Price mechanisms for wood fuels

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Preface

This publication is part of the EUBIONET III Project (Solutions for biomass fuel market barriers and raw material availability - IEE/07/777/SI2.499477, www.eubionet.net) funded by the European Union’s Intelligent Energy Programme. EUBIONET III is coordinated by VTT and other partners are Danish Technological Institute, DTI (Denmark), Energy Centre Bratislava, ECB (Slovakia), Ekodoma (Latvia), Fachagentur Nachwachsende Rohstoffe e.V., FNR (Germany), Swedish University of Agricultural Sciences, SLU (Sweden), Brno University of Technology, UPEI VUT (Czech), Norwegian University of Life Sciences, UMB (Norway), Centre wallon de Recherches agronomiques, CRA-W (Belgium), BLT-HBLuFA Francisco Josephinum, FJ-BLT (Austria), European Biomass Association, AEBIOM (Belgium), Centre for Renewable Energy Sources, CRES (Greece), Utrecht University, UU (Netherlands), University of Florence, UNIFI (Italy), Lithuanian Energy Institute, LEI (Lithuania), Imperial College of Science, Imperial (UK), Centro da Biomassa para a Energia, CBE (Portugal), Energy Restructuring Agency, ApE (Slovenia), Andalusian Energy Agency, AAE (Spain). EUBIONET III project will run 2008 – 2011.

The main objective of the project is to increase the use of biomass based fuels in the EU by finding ways to overcome the market barriers. The purpose is to promote international trade of biomass fuels to help demand and supply meet each other, while at the same time the availability of industrial raw material is to be secured at reasonable price. The EUBIONET III project will in the long run boost sustainable, transparent international biomass fuel trade, secure the most cost efficient and value-adding use of biomass for energy and industry, boost the investments on best practice technologies and new services on biomass heat sector and enhance sustainable and fair international trade of biomass fuels.

This report, which is part of Work Package 3: Price Mechanisms for Wood Fuels of the EUBIONET III project, will focus on the price mechanisms and price formation of wood fuels. The mechanisms behind wood energy price developments and how these developments affect consumers have hitherto been studied to less extent. In this report, different aspects of wood fuel price formation and price mechanisms will be discussed. The tasks included in this report are 3.2 The effect of new raw materials on pellet prices, 3.3 The effect of new sources of supply on wood fuel prices, 3.4 How does international trade affect national wood fuel prices? and 3.5 Case studies from cross border regions.

The work leading to the results presented in this report has been conducted primarily at the Department of Energy & Technology at the Swedish University of Agricultural Sciences (SLU) in Uppsala, Sweden. Two of the tasks, 3.2 and 3.3, have been accomplished mainly through Master’s Theses conducted by fifth-year engineering students at SLU. The other two tasks, 3.4 and 3.5, have been accomplished by research work conducted by SLU employees. A wide range of methodologies have been utilized to accomplish the work. Literature studies, statistics and modeling have been complemented by interviews with more than 40 industrial contacts.

[Olle Olsson, Uppsala, April 2010]

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1 Introduction

With growing demand for renewable energy, European wood energy markets have continuously increased in size from the early 1990’s to the present. In 1990, the share of “Biomass & wastes” in the energy consumption of the EU-27 countries was 2.7%. This share had by 2007 doubled to 5.4% (Eurostat, 2008). Since the lion’s share of the fuels included in the “Biomass & wastes” category consists of wood fuels (AEBIOM, 2009), this means that wood as an energy source is becoming an increasingly more important part of the European energy system.

As the use of wood energy has grown, the structure of wood energy markets has changed. What was once primarily a local or regional fuel – in the sense that production and consumption was geographically proximate – is changing into becoming more and more an internationally traded energy commodity (Junginger et al., 2008).

Despite this growth in both market size and geographical extension, there is in general a lack of knowledge concerning how wood energy markets function. This is especially true for issues regarding wood energy price development and price formation. In this report, several aspects of wood energy price formation and price mechanisms will be highlighted and discussed, with special focus on the effects of new raw materials and international trade in wood fuels. Actual price levels in different European countries will be discussed, but are not the main focus in this report.

This report will present the results from the work in tasks 3.2-3.5 in separate sections, but since the overall theme is wood fuel prices, the report begins with an overview of the available literature. In a similar manner, the report ends with a concluding section wherein the results from the different tasks are discussed in a wider context.
1.1 Wood fuels

Wood fuels, also known as wood based fuels or wood-derived biofuels, designate all types of biofuels originating from woody biomass\(^1\). (CEN, 2004) “Wood fuels” is a quite wide category that covers everything from unrefined fuel types such as firewood or wood chips to refined and rather sophisticated fuel products such as wood pellets. Wood fuels are predominantly used for energy conversion in stationary equipment for the production of space heating, industrial process heat and electricity. With further development of technology for production of liquid fuels from woody biomass, it may be expected that wood fuels - such as e.g. cellulosic ethanol - will widen the utilization of wood fuels to include the transportation sector as well.

![Firewood, hog fuel & wood pellets.](Sources: Picture a) from VTT, picture b) & c) from SLU picture archive).

The conversion of wood fuels to useful energy also occurs in many different forms and in a large variation of scales. Production of heat from wood fuels takes place in a diversity of applications from the combustion of firewood in stoves – e.g. for heating of detached houses – with an output of below 10 kW\(_{th}\), to district heating (DH) and Combined Heat and Power (CHP) plants (e.g. in Finland, Denmark and Sweden) with outputs of several hundred MW. In contrast, electricity is predominantly generated from wood fuels in medium to large scale facilities beginning with small Combined Heat and Power (CHP) plants with outputs of a few MW\(_e\), to power stations with outputs exceeding 1 GW\(_e\) that combust more than 1 million metric tonnes of biomass per annum (Essent, 2009).

1.2 Wood fuels in the European energy system

During recent decades, growing demand for renewable energy has led to a continuous increase of the share of bioenergy in the EU-27 countries. Since 1996, the share of biomass & wastes in European energy consumption has increased from 3.3% to 5.4% (see Figure 2).

\(^1\) Note that focus in this report is on solid wood fuels. This means that there are no discussions on e.g. black liquor – a residue from pulp & paper production – herein.
According to the European Biomass Association (AEBIOM), more than 70% of the bioenergy consumed in Europe has its origins in woody biomass (AEBIOM, 2009) which means that wood fuels are by far the most important biofuel in Europe today. The share of wood fuels in total bioenergy consumption is expected to decrease to below 50% by 2020 as other sources of biomass fuels - such as energy crops, agricultural by-products and municipal waste - are utilized to greater extent. However, according to AEBIOM’s estimates, the use of woody biomass for energy purposes will increase in absolute numbers by more than 30% and will remain the most important biofuel category (ib.).

The share of wood energy in the respective energy mixes of the member states varies greatly. In countries such as the UK, Ireland and Luxembourg, bioenergy and wood fuels has only a miniscule share whereas wood energy is a key part of the energy mixes of Latvia, Finland and Sweden (see Figure 3).
Figure 3. Share of “biomass & wastes” in gross inland energy consumption in the EU-27 + Switzerland, Turkey, Norway, Croatia and Iceland (Eurostat, 2008)
2 Wood fuel prices – a literature survey

Wood energy markets are inherently complex phenomena and hence wood energy prices are a function of many different variables. In a report written for the Danish Energy Agency, Boldt (2009) lists thirteen different factors that may affect bioenergy prices. Since wood energy is a sub-category of bioenergy, it is natural that many of these factors are valid for wood energy price formation as well. Some of the points listed by Boldt overlap each other and some are only valid for agricultural biomass fuels, but this is a telling example of the intricacy of the subject at hand. In this section, previous research into the field of wood energy price formation will be reviewed in order to provide a context for later chapters, in which different factors affecting wood fuel prices are analyzed in greater detail.

It is important to note that policy measures of different kinds are perhaps the important price driver for wood fuels, as well as most other forms of renewable energy. The direct effect of policy measures on the development of wood fuel prices will however not be discussed in detail in this report. The connection between different policy measures and their effect on demand for renewable energy is a very complex topic and the space permitted herein does not allow for a thorough review of the subject. Examples of sources that discuss the effectiveness of policy measures in driving bioenergy demand in particular are (Hillring, 1998; Gielen et al., 2003; Ericsson et al., 2004a; Helynen, 2004; Nilsson et al., 2004; Björheden, 2006; Thornley and Cooper, 2008).

2.1 Wood fuel production costs and price formation

Although “[p]roduction costs and [wood fuel] prices should not be confused” (Hakkila, 2004, p.51) the cost of producing wood fuel is an important factor deciding the price at which the fuel will be sold. Traditionally, production of wood fuels has been very labour-intensive. This means that the price of wood energy primarily depended on the price of labour. Hence, during time periods of rapid wage increases, wood fuel production costs and in turn wood fuel prices have increased. This is a major reason why wood fuels decreased in relative importance during the 20th century compared to e.g. oil and natural gas (Schön, 1992; Hakkila et al., 2000).

