some cases pay for the delivery of wood. Therefore it is difficult to stipulate the value of residues and wood from clearing before it is taken out of a forest. In Sweden the costs is calculated to 10 - 20 NOK/MWh. Information from Finland /11/ indicates costs in the order of 20 NOK/MWh for forest residues, and 50 NOK/MWh for whole trees from thinning, including terrain transport, but not including road transport and chipping. It is reasonable to assume that the operating costs for residues will vary in proportion to the operating costs for timber. In even terrain, operating costs will match Swedish figures, while in rough terrain and longer stretches of terrain transport, costs will increase considerably.

An estimated cost curve for forest wood used for production of wood chips, including terrain transport delivered at truck-road, but not including road transport and chipping, is shown below, Figure 2.2. Costs are based on information of 2004 prices, from Skogforsk, (Norwegian Institute of Forest Research). The volume estimates in the curve are based on information from Skogeierforeningen (Association of Forest Owners).

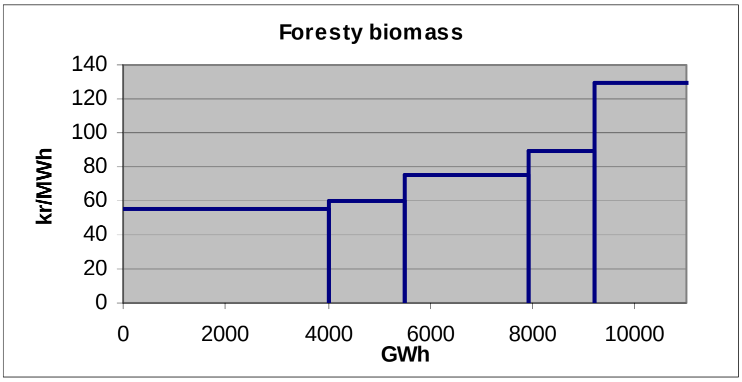

Figure 2.2. Estimated cost curve, biomass for wood chips. (1MWh = 0,5 fm^3)

Rating from the lowest price to the highest price, the bars represent: *forest residues, wood from clearing, wood from thinning, pine pulpwood and spruce pulpwood.*

(Sources: Skogeierforeningen and Skogforsk)

Chips costs, as well as chips quality, depends on the type of raw material used. Chips produced from forest residues with the lowest raw material costs has higher production costs and renders a somewhat poorer quality than chips based on pulpwood.

The prices shown in the figure are based on today's prices, and are presumed to hold with respect to the felling of wood exceeding beyond today's levels. If the demand for wood from the wood processing and wood based industry is reduced due to structural changes, this might lead to larger supplies of wood for energy purposes. This might in turn reduce prices somewhat, though if the forest owners are to fell wood, prices must exceed a certain level. In the analyses, the base price of raw material for chips is calculated using the price of pine pulpwood. The price is set to 90 NOK /MWh. In later chapters we assess how variations in the price of raw material affect the costs of bio-heat.

2.4 Residues from wood based industry

Residues from wood based industry is, according to /9/, sold as chips to the chipboard and cellulose industry (3.8 TWh) or exploited for energy purposes (1,7 TWh). The latter part is mostly used internally (for heating and drying of timber) while 0.3 TWh is used or sold as raw material for the production of pellets and briquettes.

Residues from the wood based industry is a good raw material for pellet production, but can also be used without further processing, as a fuel for energy purposes. The practical potential in exploiting this for energy purposes is estimated to 4.3 TWh /9/. But whether it can be used as fuel in the bioenergy market depends on the economic situation of the industries involved, in particular the chipboard and cellulose industry, where residues constitute an important part of the raw materials. The chipboard industry has already expressed fear of losing the supply of this raw material, if actions are made which distort competition. The ongoing discussion concerning the closure of Norwegian wood processing industries initiates discussion about redirecting the sawmill industry's supply of cellulose chips. The most apparent business potential with respect to biofuel implies that parts of the Norwegian board and wood processing industry are dismantled, thereby releasing fuel resources. This can also be affected by the fact that an increase in the demand for biofuel may pose a threat to these businesses because this can lead to higher prices for raw materials and reduced profitability.

The supply of raw materials for the production of pellets has been considered by Ståle Størdal /10/. Dry fractions from the timber industry constitute the most popular raw material because these have already been through several processing operations, and are directly suitable for energy applications. The chipboard industry is also competing for this raw material. Wet fractions rate below dry fractions from the timber industry, the first of which is raw sawdust. The fraction with the biggest quantum potential is raw cellulose chips, but this fraction has a high alternative value. Chips are rated below the wet fractions, with chips from low quality wood, so-called energy wood, at the top. Then follows pine pulpwood, spruce pulpwood and last broadleaf wood.

On the basis of today's prices, an assessment has been made of quantity and prices with regard to the potential of raw material for the production of pellets/10/. A cost curve based on that /10/ is shown below, Figure 2.3.

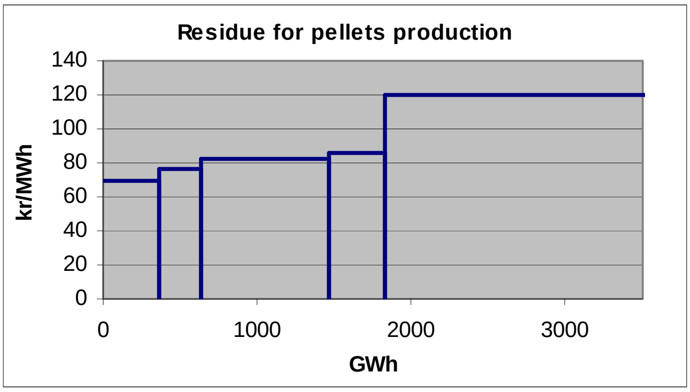

Figure 2.3. Estimated cost curve, raw materials for pellets.

Rating from the lowest price to the highest price, the bars represent: *dry chips and shavings, dry cellulose chips, raw sawdust, stubs, and wood chips (mix of pine and spruce pulpwood).*

(Source: Størdal/10/)

The competition for this raw material is great and only a small amount is used in the production of pellets today. The prices given here are the prices for alternative usage. The portion of this raw material available for pellet production, and to what price, depends on competition. If the board industry and the pulp and paper industry reduce their purchases, a substantial amount of raw material can be released for energy purposes. Accordingly, if prices increase to a level above that which competitors are willing to pay, great amounts could become available. However, there is a limit to how much the pellet producers can pay for the raw material if locally produced pellets are able to compete with other energy carriers and imported pellets.

In the analyses the base price of raw material for pellets is set to 100 NOK/MWh. In later chapters we assess how variations in the prices of raw material affect the costs of bio-heat.

2.5 Pellets

A pellet is a dried and densified form of biomass produced according to the required specifications. The main advantages of pellets compared to the raw material like for example saw dust, wood chips or fire logs are:

- pellets has a constant heating value and ash content
- since pellets is compressed and dry material it is not dusty
- pellets can be stored for a long period without degradation taking place

In principle all solid biomass are suitable for pellet production. The main application of biomass pellets nowadays is the use of wood pellets in small scale heating applications. In these cases wood pellets are most of the time produced out of clean saw dust and shavings, being residues from the wood based industry. Since these wood pellets are used in many units, often automatically operated and designed according to standards the wood pellets are produced according to strict specifications on moisture content, heating value, ash content and size.

A second application is the use of biomass pellets in large scale applications like district heating systems, power plants and Combined Heat and Power (CHP) plants. In these cases it is often not required to produce pellets according to general standards. Depending on the used technology (fluidized bed boiler, grate firing, entrained flow firing) variations in the pellets quality are allowed. In comparison with small scale applications lower grade wood residues are also used as a resource since the costs of these resources are lower. However high quality pellets are still the most common since the supply market has organized the supply chain around clean wood residues (sawdust and shavings) coming from forestry industry. In low grade quality wood pellets it is allowed to used also bark, thinning and mixtures of wood, resulting in higher ash content, lower heating values and often also higher moisture content.

3 Energy Prices

The market for bioenergy is heavily influenced by the price of alternative energy resources. In the study we have analysed three different market scenarios based on high, middle and low prices. Each of these scenarios depend on a chain of prediction, like the price of oil, coal and gas, and the extent of growth in hydropower, gaspower, the closing of nuclear power plants, cables to the continent from the Nordic countries, the price of CO_2 quotas etc. The price of power in the Nordic market is estimated by the help of different simulation models.

The calculations indicate that the price of CO_2 quotas in particular has an impact on the price of electricity. The calculations further indicate that there is a connection between the price of CO_2 quotas and the price of oil, coal and gas. Therefore it is very important to make calculations that are consistent with this correlation. The calculations done are for the wholesale market. The cost of distribution has to be added to these prices in order to make the prices comparable with the costs for bioenergy.

Table 3.1. Conditions within different calculations

	Price of coal ($/ton)	Price of crude oil. ($/ton)	Price of gas (NOK/m[3)]	CO_2-price (€/ton)
High	90	80	2,50	40
Middle	60	45	1,80	20
Low	40	25	0,80	6

1 ton coal = 1,000 kg coal equivalent at 29.31 GJ/ton

1 barrel crude oil = 159 litres crude oil = 5.736 GJ

1 ton oil = 1,000 kg crude oil at 41.87 GJ/ton

1 NOK =0,13 € = 0,15 $

1 MWh = 3,6 GJ

Examining these conditions, together with the introduction of a certificate market in order to stimulate growth in renewable energy, calculations are made herein for the development of power within the Nordic power system and the cost of this power for 2012. The results illustrate promising competitiveness for bioenergy within the market. The cost of CO_2 will initially contribute to higher energy prices over all.

It also looks as if wet years don’t contribute to as big a price fall as we have seen without the presence of this CO_2-market. This is due to the fact that in the Nordic countries- even in wet years- the marginal cost of coal does have an impact on the price level. With the limited amount of growth in the hydropower field these last 15 years a dry year would give very high prices, but the scenario that will be presented here will be based on normal years, that is to say an average for the last 15 years. For Norway the average in this period was 120 TWh in today’s hydro power system.

The calculations of future power prices in the Nordic market are made in three different scenarios. These calculations are based on supply and demand. The supply function depends on the marginal cost, and the price is set as the point of interception between supply and demand. The marginal cost for coal condense production will in many periods of the year be the deciding factor on the price of power within the Nordic market.

History shows the price of power (wholesale market) to be around 200-230 NOK/MWh, delivered from the central grid. With the conditions we have used, we get the following power prices in a normal year for 2012:

- High: 550 NOK/MWh
- Middle: 400 NOK/MWh
- Low : 250 NOK/MWh

The price of electric power for 2006 in the forward market is 290 NOK/MWh as a base The price is expected to have a linear development in the period 2006-2012. In the period 2012–2020 the price is expected to be constant in real terms.

