Development and promotion of a transparent European Pellets Market

Creation of a European real-time Pellets Atlas

Logistic management of wood pellets: Data collection on transportation, storage and delivery management

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Abbreviation

BTL: Biomass to Liquid
CCPP: combined cycle power plant
CGP: Central gathering point
CIF: Cost, Insurance and Freight
dt: dry tonne
EFTA: European Free Trade Area
EU: European Union
fw: forest waste
FSC: Forest Stewardship Council
GHG: Green House Gas
Ha: hectare
HEZ: German wood energy centre Olsberg
hr: hour
Kg: kilogram
Km: kilometer
kW: kiloWatt
kWh: KiloWatt hour
M: meter
MJ: Mega Joule
MW: MegaWatt
MWe: Mega Watt Electrical
NOK: Norwegian krone
PEFC: Pan-european Forest Certification Council
SEK: Swedish krona
SME: Small and Medium Enterprise
T: ton
UU: Utrecht University

INTRODUCTION

There is a general consensus that the deployment of bio-energy on a global scale will bring many significant energy-security environmental, socio-economic benefits. Biomass is a sleeping giant, however as far as the vast potential offered by cellulosic biomass conversion and utilisation is concerned, variation in the entire production system for biofuels supply (feedstock production, pre-treatment, conversion, utilisation) will have to take into account the differences in local available resources potential, priority needs and economies, country by country.

Biomass is a very dispersed resource and requires a significant and expensive effort for its recovery:

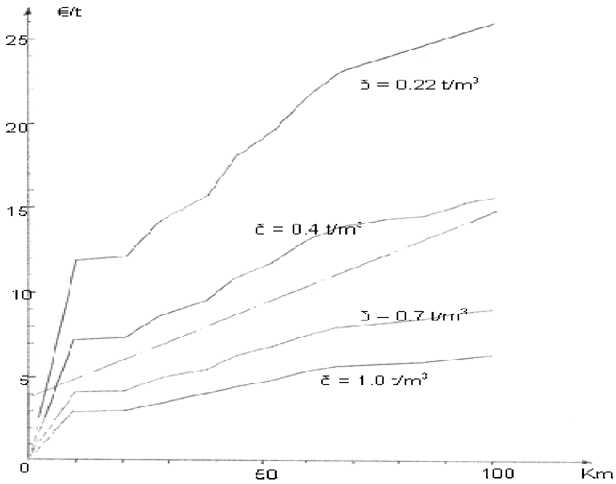
- Dedicated energy crops have a typical yield of ~ 10 to 30 dry ton/ha
- Agro-forestry residues can provide an annual amount of 1 up to 25 dry ton/ha.

For this reason high density biomass feedstock like pellets have the following important advantages:

- High stability
- They need much less space for storage and transport
- The recovery capacity (tons of dry matter per man power hour) is about 4 times higher than chopped feedstock (Schon and Strehler, 1992)

Loose Biomasses for their high moisture content and their low volumetric density pose a serious problem for their transportation and economic use as can be seen from figure here below:

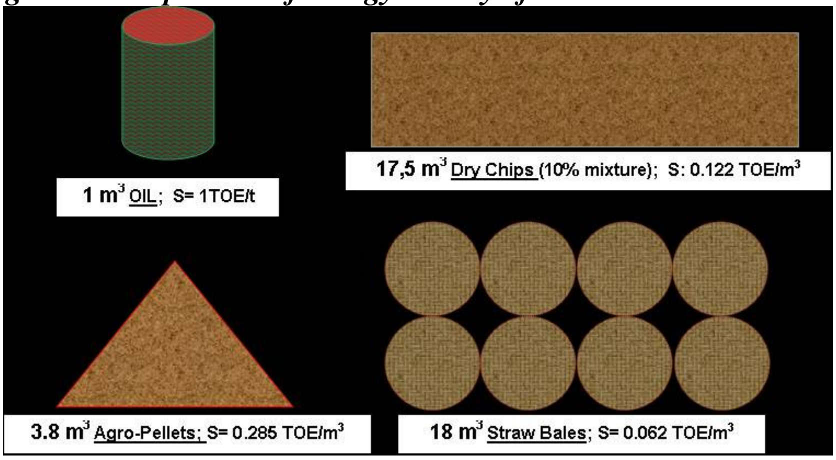
Figure 1: Typical biomass transport costs in function of density (t/m3) and of distance (Km)



Source: EUBIA

Pellets are a products obtained by basic pre-treatment, for stabilisation of humid biomasses to eliminate its bio-degradation and for increasing its specific energy content.
This transformation gives to pellets some very good logistical advantages in comparison with other biomasses (see Figure 2), facilitating the storage and transport due to the high energy content and therefore the smaller volume to be handled, and also facilitating the storage because of the low moisture content and therefore a better conservation of the product in the time. In fact Pellets can be stored in standard silos, hauled in standard rail cars, and quickly delivered in truck containers. They are made to be safe, reliable and highly transportable.

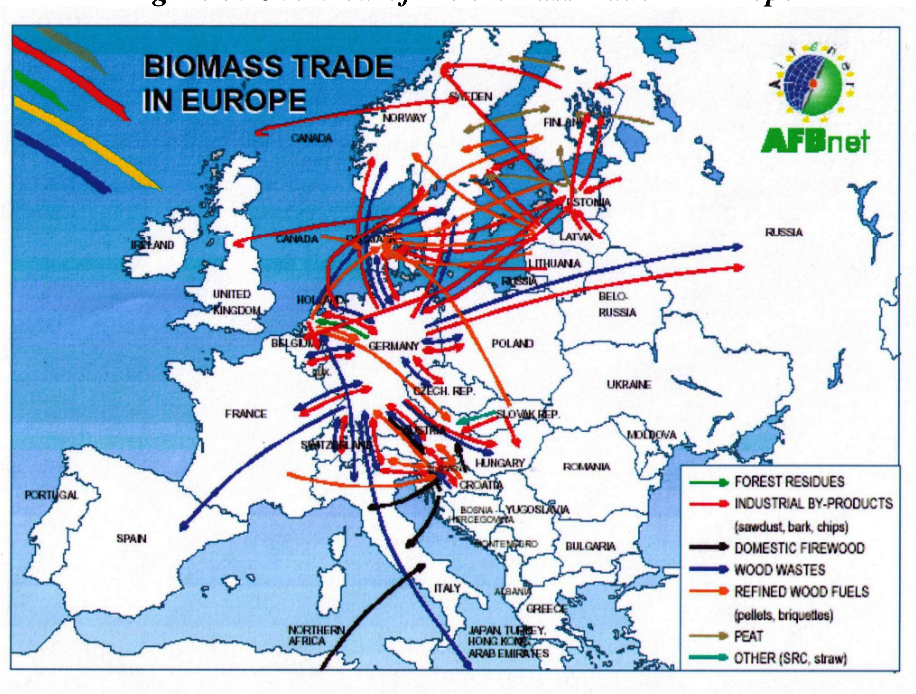
Figure 2: comparison of energy density of various biomass sources



Source: EUBIA

Approximately 7 millions tons of wood pellets are actually produced in Europe. Wood pellets can be used in pellets stoves or boilers or cofired with fossil fuels in utility boilers and become more and more popular. The energetic utilization of pellet is favoured thank to a good attitude to combustion, but is burdened by harvesting, transport and storage problems. In fact, the use of wood pellets increased rapidly in the 1990s in Europe showing that the logistic management is taking more and more importance in the global evaluation of pellet cost, mainly due to the development of the worldwide biomass trade (Figure 3).

Figure 3: Overview of the biomass trade In Europe

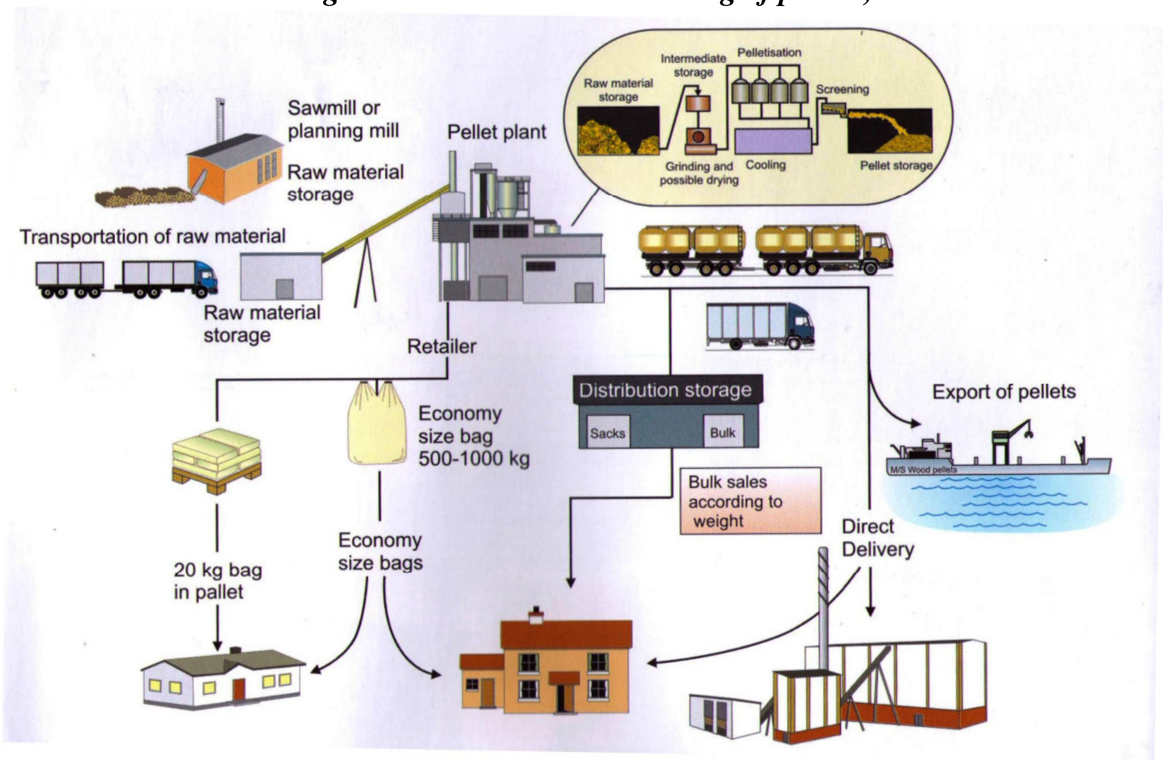


Source: EUBIONET

Therefore, actually the pellets supply chain (from Biomass sources to pellets delivery) has to be studied at international level. Actually informations regarding logistics are available but there is no real dedicated study on this issue. This report will try to give an overview of this aspect giving the main information regarding storage, transport and delivery of pellets in Europe from producer to end user.

