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The effect of new raw materials on pellet prices

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Abstract

As demand for renewable energy is increasing rapidly, the market for biomass pellets is expected to continue to grow in the near future. Most of the new raw materials that are discussed for pellet production have one thing in common; the production costs will increase compared to using traditional raw materials such as sawdust and planer shavings. The aim of this thesis is to investigate to what degree increased use of new raw materials for pellet production will affect the general pellet prices in Sweden and to survey what plans Swedish pellet producers have concerning new raw materials.

To investigate the raw material situation of the Swedish pellet producers an industry survey was performed. Literature studies were also made on previous research in the subject field. Calculations of the production costs for pellets were done for the raw materials sawdust, wet sawmill chips and energy wood respectively.

New raw materials are already used by the large-scale pellet producers in Sweden. It is mainly the large-scale producers that have started to use new raw materials such as energy wood, wet sawmill chips and dry chips. Around 65% of the respondents of the survey were planning for new raw materials. Most commonly planned for was energy wood. Most of the pellet producers in the survey were planning for raw materials that give high quality pellets.

The minimum price for pellets is in the long run set by the production costs. The raw material costs are the most important part of the production costs and according to results from the survey they also affect the pellet prices most. For pellets made of sawdust the raw material costs were typically 2/3 of the total production costs in 2009. In calculations of production costs, wet sawmill chips resulted in a decreased cost by 4% compared to sawdust, mainly because of less expensive raw material. Energy wood also resulted in decreased production costs by 4% compared to sawdust, assuming that the thermal energy needed for drying could be entirely produced with the bark from the debarking process. Both energy wood and wet sawmill chips could hence decrease the production costs and thereby the price for pellets. Even though there is a much greater maximum pellet production potential for wet sawmill chips than for sawdust the amounts of available raw material will, among other factors, depend on the development in the pulp industry.

Sammanfattning

De senaste årens ökande oljepris och fokus på klimatförändringar har ökat intresset för bioenergi, både i Sverige och internationellt. Biobränslen har möjligheter att ersätta fossila bränslen och därmed bidra till minskade utsläpp av växthusgaser. Biobränslen är också ett sätt för länder att bli mindre beroende av import av fossila bränslen samt öka energisäkerheten.

På grund av den snabba utvecklingen av marknaden för biomassa är vissa delar av marknaden ännu ej fullt kartlagda, speciellt frågor rörande prisformation och prisutveckling av biomassa. *Eubionet III – Solutions for biomass fuel market barriers and raw material availability* är ett EU-projekt med syfte att finna lösningar på hinder för en ökad handel av biomassa. Examensarbetet är en del av detta projekt.

Pellets är kompakterad, torkad biomassa i form av cylindrar med en maxdiameter av 25 mm. Till skillnad från rå biomassa är pellets ett relativt homogent bränsle. Det kompakterade bränslet får ett högre energiinnehåll som underlättar effektiv transport och lagring av bränslet. Rå biomassa kan ha en fukthalt på över 50%. Under pelleteringen torkas biomassan till en fukthalt på 5-15%. Sågspån, kutterspån och torrflis, som alla är biprodukter från sågverkindustrin, är idag de vanligaste råmaterialen använda till pelletproduktion.

Pellets är ett relativt nytt slags bränsle och det senaste årtiondet har pelletmarknaden haft en exponentiell tillväxt. Pellets är en internationell handelsvara där Sverige är en ledande nation både gällande produktion och konsumtion av pellets. I Sverige finns det idag 83 pelletsfabriker varav många är små. De 50 minsta pelletsproducenterna producerar tillsammans lika stor mängd pellets som en av de största fabrikerna. Pellets producerat i Sverige används främst inhemskt.

Det finns både små-, mellan- och storskaliga användare av pellets. Under 1990-talet dominerade storskaliga användare pelletsmarknaden men sedan början av 2000-talet har andelen småskaliga användarna ökat snabbt och står idag för en betydande del av den svenska pelletsmarknaden. Småskaligt används pellets av enskilda hushåll i pelletsbrännare eller pelletskaminer för värmeproduktion. Pellets används även mellanskaligt inom industrin och för uppvärmning av större byggnader som t.ex. skolor, kyrkor etc. Storskaligt används pellets av stora fjärrvärmeverk och kraftvärmeverk. Jämfört med storskaliga användare av pellets kräver småskaliga användare högre pelletskvalité.

Den ökande efterfrågan av pellets har lett till brist på tillgängligt råmaterial. För att ytterligare kunna öka produktionen av pellets måste råmaterialsortimentet breddas. De flesta nya potentiella råmaterial har gemensamt att produktionskostnaderna kommer att öka jämfört med traditionella råmaterial. Dessutom innebär många nya potentiella råmaterial, t.ex. bark, halm eller torv, en sämre pelletkvalité. De traditionellt använda råmaterialen till pelletproduktion, sågspån, torrflis och kutterspån, består alla av stamved. Stamved ger pellets av hög kvalité med låg askhalt och hög asksmältpunkt.

Syftet med examensarbetet är att undersöka till vilken grad nya råmaterial kommer att påverka det generella pelletpriset i Sverige samt undersöka vilka planer de svenska

pelletproducenterna har angående nya råmaterial. För att undersöka pelletproducenternas planer gjordes en enkätundersökning. Ett flertal pelletproducenter intervjuades även för att få en bättre bild av råmaterialsituationen. Litteraturstudier gjordes för att få en teoretisk bakgrund i ämnesområdet och för att kunna jämföra tidigare forskning med resultatet från undersökningen. Det gjordes även beräkningar av produktionskostnader i kalkylmodell då sågspån, sågverksflis och energived används som råmaterial. För beräkningarna användes totalkostnadsmetoden.

Resultatet från undersökningen visar att nya råmaterial redan används av pelletproducenter i Sverige. Energived, sågverksflis och torrflis används av framförallt storskaliga producenter. Runt 65% av de som svarade på enkäten uppgav även att de planerar för nya råmaterial. Det råmaterial pelletproducenterna främst planerade för var energived. I stort sätt alla producenter uppgav att de inte planerar att producera pellets av låg kvalité.

Stora producenter uppgav i större omfattning att priset på alternativa bränslen, ex. olja och el, påverkade priset på pellets till skillnad från mindre producenter som främst uppgav produktionskostnader som viktigaste faktorn för pelletspriset. De stora pelletproducenterna säljer mer till storskaliga användare än små producenter. Storskaliga användare kan använda pellets av låg kvalité. Detta skulle kunna indikera på att priset på pellets av låg kvalité är mer beroende av priset på alternativa bränslen.

Produktionskostnaderna sätter det lägsta möjliga priset på pellets. Enligt resultatet från enkätundersökningen till pelletsproducenterna är det även produktionskostnaderna som påverkar priset mest. Beräkningar av produktionskostnaderna i kalkylmodell med sågspån som råmaterial gav 99,7 €/ton, varav råmaterialkostnaden stod för 67%. Sågverksflis minskade produktionskostnaderna till 95,9 €/ton främst beroende på lägre råmaterialpris medan energived ökade produktionskostnaderna till 102,1 €/ton. Om barken antogs täcka värmekostnaderna blev däremot produktionskostnaderna 95,7 €/ton för energived.

Figures

Preface

This work was done as a part of the *EUBIONET III* project from which financing is gratefully acknowledged. The thesis is a 30 credit master thesis being a part of the Master's Programme in Energy Systems Engineering at Uppsala University and Swedish University of Agriculture Sciences. The work has been taken place at the Department of Energy and Technology at the Swedish University of Agriculture Sciences in Uppsala.

First I would like thank my supervisors Olle Olsson and Johan Vinterbäck for all help and support. As this thesis is based on a questionnaire and interviews I would also like to thank all interviewees and respondents for sharing their opinions and knowledge in the subject field.

Contents

1 Introduction

Climate change and the increasing prices of fossil fuels have put alternative and renewable energy sources on the agenda. The combustion of fossil fuels is a big contributor to emissions of greenhouse gases and today fossil fuels are the dominant energy sources in the world and makes up around 80% (IEA, 2009a) of the world's total energy supply.

In 2008 the parliament and council of the European Union stated new energy goals for the union. Accordingly in 2020 the European Union should have:

- reduced its emissions with 20%
- 20% of the energy consumption should come from renewable resources
- a 20% more efficient energy consumption (European Commission, 2010a).

The interest for bioenergy, as a renewable energy source, has increased tremendously in the last years. Bioenergy has the possibility to be a good substitute for fossil fuels and to contribute to fulfilling the 2020-commitments. Biomass fuels are also a way for countries to be more self-sufficient in energy and thereby not be dependent on import of fossil fuels (Swedish Energy Agency, 2009a).

Wood pellets is a relatively new type of fuel (IEA Bioenergy, 2007) and there has been an exponential growth of the global pellet market in the last decade (UN, 2009). Biomass pellets are dried and formed under high pressure to a product with higher energy density then the raw material. The most common raw materials for pellet production are by-products from the sawmilling industry such as sawdust and planar shavings. Sweden is a leading country both concerning production and consumption of wood pellets. The increased demand for pellets has lead to a shortage on the traditional raw materials and the raw material assortment needs to be broadened to meet continued increasing demand.

In recent years the oil price has increased and a rising global environmental awareness has amplified the demand for bioenergy. Because of the rapid increase there are some parts of the market process that are not fully understood, especially questions concerning price formation and price development for biomass. *Eubionet III – Solutions for biomass fuel market barriers and raw material availability*[1] is a European project that has the aim to find solutions for the barriers for an increased market for biomass fuels in Europe. This thesis is a part of this project.

Most of the new raw materials that are discussed for pellet production have a common factor; the production costs will increase compared to using traditional raw materials such as sawdust and shavings. The aim of this thesis is to investigate to what degree increased use of new raw materials for pellet production will affect the general pellet prices in Sweden and to survey which plans pellet producers in Sweden possible have concerning new raw materials.
The project is limited to a case-study of the raw material situation for Swedish pellet producers. To further limit the project, only producers with an annual production over 5 000 tonnes were included in the survey. The project did neither include consumers of wood pellets.

[1] See www.eubionet.net for more information about the project.

The thesis is structured with an introduction of previous research made in the subject field presented in *Chapter 2 – Background and theory* where the pellet market and pellet raw materials are described. The methodology used in the thesis is described in *3 - Methodology*. The results from a survey conducted among Swedish pellet producers are then presented in *4 – Results* followed by *5 – Discussions* where the results and previous research are compared and discussed. Finally in *6 – Conclusions* some general conclusions from the thesis are presented.

2 Background and theory

2.1 Bioenergy

Bioenergy is energy extracted from biomass. According to the European standard, CEN 14588, biomass is defined as biological material (with exception of organic material that has been embedded in geological formations, *i.e.* fossil material). Biomass fuels are biomass directly or indirectly intended for energy extraction (Belbo, 2006).

Biomass fuels include many assortments such as wood fuels, black liquors from the pulp industry and agricultural residues (Lundmark & Söderholm, 2004). In Sweden and Finland peat is considered as a slowly renewable energy source while the EU considers peat as a fossil fuel. There is a discussion whether peat should be classified as fossil fuel or as biomass fuel because of the sometimes slow growth rate (Swedish Energy Agency, 2009a). Today the growth of peat is, on a national level, much greater than the consumption (Hirsmark, 2002).

Compared to many other fuels, *e.g.* oil or coal, biomass fuels have drawbacks concerning handling, storage and transportation. Unrefined biomass often has a high moisture content, low density and is inhomogeneous. High moisture content could cause problems such as molding and degradation of the material which in turn leads to energy losses during storage of the fuel (Näslund, 2003). A low density makes the raw material difficult to transport efficiently.

2.2 Biomass fuels

Bioenergy is a renewable energy source if it is produced and used in a sustainable way. The next generation of biomass fuels will use the CO_2 released from the combustion of biomass, thus there is not a net-release of CO_2 to the atmosphere. This assumes that new plants are planted after harvest or removal of biomass. Biomass fuels can also be a possibility for the nations to be more self-sufficient in energy and increase their energy security (Swedish Energy Agency, 2009a).

Globally, 14% of the primary energy supply[2] originates from bioenergy (IEA, 2009a). Most of it is still traditional use for cooking and heating (UN, 2009). Today bioenergy is the largest renewable energy source and is used all over the world for different purposes (IEA, 2009a). In developed countries modern techniques are often used for production of biomass heat, electricity or engine fuel like ethanol (UN, 2009).

Today 19%[3] (or 28%[4] if heat losses in nuclear power plants are excluded), of the total energy input in Sweden comes from biomass fuels. In the last 20 years the use of bioenergy in Sweden has increased by in average 3.3 TWh annually. This is the main reason why Sweden has managed to decrease the emissions of greenhouse gases by nine percent since 1990 (Svebio, 2009a), while, at the same time maintaining a strong economic growth. In 2008, Sweden had a biomass fuel consumption of 123 TWh

[2] The energy supply covers the energy consumption and the conversion losses (Swedish Energy Agency, 2009a)
[3] Swedish Energy Agency (2009a)
[4] Svebio (2009a)

where a large part, 42%, was used in the industry sector, mostly by the forest products industry. The district heating sector is the second largest consumer of biomass fuels. The sector has changed from being dominated by fossil fuels in the 1970's and 1980's to be dominated by biomass fuels today (Swedish Energy Agency, 2009a). Figure 1 shows the consumption of biomass fuels in the different sectors in 2008.

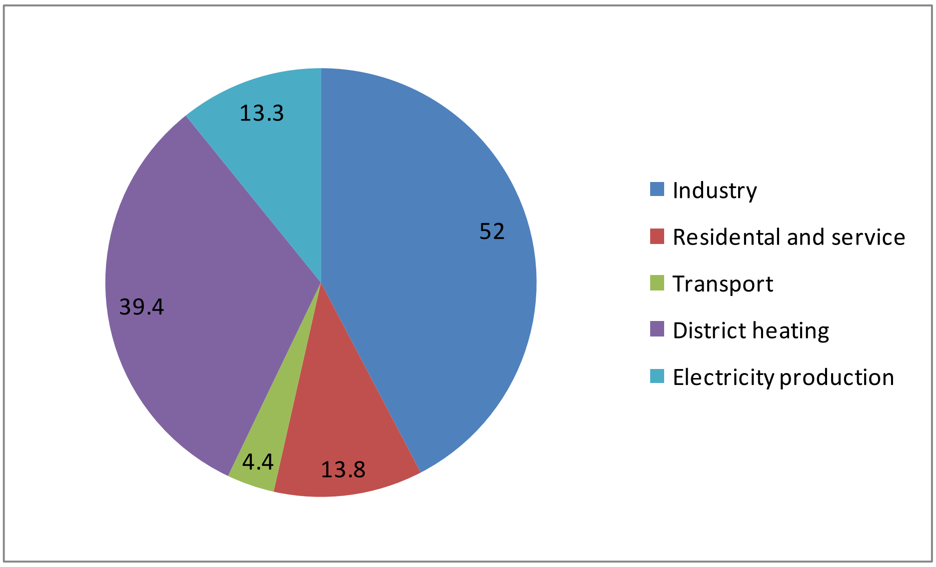

Figure 1: Use of biomass fuels (TWh) in different sectors in Sweden in 2008 (Swedish Energy Agency, 2010)

Densified biomass fuels is biomass that has been dried and formed under high pressure to a product with higher energy density then the raw material. Depending on dimensions densified biomass fuels are defined as either pellets or briquettes. Briquettes can be of any shape but the length should not exceed five times the diameter (SS 18 71 23). Pellets are normally smaller than briquettes and according to the Swedish standard, SS 18 71 20, pellets have a cylindrical shape and maximum diameter of 25 mm (SS 18 71 20). The moisture content in pellets lies between 5-15% (Zakrisson, 2002).

The raw materials most commonly used for pellet production are sawdust, planer shavings and dry chips, which all are by-products from the forest industry (Höglund, 2008). Pellets are used by both small-, medium- and large-scale consumers, for example for heating of detached houses, in district heating plants or in combined heat and power plants (CHP) (PiR, 2009).

In Sweden the Swedish standard, SS 18 71 20, is the most commonly used standard for pellets. There is also a European standard under development (Höglund, 2008). More information about standardization of densified biomass fuels is found in Appendix A. According to the Swedish standard pellets are divided into three groups with different quality requirements, where pellets in group number 1 have the highest quality and pellets in group number 3 have the lowest (SS 18 71 20). The premier group is suitable for small-scale consumers with higher demand for quality whereas the quality groups 2 and 3, with lower quality requirements, are more suitable for medium- or large-scale consumers (Höglund, 2008). The groups are defined depending on the following parameters; durability, moisture content, ash content, length, ash melting point, density, heating value and share of fine fractions. The standard can be found in Appendix A. Which quality group pellets are classified to depends mostly on the raw material used, but also on the pelleting process (Näslund, 2003).

Pellets are a renewable fuel that can be used in large CHP-plants as well as in small stoves in detached houses; pellets can thus replace fossil fuels used both for heating and electricity production (Näslund, 2003). There are many advantages for using pellets compared to using unrefined biomass. Generally, pellets have lower moisture content, a homogenous shape and higher energy density than unrefined biomass (Zakrisson, 2002). High energy density makes the costs for storage and transportation less than for unrefined biomass (Bernesson & Nilsson, 2008). There is also less degradation of the material during storage than for unrefined biomass. Pellets are a relatively well defined fuel with homogenous properties which makes it relatively easy to use and it requires less complicated and less expensive technology for the consumers compared to unrefined biomass (Kaltschmitt & Weber, 2006).

2.3 The wood pellet market

2.3.1 The international pellet industry

Wood pellets are a relatively new type of fuel (IEA Bioenergy, 2007) and there has been an exponential growth of the global pellet production in the last decade (UN, 2009). Wood pellets are traded both internationally and regionally (IEA Bioenergy, 2007) and price advantages compared to fossil fuels have increased the global demand (IEA, 2009a). The favorable properties of wood pellets such as relatively high energy density, storage and transport possibilities make pellets interesting for both consumers and suppliers.

A new policy to reduce the CO_2-emissions in EU led to the introduction of an emission trading system in 2005 (European Commission, 2010b). Most of the electricity generation in Europe originates from fossil fuels in large-scale power plants. Co-firing of biomass and coal gives both environmental and economic benefits *i.e.* decreased emission trading (IEA, 2007). Sweden has the largest pellet market, both in consumption and production, in Europe. The total production of pellets in Europe was about 8.2 million tonnes[5] in 2008 and there were a big unused capacity in the production plants. At the same time there is an import of pellets to Europe from North America, about 1 million tonnes per year. The consumption differs from country to country, *e.g.* is small-scale consumption in pellet stoves most common in Italy and France while countries like the Netherlands and Belgium mostly use pellets in large-scale power plants for electricity generation. Sweden and Denmark have consumers in all segments (Sikkema et.al., 2009). Figure 2 shows the production, import, consumption and export of wood pellets for the European countries.

[5] Metric tonnes

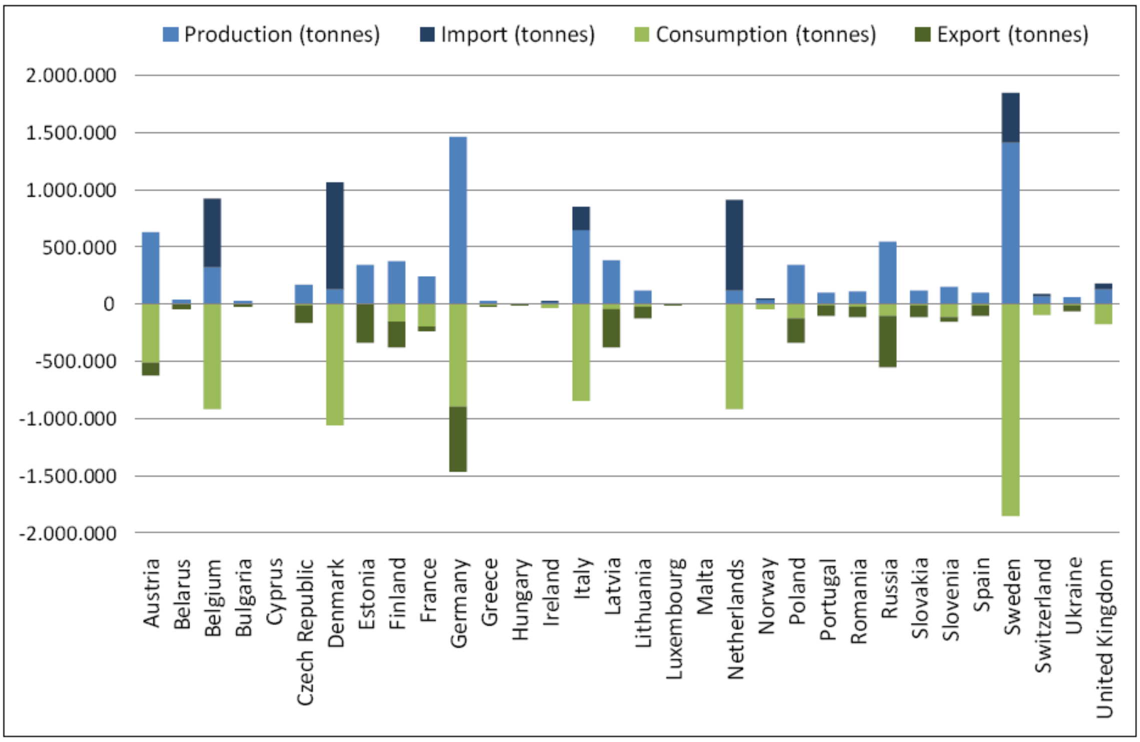

Figure 2: The balance of pellet volumes for the major European national markets in 2008 (Sikkema, et.al, 2009)

The pellet industry in North America has grown from a production of 1.1 million tonnes in 2003 to 4.2 million tonnes in 2008. The domestic market for wood pellets in Canada is small despite its large production. While Canada mostly exports pellets to Europe there is a domestic market in the USA (Sikkema, et.al., 2009). Until 2007 the production of pellets in USA was mainly for the domestic market but in the last years new pellet production plants with aim to export pellets has opened. In 2008 the world's largest pellet plant, until today, opened in Florida with a production capacity of 560 000 tonnes per year (Green Circle Bio Energy, 2009).