Following the increasingly “commercial” use of wood energy in the last 30 years – since the oil crises of the 1970’s, which in many ways proved to be the starting point for the renewed interest in wood energy – systems for wood fuel procurement have become mechanized to a continuously greater degree. An early study of price formation of wood fuels in a commercial context – in this case the Swedish market for wood fuels for consumption in the district heating sector – was conducted by Hedman (1992). The study concluded that for wood chips from cutting residues (e.g wood chips from tops and branches and low-quality stemwood), the price was set by the cost of production, whereas for sawmill residues, the price was more dependent on what competing users, e.g. the particle board industry, were capable of paying. As for refined fuels, such as wood pellets and briquettes, the conclusion from the study was that the price was mainly set by costs of production, although the price of heating oil would serve as a ceiling for how far the price of refined fuels could go.

In a paper by Radetzki (1997), the author concludes that low-cost biomass resources might be competitive with fossil fuels. However, as more biomass is demanded, increasing marginal costs will render biomass uncompetitive with fossil fuels as the latter – according to the author – are “flat-priced”. The production costs and the supply curve for Swedish wood fuels was further discussed in three papers by Hillring (1997, 1999a, 1999b). These studies clearly concur with the view of production costs as the major component in determining the price of wood energy, but Hillring concludes that despite large increases in wood fuel demand the price of wood fuels in Sweden was rather stable.
all through the 1990’s. In effect, this means that the supply curve for wood fuels was in fact more or less flat during this time period (see also Lundmark & Söderholm (2004) and Lönner et al (1998)). This development was possible due to good supply of residues from the forest industry that was able to balance the increasing demand. A similar development was seen in Finland where wood chip prices decreased during the 1990’s due to increased utilization of logging residues (Hakkila 2004).

Hillring does however conclude that the “theoretical basis of these studies is the assumption that there is a connection between wood-fuel prices and the prices of fossil fuels” (Hillring, 1997 p.42) and sums up the possible future development of wood fuel prices as three different scenarios:

- Prices of biofuels\(^2\) will be connected to the prices of alternative energy sources such as fossil fuels.
- Fossil fuel prices will become so high due to heavy environmental taxation that relevant competition will only take place within the biofuel category.
- Prices of biofuels will become higher as increasing demand will lead to utilization of more “difficult” resources (i.e. increasing marginal cost) (Hillring, 1997)

2.2 The relationship between wood fuel prices and fossil fuel prices

Since the world still gets 80% of its energy supply from fossil fuels, changes in the prices of coal, gas and especially oil affect all sectors in society. The wood energy market is no exception. However, changes in the price of oil have impacts on wood fuel prices on several levels. First, since petroleum products such as diesel and petrol are used in the process of producing wood fuels, increases in oil prices will push production costs upwards. However, these costs are in general very small (Boldt (2009) and do not have a significant impact on the development of wood fuels. If the supply chain involves long-range transport, the impact from oil price fluctuations can be much greater, which is further discussed in section 4.2 on price effects from international trade.

Another connection between the price of oil and the price of wood fuels lies in the substitutability between the types of fuel. But whereas it is fairly obvious that there is a long-term relation between wood energy prices and e.g. the price of oil – in that higher oil prices increase the demand for alternatives such as wood energy which in turn will increase wood fuel prices (Hillring, 1997; Toivonen et al., 2008; Trømborg and Solberg, 2010) – the short-term relationship is less clear. Hedenus et al. (2009) analyze price formation of solid biofuels with focus on comparing the effect of oil price volatility on residential wood pellet prices and bioethanol prices, respectively. The study finds that there “…is no statistically significant relation between the pellet prices and the oil prices, even though there is some co-movement in 2006 and 2007.” (Hedenus et al., 2009 p.5).

Kranzl et.al (2009) also touch upon the relationship between the price of oil and the price of bioenergy\(^3\). The authors find that there is some correlation between bioenergy price development and oil price volatility, although the level of interconnection varies between biofuel assortments. This is manifested both in e.g. higher bioenergy prices due

\(^2\) Of which wood-fuels is a sub-category.

\(^3\) It should however be mentioned that the study analyzes a wide variety of biomass fuels from transportation fuels of agricultural origin to wood fuels used for heating.
to increased production costs resulting from the fact that fossil fuels are utilized in the production process, but also as an effect of the coupling of energy markets (e.g. between oil and bioenergy).

Boldt (2009) discusses the connection between the price of wood chips and wood pellets to oil prices, based on empirical studies of the Danish bioenergy market. Whereas the price of straw as fuel is in part indexed to the price of oil and gas in contracts between Danish energy companies and straw suppliers, there seems to be no such indexing between the price of wood fuels and fossil fuel prices. However, the price of wood fuel still tends to be connected to oil prices, albeit with a lag of 1-2 years.

2.3 Price effects connected to the development in the forest industry sector

The wood fuel market is in intrinsically connected with the other sectors in the forest industry (see Figure 4). For example, the sawmill industry is not only a producer of sawn timber but also of by-products such as sawdust, bark and wood chips. These by-products are then in turn used as raw material in other parts of the industrial complex. For example, wood chips from sawmills are used in the pulp and paper industry and sawdust can be used to produce particle boards. Another example is how recovered (post-consumer) wood is utilized both as wood energy and as raw material for the production of particle boards (see e.g. Hillring et al. (2007)). This has as a consequence that market developments in other parts of the forest industry complex affect the wood fuel market to various extents. As wood fuel markets grow and increase in relative importance, these mechanisms will work in the opposite direction as well.

![Figure 4. Supply flows in the forest industry complex (Modified from Hälgren(2004)](image)

This interconnection has shown to manifest itself in many different ways. To begin with, much of wood fuel supply has hitherto consisted of different assortments of by-products from the other parts of the forest industry. For example, only a fraction of a tree that has been cut ends up in the final product. During various stages of the production chain,
assortments such as tops and branches, bark and sawdust become available for use as raw materials for wood energy. The availability of this inexpensive raw material has been an important factor contributing to the success of wood energy in e.g. Sweden and Finland (see e.g. Björheden (2006) and Hakkila (2006). However, this also means that wood fuel market development is vulnerable to events and developments especially in the sawmilling sector. Examples of this could be seen following the economic downturn in 2008-2009 when the sawmilling industry suffered from reduced demand of sawn timber and hence cut down production, leading to a substantial reduction in the availability of sawmill by-products and, in the end, increased wood fuel prices (see e.g. Hartkamp et al (2009).

Another example of how a disturbance to normal operations procedures in the forest industry can affect wood fuel prices can be seen in a more dramatic event that took place in Northern Europe in early 2005: the hurricane which in Sweden became known as “Gudrun”. In Sweden, the result of the hurricane was that trees corresponding to the amount normally felled in a whole year in the entire country were cut by the violent winds. During normal fellings, residues from the procedure – e.g. in the form of tops and branches - are taken care of, but in the haste that was needed in order to process as much of the timber as possible before it was damaged, there was no time to collect the residues. It was expected that this could lead to a lack of wood fuels in Southern Sweden, and hence increased prices. However, as it turned out, the storm felling of the trees meant that many trees were damaged to the point where they could be used neither as saw timber nor as pulp wood, but only as wood fuel. This meant that the lack of logging residues was to a large degree offset by the unusually large amounts of wood fuel from low-quality stemwood (Olsson, 2006; Björheden, 2007). Whether the developments following the “Gudrun” hurricane are specific to Swedish circumstances or not is unclear. In early 2009, French forests suffered heavy damage from the storm “Klaus”, but as far as the authors of this report know, no studies of the effects of the storm on the French wood energy market have been published. It has been reported that wood damaged by “Klaus” has been exported from France for use in Swedish district heating plants (Söderenergi, 2009), but no detailed analysis of the development at large is available.

Apart from being connected to the forest industry in terms of its by-products being a source of fuel, the wood fuel sector and the other parts of the forest industry have another relationship: that of being competitors for the same raw material (Lundmark & Söderholm (2004).
Figure 5. Competition for raw materials in the forest industry complex (Modified from Hällgren 2004)

Figure 5 highlights some of the new raw material flows that have developed as a result of increasing energy sector demand for wood. A common factor of all these flows is that the increased demand from the energy sector has affected the other parts of the forest industry in one way or another. Consequently, wood energy prices can influence, and in turn be influenced by, the price of wood as an industrial raw material. A problematic consequence of this is that an “...increase in the demand for wood would probably bring upward pressure on prices of industrial wood. This could reduce the competitiveness of the traditional forest industry in Europe, reduce forest industry production and lead to job losses.”(Toivonen et al., 2008 p.44). Hence, there has been a number of studies on the effects of the interaction between markets for wood fuels and industrial roundwood.

Lundmark (2006) estimated supply curves for logging residues and roundwood in Sweden. The conclusion from this study is that the supply curve for logging residues (in the form of forest chips) is much steeper than the supply curve for roundwood and as a consequence, after an additional 12 TWh of logging residues have been utilized, it is more economically rational to turn to roundwood instead. As for the sensitivity of the consumers of wood energy to fluctuations in prices, Lundmark (2009) finds that energy sector demand for biomass is relatively insensitive to price increases compared. Energy sector demand for fossil fuels is more sensitive to price increases, as is the demand for biomass from the forest industry sector. Tromborg & Solberg (2010) analyze the effect of increased energy prices on the forest industry in Norway and find that the most sensitive sectors to increased use of wood energy are the particleboard and chemical pulp industry. The sawmill industry is likely to gain from increased demand for low-grade wood since it is a large supplier of by-products.
2.4 Wood fuel prices and international trade in wood fuels

There is now a rather large international trade in wood fuels both within Europe and between continents (see e.g. Junginger et.al. (2008). The wood fuel which is primarily traded internationally is wood pellets. It has been estimated (Junginger, 2009) that up to 50% of global wood pellet production is traded internationally, a share which can be compared to e.g. 16% for coal, 29% for natural gas and 67% for oil (BP, 2009).