The following Figure 4 gives a general overview of the pellet supply chain (production and trading).

Figure 4: Production and trading of pellets;



Source: VTT

In general biomass is collected locally at smaller scale production sites and transported to a CGP. This allows for larger capacity treatment facilities, which makes the use of costs-intensive pre-treatment and conversion technologies economically more attractive. Local transport to CGP, harbour or conversion facility takes place by truck. Long distance transport is done by train or ship.

Based on this status, and in order to study the more relevant logistical aspects, we decided to structure the report as follow:

- Transportation management will be analysed from pellet producer to traders (truck, train waterway and maritime shipping), also delivery to end user will be presented.
- Storage management will be analysed mainly presenting the situation at the harbour, at the power plant and pellet manufacturer, and at the households.
- Some considerations will be done about Logistics and costs and also regarding supply chain and sustainability.
- Finally an overview of logistics aspects regarding three cases study representing the main pellet supply chains will be resumed: non industrial pellet bulk, non industrial pellet in bags, industrial pellets bulk

1 TRANSPORTATION MANAGEMENT

The most traded biomass fuel is pellets. This is due to the fact that pellets are the most compact form of solid biofuels, so the transport costs per energy unit is lowest, which is important especially with longer distances. The production costs of wood pellets range from 75-101€uros per ton of pellets on average for moist raw material and 52-81€uros per ton of pellets on average for dry raw material.

Pellets can be produced and used locally, but can also be shipped internationally to match up production and markets. This chapter will present an overview of the main way of transport from pellet producer to the traders and also the delivery to the end user.

Transportation is a fairly important factor regarding the economy of pellet industries. It is not feasible to transport cutter shavings and sawdust overlong distances, but the pellet plant should be located close to raw material sources. The long transport distances of pellets also reduce cost-effectiveness. When planning logistics, return transports should be used as far as possible to improve the cost effectiveness.

Wood pellets are sold either as bulk goods or in large or small bags. The size of small pellet bags ranges 15-25 kg, and they are packed on interchangeable pallets. The pallets are delivered to retailers, who deliver the pellets to final users. Small bags are meant for consumers, who use pellets in small scale in stoves or as additional fuel. The size of large bags ranges 1-1,5 m3, i.e. 500-1000 Kg. Transports of pellets in large bags are more economical but a forklift lorry, a crane or a front loader is needed for unloading. Hence, this transport system is unpractical for small-scale consumers, who do not often have any hoisters for conveying large bags. Large bags are especially used in farms, which have equipment to handle these bags.

Pellets can be transported in bulk by tractors or trucks under a tarpaulin. Bulk pellets are distributed by truck using pressurised air for blowing the pellets directly into the store of the end user. In this way the pellets are distributed like fuel oil. The truck may be designed especially for wood pellets, or trucks designed for animal fodder can be used. In this case, possibilities for return transport are higher. Consequently, pellet production can be located to those districts where meat and dairy production is extensive.

1.1 From Pellets Producer To Traders

The principal ways of transportation of pellets from Producer to traders depend on the distance to be covered. We will analyse those way of transportation according to two average distances:

- For short/medium distances
  - Trucks
  - Train
  - Waterway: river boat/barges
- For long distances: Shipping

1.1.1 Transport for short/medium distance

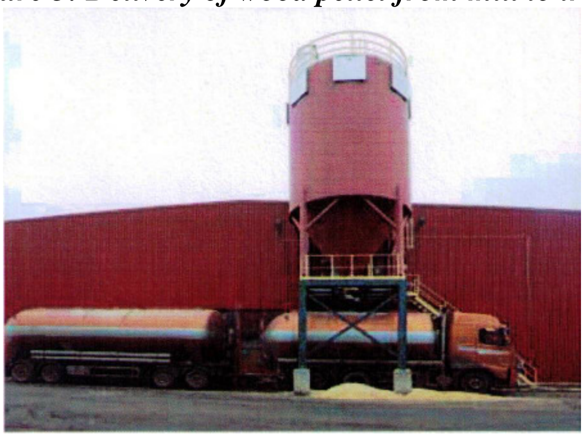
1.1.1.1 Transport by truck

The transport by truck is in Europe one of the most developed way of goods transportation, in fact considering only inland transport, it appears that the considerable growth in transport has been almost entirely realised by road transport. In 2000, it represented 75 % of the km performed in the EU and EFTA countries. The increase between 1990 and 2000 was very high in Austria, Germany and France. No country had a decrease during the same reference period and the growth of the total tkm transported by road in all the EU and EFTA countries was equal to 40 %. In 2007 the total road freight transport in Europe has been estimated to 17514 Mtones of which 562,12 Mtonnes for wood and cork transportation. The two main users of road transport are Sweden and Germany

However, due to the environmental interest of pellets and its commitment in energy and CO_2 emission saving, transportation by truck seems not the better way to make the energy and CO_2 emission balance very efficient.

Economically, the maximum profitable driving distance for truck transportation of forest fuels is evaluated at approximately 60-100 km, depending on the material transported and the logistics system. The amount of energy that can be transported by truck is rather small because of the low energy and bulk density of forest fuels. In the case of pellets the road transport over long distances (more than 200 to 300 km) is not very economical (high transport costs in relation to low product costs), so pellet manufacturers and suppliers try to establish local markets and co-operate with the local wood and timber industries.

Figure 5: Delivery of wood pellet from mill to truck



Source: Vapo Oy

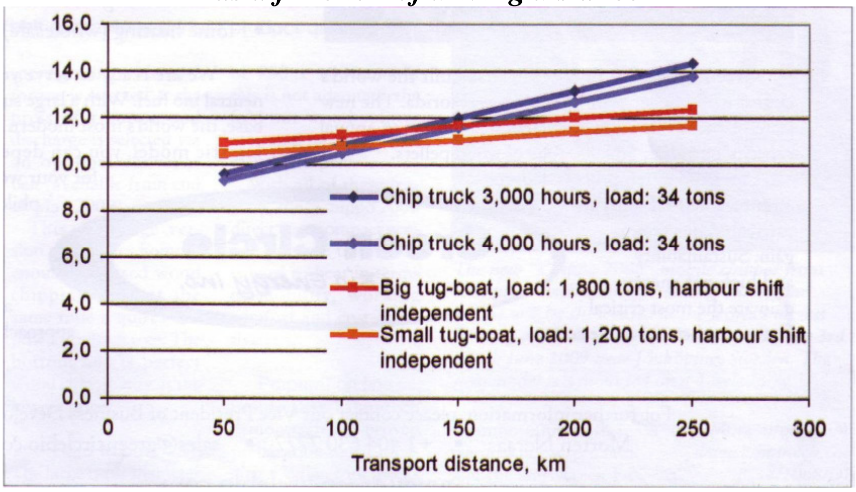
1.1.1.2 Transport by train

The railway goods transport increased during the last years, but not at all in the same pace as road transport. The conclusion is that the number of km by road is much greater than the km performed by rail. This increase is there in spite of a decreasing network and less rolling stock, which must indicate that the efficiency of the rail industry today is higher.Due to the fact of truck transport costs and low environmental friendliness the transport by truck should be preferred in the case of household delivery and train should be preferred for the medium distances between big plants like for example pellets production sites and big utilities power plant. In 2007, around 73,18 MT of wood and cork have been transported by railway in Europe, that is representing 4,5 % of the 1634,2 MT of all the goods transported by train. One of the main users of railway transport in Europe is Germany with more than 361 MT of goods transported by railway from which 114615 T of wood and cork per kilometer in 2007. Actually a lot of European countries are looking for revalorization of railway network in order to improve this kind of transportation, which could become more interesting also for pellet transportation. As example the Worlds largest Pellet manufacturing plant located in Cottondale (Florida, USA) is using trains for transportation of pellets directly from the plant to the ports (100km in the South) and where they are delivered by bottom unloaded wagons and stored in large hall of 35000 tons capacity.

1.1.1.3 Transport by waterway

According to a project financed by Finnish funding Agency for Technology and Innovation (Climbus program) and many companies dealing with the logistics of round wood and forest biomass studying the inland bar transportation possibilities, Waterway transport has proved a cost-efficient form of round wood logistics for long distances.