Europe and North America are the leading regions regarding wood pellets production and consumption but there are emerging markets in Asia and Latin America. The production in Russia is mainly concentrated to the northwestern and middle regions of the country where there are both a developed forest industry and transport infrastructures such as harbours (IEA, 2007). The world's biggest pellet plant is to be under construction in Viborg in Russia and projected annual production of 900 000 tonnes. The intended consumers are large power plants in Europe (Svebio, 2010b).

2.3.2 The Swedish wood pellet industry development

After the oil crises in the 1970's the interest for domestic fuels increased in Sweden. Partly as a result of this the production of wood pellets started in Sweden in the early 1980's. It was the municipality of Mora that started with an annual production of 40 000 tonnes in 1980 (Westholm, 1986). Unfortunately the investment costs became much higher than expected. At the same time the price for oil decreased. The techniques for pellet burners were not yet fully developed and thus the demand for pellets was low. All these factors combined led to the closure of the wood pellet production plant in Mora as early as 1986 (Mahapatra, 2007).

There were many plans for production plants for wood pellets in the 1980´s, but the market did not start to grow until 1991 when the Swedish government introduced a CO_2-tax for fossil fuels. The tax in combination with increasing prices of fossil fuels made wood pellets become an economical alternative to oil and coal (Mahapatra, 2007). Two other explanations for the fast development of the wood pellet industry are the good access to raw materials in Sweden and the extended district heating system (Hirsmark, 2002). Later the introduction of green electricity certificates also made biomass fuels, such as pellets, more profitable to use for electricity production in CHP-plants (Lundmark & Söderholm, 2004).

Sweden was estimated to have a production of 2.1 million tonnes pellets in 2009, according to PiR[6], which makes the national pellet market in Sweden the largest in Europe (PiR, 2010). Figure 3 shows the development of the Swedish wood pellet market from 1997 to 2012 (PiR, 2009).

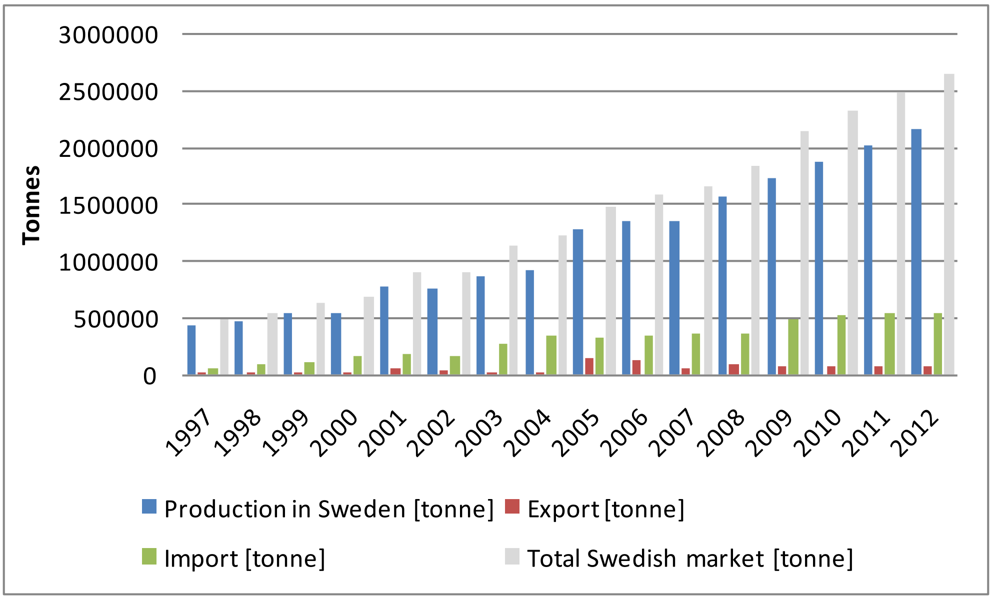

Figure 3: The Swedish pellet market 1997-2012, the values for 2009-2012 are estimated (PiR, 2009).

2.3.3 Swedish wood pellet producers

Today, there are in total 83 pellet production plants in Sweden. The large wood pellet producers in Sweden dominate the production; about 50 of the smallest plants produce together the same amount of pellets as one of the largest plants (Svebio, 2009b). The pellets produced in Sweden are primary sold to the Swedish market (PiR, 2009). Figure 4 shows the pellet production plants geographical localization and size.

[6] PiR – Swedish Association of Pellet Producers, www.pelletindustrin.org

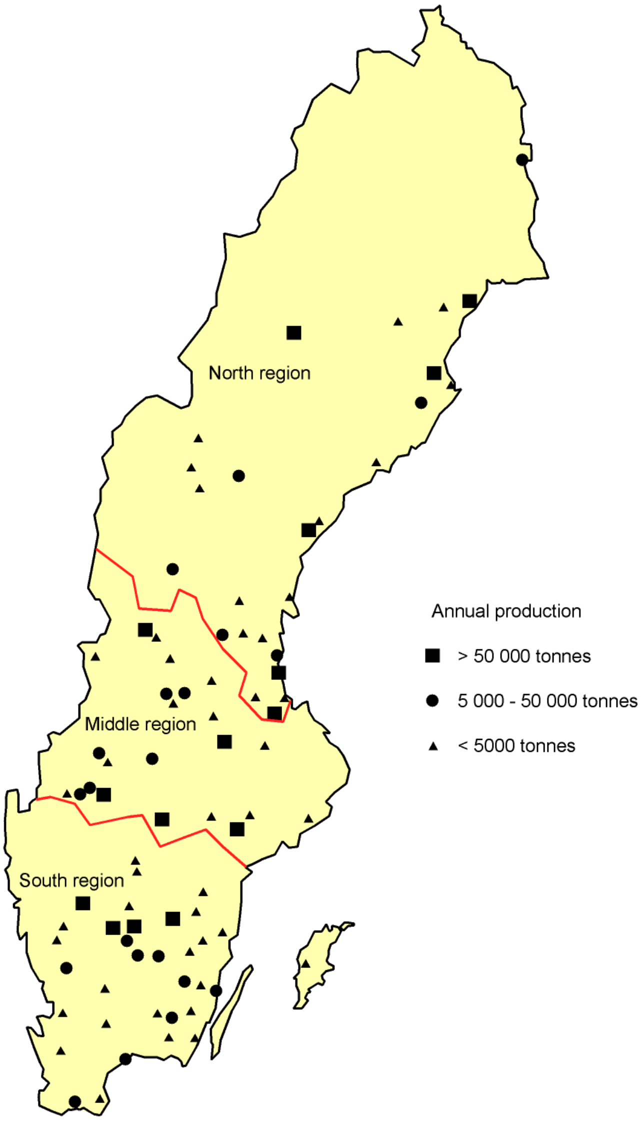

Figure 4: Geographic localization of Swedish wood pellet producers, modified from Svebio (2009b).

2.3.4 The Swedish forest industry

With 67% of the land area covered with forest Sweden is one of the richest countries of forest in Europe (Swedish Forest Agency, 2010a). The large access to forests also makes Sweden one of the leading countries in forest products worldwide (The Swedish forest industries, 2009). The forest industry has been important for the development of the Swedish economy (Lundmark & Söderholm, 2004) and around 10% of the total employments in Sweden are in the forest industry and 11% of the Swedish export consists of forest products (The Swedish forest industries, 2009).

The Swedish forest is a growing national resource where the annual growth exceeds the annual cuttings (Höglund, 2008). The forest contributes timber, energy wood and felling residues. Traditionally the forest products have been used in the sawmilling and pulp- and paper industries. The different parts of the forest industry are also connected to each other, as sawmill by-products, such as sawdust, shavings and chips, are used as raw materials in other sectors of the industry. Wood chips are to a large extent used by the paper- and pulp industries. Sawdust and shavings cannot be used in the pulp- and paper industry but are widely used in the pellet- and board industries

(Lundmark & Söderholm, 2004). Figure 5 shows the annual growth in the Swedish forests and the different forest products.

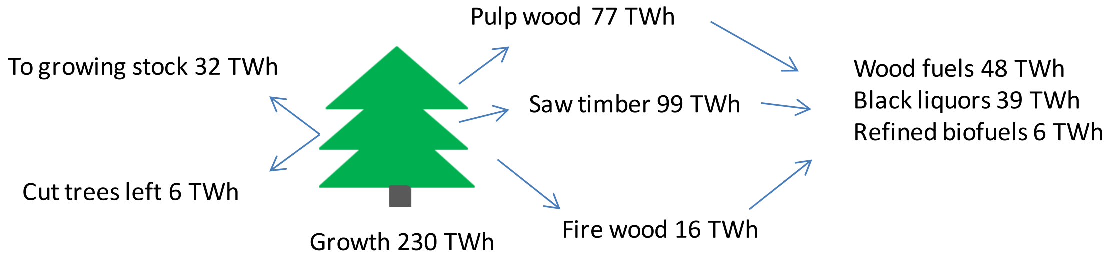

Figure 5: The annual growth of Swedish forests and usage of forest products, modified from Wetterlund (2007).

Raw materials for wood pellet production are today almost entirely by-products from the forest industry. Many of the wood pellet production plants, mainly small plants, are connected to sawmills, planeries or furniture manufactures. The interconnection between the sectors also means that the supply of by-products from the forest industry depends on the demand for forest products, especially pulp and timber (Höglund, 2008).

2.3.5 Swedish pellet consumers

The consumers can be divided into groups after installed power where the groups usually are defined as:

- Large-scale consumers: >2 MW
- Medium-scale consumers: 50 kW-2 MW[7]
- Small-scale consumers: <50 kW

During the 1990's the large-scale consumers dominated the Swedish pellet market but since 2000 the usage of pellets in the small-scale and medium-scale groups of consumers have increased rapidly (PiR, 2009). In Figure 6 the development of the Swedish wood pellet market is shown.

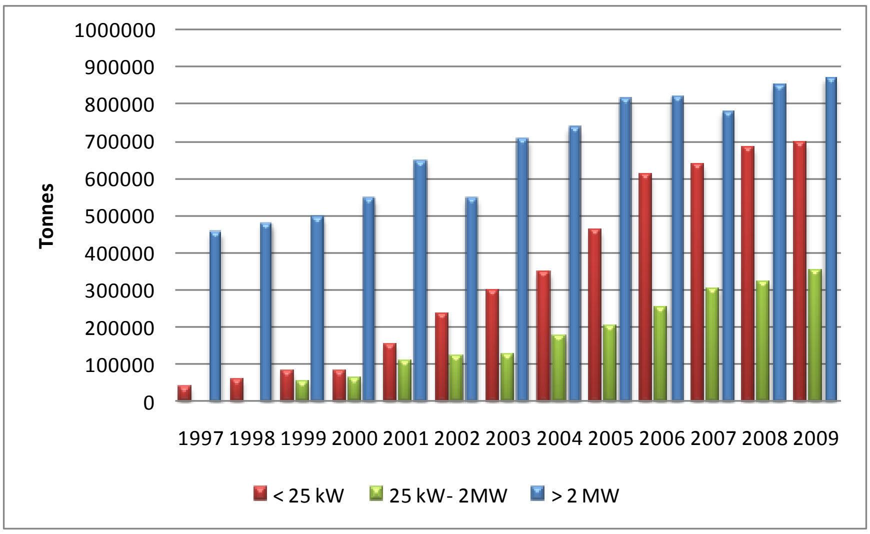

Figure 6: The development of the Swedish wood pellet market (PiR, 2010).

[7] The medium-scale group is not clearly defined and there are different variants. In this thesis the same definitions as in Höglund (2008) are used.

Small-scale consumers, < 25 kW
During the beginning of the 2000's a lot of households converted their heating system from using heating oil to wood pellets (Hirsmark 2002). High energy prices, policy measures and public opinion are mentioned as reasons for the fast increase of the small-scale market segment (Höglund 2008). Around half of the detached houses in Sweden have heating systems based on electricity or oil. Compared to both oil-fired and electric panel radiators, pellet heating systems have the advantages of less lifecycle costs and reduced environmental impact (Mahapatra, 2007).

In detached houses pellets are used in either pellet boilers or pellet stoves. For houses with water-based heating systems a pellets boiler is a good alternative to replace oil-fired or electric boilers (Swedish Energy Agency, 2007a). Electrical panel radiators for heating are also common in Sweden; this is mainly due to the low electricity price in the 1970's and 1980's. These houses do not have a central heating system for distributing the heat which makes the conversion to a pellet boiler more expensive. Here an alternative is to install pellet stoves. A pellet stove can decrease the electricity usage for heating with about 50-75% (Hirsmark, 2002).

In year 1994 there were around 300 pellet boilers installed in Sweden (Mahapatra, 2007). Until 2008 the amount of boilers increased to around 120 000 systems in detached houses. The same year there were around 20 000 pellet stoves and there is still a market potential left for conversion from electric panel radiators (Höglund, 2008). However, the market to replace oil- and electric heating systems with pellet burners is competing with district heating and heat pumps. 55 700 pellet burners were installed between 1994 and 2004. This could be compared to 40 000 heat pumps (water-based) that were installed only in 2004 (Mahapatra, 2007).

Medium-scale, 50 kW – 2 MW
The medium-scale consumers include industries, apartments, schools, public buildings etc. In 2006 the pellet consumption increased with 25% in the medium-scale segment (Höglund, 2008) and there is still a large potential for a continued increase as there are still many large buildings and industries using oil.

Large-scale consumers, > 2 MW
Until recent years large-scale consumers have dominated the pellet market in Sweden. In 1991 the government introduced a tax on CO_2-emissions, which made it profitable to convert from fossil fuels to biomass fuels (Mahapatra, 2007). The prices on fossil fuels have also increased. Many of the large district heating plants have by now converted from coal-powder to pellets or briquettes; this conversion is relatively easy and inexpensive. The large pellet consumers do not have the same quality demands as small-scale consumers (Näslund, 2003).

2.3.6 Wood pellet price formation

Price formation of wood fuels
During the 1990's the wood fuel market grew strongly at the same time as the prices were stable or even decreased if adjusted for inflation, which can be attributed to a situation where supply was greater than demand for wood fuels (Hillring 1997, 1999a). An increased demand normally results in higher prices which affects the supply. When the relation between demand and supply changes there can be periods when the market experience instability in the ratio between the supply and demand.

This imbalance is especially common for immature markets like the wood fuel market (Hillring, 1999a). During the 1990's the wood fuel market had a supply exceeding the demand and there were many producers competing for the market. This resulted in a market where the prices were set by the production costs (Hillring, 1999b).

Hillring (1997) mentions three scenarios for the development of the wood fuel market:

- that the prices for wood fuels will be closely connected with the prices on alternative fuels such as fossil fuels
- that the price for wood fuels will increase because of higher demand and thereby a usage of more inaccessible and more expensive resources when the easy available are fully utilized
- that taxes of fossil fuels will be so high that it results in a competition between different wood fuels

The three scenarios assume a price correlation between fossil fuels and wood fuels (Hillring, 1997) but in an article by Hedeneus et.al. (2009) price correlation in short term between the oil price and the pellet price was not found, although there were some co-movements between the prices in 2006 and 2007 (Hedenus et.al., 2009).

Several factors that could affect the prices for biomass fuels are mentioned in Boldt (2009). Increased oil prices affect both the production costs and the demand. The international demand, political targets and regulations affect the demand and prices for biomass fuels. Competition between different uses of raw materials, *e.g.* between the pellet industry and district heating plants, could also result in higher prices. Exchange rates are mentioned as another factor that affects the import and export and thereby the prices (Boldt, 2009).

Wood pellet price development

As mentioned the prices for wood fuels were stable during the 1990's (Hillring, 1997, 1999a). Figure 7 shows the price development for wood pellets and forest industry by-products. Since the beginning of 2000's the prices for pellets have increased, as well as the raw material prices (Swedish Energy Agency, 2009c). Even so during the end of 2008 when the oil prices dropped as a result of the global economic crisis (UN, 2009).

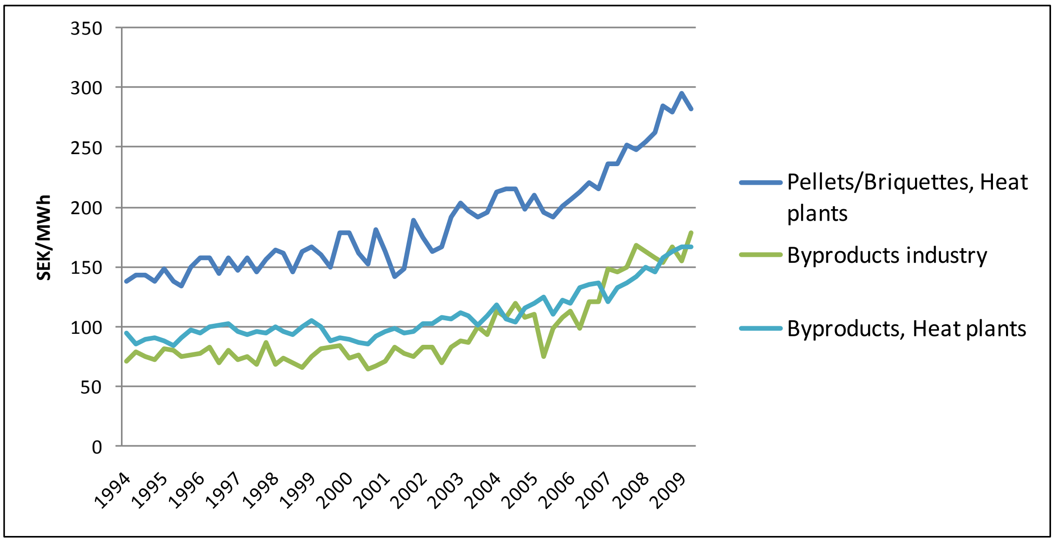

Figure 7: Price development for pellets/briquettes and by-products in SEK/MWh, excluding VAT (Swedish Energy Agency, 2009c).

In many articles the price influence of substitute fuels are discussed. Figure 8 shows the price for electricity, heating oil and pellets (bulk and bag) in 2008 and in 2009. While the pellet price is rather stable the oil and electricity prices are more turbulent. It can also be seen in the figure that the pellets were cheaper than both heating oil and electricity.

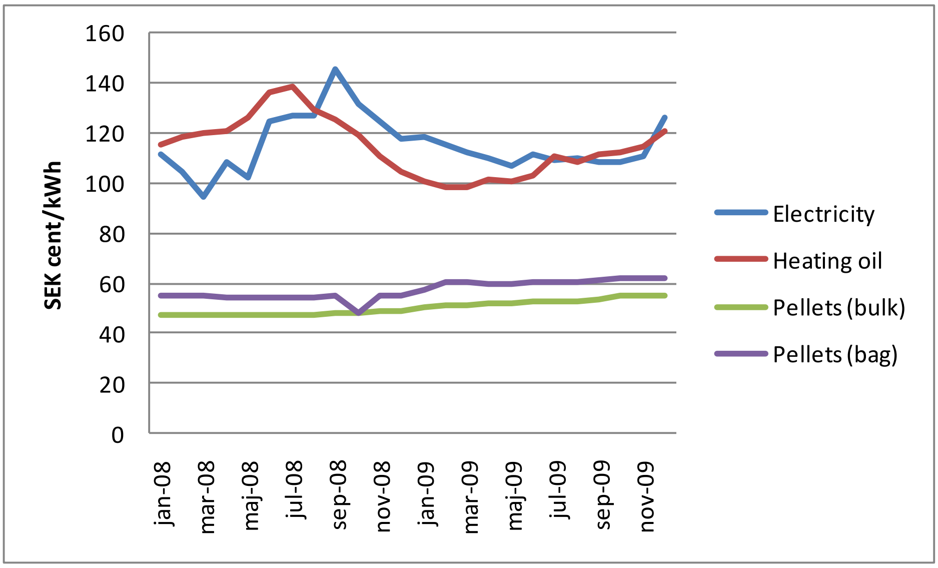

Figure 8: Prices for electricity, heating oil and pellet (SEK cents/kWh) in the residential market (ÄFAB, 2010).