Generally, as trade between countries increase, different national markets become integrated to a larger and larger degree. This means that the consequences of events affecting supply or demand in a specific national market need no longer be limited to the country wherein the specific events took place. The increasing coupling between national markets can be seen in how the prices of a specific commodity develop in the different countries. According to economic theory, if two national markets are integrated by trade, prices in the two countries will have a tendency to converge to a common level, and not differ by more than the cost of transporting the commodity between the two countries. This is in economics referred to as the Law of One Price (see e.g. Krugman & Obstfeld (2008). An example of this is the market for oil, which is a globally traded commodity and for which the entire world constitutes a common market (Kim et al. (2007). This condition manifests itself in how the price of oil in different parts of the world moves almost consistently in unison over time, as can be seen in Figure 6.

![Figure 6. Nominal prices in US$/bbl, 1980-2009, for North Sea (Brent), US (WTI) and Middle-Eastern (Dubai) varieties of crude oil. (IMF, 2009)](image)

Although the prices may not follow each other exactly consistently, market forces will make sure that they can never decouple and move entirely independently. In econometrics and time series analysis, series that are related in this manner are said to be cointegrated. The reason for the behavior in the price series is that if, for some
reason, a price difference should appear, traders will eventually realize this and make use of the spread to make a risk-free profit which eventually will close the price gap. This latter phenomenon is usually referred to as arbitrage\(^4\).

As trade in wood fuels grows and wood fuel markets become increasingly international in nature, it can be expected that wood fuel prices in different countries will, in a similar manner, tend to converge to a common level over time. This is a prospect that has been discussed in relation to European wood pellet markets – which might not be surprising since wood pellets are the most traded wood fuel – in a report from the *Pellets for Europe* project (Dahl, 2005). The authors state that although there are obstacles to the development of the European wood pellet market in the form of e.g. differences in national taxes and wood pellet standards, “...as the international market and trade of pellets grows and international information becomes more available [...] these differences are expected to diminish and slowly a "European price" [...] will form” (Dahl, 2005 p.12). Trømborg & Solberg (2010) also briefly discuss the potential effects on Norwegian wood energy prices of increased international bioenergy trade, stating that “Import of biomass represents an opportunity for bioenergy producers in Norway, but international competition for biomass can also increase biomass prices in Norway” (Trømborg and Solberg, 2010 p.45). However, there are also studies that argue that wood energy markets are likely to remain regional. One of the conclusions that Toivonen et al. (2008) draw about the future development of wood energy markets in Finland is that “...Demand and supply will develop differently in different regions and result in regional markets with regional prices unless storage and transportation technology of wood-based fuels will develop”(Toivonen et al., 2008 p. 41).

\(^4\) Defined at www.financialdictionary.net as “the buying of one item and the selling of the same item for a higher price, therefore making a profit on the difference”.
3 The effect of new raw materials on wood pellet prices\textsuperscript{5}

3.1 Introduction

As was discussed in section 2.1, production costs have hitherto been perhaps the most important factor determining wood fuel prices\textsuperscript{6}. For wood pellets, the costs of raw material – hitherto primarily byproducts from sawmills - have in turn dominated production costs. In a study from 2002 that compared wood pellet production costs in Sweden and Austria, it was found that raw material costs made up 36\% of the wood pellet production costs in Austria and more than 50\% of the production costs in Sweden (Zakrisson (2002)). This can be compared to the figures given by Witt & Kaltschmitt (2007), who estimate the raw material share of production costs to be 30-45\%, with staff costs (1/6) and milling, drying, storage and pelleting (30-50\%) making up the remainder. In Figure 7, the different components of the 2002 Swedish wood pellet production cost are shown.

\textit{Figure 7. Swedish wood pellet production costs in 2002. Modified from Zakrisson (2002).}

\textsuperscript{5} The results presented in this chapter are based on the study written by Porsö (2010).

\textsuperscript{6} However, it must also be emphasized that the connection between the price of sawmill by-products and the price of wood pellets works in both directions. On the one hand, the lack of sawmill by-products may lead to increased pellet prices, but increased demand for wood pellets has also helped push the price of sawdust and other sawmill by-products upwards\textsuperscript{6}. (Swedish Energy Agency, 2003; Fritsche et al., 2009) This can be compared to the relationship between petroleum products and crude oil (See e.g. Asche et al (2003)).
However, the amount of by-products from sawmills is limited by the production of primary sawmill products. According to Peksa-Blanchard et al (2007), the amount of wood pellets that can be produced from currently available sawdust is around 13 million metric tons. As wood pellet production already in 2008 was estimated to be above 10 million tons (see e.g. Wood Resources International (2009) and market growth is expected to continue, it is clear that new raw materials will have to be introduced.

Furthermore, the reliance of the wood pellet industry on sawmills as suppliers of raw material means that the wood pellet industry becomes vulnerable to sawmill business cycles. This dependence became clear following the downturn of the global economy that began with the financial crisis of 2008. Whereas prices of oil, coal and natural gas dropped precipitously due to decreased energy demand, prices for wood pellets actually increased. The reason is that the sawmill industry is highly cyclical and was strongly affected by the economic slowdown (see Figure 8).

As smaller amounts of sawnwood were produced, this also meant smaller amounts of by-products (Millman, 2008), which in turn meant a lack of raw material for wood pellets. This pushed prices upwards (see Figure 9 for the price development in Sweden) and actually forced some producers to stop production altogether or lay off workers. Such developments were seen in North America as early as in February 2008 (Paul, 2008) and in Europe about one year later (Andersson, 2009).
Figure 9. Price development of sawmill by-products in Sweden in SEK/MWh 2000-2009 (Swedish Energy Agency, 2009)

As these examples show, there are several reasons for why the raw materials base for wood pellets can be expected to widen in coming years. In this chapter, the effects that this might have on wood pellet prices are analyzed.

3.2 Traditional and new raw materials: overview

As the focus of this chapter is on new raw materials, it is important to examine the kinds of raw materials currently used in wood pellet production in Sweden. As can be seen in Figure 10, sawdust and shavings were the dominating raw materials for Swedish wood pellets in 2008, with 90% of Swedish firms using sawdust or shavings.
A common theme for the raw materials used in Swedish wood pellet production is that they consist of stemwood from Norway Spruce or Scots Pine. Pellets made from stemwood have several advantages, among the most important of which are low ash content and a high ash melting temperature. These characteristics are especially important for small-scale residential customers with high quality demands (see e.g. Näslund (2003)).

Although there are other industries competing with the wood pellet producers over available sawdust – primarily the particle board industry – the energy sector has in recent years become the dominant consumer of sawdust as can be seen in Figure 10.
As for new raw materials for pellet production, many different kinds of biomass – including non-woody biomass – have been suggested. In Table 1 is an overview of the characteristics of both traditional (i.e. sawdust and shavings) and new raw materials.

*Figure 11. Consumption of sawdust and shavings in Sweden 1999-2008 (SDC, 2009)*
Table 1. Characteristics of traditional and new raw materials for Swedish pellet production. The numbers within brackets (Note: the SS 187120 standard will be replaced by EN 14961-1 in June 2010)

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

3.3.1 Methodological notes

In order to get a complete picture of the kinds of new raw materials that may be introduced in pellet production and how the use of new raw materials will affect production costs and prices, an empirical survey among pellet industry representatives was conducted. The survey was divided into two parts:

- The first step was a questionnaire that was distributed to all Swedish pellet producers with an annual production above 5000 tons. This covered 36 production facilities with a combined production equal to 98% of the 2008 pellet production in Sweden. The response frequency was 62%.

- In order to deepen the analysis and acquire more qualitative information, the questionnaire was complemented by 16 interviews with pellet producer representatives.

It is important to note that the questionnaire was predominantly answered in September 2009 and that the interviews were conducted in November and December the same year. This could explain some of the conflicting results between the two.

3.3.2 General views on the market situation

- The quality is of great importance for the consumers, especially small-scale consumers.
- Most of the producers believe that there is a market for “low quality” pellets (i.e. pellets of a standard unsuitable for residential consumers) but are not planning to produce low quality pellets.
- Only one producer are planning to produce low quality pellets.

For small-scale and some medium-scale consumers, quality is of great importance and these groups are the most important customers for many of the pellet producers. Only one of the interviewed producers was planning to produce low quality pellets. However, many of the interviewed producers mention that there is an international market for low quality pellets, but the high production costs in Sweden make it difficult for the Swedish pellet producers to compete with other countries. Furthermore, the producers also argue that high quality pellets give higher incomes.

3.3.3 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 roundwood, dry chips and pulp chips.