Figure 6: Total cost of alternative logistical chains of forest chips as a function of driving distance



Source: The Bioenergy International

The study mainly based on woodchips shows that waterway transport of forest fuels by barges and vessels could complete round wood logistics and be particularly suitable in the largest inland waterway area of Finland, the Lake Saimaa region.

In fact, there are promising opportunities to transport the alternative biomass materials like pellets in many part of northern and central Europe via inland, ship canal, river or sea waterways.

What is actually important to be considered, to make this system durable is:

- the resource of biomass,
- the developed waterway supply chain logistic
- heavy users of biomass.

The main way to exploit the waterways is the use of barges.

Until now, the barges were mainly used for round wood transportation. All of the frame capacity could be used in round wood transportation to its full extent with the help of side poles. That is not possible when carrying loose material such as wood chips or pellets without wall elements.
In the Finnish study, roadside chipping and terminal chipping of logging residues were demonstrated before the long-distance transport of forest chips by a large tug-boat and hopper barge combination. The stationary chipping supply chain was demonstrated by using energy wood from early thinning from islands, and waterway transport was done using a small tug-boat and deck barge combination.
It appears that side elements are an absolute necessity for the deck barge if transporting wood chips or pellets instead of round wood, bales or whole trees, as in this case.

The combination of a small tug-boat and large scale hopper barge was also demonstrated on a waterway which had low draught and a narrow boat route. The belt conveyor was tested as a loading method. In case of pellets, its characteristic gives the possibility to get pumped by means of a fuel hose. This demonstration was organized by the Finnish power plant company, Estela Savon Energia Oy.
Demonstrations showed the potential of large-sized barges. An energy density comparison of forest chips showed the barge frame load to be on average 1 MWh/m3, which was on average 25% higher than in truck hauling. The moisture of forest chips was about 40% in both demonstrations. The maximum load capacity can be achieved by modifying barges with side elements.

We have also to consider that the large size of the barges and the compaction effect are important factors in cost-efficiency when compared to truck transport. Therefore if we consider pellets with moisture content of about 5-10 % and higher energy density than chips, we can imagine the real benefits on economics and efficiency of this way of transportation.

An inland waterway transport supply chain of pellets, including satellite terminals, could be suitable for plants that are near waterways and need more pellets than is cost-efficient to supply traditionally by trucks.

The bioenergy research group of Lappeenranta University of Technology was responsible, between 2006-2008, for the organization of the study, introduced at the beginning of this paragraph. The results of the supply chain demonstration and simulation established that the logistics of waterway transport can be more competitive than traditional truck transport of forest chips after a distance of 100 km. The logistics systems must be developed case specifically and take the needs of customer and other circumstances into consideration. Because of this promising project results, the realization for transportation is close to be started.

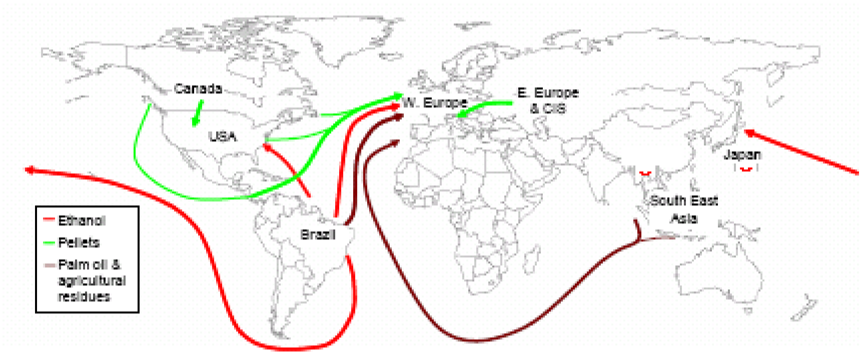
Considering what has been highlighted up to this point the use of waterway appears very interesting for transport of fuels like pellets that is energetically denser than chips. The waterway use should be increase in order to make transportation more economical and environmental efficient. In order to develop in a sustainable way this kind of transport, all the logistics issues have to be reconsidered and adapted to the pellets needed. For example ports and barges adaptations in order to facilitate the goods handling and avoid that pellets being in contact with the water and thus affect its quality during transportation.

1.1.2 Transport for long distance: maritime shipping

1.1.2.1 Overview of shipping

At present, most of pellets transported for long distance are coming from the North American and are shipped to Europe for use in power generation. Much of the Scandinavian and Baltic product is also shipped to Europe (see Figure 7). With the pellet market still being relatively new, it has experienced some imbalances of undersupply and oversupply, but stability is now being achieved.

Figure 7: World Biomass Shipping



Source: task 40 report

The expansion of 2nd generation biofuels in the future will increase the biomass demand therefore also the long-distance transport of biomass that will increase demands on maritime shipping capacity.

Intercontinental transport by maritime way can be done through 3 kinds of ships of different capacities:

- Panamax: 70 000 metric tons
- Handysize: 35 000 metric tons
- Small ships: 3 000 metric tons

The cargo vessels are also differentiated according to the kind of good transported into 3 categories:

- general cargo (loose items like boxes);
- standardized containers and wheeled cargo (e.g. cars);
- bulk cargo.

Bulk pellets are shipped in large ocean tankers. It is important to cover the goods in order to protect it against water, it must be loaded to minimize fines, and procedures are changing to minimize dangers of off-gassing and fire.

In 2007, dry cargo shipments represented around 66% of total world goods loaded. Therefore we can infer that a very intensive competitiveness of pellets shipping with the other goods will increase and will become an obstacle.

Efficient seaports are often critical to enabling cost effective transportation of biomass. The most advanced ports can accommodate large ships and offer a range of facilities for handling and storage and well as excellent land transport connections; such as Rotterdam, Singapore Hamburg and Hong Kong. The least efficient ports, often nearer to biomass sources, have low port productivity and poor transportation logistics; such as in Africa and South America.

Task 40 reports consider that more than 150 new Handysize tankers will be required for exportation of biofuels into 2014. In order to control initial costs, flexible ship designs are needed that allow with low additional costs to be converted if the pellet market doesn't remain stable in the future.
The chief biomass energy products shipped by ocean include wood pellets, wood chips, ethanol, and palm oil. Much of European pellet production is either used in the country in which it‘s produced, or is transported by land routes. In 2007, around 2.4 million tonnes of wood pellets were shipped by ocean freighter primarily from Canada, the US and the Baltic countries to western and northern Europe;

Major ports and destinations for wood pellets include:

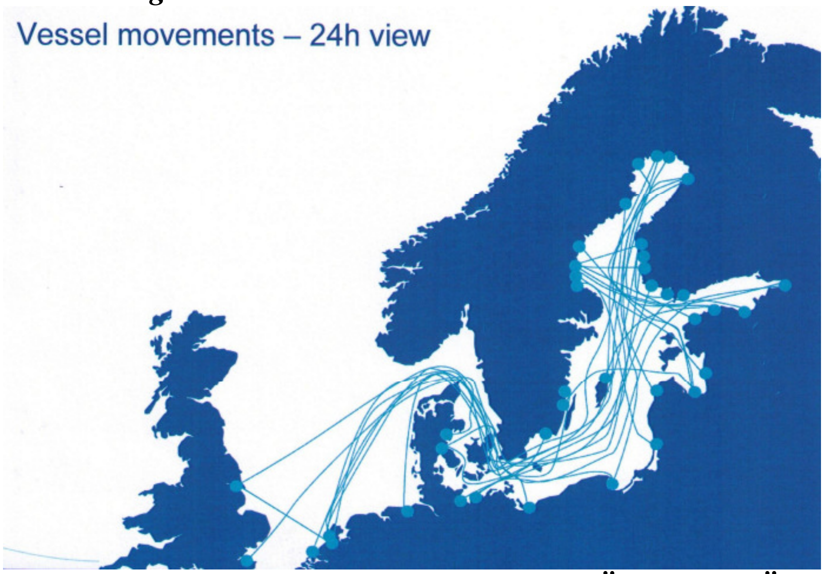
- **Vancouver to Antwerp-Rotterdam-Sweden:** 740,000 tonnes were exported by large ocean-going vessels to Europe
- **Vancouver to Japan-China-Korea:** According to UNECE Timber Section and the Canadian Pellet association, exportation of pellets started on 2008 and around 40000 tonnes has been traced until now, being a first contract with a Japanese co-firing plant.
- **St. Petersburg and Archangel to Swedish ports**: 47,000 tonnes were exported to Sweden by way of St. Petersburg
- **Finnish ports to Sweden**-Antwerp-Rotterdam: Exports from Finland peaked at 195,000 tonnes in 2006, of which 78,000, or 40%, went to Sweden.
- **Latvia-Estonia-Lithuania to EU:** In 2006 these three countries exported approximately 620,000 tonnes pellets, of which 150,000 went to Sweden.

1.1.2.2 Obstacles and barriers to shipping biomass

The actual main logistical obstacles to competitive maritime shipping biomass include:

- **World shipping demand for other products produced in low-cost countries and sent to developing market.**
  This factor should be mainly attempted the long distance transportation such as from Canada to Europe or Australia to China, and in a less weight the short distance transport such as from the Baltic to Sweden.