In order to compare the price with bioenergy, it is necessary to include distribution costs (250 NOK/ MWh), electricity fees (105 NOK/MWh) and sales commissions (40 NOK/MWh). Price forecasts for electricity to end-users, which can be compared with bio-energy, is shown in Figure 3.1.

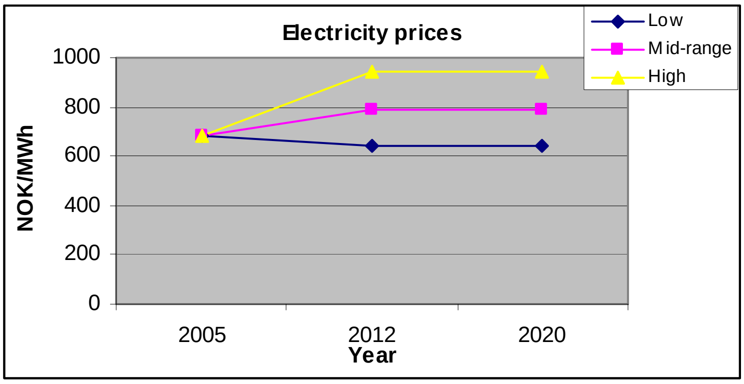

Figure 3.1. Electricity prices forecasts to end users

4 Scenarios

4.1 Foresight Process

The scenarios are developed through a *foresight process*, see Figure 4.1. The reference group, together with other persons of resource, has attended two dedicated seminars where the participants through creative processes have contributed to the formulation of the following problems:

- Which players affect the future of bioenergy
- Which factors affect the development
- Which bounded scenarios (mini-scenarios) can be pictured
- How can these mini-scenarios as a whole make up more general and adequate scenarios which can be of interest to the problem at hand
- What are the possibilities and challenges inherent in these scenarios
- What measures do these possibilities and challenges give rise to

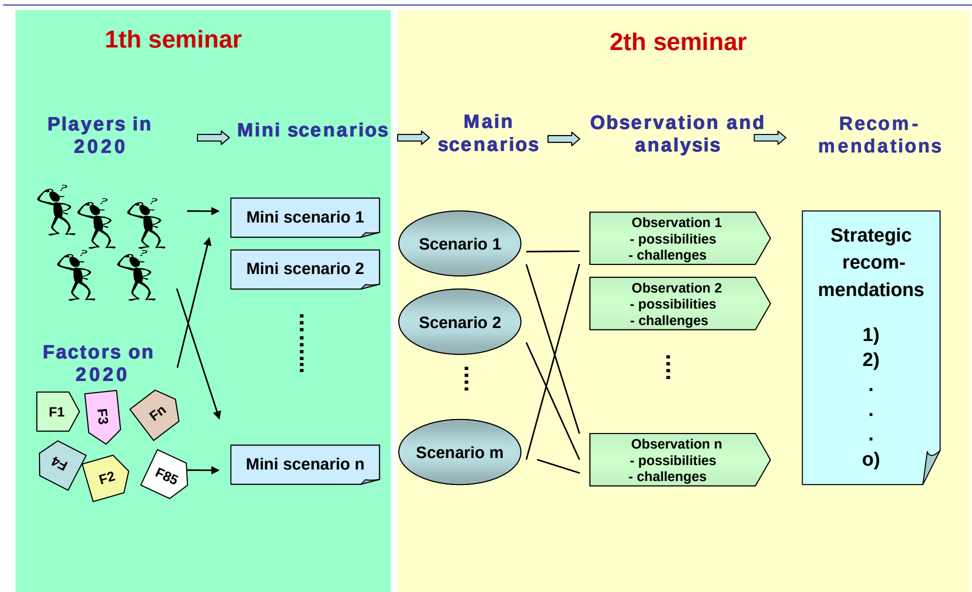

Figure 4.1. The foresight process

As a result of the foresight process, three main scenarios were drawn up which created the basis for further analyses. The scenarios give rise to different market developments, various forms of raw material supply and logistics solutions.

However, it is important to be aware of the fact that these scenarios in themselves are not meant to represent expected or wanted developments. The scenarios are tools for identifying developments that are founded in certain incidents, and for identifying the terms which must be met for these developments to take place.

4.2 Description of the Scenarios

The mini-scenarios and the main scenarios developed are described in an additional note. Presently, a shorter description of the three main scenarios is given:

1. **Bio-max**: every measure and incident with a positive effect on the use of biomass occurs.
2. **Bio-administrated**: the authorities initiate measures to reach planned objectives for the use of bioenergy.
3. **Bio-min**: no measures or incidents that affect the priorities of the users or the qualities of bioenergy systems relative to other systems occur, but there is a further expansion of district heating systems, and the bioenergy industry gradually increases its ability to compete.

In the **Bio-Administrated** scenario, the authorities employ what means they have in order to stimulate increased use of bioenergy in Norway. Such means can include subsidy and tax arrangements, together with actively employing relevant regulations and policies. An example of such stimulation is mandatory use of water-based heating in new houses and industrial buildings. Furthermore, there is an increased level of taxes on energy carriers letting out greenhouse gases. The Kyoto agreement is fully implemented, and a regime of green certificates for both electricity and heat is introduced. Electricity prices increases, but stay at a moderate level.

The **Bio-Max** scenario is basically developed from the same premises as in the "Bio-Admin" scenario, i.e. that the authorities use what means they have in order to explicitly stimulate increased use of bioenergy. In "Bio-Max", several other factors and incidents occur *in addition* to this, which strongly enhance the effect. Among these is the increase of competitiveness in the bioenergy industry, as a result of reduced costs. This happens due to improved logistics, better technological solutions, a better developed supply industry (standardization), and improved competence in the whole bioenergy delivery chain. Arrangements to even out high transport costs for forest owners with long stretches of transport are abolished. This means that these forest owners are less able to compete in the traditionally market, and they need to find other buyers. One positive effect is the growth of new, local, small production plants processing biofuel. Furthermore, new technology and new production techniques are introduced in the forest, with positive results. The forest industry control a larger part of the value chain towards the energy consumers. The bioenergy logistics chain is combined with existing logistics chains. New developments in technology make pellet ovens and boilers more user-friendly and automated. The district heating company *Viken* builds a large bioenergy plant in Olso. The plant, which is based on the best technology available, produces electricity and heat. Electricity prices are high.

A defining element in the **Bio-Min** scenario is that electricity prices stay low during the whole period, and that there is an extensive expansion of natural gas in the south-eastern part of Norway. This leads to a reduction in the competitiveness of bioenergy, compared to the other scenarios. Electricity keeps its position as the source of heating, and natural gas is the choice in many cases where bioenergy could have been an alternative.

4.3 Measures

Certain possibilities and challenges have been identified as a result of the scenarios developed. The potential for increasing the use of bioenergy is clarified and concretized through a realization of identified possibilities, and through dealing with the challenges presented in the scenarios. A selection of possibilities and challenges have been identified that each requires different measures from different interests, such as energy authorities, forest owners or others. In the following, some measures from different authorities are summarized briefly, and sorted in relation to the authority primarily responsible for carrying them out.

Energy authorities:

- Improving and obtaining competence within the different interests. Different networks for different interests in the chain will perhaps be considered. It is important to obtain experience, and to increase knowledge throughout the chain. Facilitating an industry network for transferring competence will prove effective.
- Subsidies for infrastructure, flexible solutions, and water-based heating (internal, local and central). This is a crucial component concerning increased market potential.
- Green certificates – for electricity and heating. These are two separate measures which both will affect the use of bioenergy. A certificate system for green electricity will increase electricity prices – also for heating. This will improve the competitiveness of bioenergy. A green certificate market will also improve the ability to compete against oil/petroleum, gas, and other fossil fuels.

Regional authorities:

- A change of attitude among the municipal authorities and the politicians. This is crucial when it comes to public decision-making processes concerning the construction and renovation of public buildings. Challenge related to knowledge and information which is assigned to the industry, energy and municipal authorities.

Other authorities:

- Demands from the authorities concerning new plants, in order to ensure adequate quality of what is installed.
- Subsidies for renting cultivated landscape and forest management measures.

Bioenergy authorities:

- Compiling a guide or manual with a collection of best practice.

5 Bio-heat Concepts

Within the study four biomass heating concepts are taken into consideration:

- district heating systems
- micro-grids
- central heating systems
- households

The main difference between these heating concepts is the scale on which bio-heat is produced. Due to these scale difference the technology will differ including the range of biomass that can be handled. On top, the smaller the scale the more “decentralized” the logistic system has to be. Technology, biomass and logistics, including import and export aspects, are interlinked with each other.

Table 5.1. Indications of scale and cost for bio-heating concepts

Concept	Power range	Fuel demand	Capital costs NOK/MWh	Maitenence costs NOK/MWh
District heating	10 – 100 MWth	10 – 100 kton	150-250	40-80
Micro-grid	1 – 10 MWth	0.5 – 10 kton	150-250	50-100
Central heating	100 kWth – 1 MWth	5 ton – 1 kton	150-250	70-120
Household	10 – 100 kWth	1 ton – 10 ton	200-300	50-100

Fuel demand and costs (NOK/MWh) depends on heating value, operational hours and efficiency. The costs can vary a great deal depending on local conditions. Every system must be adjusted to the specific local conditions regarded for that system, including the fuel to be used. Plants designed for moist bio-fuel is usually more expensive than plants using dry bio-fuel. On the other hand dry bio-fuel is more expensive than moist bio-fuel. The cost for district heating and micro-grids system includes costs for distribution system, and the cost for these systems are mostly based on cost estimates from a report from Norsk Fjernvarmeforening /13/.

These technologies are all commercially available at the moment in a wide range and with a large group of suppliers within Europe. On top technology developments take place which can be relevant for bio-heating applications in Norway within the given time frame until 2020. Several market drivers can be distinguished:

- larger fuel flexibility in combination with better environmental performance
- increasing energy efficiencies especially in the area of co-generation
- lower investment and operational costs
- small scale systems with the performance of large scale systems

Due to these market drivers several technology developments take place. In the area of combustion systems an ongoing evolution takes place on performing better with worse bio fuel and designing high performance small scale systems. Within Europe the market for these systems becomes more mature leading to an ongoing increase of the price/ performance ratio.

Next to combustion gasification, pyrolysis and torrefaction are upcoming technologies, but only combustion systems are assessed as commercial available within this decade. Alternative technologies can be of relevance after 2015, but is not included in the study.

Based on biomass fired heating systems related to the bio-heating concepts to be assessed in the study, a profile description can be made of the bio-fuel requirements, see table 5.2.