- 56% of the respondents of the questionnaire and 24% of the interviewed producers experienced a shortage of raw material.
- 65-70% of the respondents of the survey were planning for new raw materials.
  ○ The most popular new raw material was “energy wood”, i.e. roundwood used for energy purposes.
  ○ Sawdust, shavings, peat, pulp chips and agriculture residues were also raw materials planned for.
  ○ Whereas 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 roundwood and pulp chips.
- The cost of raw materials was estimated by the producers to be approximately 70-75% of total production costs.
New raw materials such as roundwood and pulp chips are already used by the large pellet producers. One explanation for this could be that the large producers have greater economic possibilities to invest in new equipment, e.g. a wood chipper and a debarking machine for round wood. However, the medium producers are planning for new raw materials to a larger extent than the large producers.

The results from the questionnaire show a more significant shortage of raw materials than the results from the interviews. It should however be noted that the survey did not show any clear connection between a shortage of raw materials and planning for new raw materials. An important result is that almost all contacted producers strictly plan for new raw materials based on stemwood.

Despite the focus of the contacted producers on stemwood-based raw materials, an increased international demand could quickly alter the situation. Many of the producers have investigated the possibilities for using for example Salix, reed canary grass, agriculture residues etc. and if it is profitable to sell pellets made of these materials they will probably start using them. One scenario that is presented is an increased demand for pellets in North America or Asia which could reduce the US/Canadian export of wood pellets to Europe, thereby giving Swedish pellet producers greater possibilities to export to large CHP plants in Europe.

3.4 Conclusions and discussion

3.4.1 Stemwood only?

It is evident that if pellet market growth in the near future continues at the same pace as in recent years, the raw material base has to be expanded beyond sawdust and shavings, which the industry has been built up around. This is bound to be a ground-breaking change in the development of the pellet market, and one that is also likely to further divide the pellet market into more distinctively defined submarkets. In this context, it certainly seems as if Swedish pellet producers are increasingly shifting their focus away from producing vast amount of pellets for large-scale consumption to concentrate on small-scale customers for whom high and reliable pellet quality is vital. This must be kept in mind when discussing the Swedish pellet producers' preference for stemwood-based biomass. Although there are plenty of other possible raw materials (see Table 1), the materials not consisting of stemwood all have characteristics which may cause (particularly ash-related) problems when combusted in small-scale equipment. It should of course be noted that there are other non-stemwood raw materials that seem to have quality characteristics equal or superior to stemwood (for an overview, see e.g. Ståhl (2008)), although most of these are still far from being practically and economically competitive.

3.4.2 Price effects from new raw materials

As was discussed above, Swedish pellet producers seem predominantly focused on stemwood-based biomass when it comes to expansion of the raw material base. Seeing that production costs historically have been instrumental for pellet price development, it can naturally be expected that introduction of new raw materials will affect pellet prices. As for the exact nature of how prices will be affected, this is a question not easily answered. From calculations taking into account February 2010 price levels, using pulp wood as raw material instead of sawdust increases production costs by 2.4%, whereas
the use of pulp chips actually decreases pellet production costs by 4\%\textsuperscript{7}. This means that it is not certain that the introduction of new raw materials will cause an upward shift of wood pellet prices. Furthermore, as systems for utilizing these new raw materials to a larger extent are developed, production costs are likely to decrease even more in a development similar to what has been previously studied by e.g. Junginger et al (2005). All in all, this means that the growth of the wood pellet market need not end due to a lack of sawmill residues, but it is likely that the use of e.g. roundwood and pulp chips in wood pellet production will change both the pellet industry itself as well as affect related sectors in the forest industry complex.

\textsuperscript{7} For details of these calculations, see Porsö (2010)
4 Price effects from international trade

From here on, the focus of this report will be on the effects of international trade on wood fuel price development. This chapter (4) will present results from statistical and econometric analyses of two different European submarkets for wood fuels\(^8\), whereas the following two chapters are based more on qualitative studies.

The studies presented in this chapter combined the concepts related to the Law of One Price (see section 2.4) with applications of econometric methods – in particular cointegration (Engle and Granger, 1987) – to analyze price data from European countries. Thereby, conclusions could be drawn about the interaction between increased international wood fuel trade and price development in national EU markets.

4.1 European residential wood pellet trade and price development

The first study\(^9\) presented herein puts focus on the residential market for wood pellets in Austria, Germany and Sweden. All three countries are among the most advanced in Europe in terms of wood pellet market development. Furthermore, Austria and Sweden have been two of the pioneering countries in terms of wood pellet use in Europe, whereas Germany has been the strongest growing wood pellet market in Europe in the later 2000’s. In the study, price series of wood pellets for residential consumption in the three countries were used. The German and Austrian prices represent a national average of prices, whereas the collection of the Swedish prices were conducted according to region, and hence there is one price series for North Sweden, one for Central Sweden and one for South Sweden. However, the Swedish price series were also compiled into a (non-weighted) average. All six price series may be seen in Figure 12.

\(^8\) For a more extensive presentation of the results from the studies presented in chapter 4, see Olsson (2009)

In comparison with the graph on oil prices in Figure 6, it is difficult to draw any clear conclusions on the level of market integration purely from a casual visual inspection, although it may be noted that the German and Austrian price series exhibit a largely similar behavior. However, “...cointegration may or may not exist between variables that do or do not ‘look cointegrated’, and the only way to find out is through a careful statistical analysis, rather than rely on visual inspection” (Hendry and Juselius, 2001 p.76). Hence, the series were tested for cointegration by using the test developed by Engle & Granger (1987). The results from the tests show that the Austrian and German price series indeed are cointegrated, but that none of the Swedish price series are cointegrated with either the Austrian or the German series. However, there are signs of cointegration between the different regional Swedish series but the results from these tests are ambiguous which indicates that Sweden itself does not constitute an integrated market for wood pellets.

The conclusion from this study is that Austria and Germany constitute a common market for residential market wood pellets whereas Sweden is not part of this market. The most probable reason for this separation between the wood pellet prices in Austria and Germany on the one hand and Sweden on the other is a lack of trade in residential market wood pellets between Sweden and the continent. However, since there has been little or no coherent statistics available on the level of trade in wood pellets during the time period of study, no certain conclusions can be drawn. Unofficial trade statistics (see e.g. Peksa-Blanchard et al. (2007)) report significant amounts of trade in wood pellets between Austria and Germany, but not between Sweden and the two continental countries.

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Figure 12. Residential wood pellet market price development in Austria, Germany and Sweden, January 2004-June 2008. (ÄFAB, 2009; Propellets, 2009; Rakos, 2007; DEPV, 2009)

10 Compiled by Olsson (2009)
Another interesting aspect can be added by utilizing the recent improvements in wood fuel statistics. Since January 2009, the introduction of a customs code for wood pellets\(^{11}\) has enabled collection of international wood pellet trade statistics by Eurostat. According to the import trade figures covering January-October 2009, the Austria-Germany trade in wood pellets was about three times larger than the trade in wood pellets between Sweden and the other two countries. Furthermore, it has been reported (Hiegl and Janssen, 2009) that the majority of the Swedish import from Germany is made up of “industrial” wood pellets, i.e. for use in large-scale production of heat and/or electricity. On the other hand, the trade between Austria and Germany seems to be primarily in residential wood pellets (Steiner and Pichler, 2009). All in all, it seems plausible that the discrepancy in residential market wood pellet price development between Sweden on the one hand and Austria and Germany on the other hand is indeed a result of the lack of trade in this wood pellet assortment between Sweden and the two continental countries. Hence, the question of the lack of market integration boils down to the reasons for the lack of and barriers to bioenergy and wood fuel trade between specific countries. This issue will not be discussed here since it is the main theme of another EUBIONET III work package, i.e. WP2: Solutions to overcome biomass trade barriers (Junginger et al., 2010).

### 4.2 European large scale wood fuel trade and price development

The second study\(^{12}\) shifts focus from the residential market for refined wood-fuels to the large scale market for unrefined wood-fuels. The Baltic Sea area has for some time in many ways been a leading region in wood fuel market development. Countries lining the Baltic Sea together make up 48% of the total use of biomass energy in the EU-27. Furthermore, if the EU countries are listed and ranked according to the share of biomass in the energy mix, six out of the top ten are countries that have a Baltic Sea coast. Furthermore, trade in wood fuels has taken place in the Baltic Sea since the 1990’s, with large amounts of wood chips and wood pellets flowing to Denmark, the Netherlands and Sweden from the Baltic States and – in more recent years – Russia. (Hillring and Vinterbäck, 2000; Ericsson and Nilsson, 2004; Olsson, 2006; Arets et al., 2009)

The rationale behind this trade pattern shows that trade in wood fuels is not merely a matter of countries without domestic wood fuel resources buying from countries with excess supply, but rather that there are more complicated mechanisms behind at work. The Swedish import from the Baltic States had more to do with the availability of low-cost fuel in Estonia, Latvia and Lithuania (Hillring, 1999) and the possibility of inexpensive transport by ship across the Baltic Sea, than with a per se lack of domestic supply in Sweden.