Figure 8: small distance routes in Baltic sea



Source: "Bio energy trade in the Baltic Sea" ÖSTERSTRÖMS

- **Reliability of biomass supply from plants,**
  One of the examples is Russia. In fact, despite its huge supply of biomass in the northwest region, some factors and events create a shortage of pellet raw material like for example the implementation of a massive tariff increase on the export of saw logs to Northern Europe that caused a reduction of 10 million m3 to sawmills around the Baltic Sea. Those events could create bankrupt of a large portion of the pellet production capacity in Estonia and Latvia.

- **Port inadequacies,**
  Actually, in many ports the upgraded facilities needed to keep costs down and make long-distance trade possible are lacking.
  We can make the example of Vancouver, which is a major port that recently added the new pellet terminal to complement the existing one.
  This new terminal has advanced systems for removing pellet dust in loading, but does not have a movable shipper-loader, so the ship must move to even the load.
  The old one added wood pellet handling to its business in 2005 and over 3 years constructed pellet storage silos, installed tripper-style conveyors with a full length enclosure, and modified the ship loader to allow more effective delivery of pellets to vessels.
  However, many issues can be treated in order to improve the transportation like.
    - Increase the trail system capacity. Pellets sometimes wait days to get into the terminal
    - Grain cars are used to transport pellets without being adapted for it. Therefore the volume is not used in its full capacity increasing the transportation costs.
    - Vancouver is a rainy city that is avoiding and slowing down the load,
    - When conveyors break down ships will often not wait, even for minor repair
    - There is often a lack of necessary communication between ships and loading staff

Figure 9: Example of load and transport in Vessels

Source: EUBIONET

Figure 10: Heavy conveyor at the harbour for loading straw pellets into ships.

Source: EUBIONET

Furthermore, some of the ports that serve the power companies cannot handle Panamax ships, and smaller ships will mean higher cost delivered pellets. Only a few utilities in Europe can be directly served by Panamax ships.

Figure 11: biomass logistic terminal of Amer power plant in Netherlands. Unloading equipment

Source: task 40

Figure 12: Hopper used by unloading ships for pellets and coal at the power plant

Source: EUBIONET

- **lack of back-haul**
  Competitive shipping rates often depend on shipping companies arranging 2-way flow of products. This is often impossible and ships return empty, thus placing the costs of a 2-way trip on one cargo.

- **Characteristics of the shipping business**
  The shipping business does not always lend itself well to optimized biomass transport. Despite the best estimates of arrival times, there are many factors, such as heavy weather or late departures from previous ports that play havoc with loading and shipping schedules. Despite an era of computerized manufacturing optimisation programs, shipping remains largely a manual business.
  Shipping tends to have a floor price, below which it is more profitable to scrap an old ship than keep it running, thus reducing shipping capacity. For example, the shipping cost for pellets Vancouver-Rotterdam has fallen from $100/tonne to $35/tonne. The floor price for scrapping, not including fuel and staffing cost is $21US/tonne.

- **Characteristics of pellets requiring specialty shipping.**
  Due to the fact that pellets are less dense than other commodities, Panamax ships, designed for transport of heavy goods, are not able to take a full load of pellets as it affects ship handling. For this reason, all the holds cannot be filled with pellets but it's preferred to leave at least 1/3 or half of the capacity of the ship to be filled with heavy products. The remaining pellets must wait for the next ship. Therefore the number of panamax ship is higher than the sum of their real volume capacity and increase the cost. In general special ships designed for grain and pellets do not pose this problem.

To improve the viability of trade routes to far-flung biomass sources will take major investment in ports and biomass conversion plants. Investing in ports to reduce costs is risky, unless large volumes of biomass supply are assured. Similarly investing in biomass production that must be shipped through old, inefficient ports is also risky. Something must be done to reduce those risks to enable efficient, low-cost production and transport of biomass. Options to do this include;

- Manufacturing purpose-built ships for products like pellets, bio-oil, wood chips etc
- Forming consortiums of biomass shippers
- Promoting long-term maritime shipping contracts now that shipping costs are low

- Developing “Biomass investment funds” to modernize and enhance ports and port facilities in areas of high biomass potential, supported by guarantees of volume purchases and contracted prices

1.1.2.3 Example of wood pellets transportation from Canada

In Canada, wood pellets are actually produced from saw mill residues and “standing dead wood”. The Pellet production in North America is estimated to around 2.6 Tonnes from which 1,4 Tonnes in Canada. The Canadian’s exceeding production is exported to Europe which main consumers are Netherlands and Belgium. It is planned that the European increasing consumption will be covered primarily by the increased production in Canada.

The main pellet supply chain is described here below:

- The wood residues from dead wood are transported by truck to the pellet mill at a distance of 50-75 kilometres. The biomass is cut into pellets, which are screened for size, cooled and subsequently stored and transported to ports for export.

- The pellets plants are located primarily close to the largest part of Canadian forest industry (in the same province).

- The transport is primarily by railway in British Columbia, but may also be by truck in the Eastern provinces.

- The converted products are first transported by relatively large trucks from the conversion plants to harbours at either Montreal or Quebec City.

- The average transport distance is 220 km. From these harbours, the pellets are transported by relatively large vessel (25 000 dwt), to Rotterdam harbour.

- Transport to export port and ship loading amount to another €35 tonne and sea shipping by bulk carrier to Rotterdam will cost approximately €25/tonne, bringing total Rotterdam CIF price to €140/tonne. Scandinavian CIF tariffs are slightly higher because of the longer transportation distance. In land prices are also higher because the inland transportation is higher. Prices known for Dutch power companies match well with the evaluation of €140/tonne

1.2 Delivery To End User

1.2.1 Pellet distribution systems

By their form, pellets are a pourable fuel which can be transported just like a liquid, such as oil: pellets can be supplied by tank lorry and pumped into the pellet tank by means of a fuel hose. Then, from the fuel tank, they can be automatically fed to a combustion unit by screw or piston charging. Precautions have to be taken against dust production and crushing of pellets during filling procedure.

Pellets are distributed by manufacturers and local retailers. Either pellet manufacturers have established a transport and distribution system on their own with direct sales to the end consumer or they work together with local fuel or forage retailers.

Manufacturers and retailers have been trying to establish comprehensive pellet supply networks, but there is still a lot of work to do because there are few regions with an efficient local pellet market.

As already mentioned before, road transport of pellets over long distances is not very economical, so pellet manufacturers and suppliers try to establish local markets and co-operate with the local wood and timber industries.

Traditional fuel retailers are tending to phase out wood fuels in favour of fossil fuels.

Today their main economic basis is oil products. So far only a few companies have engaged in transport and delivery of fuel pellets. One task for the future will be to motivate fuel retailers to supply wood pellets too.

Pellets are distributed in the following ways:

- **Small bags** (15- 25 kg, sold and delivered on pallets of 800 kg or as single bags).

This kind of package is appropriate for minimal pellet consumption, e.g. when pellet stoves are used only as auxiliary heating. Consumers buy the pellets in household goods stores, filling stations or agricultural supply stores and transport them to their homes on their own. The advantage of pellets sale in sacks is that the amount of fines in the fuel is very low provided that the sacks are handled properly and the pellets are protected against wetness. However, pellet prices in this package form are much higher than purchase of loose pellets.

- **Big bags** (with 1 to 1.5 m³ content). Most manufacturers also offer pellets in this way.

Big bags have to be moved by stacker track, tractor front-loader or crane, which is inconvenient, especially for transport to the end consumer, so this transport form is used mostly for transport of pellets to retailers.

- **Bulk material (**delivered in a tanker and pneumatic filling of storage bunker or silos)

This kind of delivery is becoming the main pellet distribution form in Europe. Handling is similar to fuel oil delivery and meets the convenience requirements of customers and retailers alike.

Loose pellet transport in tankers and pneumatic filling is becoming more professionally organised, but there are still several problems to be solved. Customers' storage bunkers are one of the crucial points in the delivery chain and their filling must be clean and practical. Several technologies with different air volumes and pneumatic pressures are to be tested. Filling couplings in the wall of the storage bunker have to be standardised (at present fire brigade type A couplings are the most common ones). Precautions have to be taken against dust production and crushing of pellets during filling procedure.

Different logistic systems predominate in different countries and regions. In the United States sales in small bags are the most common (mostly fired in stoves). In Norway and Sweden sale in bags is also very common but the delivery in tankers is on the increase. In Austria pellets were originally sold packed and this is still the most common form for stoves. Tankers have also been used and these are now gaining in popularity. As central heating with pellets becomes more common the delivery of loose pellets is on the increase because fuel demand is much higher.

The logistics of wood pellets – distribution, transport and delivery and to some extent storage of pellets at customers' home – is one of the most sensitive areas in the marketing of wood pellets at the moment. Areas where improvements could be made include costs, quality and customer convenience.

The actual wood pellets distribution system is growing. Fuel is normally supplied by specialist suppliers mostly dealing with fossil fuels or feed retailers, most of which are small businesses. For a nationwide distribution system to be established, these businesses need to be motivated, involved and trained to handle pellets.

For example, in Austria an efficient distribution network has been established, with pellets usually delivered loose by a special pellet truck. In the early stages of market development, some boiler manufacturers guaranteed a pellets supply at a fixed price which helped to overcome initial doubts about the security of supply. In Germany, The German wood energy centre Olsberg (HEZ) in North Rhine-Wetsphalia produces and delivers its own wood pellets, called Powerpellets. HEZ is a consortium of forest owners, saw mills, one pellet boiler company and the city Olsberg. Their wood pellets are delivered from stock to households ion 15kg bags, big bags (1 t) or by tank lorries. The delivery area includes the immediate vicinity as well as other parts of North Rhine-Wetsphalia, Lower Saxony and Hesse. On the contrary, Westerwalder Holzpellets GmbH only produces pellets and does not own silo vehicles. Numerous partners' distributors, mostly regional traders of different solid biofuels, take on delivery to households in their respective area.