The wood pellet price development is slower in the residential market than in the large-scale market. The reason is that consumers at the residential market purchase small amounts of pellets and thus have a less impact on the market (Hillring 1999b). Boldt (2009) describe the relation between low quality pellets for the industry and high quality pellets for the residential market. The author claims that the pellet prices for the different markets do affect each other although the price for pellets to the residential market can be higher than for the large-scale market. If the price differences are too high the producers will earn more by producing high quality pellets for the residential market than the low quality pellets for the industry. This could result in reduced supply of pellets for the industry and hence higher prices. If the differences in quality become larger in the future the markets for low quality pellets and high quality pellets will be more separated (Boldt, 2009).

Regional differences in the pellet price are due to transport distances and regional production prices (Hillring, 1999b). Figure 9 shows the regional (Figure 5) pellet prices on the residential market and the national pellets prices at the large-scale market from 2004 to the first quarter of 2009. In the figure it can be seen that the pellet price at the large-scale market is significantly lower than for the residential market.

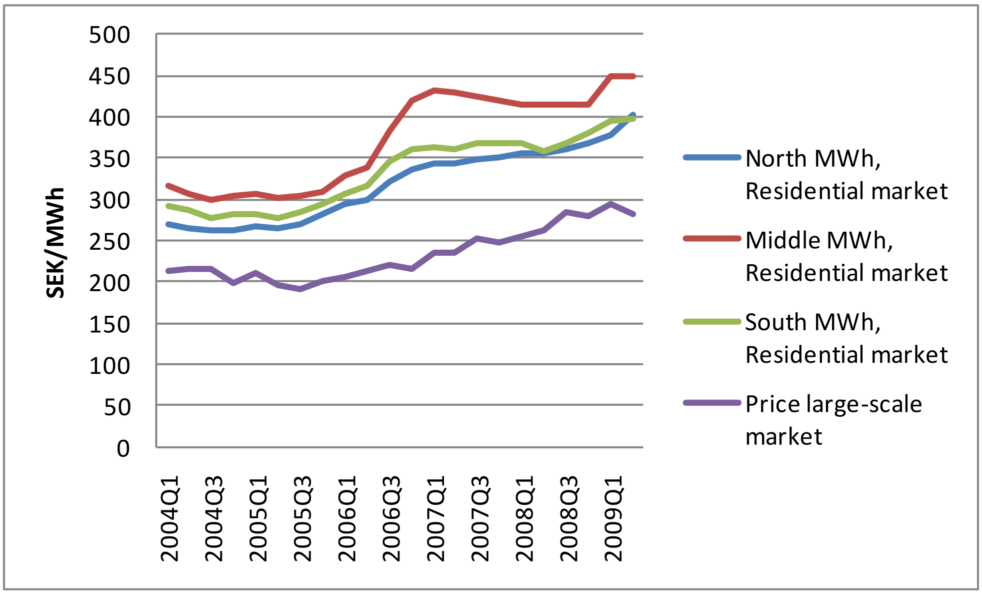

Figure 9: Pellet prices (SEK cents/kWh) in the residential market (Swedish Energy Agency, 2009c).

Production costs

The raw material cost is dominating the production cost for wood pellets in Sweden. Figure 10 shows the distribution of the pellet production cost[8] from a study made in 2002. Of the total production cost about 50% was raw material cost and it is also the fluctuations of the raw material prices that influence the total production costs most. An increase or decrease in raw material prices with 50% affects the total production cost with 26% (Zakrisson, 2002).

[8] The calculations for the production cost were made by Zakrisson (2002) and were based on production of pellets, using a sawdust as raw material with a moisture content of 57%, in a plant that annually produce 80 000 tonnes of pellets. For more information see Zakrisson (2002).

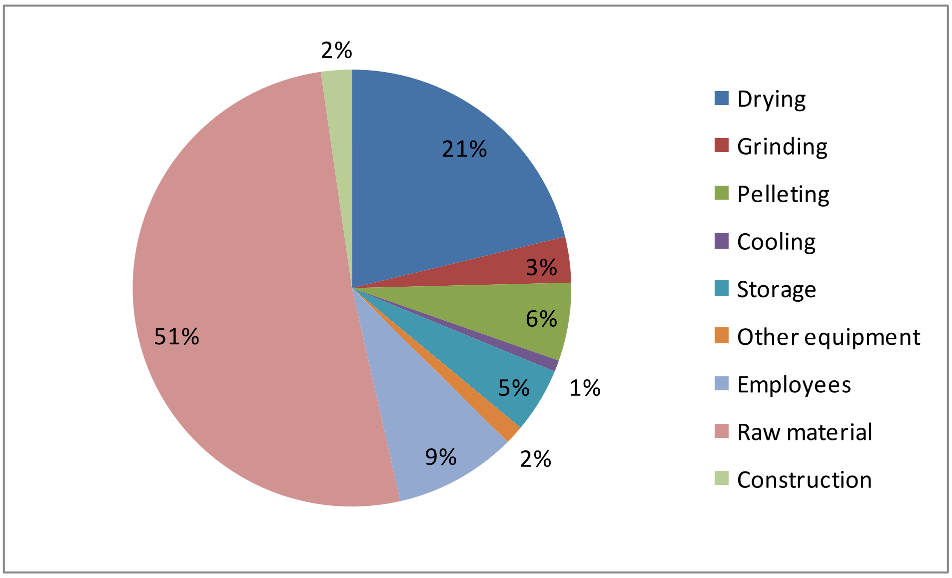

Figure 10: Cost distribution (%) for the different parts of the production, modified from Zakrisson (2002).

Drying the raw material is the most energy consuming stage in the production process but the densification process also requires a lot of energy. Changes in the electricity price with 2% change the production costs by 4% (Zakrisson, 2002).

Up-scaling large production plants have advantages (Näslund, 2003) since about one-fifth of the total annual costs for wood pellet production is investments costs (Zakrisson, 2002). At the same time large plants may involve long distances to raw materials. Pellet production plants connected to district heating lower the drying costs by selling excess heat (Näslund, 2003).

Compared to many other countries, raw material prices are more dominating in Sweden but an advantage is the low electricity price in the country (Zakrisson, 2002). The differences in price have, however, decreased due to increased electricity trading which in later years have made the Swedish electricity prices more affected by the European countries (Swedish Energy Agency, 2010). Pellets is today an international product and the production costs are important for competition on the world's pellet markets. Both in Canada and in USA are the raw material costs low (Zakrisson, 2002) which makes it less expensive to produce pellets in North America compared to many countries in Europe (Mani et. al., 2006).

In the beginning of a development of a system, the production cost is often high. In the start-up phase problems that later are solved, knowledge how to avoid problems and make the system more effective makes the production costs decline later in the development of the system. The knowledge can be spread and thereby reduce costs even for other or new actors on the market. In an article Junginger et.al. (2005) conclude that up-scaling and technological progress have decreased the cost for wood fuel chips.

Raw material prices

Costs for raw materials are dominating in the production cost for pellets, see Figure 10 (Zakrisson, 2002). In the last years the prices on forest by-products have increased, as could be seen in Figure 7. The supply of by-products such as sawdust, shavings and chips are set by the demand for forest products and the demand for these by-products has therefore a little influence on the supply (Lundmark & Söderholm, 2004). Figure 11 shows the price development for by-products from the sawmilling industry, pulpwood (energy wood) and pellets. The price differences between by-products from the forest industry and pulp wood have decreased in the last years.

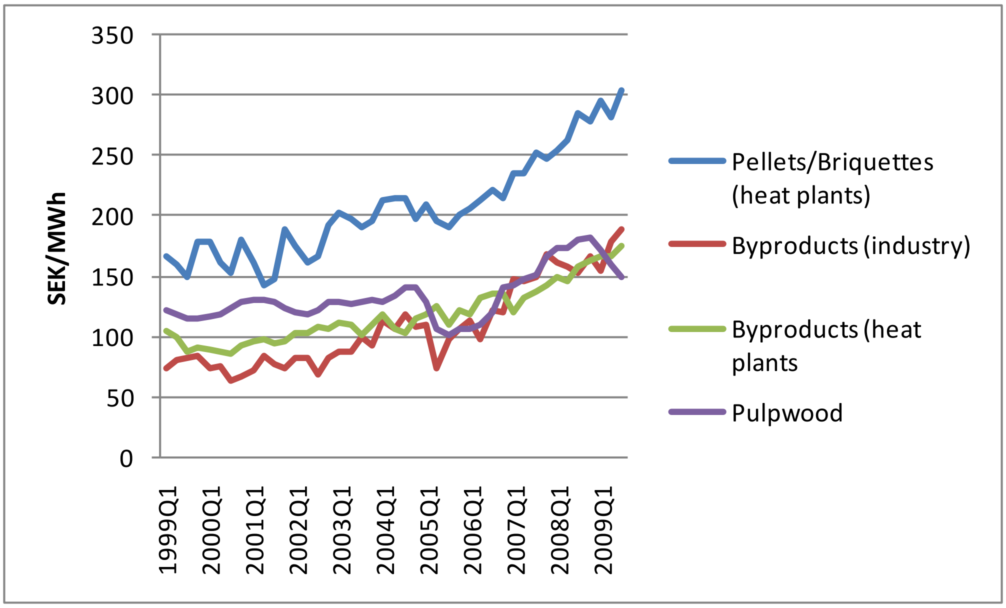

Figure 11: The price development for pellets/briquettes (weighted mean), by-products for industry, by-products for heat plants (Swedish Energy Agency, 2009c) and pulp wood (energy wood) (Swedish Forest Agency, 2010b) from 1999 to 2009.

2.4 Pellet production

More than half of the pellet production plants in Sweden are small plants[9], but the small pellet producers only contributed with around 4% of the total amount of produced pellets in 2008 (Svebio, 2009b). Small producers mostly use dry raw materials and are often connected with carpentry factories or sawmills (Höglund, 2008). Thereby they do not need expensive drying equipment (Näslund, 2003).

The main reason for building large plants is that locally there are large amounts of raw material available. Due to low energy density it is not economically profitable to transport raw materials long distances and it is therefore important to have access to raw material close to the production plant. Large pellet production plants also have better opportunities to afford drying equipment and can therefore also use fresh raw materials with higher moisture content (Näslund, 2003).

The process differs depending on what raw material that is used. Figure 12 shows an example of a production line for a large pellet plant using sawdust as raw material. The production line starts with a conditioning treatment before the material is densified. Then the pellets are cooled and screened. The purpose of the conditioning treatment is to make the properties for the raw material optimal for densification (Näslund, 2003).

[9] Pellet plants with an annual production below 5 000 tonnes.

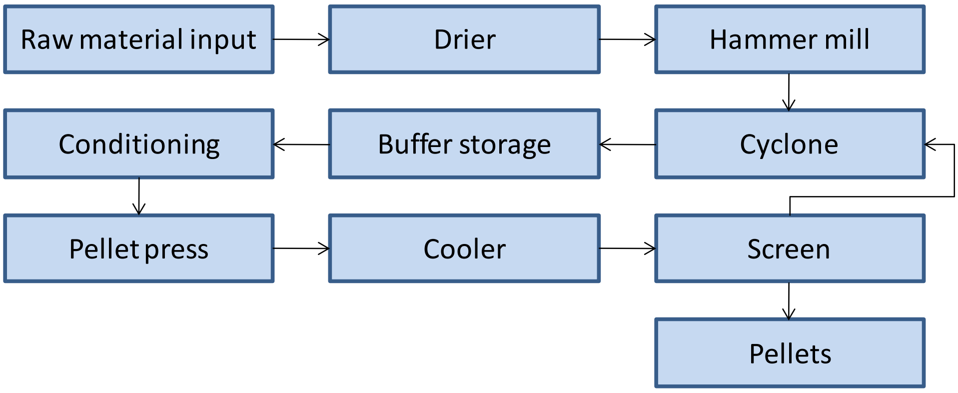

Figure 12: Production line for a large pellet plant using sawdust as raw material, modified from Näslund (2003).

Impurities, such as sand, gravel and metal, can cause heavy wear on the pelleting equipment and are therefore removed from the raw material with a screen and a metal detector (Zakrisson, 2002). If the raw material contains large fractions a hammer mill or a chipper can be used to comminute the material before drying (Näslund, 2003).

The raw material is dried to a moisture content of 5-15%. Fresh sawdust normally has a moisture content around 50% (Zakrisson, 2002). A rotating drum with hot exhaust gases is often used as drying equipment. There can be energy losses in fresh raw materials during the drying process because of volatilization of substances. After the raw material has dried it is grinded (Näslund, 2003) often by a hammer mill (Zakrisson, 2002). Smaller fractions gives better durability of the pellets but at the same time smaller fractions demands more energy in the grinding process (Näslund 2003).

To make the raw material softer and thereby reduce the energy use and wear on the densification equipment the raw material can be conditioned before the pellet press. Normally the material is only conditioned with steam but water and lignin can also be used (Näslund, 2003).

The raw material is densified in the pellet press where the material is pressed through dies consisting of tapered passages. In the passages the material is exposed to high pressure and high temperature because of the friction from the walls of the passages. The time, pressure and temperature in the passages are important factors in the process to get high durability of the pellets. The mostly used pellet press in Sweden is the ring die pelletizer, where the material is pressed through the passages from the inside to outside of a die by rollers (Näslund, 2003).

2.4.1 Properties of pellets

Sawdust, dry and wet chips and shavings are all based on stemwood. Pellets made of stemwood are often of high quality (Näslund, 2003). Many potential new raw materials for pellet production have, compared to stemwood, a high ash content and low ash melting temperature, which the burners need to handle. A high content of nitrogen and sulphur can also contribute to environmental problems such as acidification and eutrophication (Rönnbäck et.al., 2008).

Ash and ash-related problems

Ash is a rest product from combustion and consists of an unburned fraction and incombustible material. The ash content depends on factors such as handling, storage and production techniques but mostly it depends on the material used. Stemwood have ash contents around 0.3% while bark and straw have much higher ash contents, around 4% and 5% respectively (Belbo, 2006).

Barriers for diffusion of oxygen
Increased ash content can create barriers for diffusion of oxygen to the fuel and thereby result in incomplete combustion and high emissions of CO. Barriers can occur in two different ways; when ash is not transported away and glomerates on the unburned fuel or when ash forms a crust around the fuel particles that functions as a barrier for oxygen (Rönnbäck et.al., 2008).

Coatings
There are different reasons for formations of coatings; formation on surfaces that transfer heat, condensation of salt on cold surfaces and formation of glass. There are many problems with coatings, *e.g.* coatings on heat transmission elements may lead to a decreased transmission of heat, higher emissions of NOx because of higher combustion temperatures, corrosion and damages on the equipment. The boiler also needs to be stopped and opened for removal of the coatings (Bernesson & Nilsson, 2008).

Salts are formed when anions such as chlorine, sulphur or phosphor reacts with cat ions such as potassium, sodium or calcium. The formations have a relatively low melting point and condense on cold surfaces in the boiler (Bernesson & Nilsson, 2008). If the amounts of sodium and potassium are in the same range the ash gets a low melting point and it is therefore better to have either much more sodium than potassium or vice versa. Another factor that contributes to coatings from condensation of salt formations is chlorine. No chlorine at all in the fuel is optimal or to have much more sulphur than chlorine for avoiding these coatings. Glass formations are formed from silicates. Little content or none content at all are optimal for avoiding glass formations. Small amounts of free silicon compared to reactive sodium and potassium is also a way to decrease glass formations (Fredriksson et.al., 2004).

Corrosion
Sulphur, chorine and nitrogen all contribute to corrosion. Sulphuric acid, which can be formed from sulphur and oxygen during combustion, is corrosive and can damage the equipment and contribute to acidification. The acid can be filtered away from the flue gas and the acid can also form stable formations with calcium. Chlorine together with alkali metals is also corrosive, especially at high temperatures. The content of chlorine is often higher in agriculture biomass than in stemwood. Finally, nitrogen can also form corrosive oxides during combustion (Belbo, 2006).

2.4.2 Consumer quality requirements

The demand on pellet quality varies between consumers. Large-scale consumers generally have lower demand for pellet durability and share of fine fractions compared to small-scale consumers. Neither the ash content is as important for large-scale consumers as it is for small-scale consumers. The large-scale consumers normally have an automatic ash handling system but high ash contents give higher costs (Näslund, 2003). If pellets are ground before combustion the materials need to function properly when ground (Fredriksson et.al., 2004). Many of the large burners that use pellets today are converted from coal or oil. Earlier some of these plants have only been used as top-load and do not have much exhaust cleaning. It is therefore important that the combustion of pellets do not contribute to any hazardous emissions (Fredriksson et.al., 2004).

Medium-scale consumers have higher requirements for durability of the pellets compared to the large-scale consumers. There is often an automatic ash handling system in these plants but pellets with a low ash melting temperature that gives coatings are not suitable. As for large-scale consumers higher ash content gives higher costs but with a lower fuel price this can be compensated (Näslund, 2003).

Small-scale consumers demand the highest quality of pellets. The boilers or stoves do not normally have exhaust cleaning and automatic ash handling. Fine fractions from the fuel is also a greater problem in houses than in industrial facilities (Näslund, 2003). Ash-rich pellets are generally not suitable for the small-scale consumers. For combustion of fuels with high ash contents in small-scale burners, a more advanced combustion technology is necessary. Then the burners will be more expensive and there has not so far been a large demand of these kinds of burners from the small-scale consumers. Medium-scale or large-scale consumers have better possibilities of using low quality fuels (Rönnbäck, 2009).

2.5 *Pellet raw materials*

2.5.1 Raw material supply today

Shavings and sawdust are the most common raw materials used for pellet production in Sweden today. Figure 13 shows the usage of the different raw materials. The most common origin of the materials, 65%, is from the Swedish market, without any connection to the producers own businesses, while only 17% of the producers use their own production (Höglund, 2008).

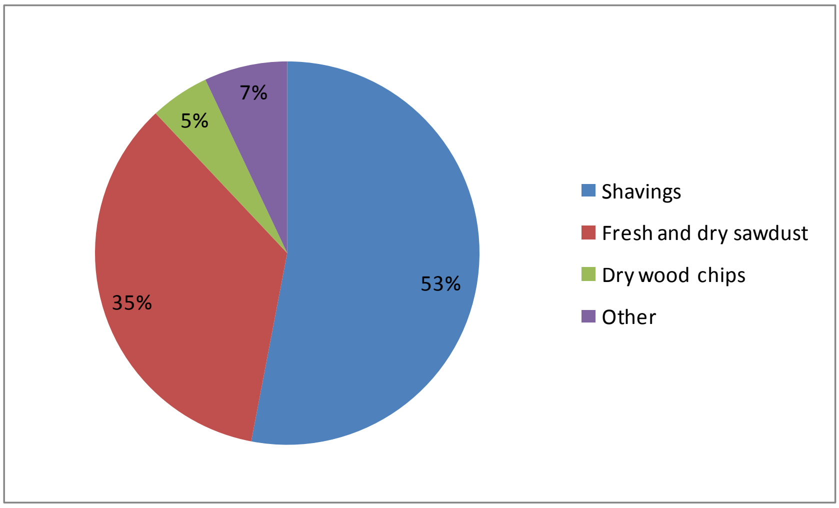

Figure 13: Raw materials used for pellet production (% of total amount produced pellets). Others include bark, grain residues, recycled wood and rejected pulp wood, modified from Höglund (2008).

Sawdust, chips and shavings

Sweden is one of the most forest-rich countries in Europe (The Swedish forest industry 2009) and the pellet industry is therefore closely connected to the forest industry. Figure 14 shows the end products at a typical sawmill where about 50% of the timber becomes by-products in the form of sawdust, shavings and chips. It is not only the pellet industry that is interested in the by-products; the paper- and pulp industry, board industry, district heating plants and CHP-plants also use the by-products (Lundmark & Söderholm, 2004).