Table 5.2. Bio-fuel requirements based on commercial available technologies

Concept	Firing system	Bio-fuel requirements
District heating	Moving grate or Fluidized bed boiler	No specific requirements, fuel flexible Pellets, chips and mixed biomass Heating value 1,8 to 5 MWh/ton
Micro-grid	Fixed grate automatically operated	Contaminants allowed between limits, pellets, chips and homogeneous biomass Heating value 3 to 5 MWh/ton
Central heating	Fixed grate automatically operated	Clean and dry bio-fuel, pellets Heating value 3 to 5 MWh/ton
Household	Stove operated by hand or semi automatic	Clean and dry bio-fuel, pellets and logs Heating value 3 to 5 MWh/ton

According to /16/ major technological barriers in bio-heat systems is not identified, but many bio-heat installations in Norway have suffered from operational problems. Generally speaking this is due to lack of experience, fluctuating biofuel quality and not optimal equipment design.

6 Bio-heat Market Developments

6.1 Heat market

In the actual area (the central eastern part of Norway), the present domestic and commercial heat requirements is estimated to 25 TWh. The energy demand required for supplying that is estimated to 30 TWh, indicating an overall efficiency in the heating system of 83 %. To day 18 % of the demand is covered by firewood, and only 1 % by bio-energy as defined in this study, see Figure 6.1. The largest part is covered by electricity with over 50 %. Process heat demand in industry is not included.

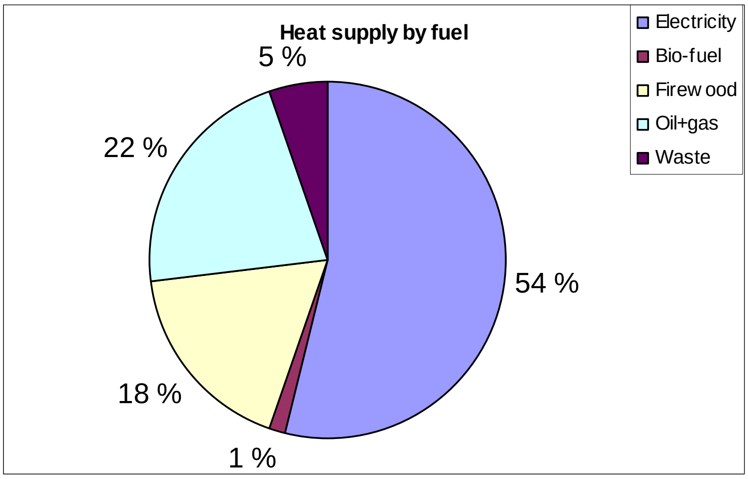

Figure 6.1. Distribution of energy carriers used for heat conversion, today's situation

About ¾ of the demand is in households or supplied by individual systems, see Figure 6.2.

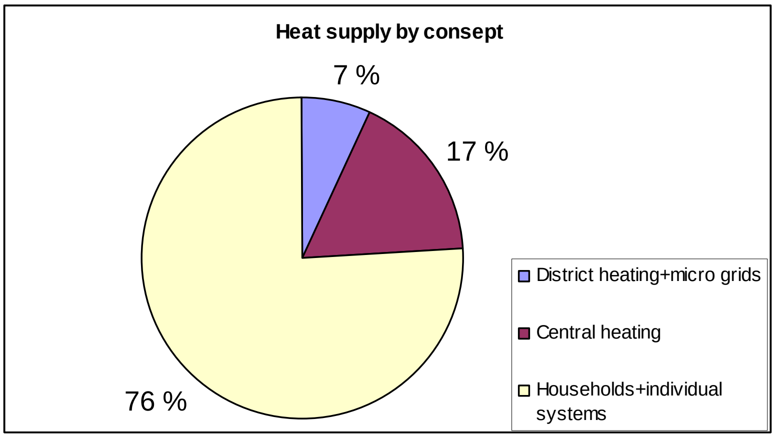

Figure 6.2. Distribution of heating systems

6.2 Development in heat demand

The most important drivers for developing heat demand are:

- population development
- increased space per resident
- increased energy efficiency (insulation)
- development of commercial sector pr inhabitant

Based on assumptions of population development given by SSB and other assumed developments, the energy supply for heating purposes in the area is expected to increase from 30 to 37 TWh in 2020.

6.3 Market development approach

The approach for the extension of the bio-heat market share can be two fold. Either bio-heat is introduced and extended within existing buildings or bio-heat is introduced in combination with the building of new houses and offices.

6.3.1 Existing heat market

In the existing heat market bio-heat has to push out the existing heating system. This is only possible when bio-heat is cheaper in use with at least the same level of convenience. In other countries in Europe (Austria, Germany, Sweden, Belgium) it is seen that when fossil fuel, especially heating oil, are used in combination with a water heating convection system bio-heat can be very competitive. In this case it is a replacement market. The existing fossil fired unit is replaced by a biomass fired unit when:

- the existing unit is at its end of life time
- the biomass price is significantly (30 to 50%) lower then its fossil equivalent
- bio-fuel storage capacity is available (basement)
- automatically operated well proven biomass fired boiler are commercially available

In case of electric heated houses the conversion to bio-heat requires a drastic rincecation of the heating system. Within a house the complete heat transfer system has to be replaced by water filled heat transport system. In existing situations the application of wall mounted radiators is most likely. Thus market penetration in existing electric heated houses is not likely to happen, unless the electricity price is very high. However, air can also be used for heat transportation inside the house, requiring less system modifications, and improving the bio-heat penetration chances. Modernisation of existing firewood system is an other replacement option in households. Especially houses with a traditional stove suited for one room are a possible market for new biomass fired units able to heat part of or the whole house. The chances for bio-heat to penetrate the traditionally firewood market is uncertain. Much of the firewood is purchased outside a market at low prices.

In existing district heating systems, an other replacement opportunity can occur. Existing heat producing unit can be modified from for example oil firing to biomass firing. This is likely to happen when:

- the existing unit is at its end of life time (replacement)
- the biomass price is significantly (15 to 30%) lower then its fossil equivalent
- bio-fuel storage capacity is available
- biomass firing fits within the existing location, permits, environmental situation
- the heat demand is increasing and an investment must be made in any case

The pre-condition of a competitive biomass price implies that enough biomass is available at a price which is low enough, also on the long term.

6.3.2 New heat market

In new buildings the market circumstances for introducing bio-heat are completely different. In these cases, assuming that the biomass price is significantly lower than the fuel price of its alternatives, bio-heat can be introduced in the market rather easily. The market growth depends in the first place on the building volume that is expected to be realised within the time frame 2005 until 2020. In the second place the market share for biomass is an important aspect. It is expected that an assessment on the market share is hard to do. Energy pricing, governmental support, public acceptance and perception, image and investment costs compared to alternatives are all factor having impact on the final market share.

Often the growth of the new heat market is slow. Existing buildings are only replaced by average once in 50 years and the demand for new building adding volume to the existing market is in developed countries limited. On top, new buildings are often more energy efficient resulting in lower heat demands. The new heating market is therefore small compared to the existing market.

6.3.3 Marked share predictions

The market shares of the heating systems are a result of choices taken by the users, especially when they are in a position to act. A heating system can always be changed, but the most likely situations happens when new buildings are built or when the building or heating system is at the end of its life-time, and should be renovated. Based on an assumed renovating of 2,5 % per year, Figure 6.3 shows the percentage of the heating systems in the area that is new, renovated and unchanged during different time periods. The figure also shows the percentage of water heating system not connected to a micro-grid or district heating system. These system can relativity easily be converted to bio-energy.

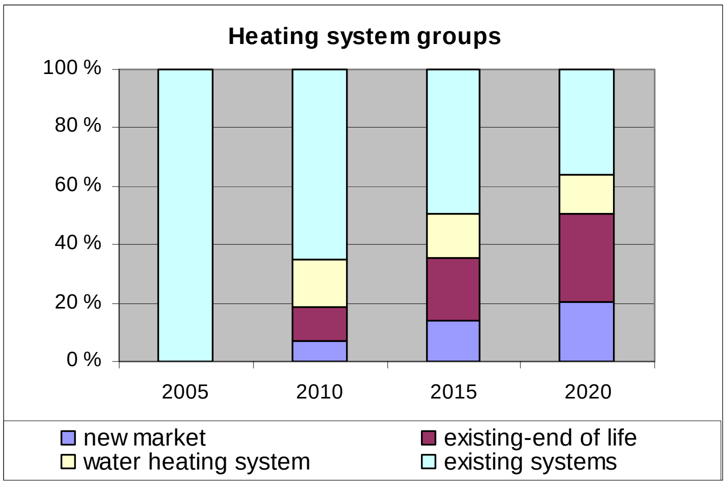

Figure 6.3. Groups of heating systems in percentage of total

Choosing heating systems are in most cases done by the owners. As a rule the system can be chosen freely, but in certain areas the system is decided by local authorities, like district or micro grid heating systems. When the owner of a building is choosing a heating system he will consider different aspects, which can be emphasized differently.

In the study we have chosen some aspects, and consider the users priorities and the different system characteristics with numbers from 0 to 4, according to these. This can be used to calculate shifts in the heating systems market shares. If nothing happens that change the users priorities or the systems characteristics, the market share will be unchanged. But if something happens that influence the priorities or the system characteristics, the market shares will change.

In the study three different scenarios affecting development of bio-heat is described. The scenarios include incidents and actions that might influence the priorities and the characteristics of the systems. The market shares of bio heating system referring to different scenarios are calculated through a systematic considering of how actions in the scenarios might influence the competition relationship of the systems.

The development of district heating and micro grids in the area is based on study from Norsk Energi /12/, where the expansion of these systems, in different municipalities, is indicated in the period until 2015. We have projected these values until 2020 based on estimates from Norsk Fjernvarmeforening of total consumption from district heating systems/19/.

6.3.4 Prediction of bio-heat demand

Based on analysis of the existing and the new heat market, and the expected market penetration for bio-heat, predictions are made for the demand of bio-energy related to the different scenarios, see Figure 6.4.

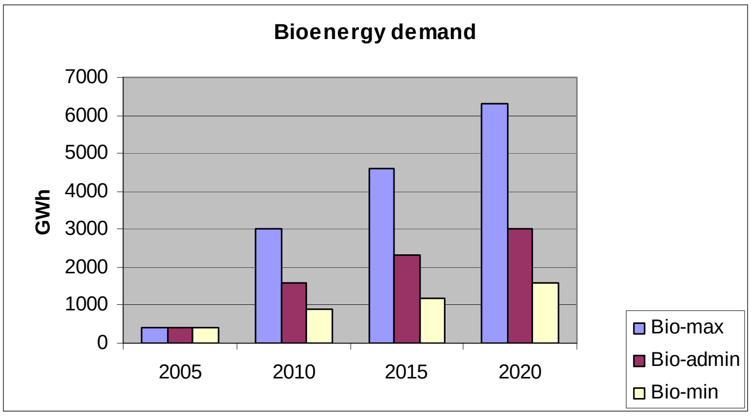

Figure 6.4. Bioenergy demand for heating in different scenarios

In the bio-max scenario the demand for bio-energy is expected to be 6,3 TWh in 2020, covering 17 % of the heat demand in domestic and commercial sectors in the area, see Figure 6.5.