This delivery and supply issues are very important for market development. In fact, in order to secure the loyalty of the consumer and make this fuel reliable, the consumer need to have confidence that a pellet supply, of consistent quality, is ensured in the long term and also need to know how to find a pellet distributor. Otherwise the risk is that they will choose other type of fuel.

In the case of delivery of bulk pellets, several weighing systems are used to monitor the amount of pellets sold. The most common system is to weigh the tanker on a weigh bridge before and after filling of the tank chambers. This is time-consuming and customers do not have direct control over amount of pellets they have bought. A better system is an on-board weighing system installed in the tanker that immediately measures the amount of loaded or unloaded pellets. The problem is that investment costs for this system are higher.

In general price can be calculated per total weight as moisture content is low and uniform because of European pellet standards.
Bulk delivery of pellets is very similar to a delivery of home heating oil and is carried out by the lorry driver blowing the pellets into the storage space, while a suction pump takes away any dust. Storage solutions include underground tanks, container units, silos or storage within the boiler room. Wood pellets do not degrade over time, as long as they are stored in dry conditions.

Wood pellets are available from a number of suppliers and producers and ordering is as simple and convenient as ordering oil or other fuel. Wood pellets can be ordered online from some suppliers. Pellets are although compact, uniform in size, easy to store and handle and are used for fully automatic heating in pellet boilers or stoves. Modern pellet heating appliances offer a high level of comfort.
Pellets have a higher calorific value than wood chips: on average 2-2.5 tonnes of wood pellets will displace approximately 1000 litres of home heating oil that is representing around half the cost of oil.

1.2.2 Distribution of pellets by Bags

The pellets delivered by bags are mainly used for small consumers. In fact, because of the difficulty to be handled, medium and large consumer prefers bulk pellet and automatic feeding of stoves.

The bagging process is composed of 3 steps
- The bag is filled, weighted and welded
- The bags are placed on a pallet
- The pallet is enclosed in plastic

The bags are generally distributed depending on the following characteristics
- 42 pallets/vehicle
- Min. 4 pallets/delivery
- 832 kg/pallet
- Crane lorries unload the pallets within a radius of 8 meters

The Crane is useful and can be used in almost all situations because of:
- Long reach (8 meters);
- Outstanding precision
- State of the road not crucial (slipperiness, snow, rough road)
- Possible to unload irrespective of obstacles (e.g. hedges, flower beds)
- No damages to the customer's garden

The main problem is that it's not possible to place pallets under roof (e.g. in garages) and therefore need further manual handling.

Figure 13: Illustration of bags' pellet delivery

Source: SÅBI

1.2.3 Distribution of bulk pellets

Pellets can be assimilated for handling to heavy fuel – oil (it can be transferred pneumatically by pressurised air). Therefore for transport and refuelling special standard containers or tank lorries cisterns as shown in figures below can be utilised.

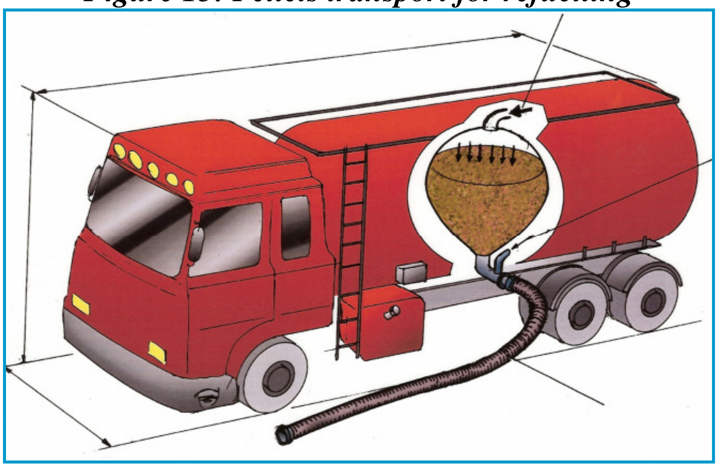
The bulk pellets are mainly distributed by truck with the following characteristics

- 38 metric tonnes/vehicle
- Min. 3 metric tonnes/delivery
- Precise weighing on every delivery
- The customer receives a bill of weight

Figure 14: example of bulk delivery in household

Source: SÅBI

Figure 15: Pellets transport for refuelling



Source: EUBIA

1.2.4 Main cost of Pellets Delivery

As already explained before, the pellets' cost is different according to the way to deliver it. In fact bulk should be preferred to bags because in large volume pellets cost is decreasing see Figure 16.

Figure 16: Example of prices for different kind of pellet delivery

Pellets delivery	Small bag (20kg)	Big bag (600kg)	Bulk (> 3 tonne)
Average Price	Price € 230 per tonne incl. vat.	Price € 210 per tonne incl. vat.	Price € 180 per tonne incl. vat.

Source: EUBIA

1.3 Transport Barriers to be solved for market development

The general problem for biomass is its variety in physical and chemical properties. These properties make it difficult and expensive to transport. Actually, the final density per cubic meter is still far less than e.g. oil given the nature if biomass, also for pellets. Pyrolysis or torrefaction may be a possible pre-treatment option, but still needs to be proven on a commercial scale.

When setting up biomass fuel supply chains, for large-scale biomass systems, logistics are a pivotal part in the system. Various studies have shown that long distance international transport by ship is feasible in terms of energy use and transportation costs but availability of suitable vessels and meteorological conditions need to be considered.

However, local transportation by truck, in exporting and importing countries, may be a high cost factor, which can influence the overall energy balance and total biomass costs. Harbour and terminal suitability to handle large biomass streams can also hinder the import and export of biomass to certain regions. The most favourable situation is when the end user has the facility close to the harbour avoiding additional transport by trucks.

The lack of significant volumes of biomass can also hamper logistics. In order to achieve low costs, large volumes need to be shipped on a more regular basis. Only if this can be assured, there will be forthcoming investment on the supply side (pellets manufactory) at this will reduce costs significantly. The bulky nature of biomass fuels and relatively low per unit would restrict availability of suitable areas for handling of these fuels in busy ports. On the other hand, this bulky nature in combination with high demand for specific biomass streams means that the present capacity (storage, handling equipment, etc.) of some harbours (Stockholm…) is fully utilized. A further increase in biomass handling would require specific investment. For this reason pellet seems the more interesting biomass treatment because should limit this need of investment.

Areas where improvements could be made include costs, quality and customer convenience. Here below are listed the main barriers and issues to be considered in order to improve the development of pellet's market.

- **Transport systems for long distance**

The necessity to transport the biomass and in particular pellets, is strictly linked to the distance between the production area and the utilization area, distance that can be remarkable if the residues are not use in the same factory, as often is the case of pellets. The transport is usually done by lorry with trailer or by articulated lorry, and the costs for the transport are strictly dependent with the distance to run and with the dimensions and the mass of the biomass transported.

- **Pellets' handling in the supply chain**

Usually loose pellets are transported from the manufacturer to the retailer's storage and then to the customer in tankers. Unloading and filling of storage silos or bunkers cause strong mechanical abrasion to pellets, which can result in large amounts of dust. Transport in tankers and pneumatic loading and unloading is best for bulk goods and was first used for transport of forage or grain, which are more compact than pellets. For pellets made of sawdust (single particles) high air pressure, air flow and velocity of pellets during pneumatic filling of storage containers or bunkers may crush the pellets and result in large amounts of fines. The development of more gentle loading and unloading technologies could help to solve the dust problem with pellet fuels.

This problem can be solved by informing lorry drivers about the correct handling of pellets and about pressures and flow rates suitable for the distribution of wood pellets. Another alternative is to employ a lorry equipped especially for the distribution of wood pellets.
Few tankers are equipped with onboard weighing systems (especially in Austria and Germany, less so in Sweden). Without these onboard weighing systems a weigh bridge has to be used with each individual order in a separate tank chamber and re-weighing of surplus pellets, if too many have been ordered, for example. Moreover customers have no real control over the quantity of delivered pellets.

- **Coordinate fuel and resource flows**

Building up and cataloguing networks of raw biomass suppliers has several advantages that allow the introduction of pellets as a mainstream fuel. The principal is to create “agents” that are able to increase market communication between (potential) pellets producers and (potential) consumers. This has several advantages namely:

- Shortening pellet delivery distances
- Security of fuel supply and demand

These advantages are described in more detail below.