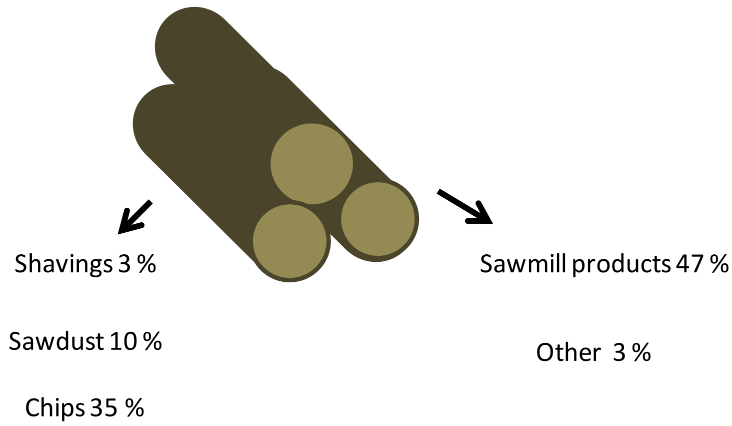

Figure 14: End products at a sawmill with an annual production over 5 000 tonnes in volume percent, modified from Lundmark et al (2004).

Sawdust has a moisture content around 50% and the main users of the sawdust are the pellet industry, board industry and district heating plants. Shavings have a lower density and lower moisture content than sawdust. Shavings is a by-products from the planing of lumber. Shavings are mainly used by the pellet industry but it is also used as animal bedding. Dry chips are by-products from lumber. Around 90% of the total amount of chips is wet sawmill chips, which is an important raw material assortment for the pulp industry (Martinsson, 2003).

Pellets made of stemwood are often of high quality and hence are suitable for small-scale consumers. The properties of pellets made of stemwood are a high heating value, low ash content and high ash melting temperature (Näslund, 2003). A more detailed table of the chemical contents of stemwood and other raw materials can be found in Appendix B.

As earlier mentioned the supply of by-products is set by the demand of forest products, such as lumber, and the demand for these products therefore influences the supply of raw materials (Lundmark & Söderholm, 2004). Figure 15 shows the average price for sawlogs in Sweden from 1999 to 2009. In the figure it can be seen that the prices for sawlogs fell in all regions in 2008 and the beginning of 2009 as a result of the general economic downturn. In the last two quarters of 2009 the prices began to rise in the south and central regions of Sweden. The storm Gudrun in 2005 caused the sharp fall in price for the Southern Sweden (Swedish Forest Agency, 2010b).

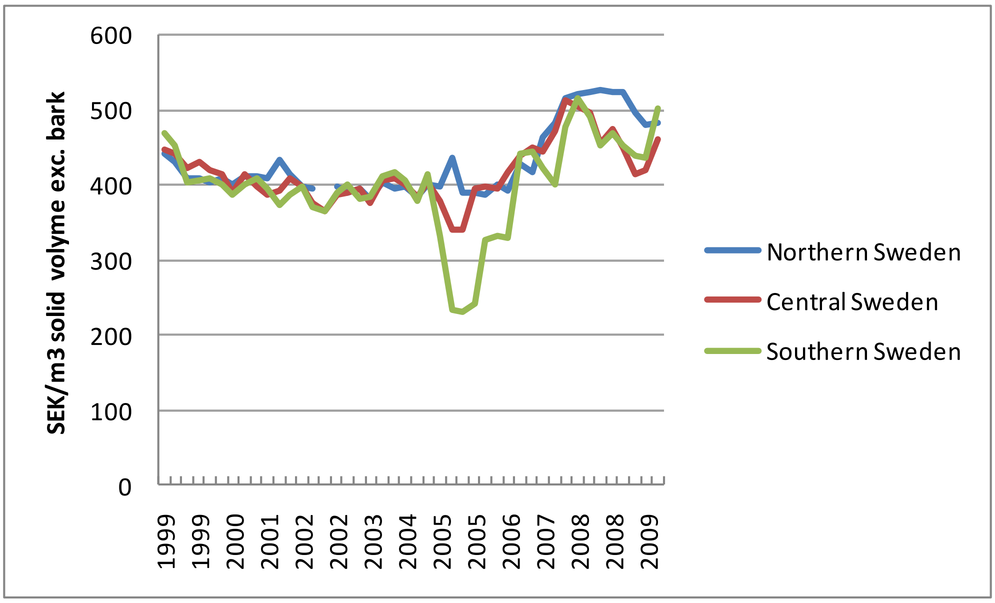

Figure 15: Average prices of sawlogs of pine, 1999-2009, in SEK per cubic meter solid volume (excluding bark), (Swedish Forest Agency, 2010b)

2.5.2 New raw materials for pellet production

Early in the development of the pellet industry in Sweden there was a surplus of sawdust. However, as result of increased usage of sawdust there became a competition for the raw material between the board industry, pellet producers and heat-/CHP-plants. This led to price increases for sawmilling residues (Näslund, 2003). The demand for pellets has also increased and the raw material assortment for pellet production needs to be broadened (Rönnbäck et.al., 2008). Until now, raw materials easy accessed have been used but for a further expansion the raw material potential not used today need to be utilized (Paulrud et. al., 2009).

In a survey among Swedish wood pellet producers from 2007 the majority of the respondents answered that they were having difficulties handling increased raw material prices. About one-third of the producers had investigated the possibility to use new raw materials. Energy wood (*i.e.* round wood of a quality usually used as pulp wood) was estimated as interesting for further use as raw material (Höglund, 2008).

If new raw materials, *i.e.* not by-products, are going to be used, costs for collection, baling, transportation and storage must be added. This could increase the production cost and make it more difficult for pellets to compete with alternative fuels (Mani et. al., 2006). For consumers, new raw materials also means costs for adjustments of the equipment and possible higher operating cost from *e.g.* higher ash content (Fredriksson et.al., 2004).

Energy wood and wet sawmill chips

Energy wood (including pulp wood) and wet sawmill chips are based on stemwood, which can give pellets with similar quality as pellets made from sawdust, shavings and dry chips. To use energy wood to produce premium quality pellets, a drum debarker and equipment for comminuting are needed in addition to the standard production equipment. These processes require high investment costs and are relatively energy demanding. For small-scale producers these requirements could be too expensive (Höglund, 2008). With high energy prices, energy wood could also be profitable to use in the energy sector (Lundmark & Söderholm, 2009). Figure 16 shows the price development for pulp wood in the last decade for different regions in Sweden.

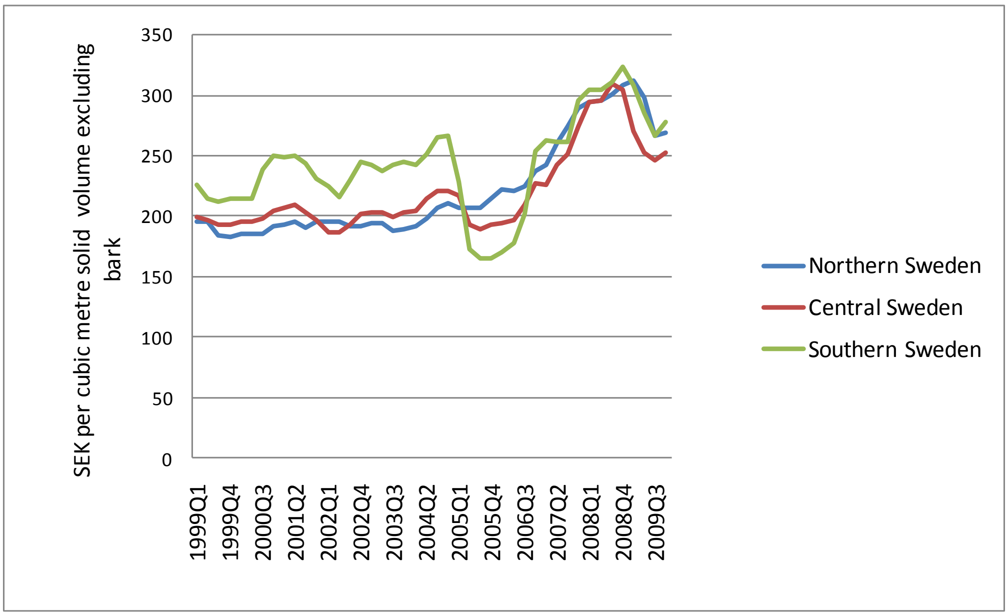

Figure 16: The price development for pulpwood in the last decade for the different regions in Sweden (Swedish Forest Agency, 2010b)

In the last years the increased demand for biomass to the energy sector has resulted in a competition for smaller logs, which earlier have gone to the pulp mills. The increasing competition for raw materials between the energy sector, pulp industry and board industry is predicted to give higher forest products prices in the future (UN, 2009).

Wet sawmill chips, often referred to as pulp chips, are to a large extent used in the pulp- and paper industry. Except chips from the sawmilling industry, the pulp industry uses pulp wood and recycled fiber as raw material.

In Table 1, the maximum production potentials for wood pellets made by by-products from the sawmilling industry are presented. The by-products are converted to pellets equivalents and to TWh. The table shows the minor importance of byproduct from smaller sawmills. As can be seen in the table the largest potential is from wet sawmill chips, which nationally represent a potential of 3.9 million tonnes of pellets. Bark is the second largest representing 1.5 million tonnes of pellets. Sawdust, one of the most commonly utilized raw materials for pellets today in third place with an annual maximum potential of 1.2 million tonnes. However, today are both bark and wet sawmill chips used for other purposes. Bark is used as fuel when drying the sawn products and wet sawmill chips is used by the pulp industry (Hirsmark, 2002). Figure 17 presents the development of the production of sawnwood in Sweden for the last 20 years. The production has increased by about 22% between 1995 and 2007. Table 1 is based on statistics from 1995 and hence the amount of by-products should have increased by approximately the same percentage.

Table 1: Maximum production potentials for wood pellets made by by-products from the sawmilling industry, modified from Hirsmark (2002).

	Sawmills > 5 000 m³sawn wood/year		Sawmills > 1 000 m³sawn wood/year	
	tonne of pellets	TWh	tonnes of pellets	TWh
Bark[1]	1 458 000	7.29	1 472 000	7.36
Sawdust[2]	1 146 000	5.501	1 165 000	5.592
Wet sawmill chips[2]	3 871 000	18.581	3 916 000	18.797
Slabs and edgins[2]	13 000	0.062	18 000	0.086
Dry chips[2]	367 000	1.762	371 000	1.781
Shavings[2]	[3]	[3]	486 000	2.333
Sum	**6 855 000**	**33.196**	**7 428 000**	**35.949**

Note: (1) Net calorific value of 5.0 MWh/tonne, (2) Net calorific value of 4.8 MWh/tonne, (3) Information missing because of lack of information

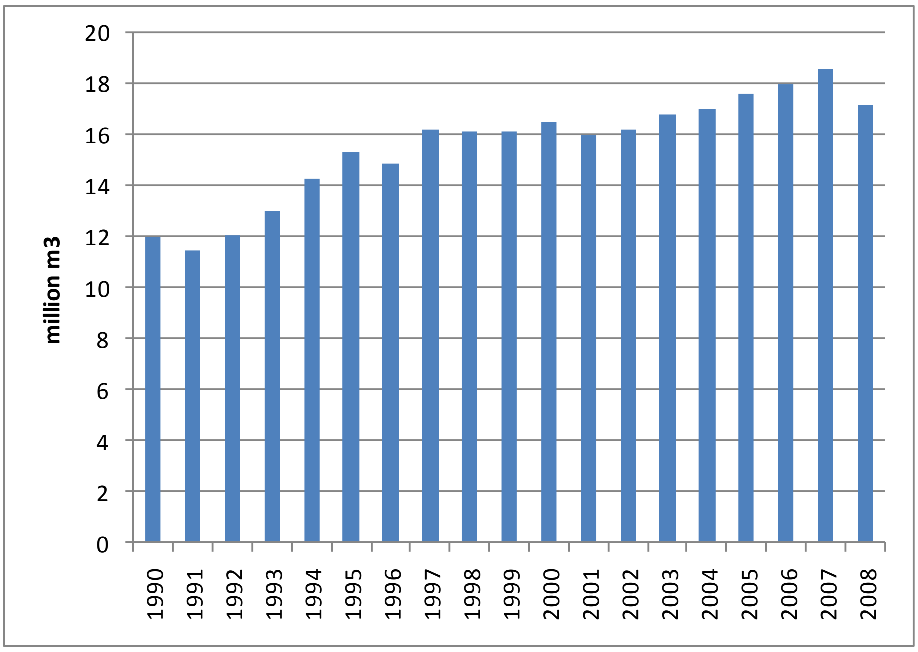

Figure 17: Production of sawnwoods in Sweden, 1990-2008. (SDC Virkesmätningsrådet, 2003, 2006, 2009 & Swedish Forest Industries 2006, 2007)

Peat

Peat is an organic soil type made by biomass decomposed in an anaerobe environment (NE, 2009). Sweden is one of the richest countries of peat land in the world, around 15% of the land area (SGU, 2009). With an annual growth of 18 TWh there is a large potential for increased use of peat in Sweden (SGU, 2009). EU considers peat as a fossil fuel and therefore certificates of emissions are required[10] for large-scale combustion of peat in EU countries (Svebio, 2010a). However, peat, classified as a slowly renewable energy source in Sweden, is included in the gre en electricity certificates system in Sweden where the production of electricity from peat is awarded with green electricity certificates (SGU, 2009). Neova produce peat pellets in Finland since the supply for wood raw material locally is too unstable with price and supply variations (Svebio, 2010a).

[10] Certificates of emissions are needed when peat is used in large-scale plants with a power exceeding 20 MW (Svebio, 2010).

There are no problems pelleting peat (Fredriksson et.al., 2004) except dusting, and the combustion properties are similar to wood pellets. Peat pellets also have a higher energy value than wood pellets (Svebio, 2010a). Peat has in general no ash-related problems (Fredriksson et.al., 2004) even though peat pellets have higher ash content and a somewhat lower ash melting point. These factors should usually not be a problem for medium-scale or large-scale consumers with more advanced ash handling system but peat pellets should be avoided in small-scale sector (Svebio, 2010a).

Bark

Bark is an abundant byproduct from the sawmilling and wood pulp industries. Most of the bark quantities are concentrated at the industries and the annual amount of bark stands for about 13-14 TWh of energy (Martinsson, 2003). There is today no surplus of bark, other than locally. The unprocessed bark is used as a fuel in the pulp industry, in heating plants or as fuel for drying wood at sawmilling industries (Näslund, 2003). One producer, Södra, is already producing bark pellets, which are sold only to large-scale consumers (Södra, 2010).

Bark has a higher heating value, higher moisture content and higher ash content than raw materials that are traditionally used for pellet production (Näslund, 2003). Compared to stemwood, bark also contains high amounts of critical elements such as chlorine, potassium, sodium, nitrogen and sulphur. This leads to higher emissions, *e.g.* SO_2, from combustion of bark pellets and therefore bark pellets are more suitable for large-scale plants with better exhaust cleaning. The large amount of ash makes the bark pellets unsuitable for small-scale consumers (Hirsmark, 2002). There is also a risk of coatings from the ash (Fredriksson et.al, 2004).

Agricultural raw materials

Agricultural fuels, such as straw, cereals and Salix, contributed in 2005 with 1 TWh to Sweden's energy supply. LRF[11] estimates a potential of around 22 TWh from the agriculture sector in 2020, were straw is considered to have the greatest potential (Swedish Energy Agency, 2009b).

According to a study from IVL[12], Salix, straw and reed canary grass are all raw materials with a possible potential, both from an economic and technical point of view, for heat production and densification in smaller production facilities. Limiting factors are the densification and combustion properties of the materials and thereby the possible usage of the pellets. It can also be difficult to compete with other new materials at larger production facilities as the agriculture products are not "naturally" concentrated and hence generally generate higher expenses for storage, handling and transportations. One solution could be to use smaller production facilities with a local market (Paulrud, 2009).

[11] LRF –The Federation of Swedish Farmers
[12] IVL – Swedish Environmental Research Institute

Salix

Salix is the Latin name for willow and already in the 1970's the interest for Salix as an energy crop started to grow in Sweden. Today there are around 16 000 hectares cultivated with Salix. The fast-growing tree is more suitable for the south of the country because of its vulnerability to frost in the spring. Advantages with Salix are that it gives large yields and can be harvested every 4-5 years for 20-25 years from the first harvest (Berneson & Nilsson, 2008). The national potential is estimated to 7-10 TWh (Näslund, 2003). In a long-term forecast Swedish Energy Agency (2009b) estimates the potential for Salix to be 40 TWh but in the last years uncertainty about the agriculture- and energy policies have led to few new Salix plantations.

Tests show that pellets made by Salix have a good durability, high density and a high heating value. According to a test made by Lantmännen there were no problems in the pelleting equipment. Tests also showed that if Salix pellets are going to be ground, for utilization in large plants, it requires more power than pellets made of sawdust (Berneson & Nilsson, 2008). Ground Salix also has bad bridging properties (Frediksson et.al., 2004).

Compared to other biomass fuels there is a high content of heavy metals in Salix, especially cadmium. Salix also has high content of extractives which can cause energy losses when the extractives are evaporated during drying under high temperatures. Salix pellets are best suitable in large plants because of the high contents of ash and nitrogen. There is also a relatively high content of potassium and chlorine which can give problems with coatings and corrosion (Berneson & Nilsson, 2008).

Straw

Straw is a byproduct from cultivation of cereal grains or oil grains. Today, around 10 000 tonnes of straw are used annually as fuel in Sweden, mostly in smaller burners at farms but also in some heating plants (Bioenergiportalen, 2009b). Straw is also used as feeding stuff and litter bedding for domestic animals. In Denmark the use of straw for energy production is more widespread. Technically there are no problems making pellets of straw but the combustion properties are relatively bad (Berneson & Nilsson, 2008) and straw pellets are best suitable for large-scale consumers (Rönnbäck et.al., 2008). The ash content in straw is much higher, compared to stemwood. The high content of chlorine and potassium in straw can cause corrosive coatings and risk for the ash to sinter in the burner at low temperatures (Martinsson, 2003). If straw is exposed to weather for some days after harvest, preferably rain, some of the chlorine and alkali metals are washed away. This makes the straw "grey" and the combustion qualities are better (Bernerson & Nilsson, 2005). The potential for straw in Sweden is estimated to around 4-7 TWh (Bioenergiportalen, 2009b).

Reed canary grass

Reed canary grass is a perennial grass that gives relatively large harvests and is tolerant against cold climate. This makes the grass suitable even for north of Sweden in contrast to Salix. The grass has low moisture content if it is harvested in the early spring/winter (Larsson et al., 2008). Undensified reed canary grass is bulky and expensive to transport and it is therefore important to locate the pellets production plant close to the cultivation (Xiong et. al., 2008).

Compared to wood pellets reed, canary grass pellets have a much higher ash-contents, which makes them more suitable for large consumers. Furthermore, reed canary grass has a higher amount of sulphur, nitrogen and chlorine which causes higher emissions of corrosive exhaust gases such as NOx and SOx during combustion (Larsson et.al., 2006). The high chlorine content can cause corrosive coatings and can also result in a low ash melting point. Pellets from reed canary grass do, however, have a good heating value and good durability (Xiong et. al., 2008). Irregular pelleting that wears on equipment is a problem when pelleting reed canary grass (Larsson, 2008).

2.5.3 Summary of raw materials[13]

In Table 2 a summary of the properties and characteristics of the different raw materials are presented.

Table 2: Summary of raw materials characteristics.

	Market situation	Potential	Pelleting and characteristics	Pellet quality (SS 187120)
Sawdust	No surplus Competition with board industry and heat-plants (1)	Increasing because of potential for increased fellings (1)	Need to be dried (1)	Group 1 (1)
Shavings	No surplus Also used as stall bedding, for briquettes prod. and in heat plants (1)	Increasing because of potential for increased fellings (1)	Do not need to be dried (1)	Group 1 (1)
Chips	Competition with paper- and pulp industry (4)	Increasing because of potential for increased fellings (1)	Dry chips do not need to be dried while fresh chips do need to be dried (1).	Group 1(2)
Energy wood	Competition with paper and pulp industry (3)		Drum debarkers and comminuting equipment are needed (2)	Group 1(2)
Bark	No surplus Used internally in the forest industry and at heat plant (1)	Increasing (increased fellings (1)	Drying the material is energy demanding , large wear on equipment (1)	High energy value, High ash content 2-4 %, Group 3 (8)
Peat	Used in district heating plants /CHP (8)	Large potential (5)	No problem to pellet, high ash content (5)	High energy value, high ash, nitrogen and sulphur content (8)
Salix	No surplus (1)	7-10 TWh/year (1)	Needs to be dried, volatilization of substances during drying causes energy losses (1)	Poss. group 1or 2, Ash content 2 %, low energy content (1)
Straw	Used in heating plants and for feeding stuff and litter bedding (5)	4-7 TWh /year (6)	High costs for transports and storage (5)	High ash content, low ash melting point and coatings (8), Group 3
Reed canary grass	Possible uses are for chemical pulp and board industry (1)	7 TWh/year (1)	Do not need to be dried, good for small-scale production , high transports costs (1)	High ash content, low ash melting temperature (8) Group 3

[13] (1) Näslund (2003), (2) Höglund (2008), (3) UN (2009), (4) Lundmark & Söderholm (2004), (5) Fredriksson et.al., (2004), (6) Swedish Energy Agency (2009b), (7) Bioenergiportalen (2009), (8) Martinsson (2003)

3 Methodology

To find out about the Swedish producers’ raw material situation a survey was conducted. To have a theoretical base, from which empirical results from the questionnaire and interviews can be analyzed, literature studies were made on previous research in the subject field. Much information in the theoretical framework was gathered from previous studies made in the subject field but also reports from organizations and authorities such as *Svensk fjärrvärme*[14], *Swedish Energy Agency*[15], *Svebio*[16] etc. Statistics were gathered from different source, for example *PiR*[17], the *Swedish Energy Agency* and the *Swedish Forest Agency*[18]. Calculations of the pellet production costs were also done for the raw materials sawdust, wet sawmill chips and energy wood.