Similar techniques are utilized when analyzing the integration of the wood-fuel markets in Estonia, Finland and Sweden, as in the study of the Austrian/German/Swedish wood pellet market discussed in section 4.1. The general hypothesis is again based on the theory of how increasing international trade between countries will have a tendency to reduce the price differences between the trading countries, eventually leading to a situation where the prices only differ by the cost of transportation. Consequently, the data material here as well mainly consists of price series of wood fuels in the respective

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\(^{11}\) 44013020 “Sawdust and wood waste and scrap, agglomerated in pellets”

\(^{12}\) Olsson O., Hillring B., Vinterbäck J., Wood fuel market integration and price convergence in the Baltic Sea area, 2009
countries. Quarterly prices from three different sources were used and harmonized according to fuel type, taxes and exchange rates in order to produce comparable data. The resulting price series can be seen in Figure 13.

![Figure 13. Wood fuel price development in Estonia, Finland and Sweden 1998-2009](image)

Figure 13. Wood fuel price development in Estonia, Finland and Sweden 1998-2009 (Metla, 2009; Swedish Energy Agency, 2009; Statistics Finland, 2009)

Again, similarly to the price series of residential wood pellets in Figure 12, it is difficult to see any clear tendency of interrelation between the prices merely from visual inspection. Hence, econometric tests are utilized here as well. The conclusion from the tests is that there is no cointegration between any of the price series and that the markets are in this respect separated along national borders.

However, in this study two additional aspects were introduced compared to the first study, namely long-run price convergence and non-constant transport costs. Long-run price convergence is a concept that is related to the propensity of prices in integrated markets to adjust towards one another and never drift away from each other indefinitely. This phenomenon, while commonly referred to as cointegration, is sometimes also called “short-run price convergence”. However, before markets are completely integrated and trade and arbitrage forces prices to continuously correct to each other, a period of slowly diminishing price differences usually occurs. The concept known as “long-run price convergence” is used to describe this development towards market integration (Gluschenko, 2005). There are several ways to quantify long-term price convergence, but the method chosen by Olsson (2009) is to study the development of the coefficient of variation – i.e. the standard deviation divided by the mean - of the three price series.
over time.\textsuperscript{13} The development of the coefficient of variation of the wood-fuel prices in Estonia, Finland and Sweden from 1999 to 2007 can be seen in Figure 14.

As can be seen, the development of the coefficient of variation seems to exhibit a downward trend over time – even when inflation is accounted for – which means that the difference between the wood-fuel prices has decreased over the time period in question, i.e. there has been a certain amount of long-run price convergence.

As has been mentioned, the law of one price indicates that prices in integrated markets should not differ by more than the cost of transporting the commodity in question between the markets. In studies of market integration and price convergence such as these discussed herein, it is common to assume that the cost of transportation is constant over time. The main reason for this is that it is generally very difficult to acquire actual transport costs. However, assuming transport costs to be constant is problematic given the large volatility of oil prices as well as the cost of ocean freight in the first decade of the 21\textsuperscript{st} century (see Figure 15).

\textsuperscript{13} A coefficient of variation of zero would indicate that all prices were the same.

\textsuperscript{14} “CV” indicates the development of coefficient of variation of the nominal prices and “CV real” indicates the development of the coefficient of variation when inflation is adjusted for.
For this reason, the analysis of the interconnection between the Estonian, Finnish and Swedish wood-fuel markets was extended to include estimations of transport costs between the three countries. By using an index of freight rates of short sea shipping\textsuperscript{15} - which is the ship type most commonly used in wood-fuel trade in the Baltic Sea – in combination with the development in fuel costs and information on actual per-ton freight costs for wood fuel that was acquired from an industry source, it was possible to obtain an estimation of the development of transport costs over the period in question. The development of the prices between the different countries can be seen in Figures 16-18.

\textsuperscript{15} i.e. a ship size of 3000-5000 dwt.
Figure 16. Wood fuel prices in Sweden and Estonia, including estimations of transport costs.

Figure 17. Development in Swedish and Finnish wood fuel prices, including estimations of transport costs.
However, even when these estimated transport costs are included, there are no signs of cointegration between the price series, indicating that there is no interconnection between prices and hence that the three national markets are not integrated.
The next issue to investigate is how the trade patterns have evolved during the time period in question. Figure 19 presents the net trade flows between the three countries in question from 1996 to 2008.

![Figure 19. Net trade in metric tons of 4401"Fuel wood, in logs, in billets, in twigs, in faggots or in similar forms" between Estonia, Finland and Sweden, 1996-2008. (UN Comtrade, 2009)](image)

As was discussed previously, it is difficult to track wood fuel trade flows from official statistics (see e.g. Alakangas et al. (2007)). The main reason for this is that unrefined wood fuels in the form of roundwood and wood chips are used not only for energy purposes but as raw materials in the production of fibreboard and pulp and paper as well. This means that it is very difficult to discern from official trade flow statistics from e.g. Eurostat whether the traded amounts of these assortments are in the end used for energy purposes or not. The only available data on trade of unrefined wood fuels strictly for energy use are found in different forms of project reports, e.g. in the studies presented by Alakangas et al (2007) and Olsson (2006). In the latter study, the author presents results from a questionnaire conducted with Swedish district heating and combined heat and power companies on the amounts of different assortments of wood fuel imported from different countries. According to this study, about 100 GWh of unrefined wood-fuels were imported from Estonia in 2003. This can be compared to 300 000 metric tonnes reported by the official trade statistics, which seems to be an overstatement\(^\text{16}\) of the amount of chips and fuelwood traded for energy purposes. Hence, although it might seem plausible that the combination of increased prices in Estonia and increased transport costs of sea transport on the Baltic Sea has contributed

\(^{16}\) 1 metric ton of wood equals approximately 2.3 MWh in energy content at a 50% moisture content (according to the EN 14961-1 standard) which means that 300 000 tons of wood equals about 690 GWh in energy terms.
e.g. to the decrease in the wood fuel trade between Estonia and Sweden showed in Figure 19, it is very difficult to verify this.

The reasons for the lack of market integration found herein- in the respect that prices are not cointegrated - are not clearly discernible. Although the actual amounts traded from Estonia to Finland and from Finland to Sweden are uncertain, there has been a rather active trade in unrefined wood fuels from Estonia to Sweden. However, despite this there seems to be no real connection between the markets in terms of prices adjusting towards each other. A major reason for this could very well be the nature of how this trade is carried out in practice. According to unpublished material from a questionnaire presented by Olsson (2006), 93% of the Swedish companies importing wood fuels used long-term contracts (longer than one year) and 57% bought their fuel exclusively through long-term contracts. An effect of these procedures is that there is lag before changes in the supply-demand balance affect prices. This could be one reason for the lack of clear connections between prices in the different countries.
5 Price effects from new sources of supply: European import of wood fuel from Canada and Russia

5.1 Introduction

With the goals set by the European Union to achieve a 20% share of renewable energy in the energy mix and a 20% decrease in greenhouse gas emissions by 2020 (DIRECTIVE 2009/28/EC, 2009) (2008) it is likely that the increase in EU demand for bioenergy will accelerate. However, it is also likely that a large share of the future use of bioenergy in Europe will be from biomass of non-European origin as the resources are unlikely to be cost-competitive compared to biomass imported from other parts of the world.

Two of the countries that have received most attention as large future exporters of wood fuels to the EU-27 are Russia and Canada. This is hardly surprising, since a) the two countries have vast forest resources and b) there is already a large import of wood fuels to the European Union from Canada and Russia. Together, the two countries made up almost 50% of the EU-27 import of wood pellets during the first ten months of 2009 (Eurostat, 2010).

In this chapter, Canada and Russia will be analyzed as present and future sources for EU imports of wood fuels. They will be investigated from a number of different perspectives that are important to grasp the characteristics, similarities and differences of wood fuel trade with these two countries.

5.2 Wood fuel exports from Canada and Russia: literature overview

Apart from the vast stock of standing forests of the two countries, another common characteristic of Canada and Russia is that they have a large production of fossil fuels. In 2008, Canada was the world’s sixth largest oil producer and Russia the second largest. Russia ranks first among global natural gas producing countries with Canada in third place. When it comes to coal production however, Canada is only the 16th largest producer with Russia at number five. Another important aspect to mention is the enormous oil reserves that can be found in Canada’s oil sands which, if included in figures of total oil reserves, make Canada the country in the world with the second largest oil reserves after Saudi Arabia (BP, 2009).

When it comes to wood energy, the large forest resources of the countries imply that there are also potentially great wood fuel resources in Canada and Russia. As to the exact magnitude of their respective wood fuel potentials however, this is still up for some debate.

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17 The results presented in this chapter are based upon conclusions from the study written by Dahlberg (2010).

18 It is important to note that most recently, the USA has climbed to the top of the world’s wood pellets exporters due to the operation of several new large wood pellet plants primarily in the South of the country.
5.2.1 Available bioenergy resources in Russia

The estimations of available bioenergy resources in Russia vary to a rather great extent depending on source. Antilla et al (2009) estimate the total potential for bioenergy in Russia to be 273-554 PJ (6.52-13.23 million toe)/per annum whereas Hansen et al (2006) estimate the potential to be about 1440 PJ (34.39 million toe) in North-Western Russia alone. A more conservative estimate of the potential in North-Western Russia – a region especially interesting due to its large forest cover and proximity to the European mainland – is 223 PJ (5.33 million toe) per annum (Gerasimov & Karjalainen 2009).