- <u>Shortening pellet delivery distances</u>

The awareness of actual and potential pellet sources allows an efficient response to consumer demand for pellets. The nearest available pellet production capacity can be identified and exploited. This reduces transport distances and as a consequence fuel cost for the consumer.
The creation of a pellets supplier network strengthens the optimisation of transport distances and encourages the development of two aspects essential to a growing pellet market:

- A change in mentality from producing pellets in areas of potential demand, to creating pellets demand (power and heat plants) near raw material sources
- A dynamic market, trading in pellets supply guarantees, futures and other supply and risk management products

- <u>Security of fuel supply and demand</u>

The second direct consequence of a strong supply network is an elevated security of supply that can be backed up by supply guarantees. These supply guarantees are an essential product for the development of pellets-based power plants (especially in the higher capacity range), that could be provided by a pellets logistics agent.
Such pellets logistics agents are not a completely new concept. Of course, such networks exist in countries with developed pellets markets such as Austria. The innovations that need to be proposed now are twofold:

- To shift the emphasis from pellets consumer networks to pellets producer networks in an environment where large-scale pellets applications dominate. In the domestic consumer market a few pelletising plants produce fuel for many consumers. In the case of industrial-scale pellets consumption, numerous pelletising plants produce for a few pellets consumers.
- To move from a market dominated by a single standardised wood pellet product, to one with two product lines: standard pellets and ‘industrial’ pellets. Industrial pellets are produced for larger scale applications and can be of lower quality and from different raw materials, depending on the boiler in which they are to be used.

2 STORAGE MANAGEMENT

The physical and chemical properties of pellets make storage easier than the other biomasses. In fact the energy density makes the volume need smaller and the low moisture content avoid problems of quality evolution and make the characteristics of the pellets stored stable in the time.

In general, pellets aimed at the household market are mainly packed in small (15 Kg to 25 Kg) and larges bags (500-1000 Kg), whereas products aimed at district or central heating plants are transported and stored in bulks. The storage period for finished products is often long, due to the fact that pellets are a seasonal product and that the demand for pellets has been low.

The pellets should be stored in a dry space to prevent them from coning into contact with water and waterdrops. Rain or condense water, snow or moisture rising through the floor of the storeroom swell the wood pellets quickly and disintegrate them into sawdust. Moisture problems should also be considered when organising transports.
Storage of bulk pellets in households is generally organised the most commonly in closed rooms and silos. Pellets can also be seldom stored outdoors under fly roofs. Precautions should be taken against mixing pellets with other stored wood fuel (wood chips). If wood chips are mixed with pellets severe problems may be experienced during pneumatic filling, conveying and combustion.

The surface to dedicate to the storage must be planned with attention, because it can be very extensive. The extension depends from the mass of a volume unit and from the way of piling up the bales; in its turn these parameter are in relation with the biomass moisture.
In order to measure the volume needed for pellets storage, we should consider the following criteria:

- The annual energy needs
- the pellet bulk density
- The number of refill cycles.
- The duration of winter for locations with difficulty of access

We can characterise and define the pellets units in 4 categories:

- Households Stoves: 2-15kW
    - Common in houses with electrical radiators;
    - Air borne or water borne heat
- Small scale pellet units: :10-40Kw
- Mid scale pellet units: 50-300kW
    - SME´s, schools, dwellings etc.
- Large scale pellet units :Load range 1 to 25MW

According to those different scales, the storage has to be adapted to the need. For this reason we can define almost the same categories of storage:

- Small scale
    - Weekly storage
    - Indoor/outdoor silo for bulk
- Mid scale and Large scale
    - Outdoor silo

In the following points, each category will be presented and developed.

2.1 Storage At Power Plant And Pellet Manufacturer

2.1.1 Main issues regarding storage

To store the residue material (like branches and wood) is not usually a difficult operation. In fact, since much time, the cut wood is often left piled on the ground of forest road for some months.
The pellets' storage has to be a bit more structured but remains quite easy. The main issues to be considered for definition of storage are listed here below.

- Pellets used for heating plant must have a low content of moisture to produce a higher amount of energy (the Heating Value is closely connected with this content). For this reason it is necessary to store it in a dried area without risk of degradation by infiltration of water or humidity.
- The second reason is connected with the necessity of storing up the pellets. The continuity of supply must be guaranteed to pledge the heating (forest works are seasonal works).

There are some different possibilities of pellets storage depending on the situations, on the different typologies of territories and on residues distribution in the territory. For example we can have:

- <u>A storage place (stock office) close to the forest.</u>

This methodology can bring some advantages and some disadvantages. One advantage is that the materials can be stored in the same place they have been pelletised and very near to the forests, thus in theory the costs, especially for transport, could be reduced. But in this way the users, in the most of cases, have to reach the stock office, which is located not so far from forest, but usually far from the using place, thus the costs still high cause to the transportation of pellets to the users.

- <u>A storage place (stock office) in a forest company.</u>

In this method the case of a private company, which harvests residues to produce pellets is considered. In fact a company could collect residues and bring them to the company buildings and here pellets them. Once the material is pelletised, the company could store it directly in its own storage place and sell it. The costs are reduced for the users staying not very far from the company's buildings and usually the cost is convenient within a distance of about 50 km.

- <u>A storage place (stock office) close to the user's buildings.</u>

This can be the case of a big heating plant or of a family company. For example:

- A big heating plant could buy pellets material and stores it.
- A family company could produce pellets and use them for self-consumption. In some cases the company could decide to sell the surplus to other users. Another possibility is that the company does not produce pellets, but it buys it from producer and then store up pellets in the company buildings.
- A stock office could be located next to the users to support them for the supplying. In fact in this case users could easily buy pellets with no high costs for transportation.

2.1.2 Storage characteristics

The main types of storage at power plant and retailers are:

- closed halls
- silos
- fly roof

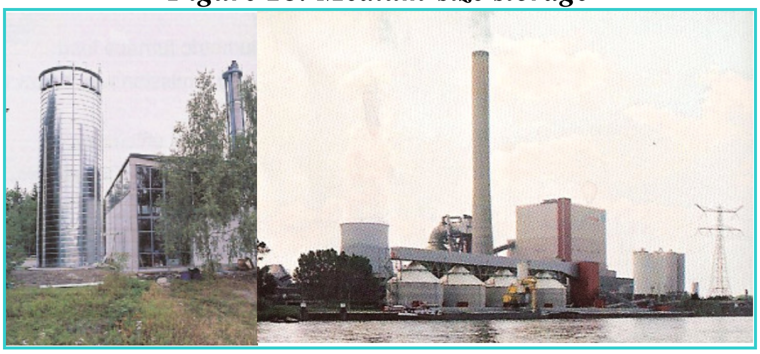
Storage in closed rooms and silos is the most common, and pellets are seldom stored outdoors under fly roofs. Pellets should be stored in closed halls or silos so as to protect against moisture and maintain quality.

Precautions should be taken against mixing pellets with other stored wood fuel (i.e. chips). If chips are mixed with pellets severe problems may be experienced during pneumatic filling, conveying and combustion.

Figure 17: Example of Large removable Storage Halls (30 m wideness)

Source: EUBIA

Figure 18: Medium-size storage



Source: EUBIA

2.2 Storage At The Harbour

The supply of large amount of Pellets for energy application of any type is relaying also on international trading among continents due to the necessity to guarantee continuous supply and functioning of large utilisation/conversion plants located in places where pellets production is actually not enough.

For example, high-level of biomass cofiring in coal power plants or future BTL conversion plants will require very high volume of Pellets (0.5 million ton/y up to 2 million ton/y) Therefore international trading could compensate lack of local supply all the year around.

As explained previously, international trade is supplied mainly by maritime shipping. Therefore, port appears as an important link in the transport chain, offering strong interfaces to other modes of transport services and good connections to the hinterland.
Ports offer equipment for loading and unloading of cargo and storage for goods. The infrastructure of ports and the logistics management of ports are crucial to the efficiency of loading and unloading and therefore to the costs of shipping.

2.2.1 logistics and port efficiency

Port efficiency varies widely from place to place. Some Asian countries (Singapore, Hong Kong) have the most efficient ports in the world, while some of the most inefficient are located in Africa and South America. Port efficiency is a crucial issue for the future development of international pellet market.

The efficiency strongly depends on the point of origin. In rural regions where the infrastructure for transport often is poorly developed biomass-loading ports are often local ports with low processing capacity.

In the case of pellets processing plants situated close to industrial areas such as in Canada, shipping efficiency benefits from the existing distribution infrastructure.
Top ports have to offer a high availability and range of traffic (rail, road, inland waterway, transhipment,…). They are generally operational 24 hours a day, seven days a week and have to offer a comprehensive range of facilities for handling and storage. The well known ports are Singapore, Hamburg and Rotterdam. High operating costs of these ports can possibly be fully compensated by a high availability and reliability of dedicated services.

2.2.2 Storage and ports relevancy

Also storage capacity is a main issue to be considered for the ports which want to be relevant in pellets supply chain. In fact, great storage's difficulty can be expected especially at the port of arrival due to the:

- Large volume to be discharged and stored;
- Limitations for pneumatic fast dispatching long distance (km),
- High renting cost of space/volume into the port.

For example, taking in consideration the situation of one of the largest world terminal like Rotterdam (total capacity of 400,000 m3 of tanks space), is that the dispatching of large volume of Pellets generates considerable infrastructure problems similarly to the present coal supply.

2.2.3 Requirements for loading/unloading – cargo handling equipment

The equipment for loading and unloading ships may be provided by private interests or public bodies. Generally the loading and unloading of dry bulk cargoes, such as pellets, are suited for high-tech mechanized and computerized handling. In the best case the type of cargo-handling equipment that is used is adaptable to the cargo. In practice it will strongly depend on the average volume of trade of a certain type of cargo in the respective port.

All-purpose equipment for loading and unloading of dry bulk cargoes are cranes and grabs. Bulk material can be loaded into large hoppers that are fixed to high capacity travelling cranes to feed railway wagons, trucks or conveyor belts. Some ports offer pneumatic handling equipment. The processing capacity of this equipment ranges from 10 to 2000 metric tons per hour.