3.1 Survey methodology

3.1.1 Aim for conducting a survey

There are earlier surveys made in the area, *e.g.* Hirsmark (2002) and Höglund (2008), but the decision was made to conduct a new survey since there are no reports focused on the plans of pellet producers for future new raw materials and price development. There is also a rapid development in the pellet market and therefore a new survey could be compared with earlier studies in the subject field to see the development of the market.

3.1.2 Construction of questionnaire

The questionnaire had three different sections; production, selling and price setting. In the first part of the questionnaire, *Production*, the purpose was to obtain information about the producers’ raw material assortment and if they have plans to expand it. The second part, *Selling*, investigated which consumers the pellet producers sell to and which segment of consumers they believed had the largest potential for increased sales of pellets. The purpose of the last section, *Price setting*, was to examine how the market-actors believed price setting for pellets works and how they believed new raw materials will affect the production costs.

For construction of the questionnaire literature about survey- and interview methodology was studied[19]. A web questionnaire was chosen to simplify answering the survey for the respondent and thereby hopefully increase the response rate. The questions were intended to be easy to answer with answering alternatives, this also to get a higher response rate. For each question there was space for the respondent to give comments, this to give the respondent an opportunity to explain their answers or comment on the questions. The questionnaire was anonymous and the purpose was to focus on the whole industry and not on particular pellet producers. The questionnaire can be found in Appendix C.

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14 www.svenskfjarrvarme.se
15 www.energimyndigheten.se
16 www.svebio.se
17 Association of Swedish pellet producers, www.pelletsindustrin.org
18 www.skogsstyrelsen.se
19 *Att får svar*, Kylén (2007) & *Enkätboken*, Trost (2007)

3.1.3 Choice of respondent

The questionnaire was sent out to all pellet producers in Sweden with a pellet production over 5 000 tonnes in 2008[20] or planned capacity expansion to over 5 000 tonnes. These criteria were reached by totally 36 pellet production plants. These 36 plants stood for 98% of the total Swedish pellet production in 2008.

Some of the 36 plants had the same owner; these were asked if they wanted only one questionnaire or one for each plant. In total, 26 questionnaires were then sent out to the producers. The respondents were:

- 5 large producers (production > 50 000 tonnes/year)
- 8 medium producers (5 000 – 50 000 tonnes/year)
- 2 small producers (< 5 000 tonnes/year).

The producers included in the survey were in a wide range of size. Most large producers had market managers while smaller producers only had few employees. The replies from both the questionnaire and interviews probably differ due to the work area of the interviewee/respondent of the questionnaire.

3.1.4 Getting the answers

The questionnaires were sent out September 14th 2009, and reminder emails were sent out October 7th. Most of the pellet producers that had not answered the questionnaire were contacted by telephone in November. The questionnaire was closed on December 15th. 16 out of the 26 producers answered the questionnaire, which gave a response rate of 62%.

3.1.5 Non-respondent analysis

A non-response analysis was made to detect similarities of the non-respondents that could have contributed to that they did not answer the questionnaire[21]. The questionnaire was anonymous but the producers could write their name, which was not connected to the results. However, some of the producers did not write their names and therefore complete information of who had answered the questionnaire was not available. Seven producers were contacted by telephone and asked whether they had answered the questionnaire. Out of these, six had not replied and the reasons they gave were that they got so many questionnaires so they did not have the time to answer them all. One said that he had not received the questionnaire. The non-respondent producers were located in all geographic regions and were of different size. Hence were no correlations found between the non-respondents of the questionnaire.

3.1.6 Interview methodology

The purpose of the interviews was to deepen the analysis of the results from the questionnaire. The respondents were selected from Svebio's list of pellet producers[22]. In total, 16 interviews were held with 17 different producers[23], where 5 of them were

[20] *Bioenergi, no 1 2009,* Svebio, Stockholm, listed all pellet producers and their respective production and capacity in Sweden 2009.
[21] The methodology used for a non-response analysis is described at pages 137-140 in *Enkätboken*, Jan Trost (2007)
[22] *Bioenergi no 1 2009,* Svebio, Stockholm
[23] One interviewed was working at two pellet production companies.

interviews held at the plants and 11 of them were telephone interviews. Generally the telephone interviews were shorter, 10-30 minutes, and the interviews at the plants longer, about an hour. In total the 17 interviews covered 27 plants, which give a response rate of 75%. The interviews held at the plants took place in November 2009, while the telephone interviews were held mostly in the end of November and beginning of December 2009. The guide that was used during the interviews can be found in Appendix D.

3.2 Calculations of production costs

New calculations for the production costs for the raw materials sawdust, wet sawmill chips and energy wood were made. For calculation of the production costs the full costing methodology was used[24]. An Excel-document developed by Thek (2002) was used for the calculations. The same basic information for the production costs as in Zakrisson (2002) was used except for some parameters. For wet sawmill chips and energy wood the excel-document were modified to include the extra equipment needed. Interviews with industry contacts and experts in the subject area together with statistics from Swedish Energy Agency and Swedish Forest Agency were used to make new estimations for the prices for raw material, electricity and extra equipment needed for using wet sawmill chips and energy wood were made. The calculations for the production costs made by Zakrisson (2002) were based on production of pellets using sawdust as raw material with a moisture content of 57%. The plant has an annual production of 80 000 tonnes of pellets. For more information about the methodology, calculations and parameters used se Zakrisson (2002) and Appendix E.

[24] Based on guidelines in VDI 2067, developed by Verein Deutscher Ingenieure.

4 Results

4.1 Survey

Production capacity

The number of respondents of the questionnaire and number of interviewed wood pellet producers are shown in Table 3. In the table, the pellet producers are categorized according to maximum production capacity[25]. "Small-scale producers" include the wood pellet producers with a maximum capacity of 5 000 tonnes annually and these were not included in the survey[26]. "Medium-scale producers" have a maximum capacity range between 5 000 and 50 000 tonnes annually and the "large-scale producers" have a maximum capacity over 50 000 tonnes annually. Table 3 also shows the total number of wood pellet production plants and the percentage of the total Swedish production and capacity for the different groups.

Table 3: Sweden's total number of wood pellet production plants, production, capacity and number of respondents of the questionnaire and interviews divided according to capacity range.

Category	Capacity range [tonnes/year]	Total plants [Number]	Production 2008 [% of tot prod.]	Capacity 2009 [% of tot cap.]	Respondents-Interviews [number]	Respondents-Questionnaire [number]
Small-scale	*< 5 000*	*47*	*3.5*	*8.3*	*not sent out to*	*not included*
Medium-scale	5 000 - 50 000	21	39.3	32.0	12 (covering 12 plants)	
Large-scale	>50 000	15	57.2	59.7	9 (covering 15 plants)	
Sum		83	100	100	17 (covering 27 plants)	16

4.1.1 Results from the questionnaire

A relatively small number of the Swedish pellet producers makes up a large share of the total pellet production in Sweden. Therefore, the results from the questionnaire were divided and compared separately according to annual production. The results from different questions are also compared. The response rate of the questionnaire was 59% where six of the respondents, 38%, had a production over 50 000 tonnes per year. 2 of the respondent answered that they had a small-scale production.

Many of the pellet producers have other business activities besides pellet production, *e.g.* sawmilling. Figure 18 shows the distribution between the different activities[27]. 67% of the responding large-scale producers were mainly pellet producers and 60% of the responding medium-scale producers were mainly pellet producers.

[25] The information about the wood pellet producers' maximum production and capacity is listed in *Bioenergitidningen no1*, Svebio, 2009.

[26] The small producers are not included in the survey or interviews and in the results medium and large producers' production are mentioned as Sweden's whole pellet production and capacity. As mentioned, the medium and large producers contributed to 96.5 % of the total amount pellets produced in Sweden in 2008.

[27] Some producers specified more than one activity in the questionnaire, *e.g.* both pellet production and saw milling.

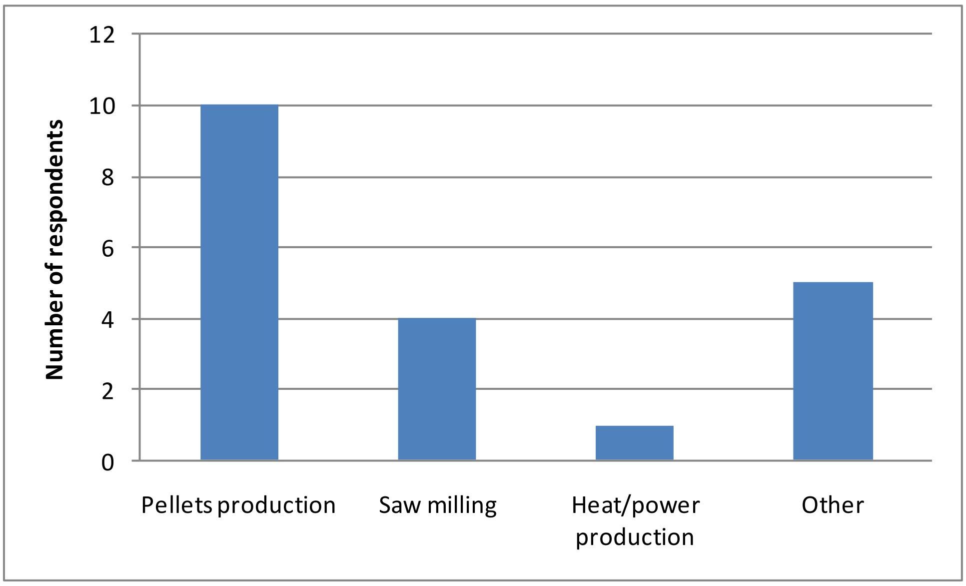

Figure 18: The producers' main activities according to the result from the questionnaire. Some producers specified more than one activity.[28]

Raw material situation

Of the respondents, 56% experienced a raw material shortage. Medium-scale producers experienced a raw material shortage to a larger extent than the large-scale producers, 70% and 33% of the respondents in each group respectively. Among the producers with pellet production as main business activity, 70% experienced a raw material shortage.

The majority of the respondents were planning, or investigating the possibilities, to use new raw materials for pellet production. Figure 19 shows which raw materials the respondents were planning for. Out of the respondents, 37% were not planning to use any new raw materials.

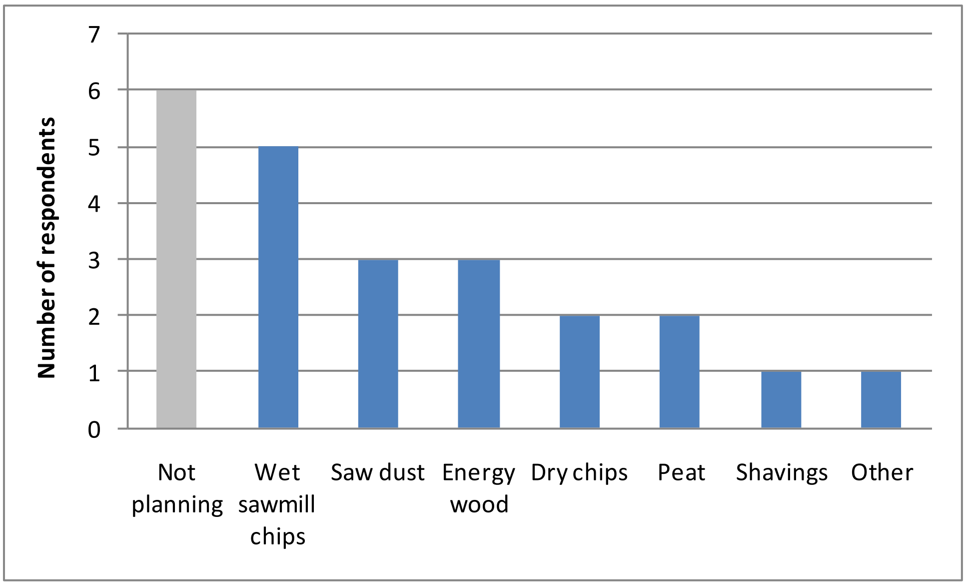

Figure 19: Not planning and planned raw material expansion for pellet production (number of respondents).

[28] Other" includes producers of: bioenergy, peat briquettes or bales.

Of the responding medium-scale producers, 80% were planning for new raw materials whereas only 33% of the responding large-scale producers were planning for new raw materials. Figure 20 shows whether or not the producers were planning for new raw materials with regard to their main business activity. 3 out of the 4 producers that also were sawmilling companies were planning for new raw materials while 4 out of 10 respondents with pellet production as main business activity, were planning for new raw materials.

The producers with sawmilling as their main business activity were planning for sawdust and shavings as new raw materials. The respondents that were mainly pellet producers were planning for a broader raw material assortment and many of them were planning for more than one new raw material. Wet sawmill chips and energy wood were most commonly planned for in this group.

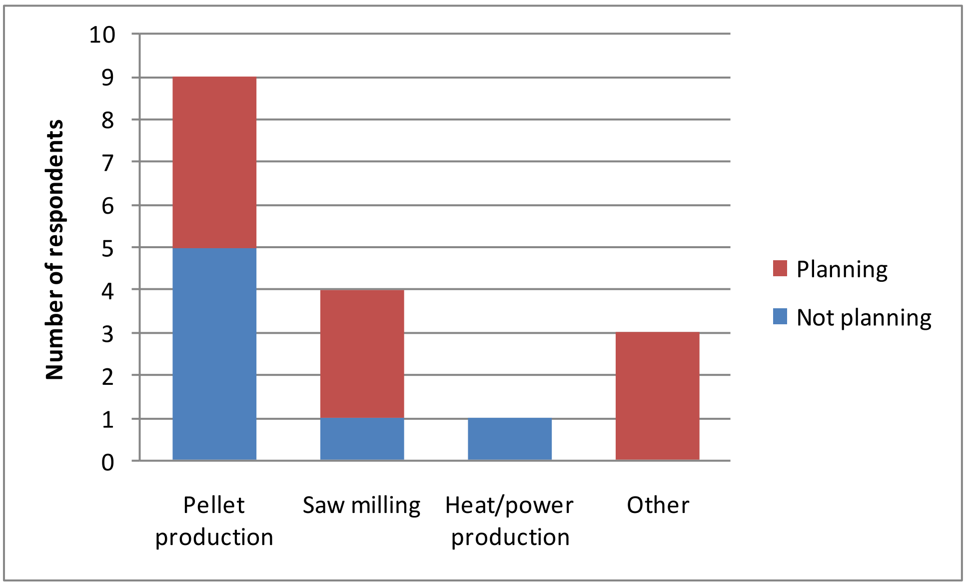

Figure 20: Planning/not planning for new raw materials with regard to the producers' main business activity.

Table 4 shows how the expansion of the responding producers' raw material assortments depends on their shortage of raw materials. For both the respondents with a shortage of raw materials and the respondents without shortage, approximately 70% were planning for broadening the raw material assortment.

Table 4: Planning of new raw materials depending on shortage of raw materials.

Shortage of raw material	Planning [%]	Not planning [%]	Total respondents
Yes	66.7	33.3	9
No	71.4	28.6	7

Figure 21 shows which raw materials the respondents had pelleting equipment for[29]. 6 out of the 16 respondents answered that they had equipment for using energy wood for pellet production.

[29] Equipment for pelleting sawdust, shavings and dry chips were not included.

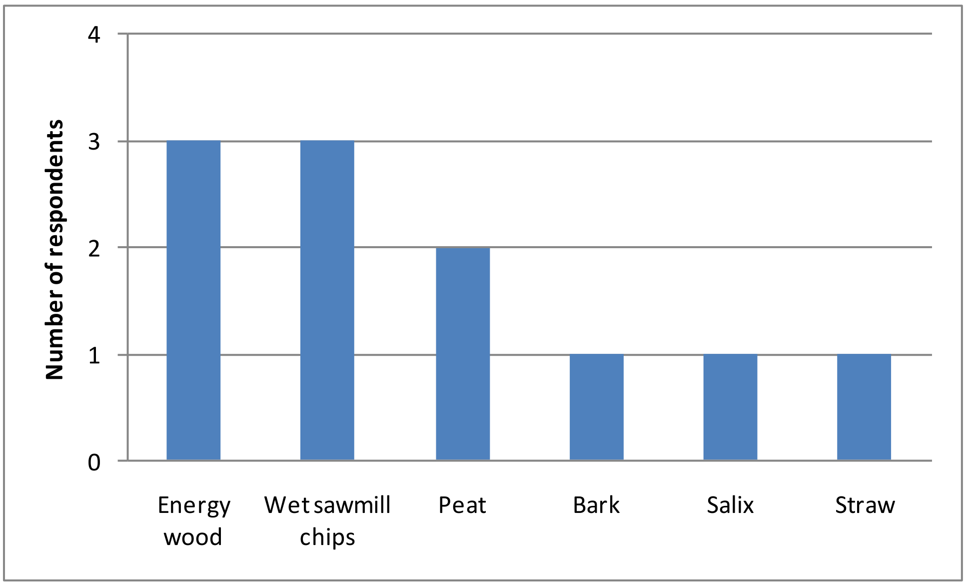

Figure 21: Number of respondents that have equipment for using new raw materials.

Market situation

The medium-scale pellet producers have, to larger extent, small-scale consumers compared to the large-scale pellet producers. In Table 5 all the respondents' market segments are listed. As can be seen in the table most of the medium-scale producers sell more than half of their pellets to the small-scale market segment. The large-scale producers sell to a larger extent to all market segments, as can be seen in the table.

Table 5: The pellet producers' different market segments as percentage of the producers' production.

	Market segments		
Large-scale producers	**Small-scale**	**Medium-scale**	**Large-scale**
1	70-80%	20-30%	0-10%
2	20-30%	20-30%	40-50%
3	20-30%	30-40%	40-50%
4	0-10%	70-80%	70-80%
5	20-30%	20-30%	40-50%
6	50-60%	20-30%	10-20%
Medium-scale producers			
1	80-90%	10-20%	0-10%
2	10-20%	80-90%	0-10%
3	90-100%	0-10%	
4	70-80%	20-30%	0-10%
5	90-100%	0-10%	0-10%
6	70-80%	10-20%	0-10%
7	40-50%	10-20%	40-50%
8	30-40%	30-40%	10-20%
9	30-40%	40-50%	10-20%
10	60-70%	20-30%	0-10%

75% of the respondents predicted that the medium-scale market segment will increase most in the coming years.

Price development and price formation of wood pellets
Of the respondents, 50% answered that the general pellet price will increase as an effect of new raw materials for pellet production. 31% answered that the price will not be affected.

45% of the responding pellet producers stated that the production costs affect the pellet price most. The respondents' answers in percent of the total respondents can be seen in Figure 22. Some of the respondents specified that the raw material costs are the most important factor in the production cost.

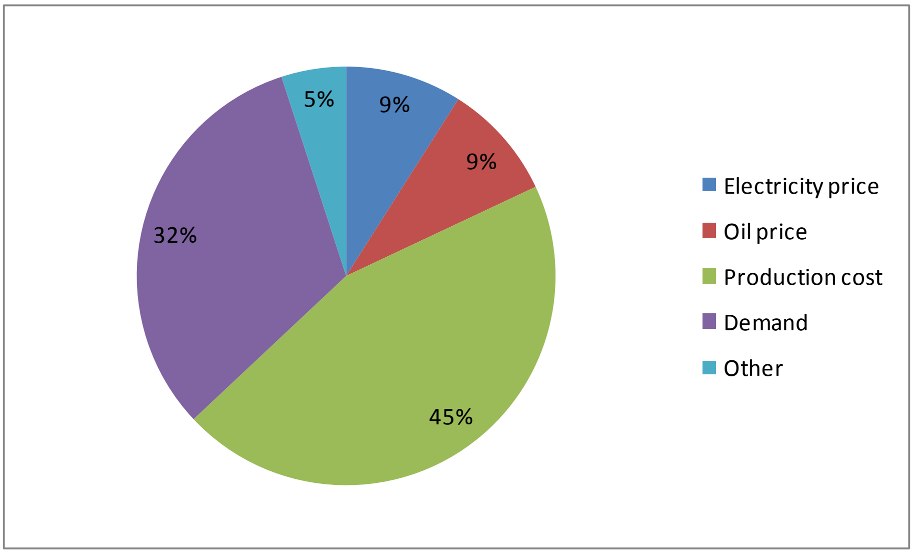

Figure 22: Most important price setting factor (% of the total respondents).