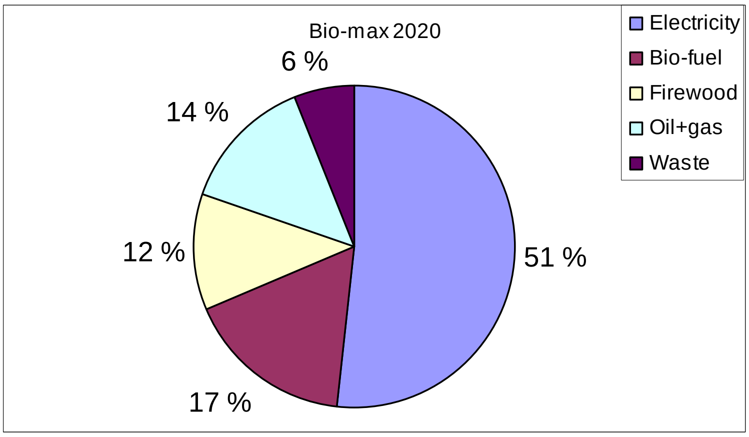

Figure 6.5. Distribution of energy carriers used for heat conversion, estimated Bio-max 2020.

Biofuel is defined as chips and pellets. Firewood is not included in the term biofuel, as used in this study. As shown also firewood is used (12%) in this scenario, and the total share of biomass (inclusive firewood but exclusive waste) for heating is 29 %. It is expected that many households will still use firewood. There has been a lot of innovation concerning firewood systems the last 20 years and there is still potential for improvement. There is an uncertainty in the Bio-max scenario concerning to what degree pellets stoves will replace firewood systems.

Given the key figure that 1 Mm3 wood equivalent equals 2 TWh, 3,15 Mm3 is required in 2020 for the Bio-max scenario. With a heating value of 4,7 MWh/ton (pellets), 1,3 Mtons per year is required. Firewood is not included in these figures.

In the other scenarios the demand for bioenergy is calculated to be roughly ½ (Bio-admin) and ¼ (Bio-min) of that. From the low figure in 2005 the yearly growth rates for bioenergy, in the short term (until 2010), will be 100 %, 40 % and 15 % for Bio-max, Bio-admin and Bio-min respectively. Handling this will be a great challenge, especially for the Bio-max scenario.

6.4 Geographical distribution of demand

Transportation is an important element in the logistic chains. The distribution of the demand and the supply in the area must therefore be taken into account when logistic chain costs are calculated. The exact locations are not known, and assumptions have to be made. In order to get a broad overview, we have divided the area into 14 sub-regions, by dividing the big counties in two sub-regions each, and keeping the smaller ones as one sub-region. The Figure 6.6 shows the distribution of heat demand (left), and the distribution of energy delivered from district heating systems (wright), in the different sub-regions, in percent of total.

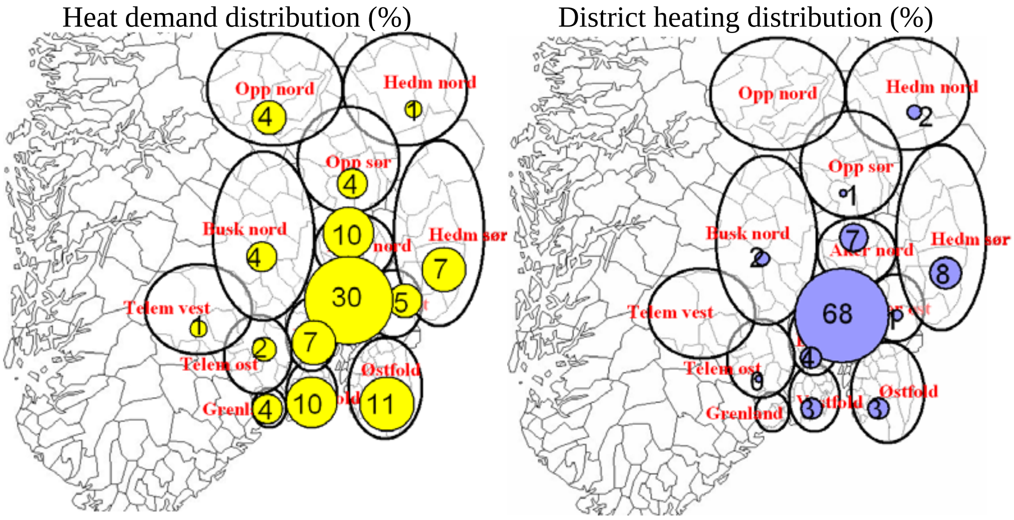

Figure 6.6. Heat demand distribution (left), and distribution of energy delivered from district heating systems (wright), in percent of total.

The total demand for heat today is 30 TWh (equal 100%), 70-80 % of the demand is located from Oslo and southward. The demand is expected to increase to 37 TWh in 2020, with a slightly different distribution.

The energy delivered from district heating systems and micro-grids, is expected to increase from 1,8 TWh to 6 TWh in the same period to 2020. Today 68 % of the district heating is located in the area Oslo + Asker/Bærum. This share will be reduced to 53 % in 2020.For the Bio-max scenario, the share of solid biofuels in these systems is expected to increase from 10 % today to 37 % in 2020 as an average in the whole area. This share is assumed to vary depending on the local access of biomass and the population density, from 80 % in the regions with most biomass and less people, to 20 % in the regions with less biomass and more people. In central heating systems and households the distribution of biofuel is expected to equal the distribution of the heat demand, minus energy delivered from district heating and micro-grid systems.

The type of solid biofuels used (%) in different heating systems is shown in table 6.1 below. In the table, Residue is residue from wood based industry.

Table 6.1. Type of biofuels in heating systems (%)

		Bio-heating system			
		District heating	Micro-grid	Central heating	Household
Bio-fuel	Chips	60	30		
	Residues	30			
	Pellets	10	70	100	100
	Total	100	100	100	100

With these assumptions the demand (in GWh/year) for different solid biofuels in the sub-regions according to bio-max scenario in 2020, is shown in figure 6.7.

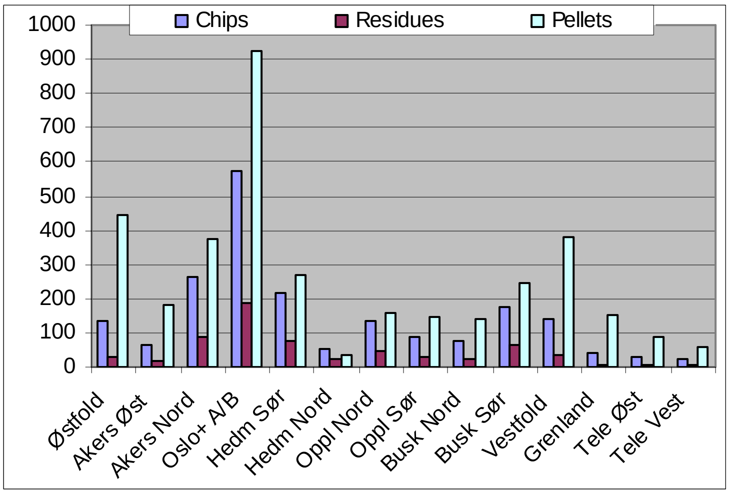

Figure 6.7. Biofuels in sub-regions –Bio-max scenario 2020.

Figure 6.8 shows the total demand for the different solid biofuels in 2020. Residues from wood based industry can be used as raw material for pellets production or directly as a fuel in district heating systems. The figure shows only the part used directly.

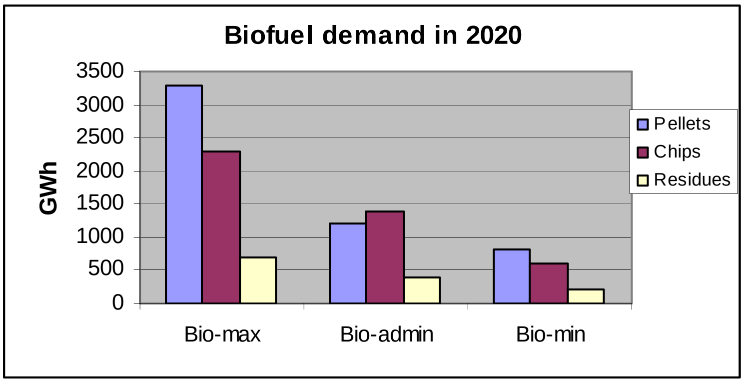

Figure 6.8. Biofuel demand in 2020

6.5 Geographical distribution of supply

It is not easy to procure statistics for local distribution of biomass resources in the area, and assumptions have to be made. It is assumed that a relation between the quantity of harvesting and the quantity of resources exists. With this assumption the percentage distribution of forest resources are shown in figure 6.9.

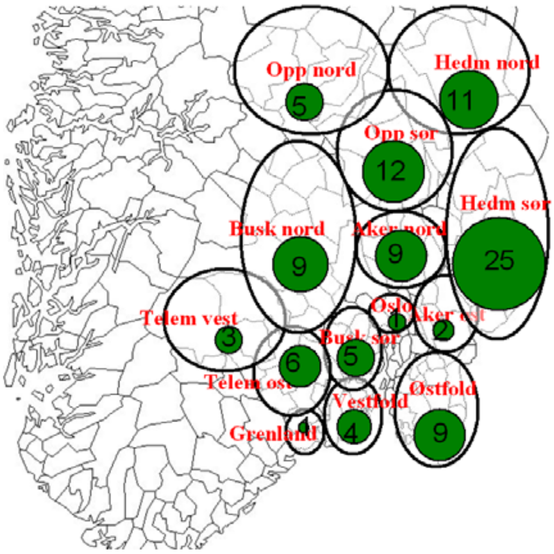

Figure 6.9. Distribution of forest resources in percent of total

In 2004, 6,5 mill m3 (100%) was harvested in the area. Figure 6.9 shows the distribution of that. It is assumed that this distribution also can be applied for the resources described in paragraph 2.3.

The calculated local distribution of residues from forestry industry is based on the purchase of timber and the location of sawmills. The distribution resembles figure 6.9, but is slightly different.

7 Logistic Chain Elements and Costs

7.1 Logistics Chain elements

In the study it is assumed that the solid biofuels distributed to the heating system are wood chips, residues from wood based industry and pellets. Logistic chains capable of delivering the amount of energy demanded must be developed. Logistic chains consist of logistic elements as shown in Table 7.1.