2.3 Storage At The Household

2.3.1 General appreciation of small scale storage of pellets at the end user

Pellets require about 0,6-0,7 kg to be added every day, although there is a lot of variation on this. Some homes require the fuel to be added more frequently, especially during cold spells. Other homes might stay comfortable with the fuel being added every 36 hours or so.

Pellet usually has a moisture content level of approx 5-10%. This is compared to normal fire wood which usually has a moisture content of approx 20%. Pellets tend to loose their effectiveness and crumble and thus become unusable if they are exposed to moisture or damp surfaces therefore it's essential that the wood pellet must remain dry for the entire storage cycle.

The best solution for a Wood Pellet Boiler or Stove is to install a Pellet Storage Unit. This is because the wood pellet is far cheaper when bough loose in bulk and the pellet storage unit can either be built either outside the house or inside. The pellets will then be transported to the boiler by an automatic feed system. This feed system usually uses a screw type auger feed mechanism which feeds fresh pellets into the stove all the time.
Some manufactures have designed and manufactured equipment to fit in well in the home with the burner sometimes integrated into the existing fireplace and the other components blending in well with the rest of the home.
Filling the wood pellet storage container is typically done just once a day; this is much less labour intensive compared to typical solid fuel appliances in the home which typically have to be cleaned out and then reloaded daily.

2.3.2 Characteristics of storage

Depending on the amount of pellets, closed storage bunkers or silos are the most appropriate storage facilities. In Austria and Germany silos are quite scarce whereas in Sweden they are more common, especially with bigger combustion units and heating plants.
The ideal storage system will depend on the building preconditions.
A typical domestic scale wood pellet boiler uses 10m3 or 6,4 tonnes per year. Pellet stoves may use far less.

Generally a silo is the best way to store fuel pellets (moisture protection, continuous sliding of the pellets towards the conveyer system, less dust production) but a silo might be taller than the local building regulations allow. It could also be installed outdoors, in which case aesthetic considerations come into play (e.g. integration of the silo into the building, panelling).

For single-family houses special storage bunkers in the cellar near the boiler room are the most common form of storage.
Storage bunkers in private houses have to comply with several requirements. The most important are:

- National or regional fire-protection regulations must be observed.
- Size of storage area: fuel quantity for at least one or one and a half heating periods should be storable. The extent to which a room can be filled depends on the shape of the room and the position of filling couplings (height).
- Inclining floor (45 degrees) can help to allow maximum and easy emptying of storage bunker as pellets continuously slide towards the conveyer system.
- Filling couplings and pipes should be made of metal (to prevent electrostatic charge).

- The door should be able to withstand the pressure of pellets.
- The room should be dry and insulated (with no condensed water on the outside walls).
- The whole room (including the door) should be sealed against dust.

Key considerations for storage of wood pellets are:

- Whether pellets are available in bags or in bulk (usually a tanker)
- Wood pellets may be supplied from further away than the other wood fuels so bulk deliveries may reduce costs and the user may wish to design the fuel store to handle bulk deliveries
- Pellets are dry and free flowing and can be blown or sucked into a fuel store providing the equipment is available
- Dust may accumulate in bulk stores-creating a health and safety hazard.

Some of the different options for pellet storage are presented below:

- Wood pellets can be delivered in bags. These are usually 15-25 kg, or large bulk bags (1t) and are convenient for stoves and boilers with integral hoppers which are manually filled. Buying pellets in bags is normally more expensive.
- Partition walls can be made "pellet bearing" and the fuel store constructed in-situ. The walls will need careful designing to ensure they are able to bear the weight of the pellets.
- A flexible pre-fabricated silo can be installed within a fireproof enclosure. The fabric material is air permeable but dustproof. The pre-fabricated silo can be constructed quickly and easily once the fire proof walls have been constructed.

Whichever choice of storage configuration is made, there are certain design requirement s of the pellet store:

- Fire protection regulations must be observed. Some local authorities may require the wall between the pellet store and the boiler to be fire proofed.
- Walls and supporting parts must be constructed in such a way that they will bear the corresponding static loads.
- A sloped floor (35-45 degrees) can help to allow maximum and easy emptying of the storage room as pellets continuously slide towards the conveyor system.
- There must be an opening of at least 400 mm diameter, able to withstand the weight of pellets.
- Two metal nozzles for delivering the fuel and removing the venting air must be installed at a distance of 50 cm. If possible, the storage room should have one external wall, which holds the nozzles. Standardized coupling with special screw tops are required for the connection to the rank lorry.
- The storage room should be rectangular and the filler and extraction nozzles should be located at one of the narrow sides.
- A deflecting mat opposite the nozzles should prevent damage to the pellets during the filling process.

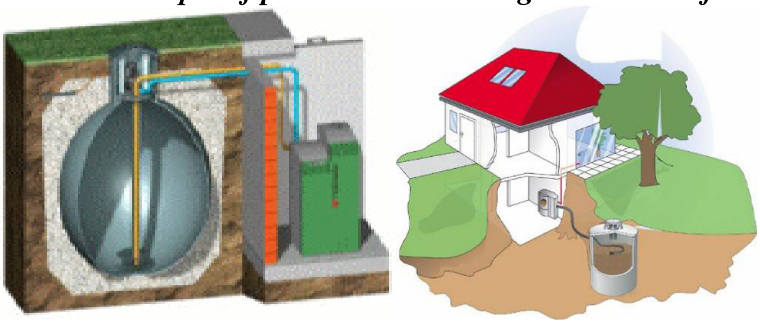
Figure 19: Example of pellet storage with direct feeding

Source: WINDHAGER

Figure 20: Example of pellet storage with indirect feeding

Source: Heutz Premium Pellet Systems

Figure 21: Example of pellet outdoor storage with direct feeding



Source: HDG ***Source: MALL***

With its unique suction feed the pellets can be transported from storage room independent of the heating room. This system completely empties storage room and is maintenance free. Bulk storage of pellets is considerably cheaper to buy and would be recommended for people looking to make big savings on energy bills.

In case of use of pellets bags, a good quantity of pellets will be stored somewhere for convenience sake and no particular characteristic for storage are needed, juts choosing a dry place. In general, at least a week's worth of Wood Pellets is stored close to where it's used.

2.3.3 Storage Volume calculation

In general, according to energy needs and logistic constraints, the pellets storage proposed are around 2 m3 (1,45 m tall and 1,20 square) to 20 m3.

The basis for calculation is presented here below.

- Per kW heating load = 0,9 m3 storage space (including empty space)
- 1 m3 pellets = 650 Kg
- Useable storage space = 2/3 of the storage space
- Energy content = 5 kWh/kg or 18 MJ/Kg

Example:

A single family house with a heating load of 15KW = 5800 kg wood pellets/year
15 kW heating load x 0,9 m3/kW = 13,5 m3 storage space (incl. empty space)
Useable storage space volume = 13,5 m3 x 2/3 = 9m3
Amount of pellets = 9 m3 x 650 kg/m3 = 5850 kg ~ 6 t
Size of pellet store = 13,5 m3 : 2,4m (heig of room) = 5,6m2 storage room surface (2x3 minimum)
Stored energy amount = 5850 kg x 5 kWh/kg = 29250 kWh (equals about 3000 litre fuel oil)

2.3.4 Example of pellet storage at end user

One of the main problems related to pellet supply to the heating plant could be the difficulty to reach the plant during the winter season mainly in forest and mountains zones due to meteorological events.
In this case, it is necessary to size the pellets storage in order to allow the widest pellet backup. On the other hand the maximum pellet storage dimension should be limited by the space available and the costs.
For this reason, in order to maximise the pellets storage volume the ground level of the heating plant room should be built at a lower level in comparison with the ground level of the storage (50~80cm difference in height), in order to allow a better storage/plant coupling; a charging slide could be foreseen in order to make the most of the available space, thus allowing a partial recovery of storage volume; makingthe storage access at trampling level through a trapdoor.

The main building work cost headings for adaptation to of the location to the projected heating plant and pellets storage rooms can be summarised in the following:

- room extension works;
- breaking ground to increase internal height;
- pulling down part of the existing building;
- new vertical walls building (fire proof);
- ground floor support building;
- bearing walls and ceiling construction;
- operating devices intervention;
- debris discharge
- door and windows frames realization;
- manpower.

2.4 Conclusion on storage

Storage requires a relatively large dry space, which may be problematic especially at refitting sites. The distance of the store from the combustion equipment should be also restricted.
Especially in the one-family houses, poorly erected stores may result in problems. The greatest ones are due to poor tightening or poor filtering of out flowing air during filling, when a lot of dust is spread to the environment during filling.

Technical requirements set by pellet use on the feed equipment are much smaller than when burning wood chips. The pellets flow onto the feed screw easily and are also easier to feed and dose to the combustion equipment than the wood chips. However, especially the fines may cause problems in the feed of pellets.