4.1.2 Results from the interviews

A relatively small number of the Swedish pellet producers account for a large part of the total pellet production in Sweden. Therefore, the results from the interviews were divided and compared separately after annual production. The results from different questions were also compared. 17 wood pellet producers were interviewed which gives a response rate of 75%[30].

Pellet producers are located all over Sweden. In Figure 4 (page 15) the geographic localization of the producers is shown. Table 6 shows how the pellet production plants are distributed between the South, Middle and North regions in Sweden. It also shows the percentage of the total Swedish capacity and number of pellet producer that each geographic group accounts for.

[30] Based on total number of large-scale and medium-scale pellet producers according to Svebio (2009b).

Table 6: The geographic localization of medium and large pellet production plants.

Localization	Capacity 2009 [% of tot cap.]	Plants [number]	Interviewed producers [number]
South	41.5	12	5 (covering 9 plants)
Middle	22.9	10	6 (covering 7 plants)
North	35.6	14	9 (covering 11 plants)
Sum	100.0	36	17 (covering 27 plants)

Note: Some pellet producers have pellet production plants in more than one region and are therefore also included in more than one region.

Raw material situation

Of the interviewed producers, 24% answered that they had a shortage of raw materials. Both medium and large producers experienced a shortage.

Table 7 shows the regional differences in shortage of raw materials in percent of the total number of interviewed in each region. In the South region none of the producers experienced a shortage of raw materials while around 30% in the Middle region and 20% of the interviewed in North region, experienced a shortage of raw materials.

Table 7: Shortage of raw materials in the different regions.

	Yes [%]	No [%]	Total producers
Total respondents	23.5	76.5	17
Region			
North	22.2	55.6	9
Middle	28.6	57.1	7
South	0.0	100.0	4

Most of the interviewed pellet producers answered that there was not a shortage of raw materials at the moment, but that there had been a lack of raw materials in the last year. One producer explained that even if there was not a shortage of raw material currently, the situation could change rapidly. Some producers mentioned that they could not purchase enough raw materials while other mentioned that they had access to more raw materials than they could handle.

To expand the pellet production in Sweden, raw materials other than those used today are necessary according to several of the interviewed producers. At the same time most of the producers were not worried about their future access to raw materials. On the Northeast coast of Sweden, where a lot of pellet production plants are situated, there seemed to be a higher competition about the raw materials, according to some of the interviewed producers.

Raw materials used by the responding producers are sawdust, wood shavings, wood chips, wet sawmill chips and energy wood. Figure 23 shows how many of the respondents that used each kind of the raw materials. Many of the companies used more than one raw material. As can be seen in the figure, sawdust and shavings are the most commonly used raw materials. 38% of the interviewed producers mostly, or exclusively, used sawdust as raw material.

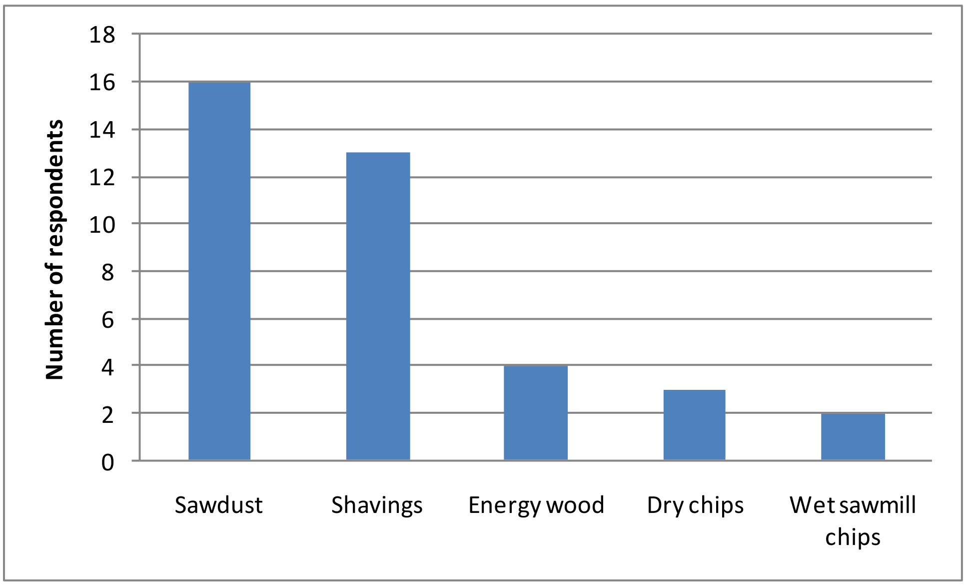

Figure 23: The number of interviewed pellet producers using each kind of raw material.

Many of the producers mentioned that they had just started to use energy wood and wet sawmill chips. The interviewed medium-scale producers almost exclusively used sawdust and shavings. Energy wood, dry chips and wet sawmill chips were mostly used by large producers. All the pellet producers that used energy wood have pellet production as their main business activity.

A majority of the interviewed pellet producers, 70%, were planning or investigating the possibilities to use new raw materials. Figure 23 shows the interviewed producers' plans for new raw materials. In the interviews, around 40% of the producers mentioned that they were planning to use energy wood. Other materials that were planned for were sawdust, shavings, peat, wet sawmill chips and agriculture residues. Raw materials investigated, but not planned for, were reed canary grass, Salix and shavings. Some producers were also planning to blend the wood pellets with peat.

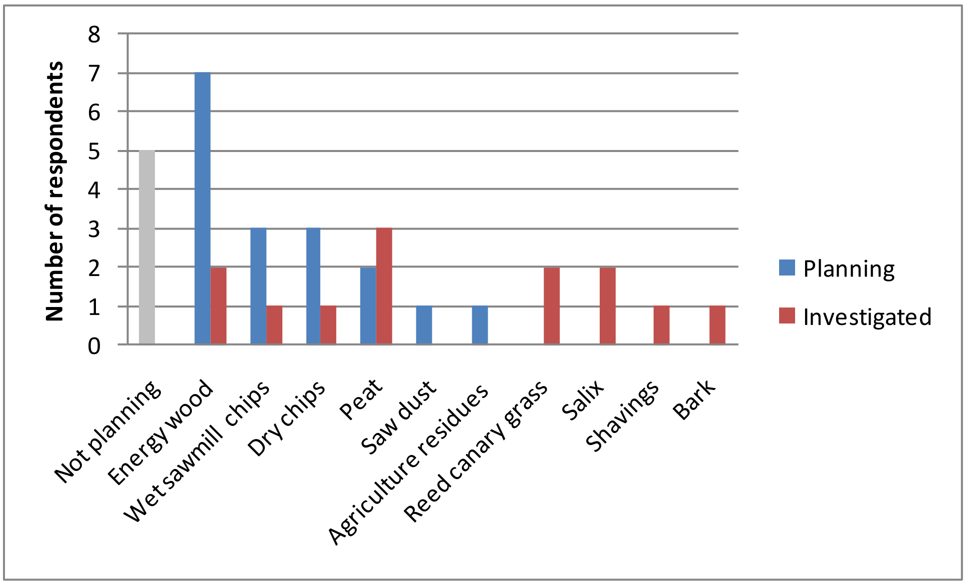

Figure 24: The interviewed producers' plans for new raw materials (number of respondents).

Table 8 shows how the plans for new raw materials depend on the current shortage of raw materials. Of the interviewed producers with a present shortage of raw materials, 75% were planning for new raw materials. Around 60% of the producers that did not experience a shortage of raw materials were, despite this fact, planning for new raw materials.

Table 8: Planning of new raw materials depending on shortage of raw materials.

Shortage of raw material	Planning [%]	Not planning [%]	Total interviewed
Yes	75.0	25.0	4
No	61.5	38.5	13

Several of the producers had experience from different raw materials. One company had tried to use Salix with good results. Because of lack of Salix in the local area, it was not profitable to continue. Another producer had tried to use peat but experienced problems in both the pelleting process and in the combustion of the peat pellets. One producer explained that reed canary grass is technically difficult to use as raw material for pellet production. It requires high energy consumption and much additive to produce pellets with good durability. Many of the producers had good experience of pelleting energy wood. One producer explained that historically, the prices for energy wood have been much higher than for sawdust and therefore never used as raw material. In the last year the difference in energy wood and saw dust prices have decreased and therefore, energy wood has become interesting for the pellet producers.

One company had investigated many different raw materials, but their experience was that the costs for using new raw materials will be higher than using traditional woody materials and that the market will not accept a higher price for the pellets. Pellets of low quality are not suitable for the small-scale market and lower quality could give increased particle emissions were mentioned by several of the producers. Small-scale burners generally have less cleaning equipment than large-scale burners. These factors make it difficult to start using new raw materials. One producer answered that they may need to organize an entirely new system for the pellet production and distribution to lower the costs.

Most of the producers agree that pellets from new raw materials, that give lower quality, are possible to use by large-scale consumers. Many producers mention that the raw materials for high quality pellets should cover the small-scale market. Still, the majority of the interviewed producers pointed out that they will not start using raw materials that gives pellets of lower quality.

Many factors that affect the development of using new raw materials were mentioned by the producers, *e.g.* national and international demands and policies. The exchange rate also influences the development of import and export, one producer pointed out.

Some producers brought up the possibilities to blend the traditional raw material with another new raw material. Accordingly a share of 5% *e.g.* peat will not significantly affect the quality of the pellets. However, peat is not always considered as a renewable resource. For large-scale consumers certificates of emissions are needed for combustion of peat pellets. Some producers had also tried additives, *e.g.* oil-seed rape cake, to lower the energy consumption during the densification.

In the interviews, the producers were asked what they believed were the greatest challenges when using new raw materials for pellet production. The dominating answer was the quality of the pellets. Most of the producers do not see any problems in the manufacturing process. The problem is to find customers that request low quality pellets. In Sweden, the prices of raw materials are relatively high and it is therefore difficult for the producers to compete with for example pellet producers in North America. Another barrier for using new raw materials is the competition for raw materials with CHP-plants. These buy raw biomass for direct combustion, for which they acquire green electricity certificates. This makes the price for raw materials depend on the electricity price, according to one of the interviewed producers.

Market situation

In the interviews, the producers were asked to which market segments they sell pellets. Some producers could even specify the percentage sold to each segment, while other just mentioned which market segments they sell to. In Table 9, the producers' different market segments[31] are listed. It can be seen that the medium-scale producers had more small-scale consumers than the large producers. The large-scale producers sell to all market segments. Of the interviewed producers, 70% believed that the medium-scale market will increase most in the coming years.

Table 9: The interviewed producers' different market segments.

	Market segments			
	Small-scale	**Medium-scale**	**Large-scale**	**Export**
Large-scale producers				
A	33%	33%	33%	
B	60%	25%	15%	
C	33%	33%	33%	
D		x	x	
E	x			
F	x	x		
G	x	x	x	
Medium-scale producers				
A	x	x	x	
B	x			
C	x			
D	x	x		
E	x			
F	67%		33%	
G	x			
H	40%		40%	20%
Total number of producers	14	8	8	1

[31] Some producers have several plants. The largest plant's capacity sets which group, large-scale or medium-scale producer, the producer belongs to.

As mentioned earlier the majority of the producers felt that the greatest challenge with new raw materials is to get a product with good quality. A majority of the interviewed pellet producers mentioned that the importance of quality is an issue of primary importance. In order to be successful on the small-scale market it is very important to be “best in test” concerning quality, because, according to the producers, many consumers look more at the quality than the price when they purchase wood pellets.

Of the interviewed producers, all produce pellets of high quality and most of the interviewed were not planning to produce pellets of low quality. The majority believed that there is a market for pellets of low quality but they were not planning to reach this market. It is especially the big coal-fired CHP-plants in Europe the interviewed producers point out as a possible market for low quality pellets. But as almost all interviewed producers were of the opinion that to be able to produce cheap pellets for the international market the production costs needs to be lower. Several of the producers also mentioned that they mostly have small- or medium-scale consumers and this group is not interested in pellets of low quality. If the prices of pellets increase or if it is possible to reduce the production costs a lot of the interviewed producers would investigate the possibilities to produce low quality pellets.

Price development and price formation of wood pellets

All interviewed producers replied that the question “How the pellet prices will change in the next years” is difficult to answer as it depends on many factors that can quickly be changed. But almost all believed that the price will continue to increase, although not as fast as in the last years.

In the interviews some producers explained that how new raw materials will affect the general pellet price depends on the raw material used, for example will energy wood not affect the equipment much and give pellets with same quality as pellets made from traditional raw materials. For many other new raw materials the whole process needs to be changed, both for the producer and the consumer of the pellets.

Table 10 shows how the interviewed producers answered on the question “What do you experience as the most important factor for price setting of pellets?[32] It was mentioned during the interviews that the production costs establish the minimum price. Other factors, such as the demand, affect the “real” price. Some producers answered that only the production costs are setting the pellet price. The electricity price also affects the production cost with changed expenditures for energy. To maintain and to get new consumers the prices for pellets cannot be too high; it needs to be cheaper to heat your home with pellets than with electricity one producer said. Raw materials costs were mentioned as the most important part of the production costs by many of the interviewed producers.

There were differences between the medium-scale and large-scale producers in which factor they believed was the most important factor for price setting of pellets. The medium-scale producers answered production cost and demand as the most important

[32] Some producers have several plants, here the largest plant capacity is deciding which group, large or medium producer, the producer is going to be in.

factors while the large-scale producers generally more answered the electricity and oil price as the most important factor.

Table 10: Replies to the question "What do you experience as the most import factor for price setting for pellets?

Price setting factor	Electricity price	Oil price	Production cost	Demand	Other
Large-scale producers					
A	x		x		
B			x		
C	x	x			
D	x		x		
E	x	x			x
F			x		
G			x	x	
H		x		x	
Medium-scale producers					
A			x		
B			x	x	
C	x			x	x
D				x	
E					x
F	x		x		
Total repondents	**6**	**3**	**8**	**5**	**3**

Note: “Others” include political decisions, price for district heating and the quality of the pellets.

4.2 Calculations of production costs

The production costs for using sawdust, wet sawmill chips and energy wood as raw materials were calculated with the method developed by Gerold Thek, BIOS, Austria (2002)[33]. In Table 11 the total production costs and costs for the different parts of the production are presented. The input used for calculations of the production costs are found in Appendix E.

Table 11: Pellet production costs when using sawdust, wet sawmill chips and energy wood respectively as raw materials in €/tonne pellets.

	Sawdust (€/tonne)	Wet sawmill chips (€/tonne)	Energy wood (€/tonne)
Raw material	67.2	57.0	59.8
Drying	13.8	12.9	12.9[1]
Grinding	2.9	2.9	2.9
Pelleting	5.1	5.1	5.1
Cooling	0.7	0.7	0.7
Storage	2.2	2.2	2.2
Personnel	5.5	7.2	7.2
Construction	1.2	1.2	1.2
Other costs	1.1	1.1	1.1
Wood chipper		5.6	5.6
Drum debarker			3.4
	99.7	95.9	95.7-102.1[1]

Note: [1] If the bark generated from the pellet production is assumed to cover the costs for thermal energy, 6.4 €/tonne, the production cost are 95.7 €/tonne. If the bark are not used in the process the productions are 102.1€/tonne, see calculations in Appendix E.

If sawdust, with a moisture content of 57%, is used as raw material the production costs becomes 99.7 €/tonne pellets produced. In Figure 25 the percentage of the costs for the different parts of the production are shown. The cost of raw materials is the largest part of the production cost, 67%, followed by drying cost, 14%.

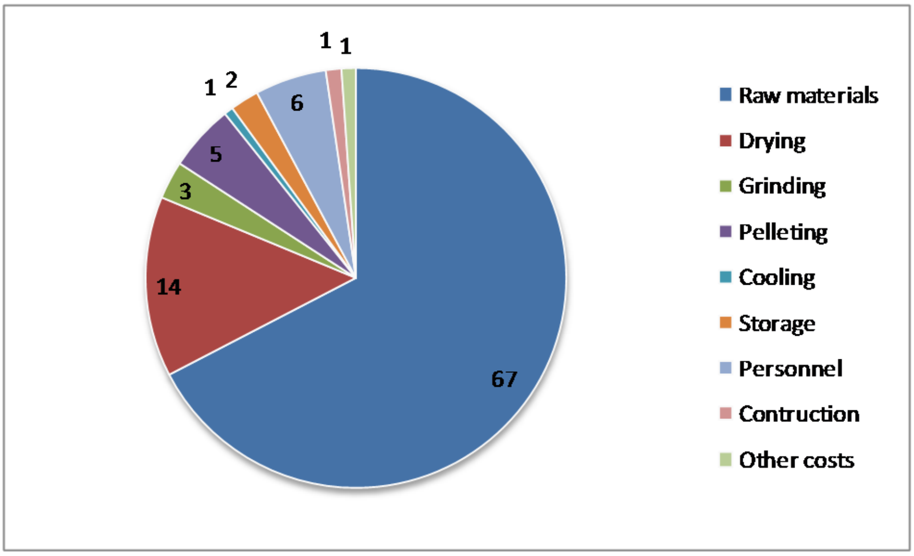

Figure 25: Cost distribution (%) for the different parts of the production.

[33] The method is modified to include the extra equipment needed for wet sawmill chips and energy wood.

To use wet sawmill chips (54% moisture content) as raw material a grinder needs to be added to the equipment. The grinder also requires more personnel. Wet sawmill chips gives a total production cost of 95.9 €/tonne pellets produced. The cost for raw materials is the largest part of the production cost, 59%, followed by drying costs, 13%. The investment for the grinder makes up 6% of the total production cost.

To use energy wood (54% moisture content) as raw material a wood chipper and a drum debarker need to be added to the equipment. Extra equipment to carry the energy wood to the chipper is also needed. The wood chipper and drum debarker also requires more personnel. Energy wood hence gives production costs of 102.1 €/tonne pellets produced. The cost for raw materials is the largest part of the production cost, 59%, followed by drying costs, 13%. The wood chipper makes up 5% and the drum debarker 3% of the total production cost. The bark from the process could be used as fuel for the thermal energy needed for drying of the raw material. The process requires 444 kWh of thermal energy for 1 tonne produced pellets. The bark from the process could cover about 405 kWh of thermal energy; see Appendix E for more information about the calculations. If the bark is assumed to cover all costs for thermal heating the production costs for energy wood will be 95.7 €/tonne pellets.

Figure 26 shows how the raw material prices for wet sawmill chips and energy wood affect the production costs. The y-axis to the right shows the corresponding price for sawdust. For example will a raw material price for wet sawmill chips of 26 €/tonne (dry content) result in a production costs of 110 €/tonne pellets. A raw material price for sawdust of 29 €/tonne correspond to the same production cost.

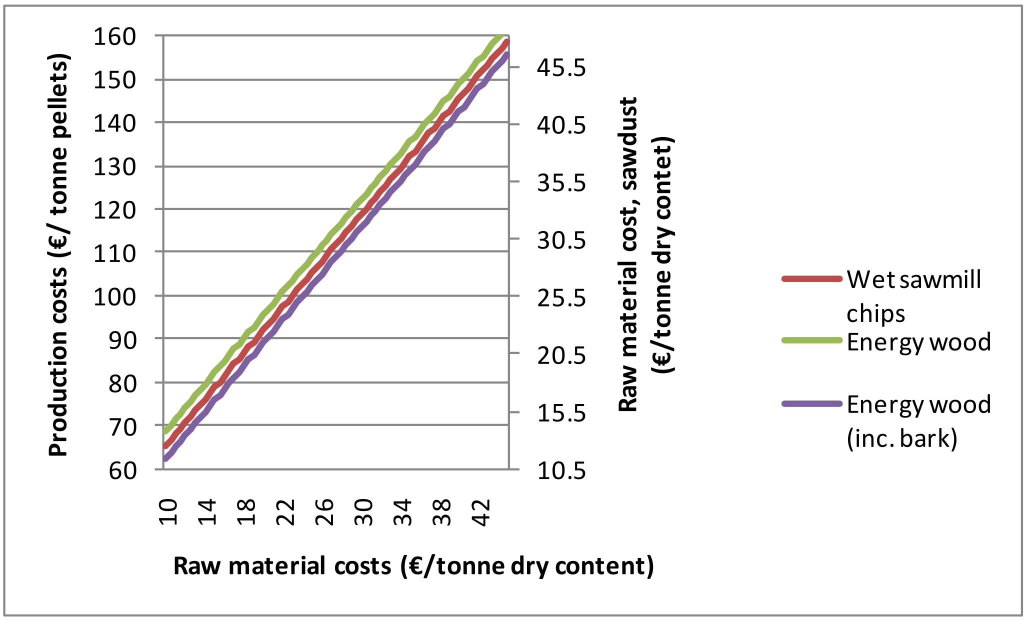

Figure 26: Production costs/corresponding raw material cost for sawdust for wet sawmill chips or energy wood.