Wood pellets have in the recent decade emerged as the wood fuel most widely traded internationally, and for this reason it might be particularly important to review the estimations of wood pellet production potentials in the Russian Federation. According to Rakitova (2008), the wood pellet production potential in North-Western Russia alone is approximately 10 million metric tons (approx. 170 PJ/4.06 million toe)) per annum. Correspondingly, the potential for the entire country is estimated to be 35 million tons (almost 600 PJ (14.33 million toe) per annum (Rakitova 2008; Karjalainen 2009). Total current production in Russia in 2009 was about 650 000 tons (about 11 PJ/0.26 million toe) although the production capacity was three times as high (Rakitova & Ovysyanko 2009).

5.2.2 Available wood fuel resources in Canada

As might be expected, several studies aiming to quantify available biomass resources in Canada have been performed in recent years. The estimates from about 300 PJ (7.17 million toe)/annum to 1440 PJ (34.39 million toe) /annum (Wood & Laysell 2003; Gerasimov & Karjalainen 2009) although Bradley (2006) puts the total amount of “unutilized biomass” at 123 million bone dry tons (BDT) which equals approximately 2280 PJ (54.46 million toe)/annum.

As for wood pellets, the maximum production from the whole of Canada is estimated to be between 15 and 20 million (short) tons/annum which is equal to 230-320 PJ (5.49-7.64 million toe) per annum (Bradley 2009; Swaan 2009). Verkerk (2008) estimates potential production from British Columbia, the territory where currently the bulk of Canadian wood pellet production is currently located, to be 24.8-60.9 PJ (0.59-1.45 million toe) in 2012 and 50-218 PJ (1.19-5.20 million toe) in 2020. Total Canadian wood pellet production was 1.4 million tons (≈24 PJ/0.57 million toe) in 2009, with a capacity of 1.8-2 million tons (30-34 PJ/0.72-0.81 million toe) (Bradley 2009; Spelter & Toth 2009).

5.2.3 Current Canadian and Russian wood fuel export patterns

5.2.3.1 Russian wood pellet exports 2008-2009

As Europe is very much the center of the global wood fuel market in general and the wood pellet market in particular, it comes as no surprise that the vast majority of both Canadian and Russian wood fuel exports have European countries as their final destination. Sweden and Belgium received the bulk of the Russian wood pellet exports in 2008 with Denmark, Italy, the Netherlands and Germany importing smaller amounts (see Figure 20).
According to recently published figures from Eurostat (2010) of the Russian wood pellet export in 2009, the main patterns from 2008 seem to remain the same, with Sweden remaining the largest importer of Russian wood pellets (43%), and with Denmark (23%) and Belgium (12%) coming next.
5.2.3.2 Canadian wood pellet exports, 2008-2009

Figure 21. Shares of Canadian wood pellet exports in 2008. (Swaan, 2009)

As for Canadian wood pellet exports, the UK, the Netherlands and Belgium were the major receivers in 2008 with a smaller share going to Sweden. Noteworthy is that Sweden, which was the first country to import large amounts of wood pellets from Canada (see e.g. (2000a), only imported very small amounts in 2008. According to Eurostat (2010) figures, this trend seems to have continued, as there are no exports of wood pellets from Canada to Sweden recorded in the Eurostat statistics for 2009. Although these statistics seem to be a bit incomplete as of yet – with e.g. differences between national UK trade statistics and Eurostat figures – it may at least be noted that the large exports to Belgium and the Netherlands continued in 2009.
5.2.4 Logistics issues

As has been well-documented in previous research (Hamelinck et al., 2005; Uslu et al., 2008) on international trade in wood pellets, a well-functioning and cost-effective logistics system is a vital factor. Exports from Canada and Russia to Western Europe are no exception, although the key issues differ somewhat between the two countries depending on geographical as well as infrastructural and institutional circumstances.

The Canadian export of wood pellets usually takes place by transport in sea vessels of the Handymax (35 000-60 000 dwt\textsuperscript{20}) and Panamax (65 000-80 000 dwt) class. Using ships capable of carrying large amounts of cargo is essential in order to make this trade pattern profitable as the route from Western Canada to Western Europe covers a distance of more than 15 000 km. This is especially important considering the fact that wood pellets – despite being energy-dense compared to other wood fuels - have a rather low value per volume unit compared to e.g. coal. When shipping rates climbed to record-high levels just before the financial crisis of late 2008, it was largely thanks to 3-5 year fixed shipping price contracts that Canadian exporters could continue to ship wood pellets to Europe. Between 2004 and 2007 the shipping cost from Vancouver to Rotterdam rose from 35 US$ (28 €)/short ton to 100 US$ (73€)/short ton. With the economic downturn that followed in 2008-2009, freight rates decreased dramatically. Nevertheless, it is clear that the Canadian-European pellet trade is vulnerable to fluctuations in the cost of sea transport. (Bradley et. al, 2009)

Apart from the actual distance itself, issues regarding the actual loading in ports have also been discussed in the literature. An important matter is that the majority of the Canadian wood pellet production is located in the hinterland further inland from the coast of British Columbia. This is of course only natural given that this is where the biomass resources are, but it complicates the logistics as the pellets have to be transported by train from the production sites to the port in e.g. Vancouver – the dominating Canadian wood pellet export harbor - and then moved from the train cars to the ships. In general however, the port in Vancouver is modern and has terminals especially designed for handling wood pellets.

Compared to Canada, Russian wood pellet exporters aiming at the West European market has a competitive advantage in the much shorter shipping distance, roughly 2000 kilometers. As might be expected, the vast majority of the Russian wood pellet export makes its way to Western Europe via ports in the Baltic Sea, with 60-70% going through the port of St. Petersburg and about 15% through ports located in the Baltic States and the rest being transported by truck (Neginskaya, 2009; Alexandrova 2008; Bradley 2009; Rakitova & Ovsyanko 2009).

5.3 The importers’ view of Canada and Russia as sources of wood fuel supply

5.3.1 Introduction and methodology

In order to complement the information on Russian and Canadian wood fuel export available in the literature, the 50 largest district heating companies in Sweden and Denmark were contacted and asked to answer a questionnaire about their opinions of

\textsuperscript{20} Dead weight tonnes
Russia and Canada as sources of wood fuel supply. For Sweden, the response frequency was 50%, whereas it was only 20% in Denmark\textsuperscript{21}. The second step of this empirical survey consisted of contacting 15 company representatives with whom in-depth interviews were conducted.

5.3.2 Results from the questionnaire

In Denmark, none of the respondents stated that they imported wood fuels from Canada or Russia. When asked whether they thought that they would import fuels from either country in the future, they were uncertain or negative towards this. Most did however think it more likely that they would import from Russia than from Canada.

In Sweden, 30% of the companies who answered the questionnaire imported wood fuels at all. 20% of the companies stated that they bought wood fuels from Russia and 8% that they bought wood fuels from Canada. From Russia, a rather wide range of fuels were imported, including pellets, wood chips and round wood. From Canada, only wood pellets were imported. None of the companies who answered the questionnaire imported more than 20% of their fuel supply from either country.

In the questionnaire, the company representatives were asked to grade from 1 (“Very bad”) to 5 (“Very good”) Russia and Canada as wood fuel suppliers from five different perspectives: available resources, fuel quality, fuel price, logistics and reliability of suppliers. Judging by the average grades that were awarded the two countries, the respondents of the questionnaire think that resources and fuel quality are “good” or “very good” in both countries. There are some differences in the other categories however.

- Canada is deemed to be “bad” when it comes to fuel prices whereas Russia is “OK”.
- When it comes to logistics, Canada is ranked to be “good” or “very good” whereas Russia is “bad” or “OK”
- For “reliability of suppliers” where Canada gets “good” or “very good” whereas Russia is deemed to be “bad”.

Most of the comments in the questionnaire revolve around the Russian trade flows, which is only natural given that many more of the respondents had experience of importing from Russia than from Canada. The comments give some closer idea as to the issues related to importing from Russia. Several comments deal with logistics issues, such as the substandard quality of the Russian road network which leads to delayed deliveries and unspecified problems in the port of St. Petersburg. However, there are also comments criticizing conditions in Swedish ports, especially the limited working-hours. Many comments also touch upon institutional problems in dealing with Russian traders, such as corruption and a tendency of sellers to break contracts.

When the companies were asked whether they thought that they would import wood fuels from Russia in the future, answers were mixed. Interestingly however, a large

\footnote{The reason for the low response frequency might be that – as was discovered during the later interviews – Danish company representatives in general were a lot more restrictive about discussing company matters with outsiders than their Swedish colleagues.}
majority of the companies believed that the total import of wood fuels to Sweden from Russia would increase in the future.

As for the comments concerning Canada, the Swedish importers seem to be content with most issues related to importing wood fuels from Canadian partners, with the major exception being the high costs, which in turn are mainly due to the high costs of transportation.

5.3.3 Results from the interviews

In general, the results from the questionnaire are supported by the results from the interviews\textsuperscript{22}. Regarding Canada, the interviewed Swedish importers generally speak of good experiences with Canadian business partners, but that due to the exceedingly high shipping costs of recent years, imports from Canada have virtually disappeared. One trader says that because of the high shipping costs, buying pellets from Canada is “hopeless to implement”.