Table 7.1. Elements in different logistic chains

	Biomass products						
Logistic elements	Wood chips	Residue (from foresty industry)	Pellets (based on residue)	Wood chips	Pellets	Pellets	Pellets
Biomass							
Harvesting	●			●			
Storage at roadside	●			●			
Residue from forestry industry		●	●		●	●	●
Transport	●	●	●	●	●	●	●
Sales			●		●	●	●
Pretreatment and logistics							
Central storage	●	●	●	●	●	●	●
Central chipping	●			●			
Central drying			●		●	●	●
Pelleting			●		●	●	●
Central transport	●	●	●	●	●	●	●
Storage retailer						●	●
Local transport						●	●
Sales	●	●	●	●	●	●	●
Heat conversion							
Heat conversion	●	●	●	●	●	●	●
Distribution	●	●	●	●	●		
Sales	●	●	●	●	●		
	District heating	District heating	District heating	Micro-grid	Micro-grid	Central heating	Household
	Heating systems						

The cost of a logistic element in the chain depends on three conditions:

- *production*, i.e. the size of the biomass or solid biofuel being treated
- *size of the task*, i.e. the work that has to be done with the biomass, e.g. moving the biomass from one place to another
- *system*, i.e. the apparatus or component employed to solve the task. Unit costs per task unit and production unit can be attributed to the system. The unit costs depends on the technology, the capacity etc.

The cost related to a logistics element can be calculated as the system's unit cost multiplied by the size of the task and the production. Based on colleted data unit costs curves are estimated in the study, see reference /1/. The production and the size of the task are related to different scenarios, distribution of demand and raw material (biomass) in the area, and different logistic strategies.

7.2 Wood chips chain cost structure

According to Norsk Bioenergiforening /17/ , 15.000 tons of wood chips were used in 17 bioenergy district heating and micro-grid systems in Norway in 2004. The increase from 2003 was over 80 %.

7.2.1 Description

The logistics chain for the different types of chips starts with the harvesting of the raw material in the forest, before sorting and transport to a forest road. The timber dries naturally, with no additional energy, for approximately one year before chipping. The drying process can take place in the forest, beside the road or in a terminal. The chipping is done using a chipping machine in the forest, by the road (or in a terminal) or at the heating plant if they can provide the space needed. The challenge with respect to logistics lies in where the timber can be stored and where it is chipped, and if it must be handled a number of times while in the terminal. The terminal cost thereby consists of two components in addition to the chipping cost: One component is storage; the other is in connection with loader handling. When the timber is chipped, it is treated as fresh produce. Consequently, chipping is carried out only when a customer is ready to receive the chips.

The chain of logistics for forest residues and whole trees differentiates from stem wood in that the entire drying and chipping process takes place in the forest, by the road. The wood is transported to a road during the summer, while chipping is done in the winter. As is the case with timber in the terminal, it is important that residues and whole trees are stored in a way that minimizes the moving of both the wood and the chipping machine, and also the number of chip piles. Because residues and whole trees are stored in the forest, there are no costs with regard to storage, beside the cost of transportation to a road and immediate costs in connection with the use of cardboard for protection against moisture. In this report the transport costs in the terrain are included in the raw material cost. The drying period for residues will vary somewhat between 12 and 18 months. An other alternative is to chip the raw material directly.

District heating based on residues from sawmills and wood-based industry has the simplest logistics chain, as there are no links or processing between the supplying industry and the heating plants. The residues consist of bark, shavings, chips and stubs. Stubs are often ground to chips before it is delivered to heating plants. Transport takes place mainly from sawmills or wood based industries to heating plants by container trucks or chip trucks

7.2.2 Costs

Typical logistic costs for wood chips in the Norwegian market today, including costs for the biomass, are shown in figure 7.1. There is a scale effect in chipping, but after a production of 10.000 ton/year, the cost curve is rather flat.

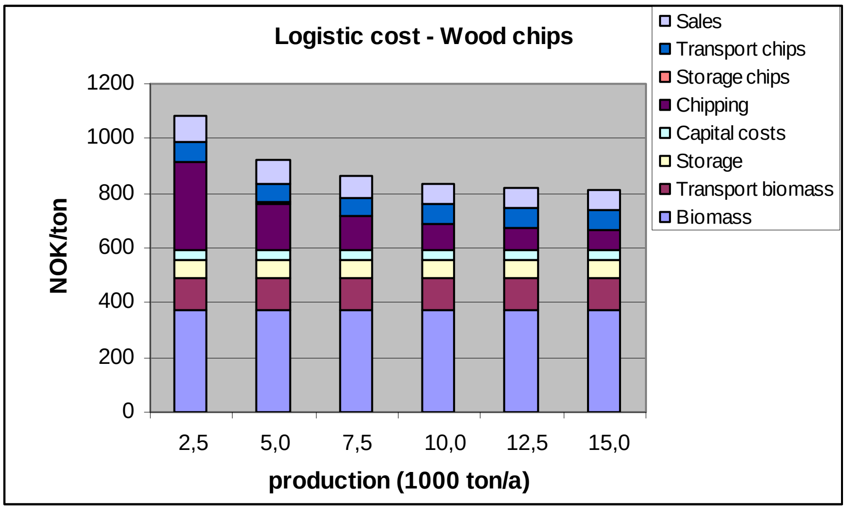

Figure 7.1. Wood chips logistic chain cost structure, including cost for biomass

The figure is based on the price for pulpwood pine as the biomass resource, and chipping in a terminal. As described earlier also other biomass resources can be used, and the chipping can be done either in the terrain, by the road or by the energy plant. The figure 7.2 below shows typical costs for different biomass resources chipped either by the road (residues and whole trees) or by the plant (pulpwood pine and spruce).

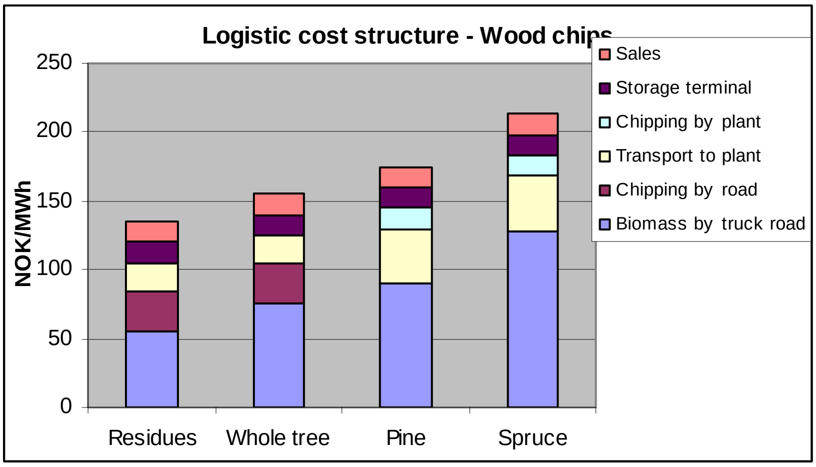

Figure 7.2. Different wood chips logistic chains, including cost for different biomass

According to this figure the costs for wood chips delivered at the plant based on pulpwood are typically 175-215 NOK/MWh, and based on residues and whole trees typically 135-155 NOK/MWh, including cost of biomass. The biomass cost can however vary within wider limits, and the costs in the figure must be regarded as examples.

The average logistic costs for supplying wood chips in the area, corresponding to the demand in 2005 and 2020 (bio-max scenario), is shown in Figure 7.3. In this figure the cost for biomass is not included.

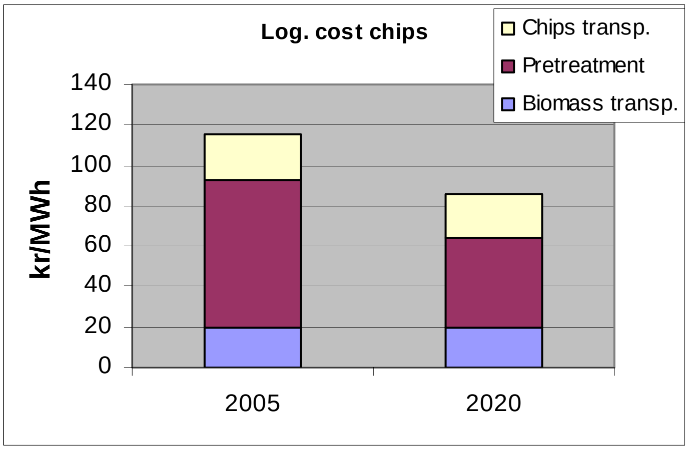

Figure 7.3. Logistic costs for wood chips in the area, exclusive cost of biomass – Bio-max scenario

Because of the increased market volume from 2005 to 2020 the logistic costs are reduced with 30 NOK/MWh. In the wood chip chains it is important to reduce the transportation costs. A decentralised logistic structure, using as much as possible of the local biomass in local bioheat systems, must be aimed at.

Most relevant for Norwegian conditions, is to chip at the roadside. For big district heating system, baling and central chipping can be economical. This fit in with experiences from Sweden and Finland. In Denmark it is most commend to chip in the forests, but that is difficult in the Norwegian terrain.

7.3 Pellets chain cost structure

According to Norsk Bioenergiforening /17/, 25.000 tons of pellets were sold in Noway in 2004, and 35.000 tons were produced by the 9 pellets producers. The increase in the inland sales from 2003 was 60 %.

7.3.1 Description

The production of pellets is nowadays mainly based on residues from sawmill and wood-based industries. However, there is also some production from timber and bark. The supply chain of pellet production based on timber starts with harvesting of wood in the forest, which in turn is transported to the producer, where the raw material is chipped, dried and densified. Production based on residues from sawmills and wood based industries have a logistics chain starting with the supply of raw materials. The raw materials usually consist of shavings or sawdust. These raw materials have a substantially larger volume than the finished products, and considering transport costs it is expedient that production takes place close to the raw material. Depending on the quality of the raw material, it is ground, dried and pressed into pellets. Production based on sawdust does not require any grinding before drying and pressing, whereas production based on shavings requires densifying only. The finished goods aimed at the household market are mainly packed in small or large bags, whereas products aimed at district or central heating plants are transported and stored in bulks. The storage period for finished products is often long, due to the fact that pellets are a seasonal product and that the demand for pellets has been low.

Pellets are transported partly by regular trucks (tipping from the sides or from the back), whereas pellets delivered in bulks are transported in container trucks, where the pellets are blown from the truck into a silo or container at the heating plant. In bulk distribution, possibilities for return transport are limited, but the trucks that are used can also transport animal feed. Consequently, pellet production can be located to those districts where meat and dairy production is extensive.

7.3.2 Costs

The cost structure for production and delivery of pellets, for small scale application, in the Norwegian market today, is estimated to 1600-1800 NOK/ton, see Figure 7.4. The average price for pellets in Norway delivered in small bags, transport cost not included, is 1600 NOK/ton according to /17/.