In Table 12, the externally required energy demand for the pellet production is shown. To use wet sawmill chips or energy wood instead of sawdust as raw material gives higher electricity consumption because of the added equipment. The thermal energy consumption is less for wet sawmill chips and energy wood compared to sawdust as theses raw materials have lower moisture content. Bark will be released when energy wood is used as raw material. The bark is possible to use for heat production and thereby reduces the externally required thermal energy. For production of pellets from energy wood the cost for thermal heating is 6.4 €/tonne pellets. If all the thermal heat could be produced with the bark from the raw material this would give a total production cost of 95.7 €/tonne.

Table 12: The required energy demand for pellet production of sawdust, wet sawmill chips and energy wood.[34]

	Sawdust (kWh/t w.b)	Wet sawmill chips (kWh/t w.b)	Energy wood (kWh/t w.b)
Electricity	106	174	217
Thermal	504	444	444
Total energy	610	618	661

4.2.1 Sensitivity analysis

In Figure 27-27 the raw material prices, electricity price, interest rate and investment costs (for the wood chipper and drum debarker) are varied up and down by 20% respectively. As can be seen in the figures the changes in raw material price affect the production cost most for all the raw material assortments.

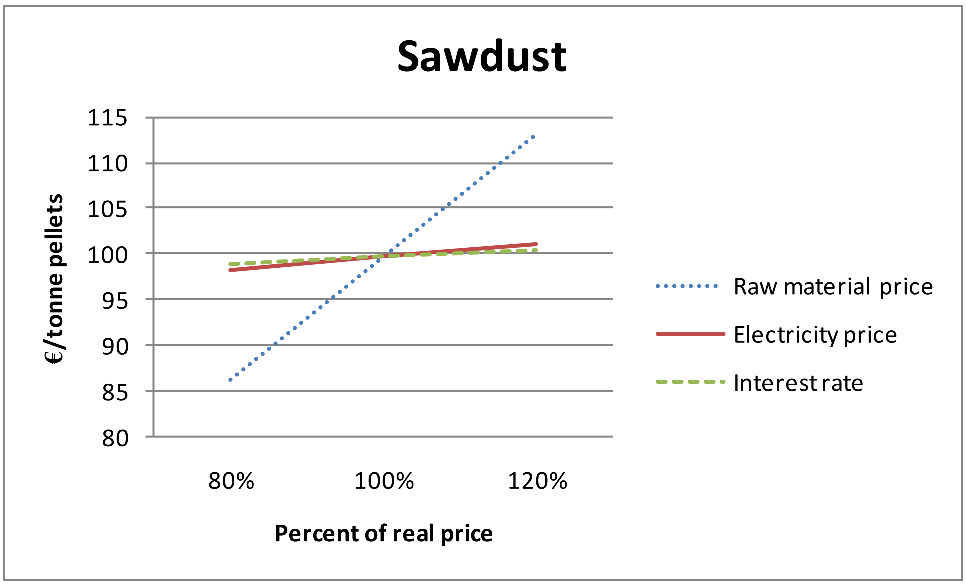

Figure 27: Influence on the production costs from sawdust by percental changes of raw material price, electricity price and interest rate

[34] wb=wet base

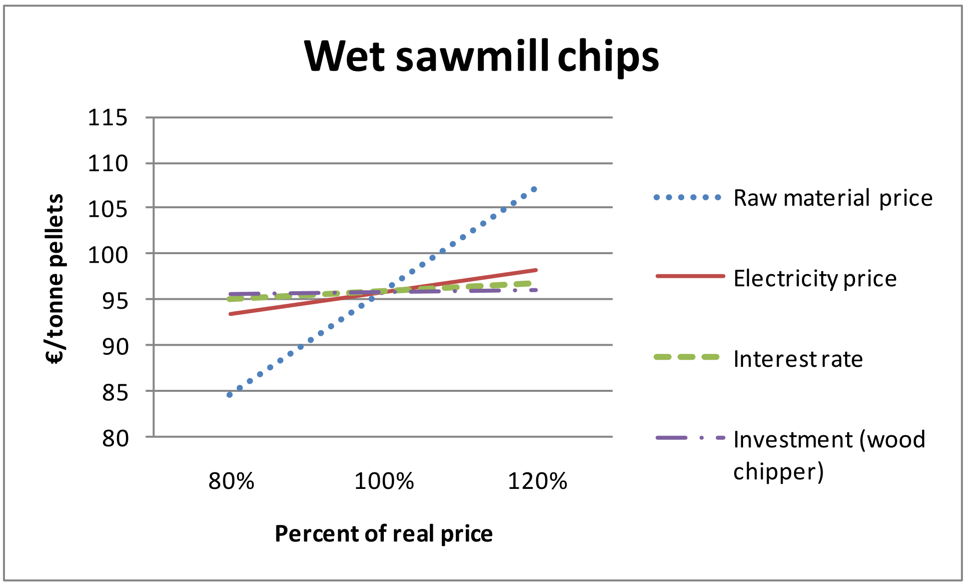

Figure 28: Influence on the production costs from wet sawmill chips by percental changes of raw material price, electricity price, interest rate and investment cost respectively.

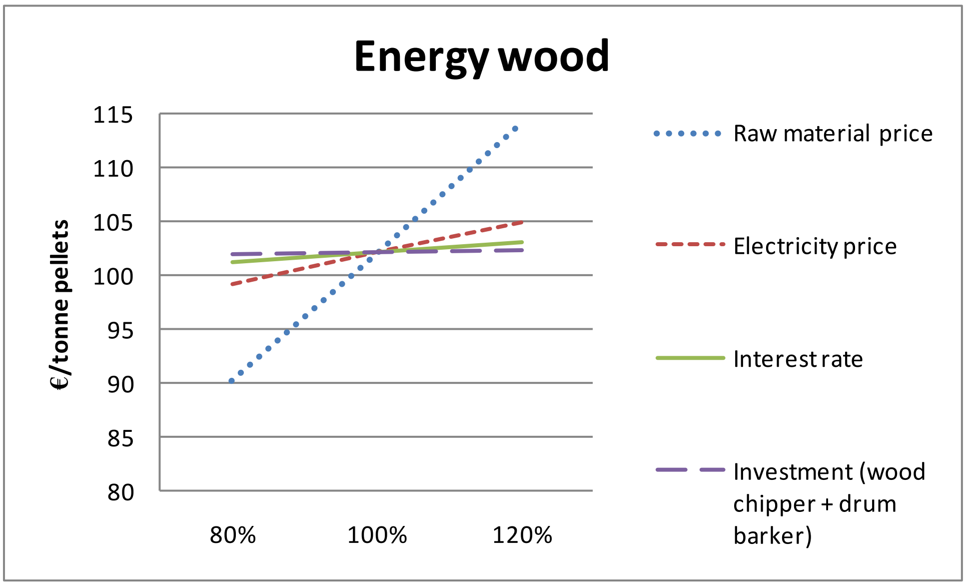

Figure 29: Influence on the production costs from energy wood (energy wood) by percental changes of raw material price, electricity price, interest rate and investment cost respectively.

4.3 Summary of the results

The raw material situation

- Sawdust and shavings were most commonly used as raw materials for pellet production. Some producers, mainly large producers with pellet production as their main business activity, also used energy wood, dry chips and wet sawmill chips.
- 56% of the respondents of the questionnaire and 24% of the interviewed producers experienced a shortage of raw material.
    - Medium-scale producers experienced to a larger extent shortage of raw materials than large-scale producers.
    - None of the interviewed producers in the South region had a shortage of raw materials.

- 70% of the interviewed producers and 63% of the respondent of the questionnaire were planning for new raw materials respectively.
    - About 40% of the interviewed producers planned for energy wood
    - Sawdust, shavings, peat, wet sawmill chips and agriculture residues were also raw materials planned for.
    - Most of the respondents that planned for new raw materials were medium-scale producers.
    - While the producers with sawmilling as their main business activity were planning for raw materials such as shavings and sawdust the pure pellet producers were planning for energy wood and wet sawmill chips.
    - A majority of the producer included in the survey (both questionnaire and interviews) were not planning to produce low quality pellets.

Market situation

- The medium-scale producers sell more pellets to small-scale consumers while large-scale producers sell to all market segments.
- The pellet quality is of great importance for the consumers, especially the small-scale consumers.
- The medium-scale segment is predicted to increase most in the coming years.
- Most of the producers believe that there is a market for low quality pellets but are not planning to produce low quality pellets themselves.
- Only one producer was planning to produce low quality pellets.

Price development and price formation of wood pellets

- According to the respondents (questionnaire and interviews), the most important factors affecting the pellet prices were the production costs followed by the demand for pellets and the electricity price.
- 44% of the respondents (questionnaire and interviews) believed that the pellet price will increase as an effect of new raw materials for pellet production.

Production costs

- In a case study of a “typical” large-scale pellet producers sawdust as a raw material gives production costs of 99.7 €/tonne
- Wet sawmill chips as a raw material gives production costs of 95.9 €/tonne
- Energy wood as a raw material gives production costs of 102.1 €/tonne. If all the thermal heat could be produced with the bark from the raw material this would give a total production cost of 95.7 €/tonne.
- The raw material cost is dominating in the production cost for all the examined raw materials.

5 Discussion

New raw materials such as energy wood and wet sawmill chips are already used by the large-scale pellet producers. The large-scale producers have probably greater economic possibilities to invest in new equipment for new raw materials. However, the medium-scale producers are planning for new raw materials to a larger extent than the large-scale producers, which indicates that they are catching up in the development. There were also mainly medium-scale producers that experienced a shortage of raw materials.

The results from the questionnaire showed a larger shortage than the results from the interviews. In the South region none of the interviewed producers experienced a shortage of raw materials. It differed approximately two months between the questionnaire and the interviews. As could be seen in Figure 15 the prices for sawlogs were increasing in the South and Middle regions of Sweden in the end of 2009 which could indicate on an increased production at the sawmills. An increased production at the sawmills gives increased raw material supply. However the results from the survey did not show any connection between shortage of raw materials and planning for new raw materials.

The most common raw material planned for was energy wood. Producers with sawmilling as their main business activity were mainly planning to use more by-products from the saw milling such as dry chips. Producers with pellet production as their main business activity probably do not have the same access to raw materials as the sawmilling companies and here raw materials that are not necessarily by-products, *e.g.* energy wood, are planned for. The "easiest" and cheapest raw materials are used first. When the by-products from the sawmilling industry are fully utilized the "second easiest" raw materials are being planned for. Energy wood and wet sawmill chips, are relatively easy to use. Some extra equipment is needed but the material is based on stemwood which give similar quality as pellets from sawdust.

Only producers with an annual production over 5 000 tonnes were included in the survey. For some raw materials, such as agricultural residues, the low density makes long transports expensive and here would small or portable plants be preferable. If small producers also were included maybe more ideas and plans for new types of raw materials might have been identified. Furthermore, it is possible that it is not the current producers that will change the raw material assortment but instead new actors in the market with other experiences, *e.g.* a small-scale agricultural background.

For small-scale consumers, and also some medium-scale consumers, the fuel quality is of outmost importance and these groups are the main market segments for many of the pellet producers. Most of the producers advertise their good quality of the pellets which could indicate that the consumers are choosing pellet supplier not just after the price but also depending on the pellet quality. In the future it is also possible with a development with more fuel-flexible small-scale burners on the market.

Only one of the interviewed producers was planning to produce low quality pellets even though many of interviewed producers mention that there is an international market for low quality pellets. High production costs make it difficult for the Swedish pellet producers to compete with other countries and high quality pellets to the small-scale market give higher incomes. An increased international demand could rapidly change the raw material situation. Many of the producers have investigated the possibilities for using for example Salix, reed canary grass, agricultural residues etc. and if it is profitable to sell pellets made of these materials they will probably start using them. For example could an increased demand for pellets in North America or Asia change the trade flows of pellets and thereby give Swedish pellet producers large possibilities to export to large CHP-plants in Europe.

Pellets are used by both large-, medium- and small-scale consumers which have different demand for quality. According to Boldt (2009) the pellet prices of the different markets affect each other. If the differences between low quality pellets to the large-scale market and high quality pellets to the small-scale market are too large the producers will earn more on producing high quality pellets to the residential market. This was mentioned by many of the interviewed pellet producers. The small-scale consumers are the producers' most important costumers because they pay most for the pellets. Most of the producers are also not trying to reach the large-scale market but concentrate on high quality pellets for the small-scale market.

Boldt (2009) also concluded that if the different markets will be more separated, both in quality and price, the situation will probably change and the two pellet markets will become more separate. Sweden has large amounts of raw materials based on stemwood and for the pellet producers to invest in raw materials that give high quality pellets first seems quite logical. One of the scenarios Hillring (1997) mentioned was that the prices for wood fuels will increase because of higher demand. A higher pellet price makes it profitable to use more expensive raw materials when the easy available are fully utilized. With a rapidly growing market for pellets more raw material assortments may be possible to use. The differences in price between energy wood and sawdust have decreased in the last years. This makes energy wood more feasible to use for pellet production, which also many of the producers have started with.

In a long-term perspective, the demand for pellets also depends on the alternative energy sources. The development of heating systems in detached houses such as heat pumps or the usage of coal or natural gas in large heat-/CHP plants are examples of factors that will affect the future demand for pellets. In a short-term perspective the prices of alternative energy sources are less important. The consumers cannot change all heating systems immediately. In that perspective changes in the residential market are slow in a macro perspective and not affected by short-term fluctuations in the pellet prices but still affected by the prices of alternative energy in a long perspective.

Some large heat-/CHP plants are relatively fuel-flexible. Here the price fluctuations of alternative fuels can affect the demand for pellets more rapidly. The low quality pellets will thereby be more dependent of alternative energy prices. Polices also affect the demand for renewable energy, where usage of pellets can decrease CO_2-emissions and help producers to fulfilling regulations. According to Boldt (2009) the pellet prices are depending on the diesel oil but with a time lag of 1-1.5 years.

The minimum price for pellets is, in a long perspective, set by the production costs. According to results of the survey, the production cost also affects the pellet price most. However, there are differences between the medium-scale and large-scale producers in which factor they believed was most important for price setting of pellets. The medium-scale producers mentioned production cost and demand as the most important factors whereas the large-scale producers generally more choose the electricity and oil prices as the most important factors. The large-scale producers also have more large-scale consumers, which is consistent with this reasoning.

Costs for raw materials are a large part of the productions costs. The prices for by-products from the forest sawmilling industry have increased in the last years which have made the raw material costs even more important. The raw materials costs were calculated as around 50% in 2002 (Zakrisson, 2002). In the interviews raw materials costs was mention as high as 70-75% of the production costs. In new calculations the typical raw material cost was 67% of the total production costs for pellets if sawdust was used as raw material.

The price difference between by-products from the sawmilling industry, such as sawdust or wet sawmill chips, and energy wood has decreased in the last years. The prices for both wet sawmill chips and energy wood have periodically even been lower than the price for sawdust. From the results is can be concluded that the cost for new equipment, both the investment and the operating costs, affects the total production cost less than increased or decreased raw materials costs. The pellet producers are mainly planning for the energy wood and wet sawmill chips as new raw materials. According to the calculations, the productions costs are lower for wet sawmill chips and energy wood than for sawdust, assuming that most of the thermal energy could be produced with the bark from the debarking process when using energy wood. Even though the production equipment needs to be modified for new raw materials and new equipment might need to be added to the production process it can thus be profitable to use new raw materials.

The maximum production potential for wood pellets made by wet sawmill chips is 4.7 million tonnes annually. For sawdust, which is to a big part used as raw material today, the total maximum potential are 1.8 million tonnes of pellets. But even if the potential for wet sawmill chips is greater this by-product is also used in the pulp industry. The future demand for wet sawmill chips from the pulp industry could hence affect the amount of available raw material for pellet production and thereby the pellet prices.

In an article the development of production costs for bioenergy assortments over time is described (Junginger et.al., 2005). In the early stages of a system production costs are often high but up-scaling and spreading of knowledge makes the production costs decrease. New raw materials for pellet production will probably increase the production costs initially but maybe not in a long-term perspective.

6 Conclusions

New raw materials are already used by some large-scale pellet producers in Sweden. It is mainly the large-scale producers that have started to use new raw materials such as energy wood, wet sawmill chips and dry chips. Around 65% of the respondents of the survey were planning for new raw materials. Energy wood is the raw material most commonly planned for. Most of the pellet producers in the survey were not planning for raw materials that give low quality pellets.

In a long-term perspective, the demand for pellets depends on alternative energy sources, but in a short-term perspective the prices for alternative energy sources are less important, especially for the small-scale market. Some large heat-/CHP plants are relatively fuel-flexible. Here, the price-changes on alternative fuels can affect the demand for pellets more rapidly. The low quality pellets will thereby be more dependent of alternative energy prices.

The minimum price for pellets is in the long run set by the production costs. The raw material costs are the most important part of the production costs and according to results from the survey it also affects the pellet prices most. For pellets made of sawdust the raw material costs were typically 2/3 of the total production costs in 2009. In calculations of production costs, wet sawmill chips resulted in a decreased in cost by 4%, mainly because of less expensive raw material. Energy wood also resulted in decreased production costs by 4% compared to sawdust, assuming that the thermal energy could be covered by internal bark. Both energy wood and wet sawmill chips could hence decrease the production costs and thereby the price for pellets. Even though there is a much greater maximum potential for wet sawmill chips than for sawdust the available raw material will depend on the development in the pulp industry.

7 Future outlooks

Torrefaction is mentioned as a thermal chemical way to improve the combustion properties for biomass. If the method works, many raw materials are possible to use and still give high quality pellets. The development in the area would be interesting to for future outlooks. Small producers' plans for future raw material would also be interesting to survey as well as the development of the small-scale burners.

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Appendix A– Standardization

There are several different standards for densified biomass fuels in the different nations in Europe, there are also a common European standard, CEN 14961, under construction. In Sweden the Swedish standard, SS 18 71 20, are the most used standard for pellets even though many producers plan for using the European standard in the future (Höglund, 2008).

According to the Swedish standard, SS 18 71 20, pellets are divided into different quality-groups. Figure A1 shows the Swedish standard for pellets. There are three groups where group number 1 has the highest quality and group number 3 has the lowest quality (Hirsmark, 2002). The groups are defined depending on the parameters durability, moisture content, ash content, length, ash melting point, density, heating value and share of fine fractions. Which quality-group pellets are classified to depend mostly on the material used, but also on the pelleting process (Näslund, 2003). The first group is supposed to be suitable for small-scale consumers with higher demand for quality while groups 2 and 3, with lower quality, are more suitable for large-scale consumers (Höglund, 2008).

Property	**Test Method**	**Unit**	**Group 1**	**Group 2**	**Group 3**
Dimensions: diameter and length in producer's store	By measuring at least 10 randomly selected fuel pellets	mm	To be stated as max 4 times ∅	To be stated as max 5 times ∅	To be stated as max 5 times ∅
Bulk density	SS 18 71 78	kg/m^3	≥ 600	≥ 500	≥ 500
Durability in producer's store	SS 18 71 80	Weight of fines < 3 mm, %	≤ 0.8	≤ 1.5	> 1.5
Net calorific value (as delivered)	SS-ISO 1928	MJ/kg	≥ 16.9	≥ 16.9	≥ 15.1
		kWh/kg	≥ 4.7	≥ 4.7	≥ 4.2
Ash content	SS 18 71 71	% w/w of DM	≤ 0.7	≤ 1.5	> 1.5
Total moisture content (as delivered)	SS 18 71 70	% w/w	≤ 10	≤ 10	≤ 12
Total sulphur content	SS 18 71 77	% w/w of DM	≤ 0.08	≤ 0.08	To be stated.
Content of additives		% w/w of DM	Content and type to be stated.		
Chlorides	SS 18 71 85	% w/w of DM	≤ 0.03	≤ 0.03	To be stated.
Ash dissolution	SS 18 71 65 / ISO 540	°C	Initial temperature (IT) to be stated.		

Figure A1: Swedish standard for pellets, SS 18 71 20 (SIS, 1998)

The European Union has ambitious goals to increase the use of bioenergy in Europe. Differences in quality on pellets from different producers cause problems with credibility for the industry and are a barrier for international trade. The process with establish a common standard are hopefully going to make it easier for the consumer to know what quality they are buying and thereby increase the use and trade of biomass fuels. The process for establish the standard, CEN/TC 335 for Solid Biomass fuels, started in 2000 are still under process (Belbo, 2006). The standardization process is time consuming, only after discussions with experts from different countries and the Technical Committee approved the standard it is published as a new standard. The standard CEN 14961 define fuel specifications and classes for solid biomass fuels such as pellets (Höglund, 2008).