Regarding Russia, the interviewees speak of the country as having “fantastic potential” as a bioenergy exporter, but that there are large cultural and institutional problems with dealing with Russian conditions, especially regarding port operations. One interviewed importers says that it is absolutely necessary to have a long-term contract in the ports whereas another interviewee claims that it is necessary to pay almost 50,000 € in kickbacks every month in order to get operations in the port of St. Petersburg to run smoothly. Another problem is that controls in receiving Swedish ports take very long time.

A more positive view of importing wood fuels from Russia is given by an actor who has been importing wood chips and round wood for energy purposes. The company in question has worked with the same intermediary for several years and the trade has been working satisfactorily. In this case, the trade has not been going via the Russian ports on the Baltic Sea, but instead by way of the Russian river system. A problem with this is of course that the rivers freeze in wintertime which makes delivery seasons limited.

5.4 Conclusions

Trading wood fuels is always complex due to the biomass itself being both low in value per volume unit as well as difficult to store and transport as a result of it being a “living material” and hence susceptible to degradation from biological processes. As can be discerned from the previous sections of this chapter, the trade of wood fuels from Canada and Russia to Western Europe is surrounded by a wide range of issues that add to the complexity. Both countries hold vast – albeit unclear how vast – unutilized woody biomass resources that potentially can have a large impact on the European wood fuel market, but the process of getting beetle-damaged wood from British Columbia or substandard round wood from Western Siberia to West European energy plants involves a lot of difficulties.

In summary, the main issue with Canadian imports from the perspective of the Swedish importers is that they cost too much. This does however not seem to have discouraged importers in the other parts of Europe – primarily in Belgium, the Netherlands and Great

\textsuperscript{22} For detailed accounts of the interviews see Dahlberg (2010).
Britain - who continue to buy Canadian wood pellets. The reasons for this changing trade pattern is likely to be connected both to the prices of competing fuel suppliers and the cost of transport, with large customers in North-Western Europe being better equipped to handle Panamax-size ships than Swedish buyers.

As for Russia, the problems seem to boil down to two matters: logistical problems – particularly in the port of St. Petersburg – and a business climate that is perceived to be unreliable and corrupt. In a way, the logistical problems are – despite their being a serious obstacle to an efficient Russian wood fuel export – a smaller problem than the difficulties that Swedish importers report with the Russian business climate. Ports can be modernized and logistical systems made more efficient, but changing a culture or an established modus operandi is likely to be more difficult.
6 Case study from a cross-border region: price effects from trade in wood pellets between Sweden and Denmark

6.1 Introduction

The focus of this case study is the development of the trade in wood pellets from Sweden to Denmark and the factors affecting prices and trade flows. There are several reasons for the choice of this particular trade. First, the two countries are among the leading in both Europe and the world in terms of wood energy market development. If the countries of the EU-27 are ranked according to the share of “Biomass & waste” in their respective energy mixes, Sweden ranks third at approximately 19% of total inland energy consumption and Denmark ranks fourth at roughly 14% (Eurostat, 2008). Second, the two countries have in recent years become increasingly integrated economically since the opening of the Øresund bridge between Malmö - the third largest city in Sweden - and the Danish capital Copenhagen. There is now plenty of movement in goods and services as well as labor between the two countries, as there were about 20 000 daily commuters between Malmö and Copenhagen in 2008 (Øresundbron webpage, 2010). Third, despite the fact that the two countries in many ways are becoming increasingly integrated, they have separate currencies, SEK and DKK, respectively. Hence, exchange rate volatility can have a great impact on the interaction between Danish and Swedish markets. Fourth and finally, the Danish wood pellet market is highly international and dynamic in nature with companies from a rather large number of countries being active on the market (see e.g. Force Technology (2009). This means that Denmark is in itself an interesting case to study to illustrate how the internationalization of wood pellet market is developing.

6.2 The importing side: the Danish wood pellet market

6.2.1 Overview

The wood pellet market in Denmark has – as in Europe at large – grown rapidly in the 2000’s. From a market size of about 400 000 metric tonnes in 2001, the consumption of wood pellets increased to more than 1 million tonnes in 2008, which makes the country one of the leading in the world in terms of pellet market size (Hansen, 2009). Wood pellet consumption in Denmark first began in the district heating sector, but with governmental programs supporting the use of renewables in small-scale heating applications, the residential market developed in the 1990’s which was the largest market segment at least until 2006 (Force Technology, 2009). In most recent years however, the strongest growth has taken place in the Combined Heat and Power sector. This has led to the large scale market now being the biggest segment at about 45% of total Danish wood pellet consumption (Hansen, 2009; Force Technology, 2009). However, the residential sector is just slightly smaller, which can be seen in Figure 22.
6.2.2 Danish wood pellet imports

While the Danish consumption of wood pellet has increased remarkably in the recent decade, domestic production of wood pellets has taken a downward turn. From 2005, domestic wood pellet production has decreased 30% from a peak level of about 190 000 tonnes to 134 000 tonnes in 2008 (Hansen, 2009). An important reason for this decrease has been a lack of raw material due to the fact that parts of the Danish woodworking industry have shut down or moved abroad (Hansen, 2009; Force Technology, 2009).

An obvious consequence of a rapidly growing consumption and a stagnating domestic production is that the Danish import of wood pellets has increased dramatically, as can be seen in Figure 15.
6.2.3 Which countries export wood pellets to Denmark?

Over the years, the structure of the Danish wood pellet import has also seen some changes, especially in the terms of the origins of the imported pellets. Although the Baltic States – Estonia, Latvia and Lithuania – remained the leading countries all throughout this period, there has been some variation between years as to which the other important countries are, as can be seen in Figure 24.
Imports are commonplace in the residential as well as the large-scale sector. A survey\textsuperscript{23} of Danish retailers of residential wood pellets showed that Danish small-scale consumers of wood pellets can choose among pellet brands from at least ten different countries. The countries represented on the residential market comprise most of the countries included in Figure 24, and there are also wood pellets with a vaguer region of origin, e.g. one retailer simply stated that one brand of pellets came from “Asia”. “No-name” pellets, sold in transparent plastic bags without any brand name or information on geographical origin are also rather common.

6.3 The exporting side: the Swedish wood pellet industry

6.3.1 Overview

The Swedish wood pellet industry first began in the early 1980’s with the establishment of a production facility in Mora in the middle of the country with an annual production capacity of around 40 000 tonnes. (Mahapatra et al., 2007). Market development was rather slow and problematic during the 1980’s\textsuperscript{24} (Vinterbäck, 2000b), but from about 1990, a period of more steady growth began. From 1990 to 1996, production grew from 10 000 tonnes to 500 000 tonnes based primarily on demand from large-scale facilities (Hillring and Vinterbäck, 1998). From 1997 to present time domestic demand has

\textsuperscript{23} Conducted during the process of writing this report.

\textsuperscript{24} The plant in Mora was shut down in 1986.
increased in all market segments and the industry has continued to expand as can be seen in Figure 25.

![Diagram showing Swedish wood pellet production and international trade 1997-2009](image)

**Figure 25. Swedish wood pellet production and international trade 1997-2009 (Swedish Association of Pellet Producers, 2009).**

### 6.3.2 The Swedish export to Denmark

The Swedish wood pellet market has been influenced by international trade since the mid-1990’s when Swedish district heating and combined heat and power plants began importing wood pellets from the Baltic States and North America (Vinterbäck, 2000b). *Exports of wood pellets from Sweden have been at a lower level, but have picked up speed since 2005 (see Figure 25). Although there is not much historical data on the Swedish export, it was earlier primarily been directed at Denmark, with smaller portions going to the UK (Ericsson et al., 2004b).*

In the first ten months of 2009, Sweden exported approximately 60 000 tonnes of wood pellets at a total value of slightly less than 11 million €. Out of this, about 80% was exported to Denmark, with Norway and Germany at 9% and 8% making up almost all the remainder (Eurostat, 2010).

The trade flows going to Denmark have consisted of wood pellets aimed both at the large-scale and small scale sector. Pellets aimed for use in large-scale Danish production of heat and power have been transported by bulk in ships in sizes around 3000 dwt e.g. via freshwater ports in Sweden’s largest lake Vänern via the Göta Älv river to Danish ports (Anon., 2005; Öster, 2006).
6.3.3 The exporters’ view of the Danish residential market

A handful of Swedish wood pellet brands are available at Danish retailers\(^\text{25}\). In order to further investigate the nature of this trade, a number of Swedish wood pellet producers established on the Danish market were contacted and interviewed on their opinions of Denmark as a wood pellet market and the factors impacting trade.

A common view among the contacted Swedish pellet producers is of Denmark as a very dynamic market, especially compared to the Swedish market, which is rather stable over time. Several of the interviewees speak of Denmark as a form of “dumping market” in the sense that producers from many countries in Northern Europe sell their excess supply to Denmark. As for the reason for this development in Denmark, there is no clear consensus among the Swedish producers, but the geographical proximity of Denmark to Sweden, Germany and the Baltic States – some of the largest wood pellet producers in Europe – and the decline in Danish production coupled with a very strong growth in demand, are some reasons that were mentioned\(^\text{26}\). Another example of the rapid shifts in the Danish market is the perceived tendency of Danish retailers to switch relatively often between the brands that they market, whereas e.g. Swedish retailers tend to be more “loyal”.