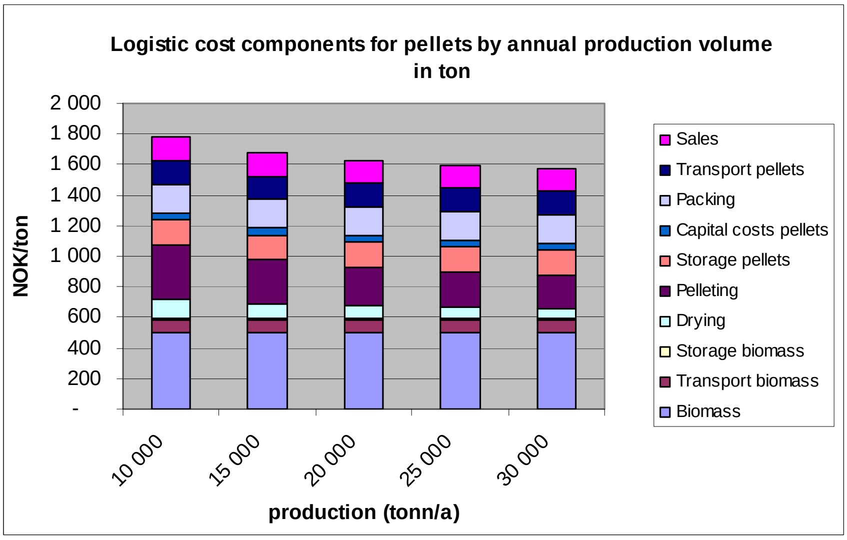

Figure 7.4. Pellets logistic chain cost structure, including cost for biomass

About 30 % of the cost is the cost for biomass (raw material), see figure 7.5, about 15 % is transportation, 10 % is sales and 45 % production of pellets including storage.

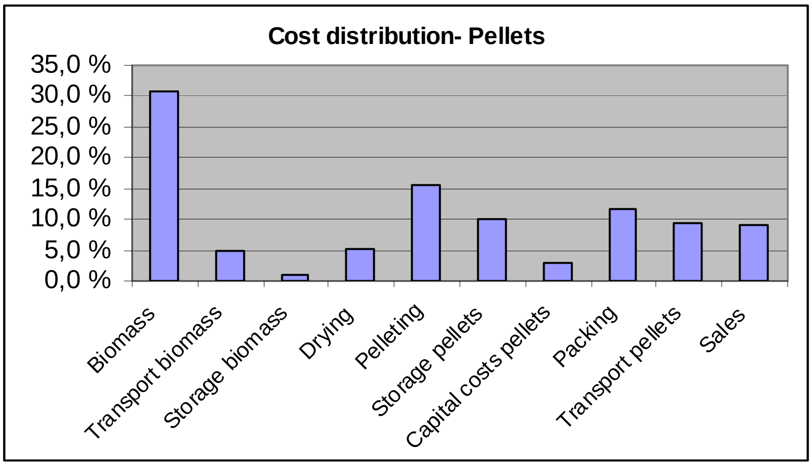

Figure 7.5. Cost distribution in pellets logistic chain.

The typical size for a pellets factory in Norway is rather small, around 7,5 kton/year. There is an effect of scale in pellets production, but the cost curve for pelletizing and drying is rather flat from around 40 kton/year output. In the pellets chain logistic the sizing and placing of the production plants must be in accordance with the logistics for the raw materials and the demand for pellets. The analysis carried out indicates that with a low demand for pellets, or if the raw material doesn't have to be transported, the area can be covered with one production plant. If raw material has to be transported from other places in the area, it is cost effective to increase the number of production plant dependent on the development of the demand. The production plant must be placed as close as possible to the raw materials. In the Bio-max scenario the analysis shows that 9 production plants is the optimum between the upfront logistics and the economy of scale of the pellet plants in 2020. The plants are distributed over the area with a minimum size of 20-25.000 ton/year, and a middle size of 60.000 ton/year (300 GWh).

The logistic costs is depending on the market volume for pellets, see Figure 7.6. The figure shows the average logistic costs in the area, excluding costs for raw materials and sales, for pellets delivered as bulk and for pellets in bags for 2005 and for the different scenarios in 2020. Compared with the market volume in 2005, the logistic costs in 2020 are reduced with 20-35 NOK/MWh.

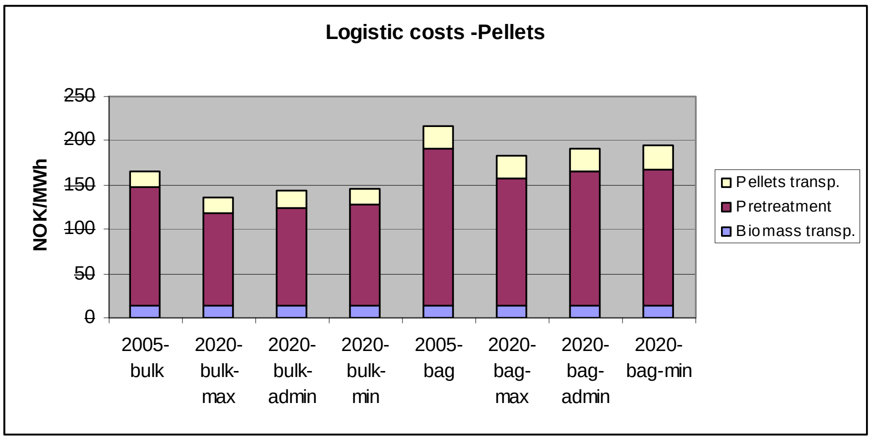

Figure 7.6. Logistic costs for pellets in the area, exclusive cost of biomass –Bio-max scenario

7.4 International pellet prices in the end user market

7.4.1 Small scale applications

In the today's end users market the wood pellets price varies by country. The price small scale end users have to pay for wood pellets (3 to 5 ton delivery per annum by truck) is in average in Europe 150 to 170 Euro per ton (1170-1330 NOK/ton) /18/. The highest price is paid in Sweden, being 210 Euro per ton (1640 NOK). The lowest price is paid in The Check Republic, being 110 Euro per ton (860 NOK). The explanation for the high price in Sweden is the tax on fuel oil for heating applications in combination with the rapid growth of the demand for pellets over the last years. Although the pellet price in Sweden is high, the difference with the fuel oil price is high enough to increase the market share of wood pellets. The end consumer price of wood pellets is 50% of fuel oil. Although Sweden has a large inland production (1,600 kton/year) there are also needs to import wood pellets to fulfill the national demand. The explanation for the low prices in countries in Eastern Europe is in general the low prices of competitive energy resources. Wood residues are still cheap and are often regarded as waste, making it possible to produce, in combination with cheap labor, wood pellets at low prices. A typical example for the Norwegian market is Austria with a mature wood pellet market mainly based on the national production of wood pellets. In Austria wood pellets for heating are in competition with existing electric and fuel oil based heating systems and the upcoming alternative of heat pumps. Typical small scale end user prices in Austria are around 165 Euro per ton (1300 NOK).

7.4.2 Large scale application

Typical examples of large scale application of wood pellets can be found in Sweden (industry and district heating), Denmark (power plants and district heating) and the Netherlands (power plants). The prices for wood pellets, still mainly based on high quality raw material are significantly lower then the prices for small scale application. Typical figures are between 5.50 and 7.00 Euro/GJ (160-200 NOK/MWh or 750-950 NOK/ton). In Norway the middle price are 230 NOK/MWh (1100 NOK/ton) /17/.

7.4.3 Future expectation

Historical price developments learn that the price of wood pellets is stable. In this way wood pellets behave more like coal then like natural gas, oil and electricity. To a certain extend it is expected that prices will stay stable also in the future due to the fact that the world wide resources are so large and so diversified over countries and regions that scarcity is unlikely to occur. Also because of the fact that it is likely that low grade wood resources will be used more and more for large scale applications. However scarcity can be a problem in the upcoming 10 years in case the development of the supply side is not able to follow the development of the demand side. Especially when large scale application like co-firing in power plant are going to use huge volumes of wood pellets temporarily market distortion is likely to take place.

It is likely that the pellet price for large scale applications will be around 100 to 120 Euro/ton (5.70 to 6.90 Euro per GJ, 160-200 NOK/MWh) and for small scale application around 150 to 200 Euro/ton (8.60 to 11.50 Euro/GJ, 250-330 NOK/MWh)

7.4.4 Limitations on pellet costs

There is only a market for pellets and pellet heating systems when its price in daily use is competitive with its alternatives in combination with the trust of the end user that the price of wood pellet heat on the long term is the lowest compared to its alternatives. Experience in the market development in the German speaking countries and Sweden showed that the market is seriously interested in wood pellet heat on the natural moment for investments in a heating systems (new house, replacement of old system) when the energy price based on pellets is around 30% lower then the energy prices based on the alternative fuel. The price has to be significantly lower since investment costs are higher, 3 or 4 times a new gas or oil fire system. The difference in maintenance cost is not that significant.

8 Bio-heat Costs

8.1 Total costs

Based on investment and maintenance costs as shown in Table 8.1, and the costs for raw material and logistics described earlier, total costs for different bioheating system are calculated.

Table 8.1. Estimated costs for bioenergy heating systems (NOK/MWh,year)

		kr/MWh/a			
		Capital		Maintenance	Sum costs
Heating system	Efficiency	Central	Distribution		
District heating	80 %	100	100	60	260
Micro grid	80 %	150	50	80	280
Central heating	80 %	200	0	90	290
Households	80 %	250	0	50	300

With today's logistic costs, the costs for district heating systems using wood chips are 500 NOK/MWh and 600 NOK/MWh for wood pellets. These figures will be reduced to 450 and 550 NOK/MWh in 2020 for the Bio-max scenario, see Figure 8.1. The logistic costs amount to 20-40 % of the total costs. The costs are 10-25 % less than the todays price for electricity, but 40-50 % lower than the high electricity price.

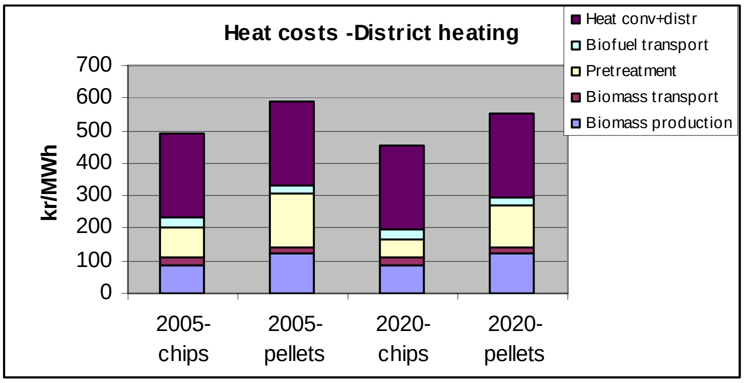

Figure 8.1. Bio-heat costs- District heating systems

Equivalent costs for pellets delivered to household, is shown in figure 8.2.