There is also a process ongoing to establish an international standard for solid biomass fuels. The Swedish Standard Institute, SIS, has the mission to lead the work for making a global standard for biomass fuels (Ny teknik, 2007). It is the international organization, ISO, which is a federation for national standards, which is developing new international standards (Belbo, 2006).

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Appendix B – Chemical raw material contents

Table B1: Typical content for different fuels, modified from Martinsson (2003).

	Net calorific value	Ash content	K	Cl	S	N
	MJ/kg	% of dc (1)	% of dc	% of dc	% of dc	% of dc
Stemwood (2)	18.2	0.3	0.03	<0.01	<0.01	0.08
Bark (3)	19.2	4.5	0.10	0.01	0.03	0.48
Reed canary grass (4)	17.6	5.6	0.27	0.09	0.09	0.88
Salix	19.2	1.6	0.25	0.005	0.04	0.40
Straw	17.3	6.9	0.60	0.90	0.20	0.40
Peat	21.0	4.3	0.04	0.03	0.20	1.80

Note: (1) dc = dry content, (2) Spruce and pine and spruce, (3) Spruce, (4) Harvested at spring

References:

Martinsson Lars, 2003, *Råvaror för framtida tillverkning av bränslepellets i Sverige*, Värmeforsk, Stockholm

Appendix C – Questionnaire

Nya råmaterials påverkan på pelletspriser i Sverige

Sektion 1: Produktion

1.1 Företagsnamn:

Informationen i denna fråga är helt frånkopplad från resten av enkäten. Informationen är endast till för att se vilka som svarat på enkäten.

1.2 Hur stor är er årliga produktion av pellets i Sverige?

Mer än 100 000 ton/år	☐ *2 svarande (12,5%)*
50 000 – 100 000 ton/år	☐ *4 svarande (25%)*
25 000 – 50 000 ton/år	☐ *4 svarande (25%)*
5 000 – 25 000 ton/år	☐ *4 svarande (25%)*
Mindre än 5 000 ton/år	☐ *2 svarande (12,5%)*

Kommentarer:
…………………………………………………………………………………………
…………………………………………………………………………………………
…………

1.3 Vilket/vilka råmaterial använder ni idag till er pelletsproduktion i Sverige?

Ange i ungefärlig del av pelletsproduktionen i %.

Sågspån	……………………
Torrflis	……………………
Grönflis/cellulosaflis	……………………
Kutterspån	……………………
Helträd	……………………
Torv	……………………
Bark	……………………
Salix	……………………
Halm	……………………
Rörflen	……………………
Annat	……………………

Kommentarer:
…………………………………………………………………………………………
…………………………………………………………………………………………
…………

1.4 Vad/vilken är företagets huvudsakliga sysselsättning?
Observera att flera alternativ kan kryssas i.

Pelletsproduktion	☐ *10 svarande (62,5%)*
Sågverk	☐ *4 svarande (25%)*
Snickeri	☐ *0 svarande (0%)*

Värme-/kraftvärmeproduktion ☐ *1 svarande (6,25%)*

Pappers- och massaproduktion ☐ *0 svarande (0%)*

Annat………………………………… *5 svarande (31,3%)*

Kommentarer:
………………………………………………………………………………………
………………………………………………………………………………………
…………

1.5 Planerar ni för att börja använda nya råmaterial till er pelletsproduktion de närmsta åren?

Observera att flera alternativ kan kryssas i.

Nej	☐	*6 svarande (37,5%)*
Ja, sågspån	☐	*3 svarande (18.8%)*
Ja, torrflis	☐	*2 svarande (12,5%)*
Ja, grönflis/cellulosaflis	☐	*5 svarande (31,3%)*
Ja, kutterspån	☐	*1 svarande (6,3%)*
Ja, helträd	☐	*3 svarande (18,8%)*
Ja, torv	☐	*2 svarande (12,5%)*
Ja, bark	☐	*0 svarande (0%)*
Ja, Salix	☐	*0 svarande (0%)*
Ja, halm	☐	*0 svarande (0%)*
Ja, rörflen	☐	*0 svarande (0%)*
Annat	☐	*2 svarande (12,5%)*

Kommentarer:
………………………………………………………………………………………
………………………………………………………………………………………
…………

1.6 Till vilka råmaterial har ni idag utrustning för att pelletera?
Observera att flera alternativ kan kryssas i.

Sågspån	☐	*12 svarande (75%)*
Torrflis	☐	*12 svarande (75%)*
Grönflis/cellulosaflis	☐	*3 svarande (18,8%)*
Kutterspån	☐	*15 svarande (93,6%)*
Helträd	☐	*3 svarande (18,8%)*
Torv	☐	*2 svarande(12,5%)*
Bark	☐	*1 svarande (6,3%)*

Salix ☐ *1 svarande (6,3%)*

Halm ☐ *1 svarande (6,3%)*

Rörflen ☐ *0 svarande (0%)*

Annat ………………… *1 svarande (6,3%)*

Kommentarer:
…………………………………………………………………………………………
…………………………………………………………………………………………
…………

1.7 Varifrån får ni huvudsakligen ert råmaterial?

Egna biprodukter ☐ *6 svarande (37,5%)*

Köper inom koncernen ☐ *2 svarande (12,5%)*

Köper utom koncernen, inom Sverige ☐ *11 svarande (68,9%)*

Importerar ☐ *1 svarande (6.3%)*

Kommentarer:
…………………………………………………………………………………………
…………………………………………………………………………………………
…………

1.8 Upplever ni brist på ert nuvarande råmaterial?
Om ja, kommentera gärna vad ni tror är anledningen till råvarubristen.

Ja ☐ *9 svarande (56,3%)*

Nej ☐ *7 svarande (43,8%)*

Vet ej ☐

Kommentarer:
…………………………………………………………………………………………
…………………………………………………………………………………………
…………

Sektion 2: Försäljning

2.1 Vilka är era köpare av pellets?
Ange del av sålda pellets i % till de olika användargrupperna.

Småskaliga användare, upp till 50 kW (ex. enskilda hushåll, mindre anläggningar) ………………………

Mellanskaliga användare, 50 kW-2MW (ex. värmecentraler, skolor, industrier) ………………………

Storskaliga användare, över 2 MW (ex. värme-/kraftvärmeverk) ………………………

Export ……………………....

Vet ej ☐

Kommentarer:
……………………………………………………………………………………………
……………………………………………………………………………………………
…………

2.2 Från vilken kundgrupp tror ni att efterfrågan kommer öka mest i under de närmaste åren?

Småskaliga användare ☐ *2 svarande (12,5%)*

Mellanskaliga användare ☐ *12 svarande (75%)*

Storskaliga användare ☐ *3 svarande (18,8%)*

Kommentarer:
……………………………………………………………………………………………
……………………………………………………………………………………………
…………

Sektion 3: Prissättning

3.1 Vilken anser ni är den viktigaste faktorn vid prissättning av pellets?

Elpriset ☐ *2 svarande (9%)*

Oljepriset ☐ *2 svarande (9%)*

Kolpriset ☐ *0 svarande (0%)*

Produktionskostnaden ☐ *10 svarande (45%)*

Efterfrågan ☐ *6 svarande (32%)*

Annat **. . . . .** *1 svarande (5%)*

Kommentarer:
……………………………………………………………………………………………
……………………………………………………………………………………………
…………

3.2 Hur tror ni att en ökad användning av nya råmaterial till pelletsproduktion kommer att påverka det generella pelletspriset i Sverige inom de närmsta åren?

Pellets kommer att bli dyrare ☐ *8 svarande*

Pellets kommer att bli billigare ☐ *1 svarande*

Priset kommer vara oförändrat ☐ *5 svarande*

Vet ej ☐ *0 svarande*

Kommentarer:
……………………………………………………………………………………………
……………………………………………………………………………………………
…………

3.3 Vart ni tror en **kostnadsökning** kommer att ske jämfört med att använda traditionella råmaterial som sågspån.

	Dyrare råmaterial	Dyrare utrustning	Mer slitage på utrustning	Mer energi-förbrukning	Dyrare transporter
Flis	☐	☐	☐	☐	☐
Kutterspån	☐	☐	☐	☐	☐
Helträd	☐	☐	☐	☐	☐
Torv	☐	☐	☐	☐	☐
Bark	☐	☐	☐	☐	☐
Salix	☐	☐	☐	☐	☐
Halm	☐	☐	☐	☐	☐
Rörflen	☐	☐	☐	☐	☐

Kommentarer:
……………………………………………………………………………………………
……………………………………………………………………………………………
…………

3.4 Vart ni tror en **kostnadsminskning** kommer att ske jämfört med att använda traditionella råmaterial som sågspån.

	Billigare råmaterial	Billigare utrustning	Mindre slitage på utrustning	Mindre energi-förbrukning	Billigare transporter
Flis	☐	☐	☐	☐	☐
Kutterspån	☐	☐	☐	☐	☐
Helträd	☐	☐	☐	☐	☐
Torv	☐	☐	☐	☐	☐
Bark	☐	☐	☐	☐	☐
Salix	☐	☐	☐	☐	☐
Halm	☐	☐	☐	☐	☐
Rörflen	☐	☐	☐	☐	☐

Kommentarer:
……………………………………………………………………………………………
……………………………………………………………………………………………
…………

Appendix D – Interview guide

Ämne:

Under de senaste åren har efterfrågan på pellets ökat kraftigt och därmed har även efterfrågan på traditionella råmaterial såsom sågspån och flis ökat. Detta har lett till brist på råmaterial i vissa delar av landet. Ett sätt att möta den ökande efterfrågan på pellets är att börja använda nya råmaterial.

Problem:

Hur kommer det generella pelletspriset i Sverige påverkas av att nya råmaterial?

Intervjuguide:

1. Vilka råmaterial använder ni er av idag? (Hur stor del av produktionen står de olika materialen för?)

2. Planerar ni för några nya råmaterial? Vilka råmaterial har ni idag utrustning för att pelletera?

3. Vad krävs det för utrustning för XX material? Något som ni redan har? Kommer det bli en stor kostnad att investera i utrustningen?

4. Vad är det största utmaningen med att använda nya råmaterial?
5. Varifrån köper ni in råmaterial idag?

6. Upplever ni en brist på råmaterial? Om ja, vad tror ni är anledningen till detta?

7. Vilka är era köpare?

8. I vilken grupp köpare tror ni efterfrågan kommer att öka mest de närmsta åren?

9. Hur viktigt är det för er att sälja pellets av bra kvalité?

10. Kan ni tänka er att börja producera pellets av en lägre kvalité? Tror ni att ni kommer att få sålt dem? (till vilka i så fall?)

11. Om man kollar på pelletsanvändares forum på Internet (ex pelletsinfo) är det ganska mycket kritik kring utrustning och kvalité på pellets, det pratas även en del om att övergå till värmepumpar. Är ni rädda för att förlora kunder om ex. pelletspriserna går upp eller kvalitén försämras? Gör ni något för att ”hålla kvar” dessa kunder? För värmeverk är ju även priset på bränsle en viktig fråga, tror ni att ni kommer förlora många kunder om priset höjs?

12. Tror ni att priset på pellets kommer att höjas de närmsta åren? I så fall varför?

13. Vad tror du är den viktigaste faktorn vid prissättning. (el-, kol-, oljepriset, efterfrågan, produktionskostnaden, annat)?

14. Tror ni att det finns en långsiktig möjlighet att pellets blir en enhetlig produkt i den meningen att man inte kommer att kunna konkurrera med kvalitetsargument utan att man som med bensin i princip enbart kollar på priset?

Appendix E - Input for the calculations of the production costs

Table E1: Input for the calculations of the production costs. Input values from Zakrisson (2002). New estimations are made for the values with a footnote.

General conditions	unit	Sawdust	Wet sawmill chips	Energy wood
Price for electricity	€/MWh	67.4[1]	67.4[1]	67.4[1]
Interest rate	% p.a.	5[2]	5[2]	5[2]
Other costs	% p.a.	0.50	0.50	0.50
Equipment avalibility	%	91.00	91.00	91.00
Simultaneity factor (electric installations)	%	85.00	85.00	85.00
Service life construction	years	50.00	50.00	50.00
Service and maintenance costs construction	%	1.00	1.00	1.00
Investment costs data construction	€	870 000.00	870 000.00	870 000.00
Service life office and data processing	years	5.00	5.00	5.00
Service and maintenance costs office and data proc	%	0.50	0.50	0.50
Investments costs data processing	€	100 000.00	100 000.00	100 000.00
Service life market introduction	years	10.00	10.00	10.00
Service life and maintenance costs market introduct	%	3.00	3.00	3.00
Investment costs market introduction	% of Inv.-costs	1.00	1.00	1.00
Raw material data				
Raw material	Decription	Sawdust	Pulp chips	Pulp wood
Water concent	Weight % wb[11]	57.00	54[3]	54[3]
Bulk density	kg TS/m^{3}loose	150.00	159.1[12]	159.1[12]
Raw material price	€/m^{3}loose	10.96[4]	9.85[5]	10.34[6]
Drying data				
Dryer	Type	Rotating drum	Rotating drum	Rotating drum
Specific heat costs (steam)	€/MWh	17.95	17.95	17.95
Profit heat-selling	€/MWh	21.70	21.70	21.70
Required electric power (including feeding)	kW	350.00	350.00	350.00
Heat demand for drying (per tonne vaporised water)	kWh/$t_{evaportaed\ water}$	861.00	861.00	861.00
Recoverable heat	%	50.00	50.00	50.00
Service life	years	10.00	10.00	10.00
Service and maintenance costs	%	2.50	2.50	2.50
Investment costs	€	2 400 000.00	2 400 000.00	2 400 000.00
Grinding and sieving data				
Unit	Type	Hammer mill	Hammer mill	Hammer mill
Required electric power	kW	250.00	250.00	250.00
Service life	years	10.00	10.00	10.00
Service and maintenance costs	%	18.00	18.00	18.00
Investment costs	€	360 000.00	360 000.00	360 000.00
Pellet mill data				
Pellet mill	Type	Ring die	Ring die	Ring die
Required electric power	kW	500.00	500.00	500.00
Steam consumption for conditioning/t pellets	Weight %	2.50	2.50	2.50
Specific heat costs (steam)	€/t	11.00	11.00	11.00
Tools	%			
Costs for bio-additivies	€/$t_{Pellet-FS}$			
Service life	years	10.00	10.00	10.00
Service and maintenance costs	%	13.00	13.00	13.00
Investment costs	€	600 000.00	600 000.00	600 000.00

Cooling data				
Cooler	Type	Counterflow	Counterflow	Counterflow
Required electric power	kW	50.00	50.00	50.00
Service life	years	15.00	15.00	15.00
Service and maintenance costs	%	2.00	2.00	2.00
Investment costs	€	240 000.00	240 000.00	240 000.00
Storage data				
Kind of storage		Warehouse	Warehouse	Warehouse
Service life	years	50.00	50.00	50.00
Service and maintenance costs	%	2.50	2.50	2.50
Investment costs	€	870 000.00	870 000.00	870 000.00
Storage capcity (in % of annual pellet output)	%	36.00	36.00	36.00
Retail price for pellets (exclusive of xx of VAT)	€/t (w.b)	143.50	143.50	143.50
Peripheral equipment data				
Required electric power	kW	100.00	100.00	100.00
Service life	years	20.00	20.00	20.00
Service and maintenance costs	%	1.50	1.50	1.50
Investment costs	€	435 000.00	435 000.00	455 000.00[10]
Pellets data				
Pellet production rate	t (w.b)/h	10.00	10.00	10.00
Water content pellets	wt. % (w.b)	8.00	8.00	8.00
Bulk density pellets	kg (w.b)/m³	350.00	350.00	350.00
Diameter pellets	mm	8.00	8.00	8.00
Kind of shift work				
Shift per day		3.00	3.00	3.00
Working days per week		7.00	7.00	7.00
Personnel data				
Hourly rate	€/h	15.70	15.70	15.70
Persons per shift		2.30	3.3[7]	3.3[7]
Persons for substitutions		0.10	0.10	0.10
Personnel for adminstration and marketing	€/a	110 000.00	110 000.00	110 000.00
Wood chipper[8]				
Wood chipper	Type	CBI Magnum Force	CBI Magnum Force	CBI Magnum Force
Required electric power	kW		800.00	800.00
Service life	years		30.00	30.00
Service and maintenance costs	%		5.80	5.80
Investment costs	€		606 700.00	806 700.00
Drum debarker[9]				
Drum barker	Type			
Required electric power	kW			500.00
Service life	years			30.00
Service and maintenance costs	%			4.50
Investment costs	€			555 800.00

[1]Price for electricity (for the industry): 667 SEK/MWh (Swedish Energy Agency, 2010)
Exchange rate: €/SEK: 9.8954 (Valuta.se, 2010) →Electricity price: 67.4 €/MWh
[2]Interest rate: 5% (Almi, 2010)
[3]Water content: 54% (Ringman, 1995)
[4]Raw material price (sawdust): 167 SEK/MWh (price for by-products the third quarter in 2009), (Swedish Energy Agency, 2009c)
Energy density: 0.65 MWh/m^{3}loose (Wernius, 1995), Exchange rate: €/SEK: 9.8954 (Valuta.se, 2010)
→ (167 SEK/MWh)/(1/0.65)m^{3}loose=108.4SEK/m^{3}loose
→ (108.4 SEK/m^{3}losse)/9.8954=10.96€/m^{3}loose
[5]Raw material price (wet sawmill chips): 323 SEK/ raw tonnes (anonymous industry contact)
Bulk density (raw softwood): 300 kg/m^{3}loose (Ringman, 1995)
325SEK/((1000kg)/(300kg/m^{3}loose)) = 97.5 SEK/m^{3}loose
Exchange rate: EURO/SEK: 9.8954, (Valuta.se, 2010)
→97.5/9.8954=9.85€/m^{3}loose
[6]Raw material price (energy wood): 270 SEK/m^{3}solid excluding bark (Swedish Forest Agency, 2010b)
1 m3 solid excluding bark = 2.64 m^{3}loose, exchange rate: EURO/SEK: 9.8954, (Valuta.se, 2010)

→ (270 SEK/m^3loose)/(2.64) = 102.3 SEK/m3loose
→102.3/9.8954 = 10.34 €/ m^3loose
[7]Personnel data: 1 extra person needed (when wet sawmill chips and energy wood are used as raw material one more person is needed), (Allan Bruks, 2010)
[8]Wood chipper: Type: CBI Magnum Force, electric power required: 800 kW, investment costs: 606 700 €, service life: 30 years, service and maintenance costs: 5.8% (Allan Bruks, 2010). In the calculations it is assumed that chipping is allowed at even at nights.
[9]Drum debarker: Electric power required: 500 kW, investment costs: 555 800 €, service life: 30 years, service and maintenance costs: 4.5% (Allan Bruks, 2010)
[10]Grabber: Investment costs: 20 000 € (the investment cost for a grabber is added to peripheral investment costs)
[11]w.b.=wet base
[12] Bulk density (wet sawmill chips and energy wood wood): 159.1 kg dw/m³loose (dw=dry weight)
Bulk density (raw softwood): 410-450 kg/dw, → mean value: 430 kg/dw →159.1kg/ m^3 loose (Ringman, 1995)

Bark from energy wood

To use energy wood the logs need to be debarked. The bark could be used in the drying process. The amount of bark generated from production of 1 tonne of pellets is calculated below. Moisture content for wood pellets is maximum 10%. One tonne of pellets therefore requires minimum 0.9 tonnes of dry material.

Density, dry matter (energy wood): 350-380 kg/m^3solid (mean value 365 kg/m3solid), (Ringman, 1995).

Amount of dry raw material (bark excluded): 900 kg/(365 kg/m^3solid) = 2.47 m^3solid

Percentage of bark on log (in m^3solid): 9.6% (Björklund, 2004)

Amount of raw material (bark included) = X = 2.47 + X*0.096
→X = 2.47/(1-0.096) = 2.73 m^3solid

Amount of bark (per tonne pellets): 2,73*0.096 = 0.26 m^3solid
Density, dry matter (bark): 320 kg/m^3solid, (Ringman, 1995)
→Amount of bark: 0.26 m^3solid*320 kg/m^3solid = 83.2 kg

Higher heating value (bark): 19.2 MJ/kg dm=5.33 kWh/kg dm, (Svenska Bioenergiinstitutet, 1994)

Energy content in 83.2 kg bark: 83.2kg*5.33 kWh/kg = 444 kWh

The process for pelleting energy wood requires 444 kWh of thermal energy per produced tonne pellets. The amount of available energy from the bark, see the calculations above, show that the bark could contribute to a large part of the need for thermal energy.
The amount of bark and energy generated from production of 1 tonne of pellets is an approximated value. The real value will be in an interval (the values vary for: the moisture content in pellets, percentage of bark on log and dry matter density of the energy wood).

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