6.4 The impact of currency fluctuations

An important economic difference between Sweden and Denmark is that the countries have different currencies - albeit with similar names - the Swedish Krona (SEK) and the Danish Krone (DKK). Both countries are members of the European Union (EU) but neither has so far joined the EU:s Economic and Monetary Union (EMU) or adopted the Euro (€). However, the Danish Krone is pegged to the Euro which means that its value stays within a defined narrow range compared to the Euro (Danmarks Nationalbank, 2003). An effect of this is that when the Swedish Krona weakened significantly relative to the Euro in the wake of the financial turbulence of the second half of 2008, the SEK lost in value compared to the DKK as well (see Figure 26).

\(^{25}\) A non-scientific study comparing the brands available in East (Sjaelland) and West (Jylland) Denmark indicate that Swedish brands are more common in the East, closer to Sweden, which seems logical.

\(^{26}\) One producer also claims that Danish consumers are more focused on price than Swedish consumers, and that the Danish are more prepared to accept some combustion nuisances that can be associated with pellets of a lower quality if they can get a lower price.
The strengthening of the Danish Krone compared to the Swedish Krona that took place between late 2008 and early 2009, and the continuing high DKK/SEK ratio compared to before the 2008 crisis, meant that Swedish wood pellets became up to 20% less expensive for Danish consumers.

The question is if the declining value of the SEK has increased the market share of Swedish pellets on the Danish market compared to countries such as Germany or the Baltic States, who either have adopted the Euro (Germany) or have their currencies pegged to the Euro (the Baltic States). Figures from Eurostat of the Danish wood pellet import in January to October 2009 do imply that there has been a significant increase in the Swedish export to the Danish market compared to 2008, both in absolute terms (from 37 000 to 92 000 tonnes) and in market share (from 4% to 16%) (Force Technology, 2009; Eurostat, 2010). Although this certainly points to the existence of a “currency effect”, one should be careful to draw solid conclusions before fully comparable statistics are available. However, when the Swedish exporters where asked whether they had noticed a “currency effect” in the level of their competitiveness on the Danish market, all acknowledged that this exists\(^ {27} \). A representative from the Danish bioenergy industry also believed that the currency fluctuations had provided a boost to demand for Swedish wood pellets on the Danish market.

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\(^ {27} \) However, it should be mentioned that the interviewed representatives were at the time of the interviews – January 2010 – mostly concerned about the strengthening of the SEK vis-à-vis the DKK in late 2009, which – using the same reasoning – might result in a deterioration of the competitive advantage of the Swedish producers.
6.5 The future of Swedish-Danish trade in wood pellets

If the recent data from Eurostat – that were discussed above – are correct, it certainly seems as if there has been a steep increase in the Swedish export of wood pellets to Denmark. It is interesting to note that the Eurostat figures of the Swedish export to Denmark in January-October 2009 exceed what the Swedish Association of Wood Pellet Producers has forecast would be the total Swedish wood pellet export in 2009 (Swedish Association of Pellet Producers, 2009). However, the interviewed Swedish producers all believed in a continuing strong growth in the Danish residential market and increased opportunities for Swedish wood pellet producers.
7 Conclusions and discussion

The speed at which bioenergy markets and - in particular - wood fuel markets have been growing and developing in the first decade of the 21st century is remarkable. Furthermore, it can be expected that demand will continue to grow in the coming decade, continuously being fuelled by high and volatile fossil fuel prices as well as increasingly ambitious policy measures aiming to mitigate emissions of greenhouse gases. As wood fuels are becoming an ever more important part of the European energy system, it is vital – from an environmental as well as an economic point of view - to obtain a firm understanding of how wood fuel markets function. This report has focused on wood fuel prices and the different aspects influencing wood fuel price development. Several factors of heterogeneous character have been discussed herein, which is only to be expected given the complexity of bioenergy markets, and primarily the inherent tendency of different parts of the bioenergy system to be connected to other techno-economical systems.

As for the specific factors driving wood fuel price development, it is important to note that there is a distinction between factors that affect prices in the long and short run. For example, it is sometimes casually said that bioenergy prices rise because of higher oil prices. This is in one sense a valid statement, but it is important to be aware of the fact that this statement only seems to be true in a period over one or several years whereas there is little connection between e.g. the prices of crude oil and wood pellets if one looks at a short-run price variations (Hedenus et al., 2009). In the long run, it is natural that high oil prices increase the incentive to use alternatives such as wood pellets, which in the end increases pellet demand and pushes prices upwards. Then again, this is a process that involves investments in new equipment and other long-term decisions and hence it is not strange to find a lag of a year or more between oil price hikes and subsequent increases in bioenergy prices, as is discussed by Boldt (2009). However, the connection to the prices of alternative fuels is likely to be substantially more important in the large-scale sector, which is more fuel flexible and can potentially switch between coal and wood pellets depending on the price of respective fuel (and emission permits). Co-firing of wood pellets with coal in large-scale power stations is already an established practice in the Benelux countries and there is great potential in Europe for expansion of wood fuel co-firing (see e.g. Hansson et al (2009). The potential for fuel switching between coal and e.g. wood pellets is likely to lead to connections between prices of the two fuels. This development is further supported by technological developments in the wood fuel sector, especially the expected commercialization of torrefied pellets, also known as “bio-coal”. Torrefaction of wood and other biomass enables the production of pellets with characteristics very similar to coal in regards to both logistics and combustion issues. (see e.g. Bergman (2005)

The factor that hitherto has been dominant for the short-term development of wood fuel prices has been production costs. A clear example of this was seen in the wake of the financial crisis in late 2008 and early 2009 when prices of oil, coal and natural gas plummeted but the prices of wood fuels instead increased. Also, as was shown in chapter 3, the cost of purchasing raw materials is in turn the biggest part of production costs, which further highlights this crucial part of especially the wood pellet production chain. As discussed in chapter 3, the traditional and “easy” raw materials base for wood pellet production is now starting to become stretched, leading to increased interest in other raw materials. However, the introduction of untraditional raw materials need not automatically lead to higher wood pellet prices as this a factor that depends much on demand for the new raw materials from other industrial sectors. The increased demand for raw materials for wood pellets will however in all likelihood lead to more discussions about the competition for round wood and saw mill by-products between an energy sector continuously demanding more fuel and a pulp & paper industry struggling with a weak market, especially for low-quality products such as newsprint.
Regarding the impact of international trade, this is a factor that has only begun to change the nature of the wood fuel market. As trade in wood fuels increases, factors such as freight rate and exchange rate fluctuations will become increasingly important. Hence, the future development of national and regional wood fuel prices is likely to be affected by plenty of issues that by no means will be limited strictly to local supply/demand balances. Petrol consumers are by now not surprised by increased prices at the pump being explained as ripple effects from developments in the crude oil market, be it unusually cold weather in the North-East US, droughts in Venezuela or hostilities in the Niger Delta. Although it may take some time before e.g. the wood pellet market has reached this level of internationalization and interconnectedness, the speed at which the wood fuel market is developing is a harbinger that the truly global wood fuel market might not be that far into the future.
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Appendix A: Wood fuel definitions

Wood pellet (FprEN 14588)

Densified biofuel made from pulverised woody biomass with or without additives usually with a cylindrical form, random length and typically 5 to 40 mm, with broken ends

NOTE: The raw material for wood pellets is woody biomass in accordance with Table 1 of EN 14961-Part 1. Pellets are usually manufactured in a die, with total moisture content usually less than 10 % of their mass.

Wood briquette (FprEN 14588)

Densified biofuel made with or without additives in the form of cubiform or cylindrical units, produced by compressing pulverised biomass

NOTE 1: The raw material for wood briquettes is woody biomass in accordance with Table 1 of EN 14961-Part 1.

NOTE 2: Biofuel briquettes are usually manufactured in a piston press, with the total moisture content usually being less than 15% of the mass.

Wood chips (FprEN 14588)

Chipped woody biomass in the form of pieces with a defined particle size produced by mechanical treatment with sharp tools such as knives

NOTE 1: Wood chips have a subrectangular shape with a typical length of 5 to 50 mm and a low thickness compared to other dimensions.

Firewood (FprEN 14588)

Cut and split oven-ready fuelwood used in household wood burning appliances like stoves, fireplaces and central heating systems

NOTE: Firewood usually has a uniform length, typically in the range of 150 mm to 1000 mm.

Hog fuel (FprEN 14588)

Fuelwood in the form of pieces of varying size and shape, produced by crushing with blunt tools such as rollers, hammers, or flails

Logging residues (FprEN 14588)

Woody biomass residues which are created during timber harvesting

NOTE: Logging residues include tree tops with branches and they can be salvaged fresh or after seasoning.

Stemwood (FprEN 14588)

Part of tree stem with the branches removed
Wood processing industry by-products and residues (FprEN 14588)

*Woody biomass* residues originating from the wood processing as well as the pulp and paper industry
Appendix B: Energy conversion factors

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<th>GJ</th>
<th>MWh</th>
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