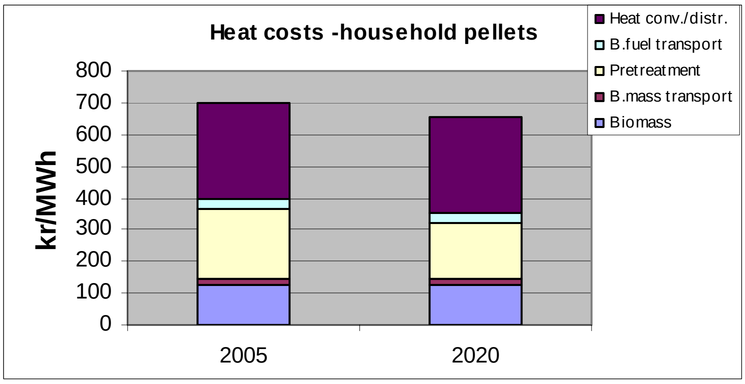

Figure 8.2. Bio-heat costs- Households

The total heat costs are 650-700 NOK/MWh, of which logistic costs come to 35 %. The cost in 2005 equals the electricity price, but is 30 % under the high development of that price, see Figure 8.3.

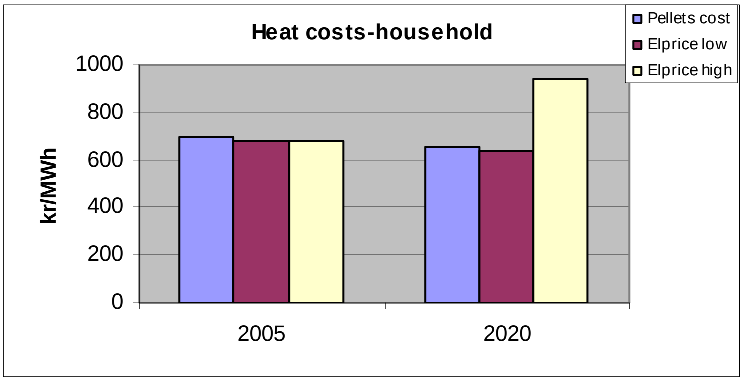

Figure 8.3. Bio-heat costs households compared with electricity prices.

In this comparison (Figure 8.3) the heat cost for pellets includes the costs for the heating system, while the electricity price doesn't. The comparison is therefore relevant for bio-heat competing in an existing market. In a new market competition, the cost for the electric system must be added to the electric price, and the difference will increase in favour of bio-heat.

8.2 Sensitivity analysis

In the calculation of the total bioheat costs five different system component are distinguished; biomass production, biomass transportation, pre-treatment, transport of biofuels and energy conversion. The pre-treatment contains both production processes (sizing, drying and densification) and storage. The sum of the transportation and the pre-treatment is regarded as components in the logistic chains in the study. The length of the transportation of biomass and the solid biofuels depends on the location of the production compared to the location of the raw material and the market.

In order to gain insight in the relative influence of variables, a sensitivity analysis is performed for the total heat costs. Some results are presented in the figures below, given the variation values at the x-axis, (100% is the default value that gives the results in chapter 8.1), and the total heat costs at the y-axis.

For both district heating systems and households, heat conversion and distribution is the component with the greatest influence on the heat costs, and therefore variations in this cost component has the greatest impact on the heat costs. A 50 % reduction of the costs for the heating systems, affects the total heat costs with 20-25 %.

In the wood chip logistic chain supplying district heating system, variation in the costs for biomass, transportation and pre-treatment have roughly the same effect on the heat cost. A 50 % decrease in the costs, will reduce the heat costs from 500 to 450 NOK/MWh (10 %) for each component. See Figure 8.4.

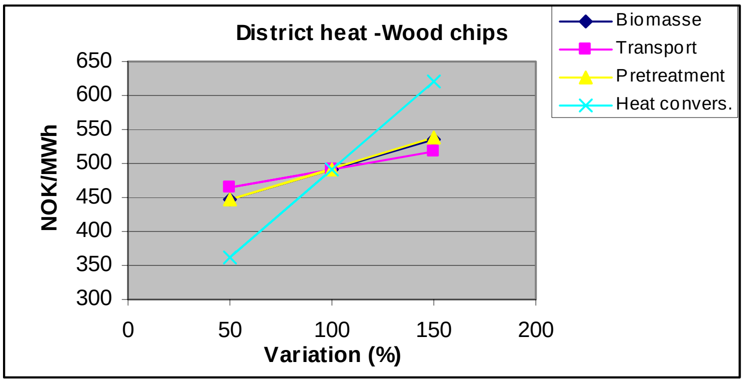

Figure 8.4. Sensitivity analysis – Wood chips in district heating

For the pellets chain supplying households a reduction in the pre-treatment costs have the greatest influence of the components in the logistic chain, a reduction of 50 % affects the total costs with 15-20 %. Variations in the transportation costs have a minor effect on the total heat costs. See Figure 8.5.

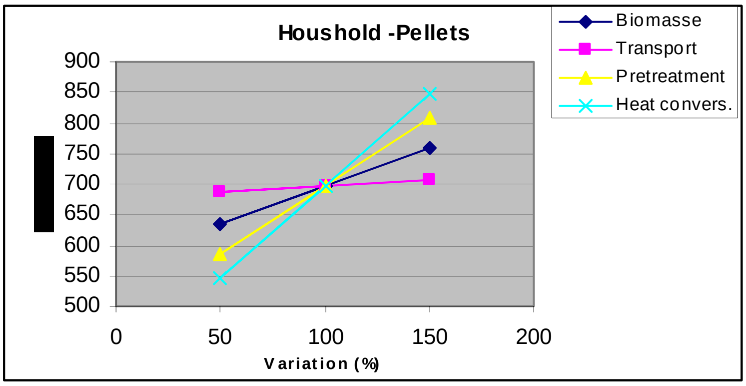

Figure 8.5. Sensitivity analysis – Pellets in households

9 Market Drivers for Import and Export

9.1 Export

In general export can take place when there is almost no national demand (or supply potential exceeds the demand) and when the production of bio-fuels can take place at low costs. To be successful in export means that bio-fuels, including the cost of handling and transportation, are competitive in price in other markets. As a rule of thumb the price in the destination harbor has to be around or below 6 Euro/GJ (170 NOK/MWh), taking today’s energy prices in account. The price on board in Norway has to be around 4 Euro/GJ (110 NOK/MWh). When export can be combined with ongoing export activities in the area of timber and paper industry synergy advantages can be achieved.

When a national bio-heat market is developed an extension can take place towards exporting of bio-fuels to the European bio-energy market. This market is likely to grow very rapidly in the upcoming decade due to increasing promotion efforts. Compared to electricity and natural gas bio-fuel is a less convenient energy resource to export with higher cost and a more complicated logistic infrastructure involved. So instead of exporting bio-fuels a strategy can also be extending the export of (hydro) electricity and natural gas and reducing its national use through a shift toward bio-heating systems.

9.2 Import

In general import will only take place when strong market drivers exist, and only when large volumes are involved, since this is the only way to compensate the often higher transportation and handling costs. A demand for large volumes can occur due to two developments. The first development, with Sweden as an example, is a main stream market for bio-heat. Bio-fuel is very competitive and applicable in several market segments resulting in a rapid increase of the national demand (900 kton/year wood pellets). Import is the solution to cope with the demand growth (200 kton/year). Although the national production of bio-fuels is the largest in the world, Sweden is a net importing country of bio-fuels. The second development, with the Netherlands (but also Denmark) as an example, is a market for large scale bio-energy applications. Due to the promotion of co-firing biomass in coal fired power plants a large demand is created (above 1,000 kton/year). Importing is nowadays common practice.

Transferred to the Norwegian situation bio-fuel import can be relevant in case of:

- a main stream market where biomass is applicable in households and large and medium scale units in industry and district heating systems.
- a large (> 200 kton/year) biomass fired district heating or CHP plant located near a harbor, near a main railway track or along the coast allowing a more cost rincetive use of imported biomass instead of biomass originating from the hinterland.

On the short term (2010) the second case is likely to be most relevant. But in the Bio-max scenario also the first case can be a market driver on the short term. The estimated demand for pellets in 2010 in the Bio-max scenario is 300 kton/year, with a demand growth of 55 kton/year. This demand growth is higher than today's production, and import can temporary be a solution to cope with the demand growth.

Development of import and export is likely to happen on mid term and long term and only when pre-conditions are good. For the moment, based on experience and taking into account the available information, only import is expected to play a role on the short term. The possibilities of importing can be assessed in relation to the intention of Viken Fjernvarme to build a large biomass fired CHP plant in Oslo. Export is not expected to be an issue on the short term.

It is not common to transport wood chips over great distances for energy applications (200 km or more) and thus import and export wood chips is not likely to happen, due to the fact that the energy density per unit volume is low. It is 2.5 to 3 times more efficient to transport pellets made from wood chips instead of wood chips. However import and export can take place due to temporarily shortages in the market supply, and over the boarder to Sweden by truck.

Timber is imported to the paper and wood based industries. If the price for stem wood is low enough, and import can be combined with ongoing timber import creating synergy advantages, timber may also be imported for energy purposes, in connection to large systems near the cost, e.g. a CHP plant in Oslo.

9.3 Export and import from the local area

In paragraph 7.3 logistic costs for supplying the area with locally produced pellets was calculated. An alternative strategy is to import pellets to the whole area or to some regions close to the coast. The difference between the international price for pellets and the price for the raw materials for local production, decides whether local production or import is most profitable, see Figure 9.1.

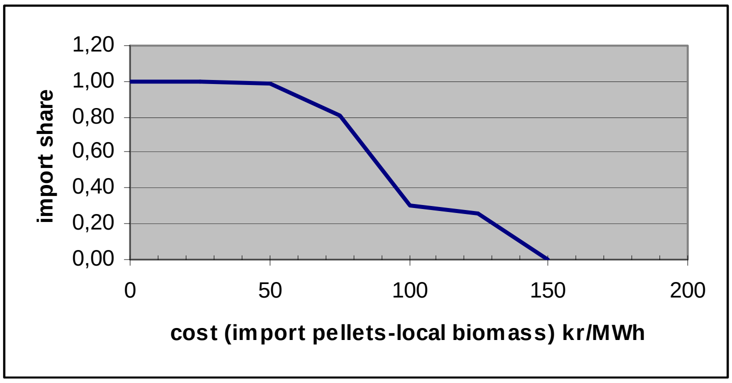

Figure 9.1. Share of imported pellets in the primary region, as a function of the difference between the price of imported pellets and cost of local biomass.

The figure shows the import market share as a function of this difference. If the price for biomass for local production of pellets is 100 NOK/MWh, and the international pellets price (free on board) is less than 150 NOK/MWh, it is profitable to import 100

% of the pellets, and if the international pellets price is over 250 NOK/MWh, import is not profitable. The reason for the shape of the curve is the division of the region in sub-regions. These results are based on the logistic costs calculated in this study. Local conditions can change the costs and give other conclusions.

Typical nowadays CIF prices (import by sea including loading costs, ocean freight and insurance) are in the range of 100 to 120 Euro per ton for wood pellets (heating value around 17 GJ/ton)(165-200 NOK/MWh). At this price wood pellets can be imported in the EU, including Scandinavian countries, from for example Canada, United States, Baltic States and Russia. In this case import takes place at a large scale in freight volumes from 10,000 to 50,000 ton. With these prices import is profitable (cost for ocean fright is estimated to 50 NOK/MWh). To be competitive with imported pellets in this area, the cost for the raw material (biomass) has to be less than 85 NOK/MWh.

Based on the logistic costs in this study pellets export is profitable if the difference between the international price for pellets and the price for the raw materials for local production is higher than 180 NOK/MWh. This means that if the price for raw material for local production is 100 NOK/MWh, the international price must be higher than 280 NOK/MWh to make export profitable.

Experience from Netherland /15/ is that export can take place when wood pellets are FOB (Free on board in the harbour of dispatch) in a price range of 60 to 80 Euro per ton (100-130 NOK/MWh), leaving at least 30 Euro per ton (50 NOK/MWh) for intercontinental transportation including insurance. With these prices export is not profitable.

10 A Marketplace for Bioenergy

The biofuel market is complicated, in that there are a number of cost components which are not easily mapped. It is important that the industries involved know these cost components if competition is to function satisfactorily, and in order to estimate the level of consumer prices in relation to oil and electricity prices. In the oil and electricity market there are market prices for immediate supplies and future supplies. These known prices contain a great deal of the information needed for the consumers to make rational choices.

The organization of the biofuel market is characterized by the fact that there are no central, regional or local marketplaces. Consequently, prices of immediate and future supplies are not transparent. This makes it very complicated for consumers to make investments that render the use of biofuel possible, as it is too difficult to gain a complete overview of every condition relevant to an investment. Hence, it is safe to conclude that the biofuel market relies on an involvement of the authorities or others in order to establish a more functional market, thus initiating the expansion of the market for which the calculations indicate profitability.

Energy price calculations show that in dry years, the electricity prices in the Nordic countries will rise significantly compared to prices in years with average rainfall, as presented in this report. Even in the mean price scenario, a dry year will lead to prices that exceed the prices in the high price scenario. This indicates that the utilization of biofuel can play an important part in easing the effects of variations in water power production. Thus, the use of biofuel can have social-economical implications beyond the profitability implied for an average year. This constitutes a further argument for the suggestion that the authorities, in collaboration with the power industry, involve in the organization of the market, and in establishing marketplaces which can contribute to a more functional biofuel market.

Some marketplaces can be said to exist worldwide, but these do not facilitate financial trade or the choice between supply and non-supply. Several of these marketplaces compare more to information exchange places where the objective is to give transparent prices that will facilitate trade in the OTC market. The premise for establishing a functional marketplace for biofuels which will also facilitate financial trade is that the interests involved have a choice concerning supply or non-supply. In order for such a marketplace to function, factors such as homogenous products and adequate storage capacity are crucial.

A natural course in the aftermath of this project would be to further consider the possibilities for a marketplace for bioenergy, and to look at how the organization should be conducted in order to create efficient logistics chains. In such a project, cooperation between the authorities and the different players in the biofuel and power markets should be facilitated. The role of the authorities could be to create a framework for a functional biofuel market, primarily by considering different possibilities for assigning parts/roles and for organizing the market, in collaboration with the said parties and with consumer interests.

This work should be closely linked to international activities, concerning the defining of product standards and supply conditions. The objective should be to establish a marketplace in Norway which reflects prices of homogenous products, which in turn can be easily compared to international prices for similar products. In time, new product standards and supply conditions are likely to settle, and the prices set at the marketplace can be used as references, c.f. the gas market, which to a great extent uses the price of oil as a reference in OTC contracts.

11 Effective Logistic Chains

Logistics costs must be continuously controlled and the efficiency in the chains must be evaluated and improved. This is the responsibility of the market players. In rincepal, there are four main approaches to increasing efficiency:

- *The first approach* involves measures which contribute to more efficient processes within the frames of existing industry structures.
- *The second approach* involves measures which contribute to a tighter cooperation (or fusion) between companies within the same industry.
- *The third approach* involves measures which contribute to a tighter cooperation (or fusion) between companies and their suppliers (upstream) or customers (downstream).
- *The fourth approach* involves measures which lead to a tighter cooperation with companies in parallel value chains; i.e. companies in other industries.

Efficient logistics chains are closely interlined with the organization or the structure of the bioenergy business sector. It is difficult to develop efficient chains if the sector consist of many small parties, each operating within only a small part of the chain. This might result in a logistics system which is not optimal, with too many transaction links and consequently high costs. On the other hand, too few players may lead to a lack of competition and monopoly tendencies. In order to harvest synergy effects, it is vital that the possibilities for combining bioenergy logistic chains with other chains, is looked for and exploited. This must be investigated for every element in the chains.

The authorities can hardly intervene in order to develop an efficient industry structure. This is the responsibility of the players in the marked. However, the authorities ought to employ their means in a way that stimulate a wanted development. We expect that developing of a marketplace for bioenergy will prove an important contribution to the development of efficient logistics chains, and we recommend that Enova initiates a project for developing such a market, as described in chapter 10.

Investigations of different business models for the bioenergy market could also be a measure for developing effective logistic chains. This will require work in close cooperation with the players in the market. Demonstration plants for district heating and micro-grid systems, based on the best technology available, showing the economics, environmental performance, energy efficiency etc. in modern bio-heat systems, is also considered to be a measure for market development.

It is a topic for discussion if this project should be followed up with more detailed analyses of the logistics system, using better analyzing tools. This should be considered, but there is doubt as to whether such further insight in logistic chain cost structure will contribute to more efficient logistic chains and the development of the bioenergy market. Whether the authorities ought to use measures regarding bioenergy logistics chains, can be discussed The authorities ought rather to facilitate the development of a sound bioenergy market, by drawing up framework conditions regarding the supply side and stimulating the demand side. There is reason to believe that when the demand for bioenergy increases, the industry will develop efficient logistics chains of its own accord. Create a demand and the supply side will follow.

Boundary condition for the supply side however, must be defined and clarified in order to get a sound and sustainable system.

In order to develop the bio-heat market in a stable way, market research is required on the perception and needs of main stream consumers and market segments. Market development of bio-heat must start in market segments with a positive attitude, offering economic benefits and not suffering from competition. Bio-heat has to be sold to the market under the umbrella of one clear, challenging and appealing statement subscribed by all stakeholders involved.

Bio-heat has to penetrate a market which is dominated by electric heating systems. Next to electric heating natural gas is likely to be an upcoming heat source too. To become a factor of importance in the heating market bio-heat has to comply with the requirements of the main stream market. A market development strategy involving all stakeholders is thus required and has to be based on the competitive advantage of bio-heat within the Norwegian market conditions. Next to advantages also disadvantages, including public perception, will play an important role in the development of the bio-heat market. Being aware of the disadvantages, including the development of an approach on how to tackle them, is one of the key success factors in market development.

12 Conclusions and Recommendations

There is no lack of resources exploitable to bioenergy in the geographical region studied in this project. It is however difficult to account for the costs attached to procure these resources for energy purposes. A problem with respect to the pulpwood market is that it is small, it has few players, and it is not very transparent. This makes it hard to gain complete overview of costs and price structure, and to estimate how the prices of the raw material might develop under different premises and towards other markets. Structural changes affect not only the part of the market involved; it may have general implications as well.

A lot of firewood is used for heating purposes in Norway, but the market for bio-heat, as defined in this project, is currently a niche market. Bio-heat has to compete with electric heating systems in terms of convenience and price. Due to low electricity prices and the immature bioenergy market, bio-heat is hardly competitive with electric heating today. For bioenergy to be competitive, the price for other energy carriers, especially electricity, has to increase, or the cost of supplying bio-heat has to decrease. The bio-heat costs includes costs for the biomass (raw material), investments and maintenance costs regarding the heating system, as well as costs in relation to the logistics system for the distribution of bioenergy. Composition of logistic chains influences the costs for bio-heat.

In order to embed the logistic chains in a context, the project has developed, though a so-called foresight process, different scenarios determining the demand for bio-heat and the supply of bioenergy. In the so-called ”Bio-Max” scenario, the demand for bioenergy in the area increases significantly, up to 6.3 TWh in the year 2020, i.e. a tenfold increase in the course of 15 years. In the so-called “Bio-Min” scenario, the increase is relatively low, up to 1.5 TWh in 2020, i.e. a threefold increase in the course of 15 years. A so-called bio-controlled scenario is an intermediate scenario yielding an increase in the demand for bioenergy up to 3 TWh in 2020. Linked to these scenarios are presumed developments of the energy market, based on different energy prices.

A tenfold increase in the market over the course of 15 years, as in the ”Bio-Max” scenario, constitutes a strong development which poses certain demands for market organization and market moves. It is likely that import (of both fuel and hardware) can be a solution to cope with the demand growth. From this perspective it is recommended that a national business policy is followed, promoting local industry and local biomass supply in the first 5 years (slow growth, establishing a sound and stable national market) for small scale applications, in combination with the preparation of large scale projects in this period. Rapid growth, including import, is stimulated after 5 years.

The logistics chains cost structure has scale advantages for the production of wood chips and pellets. These scale advantages seem to even out when the production volume reaches 15,000 tons of chips per year and 40,000 tons of pellets per year. However, the scale advantages are small enough to be compensated for by increased transport costs. Large scale production might lead to longer stretches of transport of raw materials and of the finished products to the market. Transport costs are highest for raw materials, so production should be situated as close to the raw materials as possible. In the “Bio-Max” scenario the analysis shows that 9 production plants for pellets in the area is the optimum between the upfront logistics and the economy of scale of pellets production. The plants are distributed over the area with a minimum size of 20-25.000 tons/year, and a middle size of 60.000 tons/year (300 GWh). The logistics costs in 2020 are reduced with 20-35 NOK/MWh compared to 2005.

In the other scenarios, the pellet factories should also have a minimum size of 20-25.000 tons. A premise is that there are adequate sources of raw materials in reasonable vicinity. Location and size of a pellet production plant should be assessed with regard to local conditions in each case. However, it is important to regard each production in relation to the bigger picture, in order to develop logistics systems which are efficient and robust with respect to possible market developments.

The organization of the bioenergy market is characterized by the fact that there are no central, regional or local marketplaces. Consequently, prices of immediate and future supplies are not transparent. This makes it complicated for consumers to make decisions about the use of bioenergy, as it is difficult to gain a complete overview of every condition relevant to an investment. Hence, it is safe to conclude that the bioenergy market relies on an involvement of the authorities or others in order to establish a more functional market, thus initiating the expansion of the market for which the calculations indicate profitability. A natural course in the aftermath of this project would be to further consider the possibilities for a marketplace for bioenergy, and to look at how the organization should be conducted in order to create efficient logistics chains.

Bioenergy offers an opportunity to use local and regional available renewable energy sources. It can also contribute to the development of local and regional economy and employability. Under certain conditions the bioenergy market can grow rather rapidly. The use of bioenergy can create new opportunities for the Norwegian energy market and contribute to economic development and deployment, but market reordering is required.

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