The technical solutions suggested to overcome the barriers occurring at the storage stage are relatively easy to be solved from a technical point of view, and it is the investment cost for the changes to be made that is decisive for the end user like power plant operator. Some of the main barriers for this field are given below:

- Limited space and equipment for pre-processing of the received biomass. Storage of e.g. wood biomass requires better design of the power station.
- During the receiving and handling of the biomass – and depending on the source of biomass- the appearance of dust might cause occupational health problems. Therefore, the handling in closed and overpressure ventilated cabins, or the indoor receiving of pellets is recommended. Health precautions for the personnel should be taken. Non-professional installation of storage bunkers, inefficient sealing and incorrectly fitted filling couplings may cause problems through too much dust during filling. Dust may also be caused by inefficient filtering of the outgoing air by a dust collector during the pressurised filling of the storage bunker.
- Blocking of the feeders is also a potential hazard for malfunction, therefore the use of reliable feeders and experimentation with several feeding points and different feeding rates to find the optimum is needed.

The above mentioned barriers vary substantially between different operation in different power plants, depending on the combustion technology used and the co-combustion method. It can be commented that in most cases these barriers are relatively easy to handle and the additional investments required are not alarmingly high.

3 PELLET SUPPLY CHAIN AND SUSTAINABILITY

In this report it seems interesting also to give some words about the sustainability evaluation of the pellet supply chain.

In fact according to the framework of climate changes and the development if bioenergy production, pellets seems to be one of the main interesting way to save carbon dioxide emission. But in order that Pellets produce the more efficient carbon saving system, it seems important to have a good overview of the overall supply chain and evaluate its sustainability in order to improve the eventual weak points.

Most of the activities that will be considered in this supply chain likely to be part of the weak points are part of logistic (storage, transport …).

The pellets supply chain can be defined in 4 main steps (Forest Exploitation, Sawmill/wood based industry/ pellet production/ End user like power plant).

The criteria to be considered in this kind of study are:

- Energy consumption: for production and transportation
- Sustainability of the raw material: Land use change & Overexploitation
- Socio-economic issues
- Biodiversity issues

The verification procedure of sustainability is developed according to the following steps:

- **Supplier declaration**
- **Audit of production unit by local inspector to know:**
    - The origin of wood materials
    - The evaluation of energy input evaluation the electricity consumption, heat energy consumption (biomass, cogeneration etc…) and also part of the consumption coming from fossil fuels

  all those data ate reported in a check list document.
- **Audit of Transportation:**

The transportation is evaluated following 3 main steps:
Transport scheme from raw material to finished product (location of the plants, transportation distances between each main transformation step)
For each step it is important to evaluate the average distance covered, the mean of transport used, and the specific consumptions for these distances. All those data are gathered through local verification and also asking data to the transport companies involved.

- **Reporting on regional forest sustainability:**

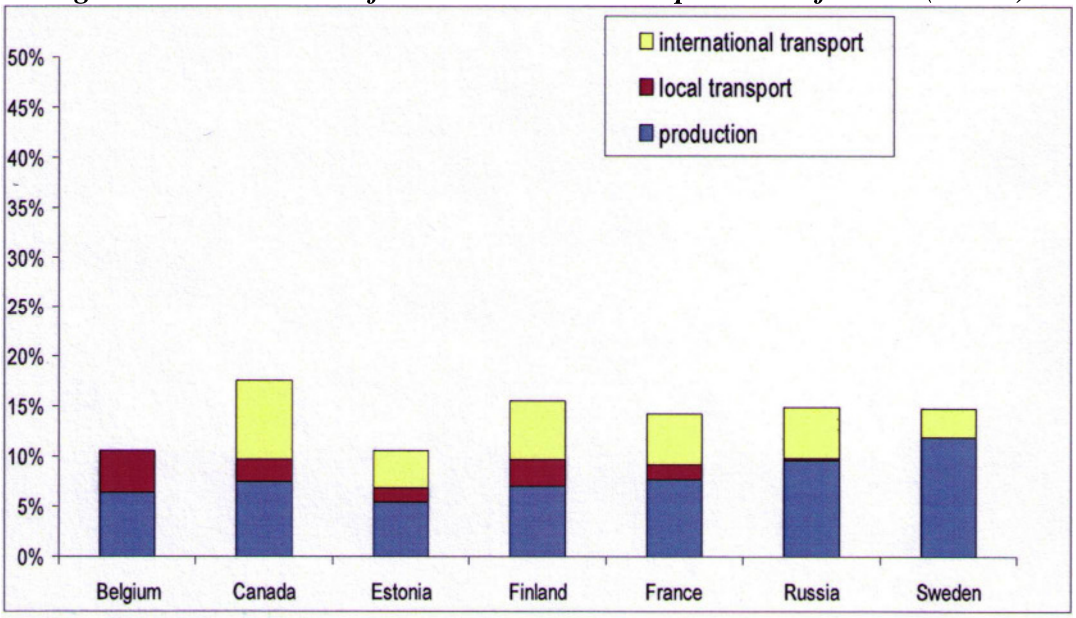
The sustainability of forest exploitation has to be done at 2 different levels:

- Assessment at the individual level (micro scale) verifying the certifications (FSC, PEFC, …)
- Assessment at the regional level (macro scale) checking regulation, management of forests, annual growth vs. annual cut, evolution of forest surfaces and certifications (FSC, PEFC,…).

- **Computation of the energy/carbon balance**

According to a previous SGS evaluation, the characterization of carbon emission of pellets in different countries is presented here below.

Figure 22: Evaluation of Carbon emission compared to reference (CCPP)



Source: SGS, February 2009

We can see that Transport is representing the main origin of carbon emission in the case that distances between production site and end-users are very long. They can even exceed the emission due to pellet production.

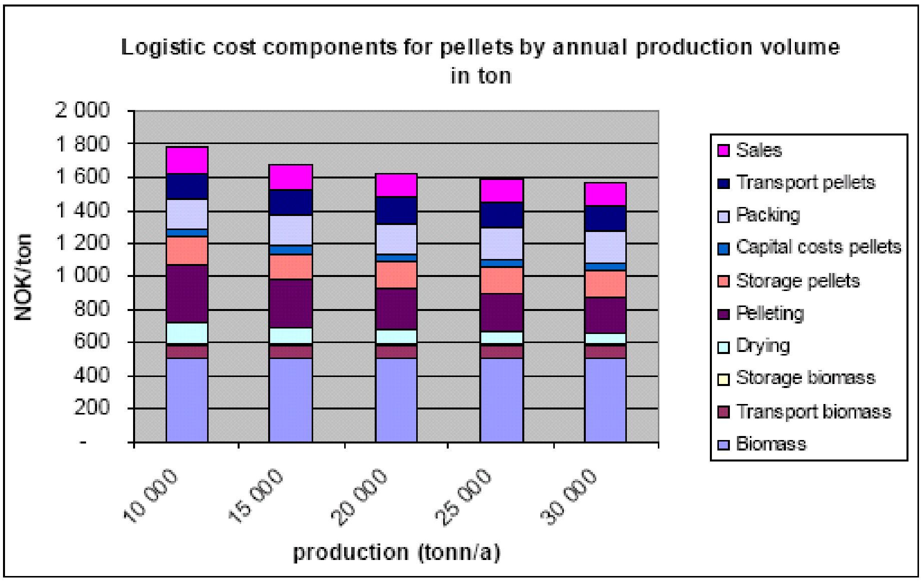
This paragraph confirms that transport, and logistic in general, is a very important issue to be considered and improved for larger development of pellets market worldwide because in parallel of the risk of low carbon emission efficiency the bad organization of the market bring about more costs and therefore more expensive prices on the market making pellet less competitive.

4 LOGISTIC AND COSTS

4.1 Overview Of Logistic Costs

The following figure show the Norvegian situation of pellets logistics costs in case of production and delivery of small scale application. The average cost of pellets delivered in small bags is around 1600 NOK/ton (around 185€).)
We can see that about 15% of the cost is due to transportation and 45 % is represented by production and storage.

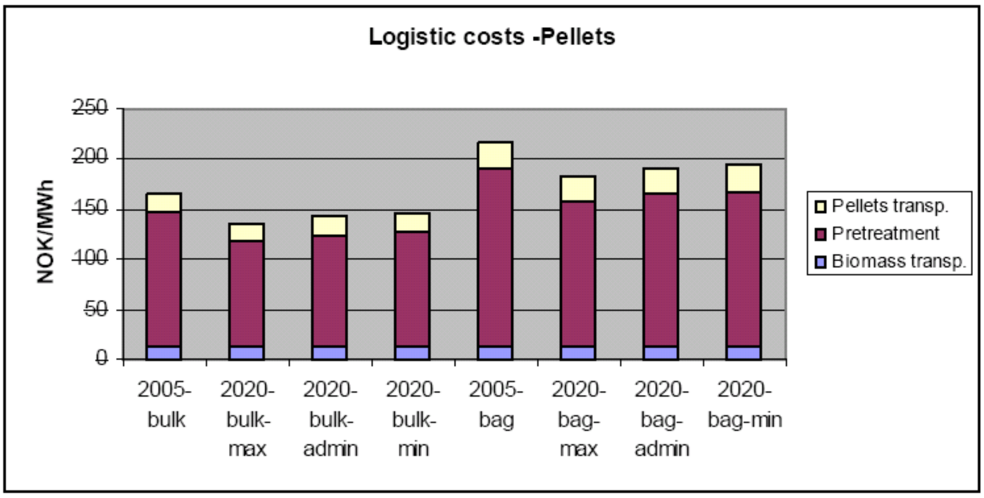
Figure 22: Pellets logistic chain cost structure, including cost for biomass



Source: Energidata AS; Transportøkonomisk Institutt and KEMA consulting

According to Norvegian situation, where pellets factory are rather small (7,5 kton/year), the logistic costs is depending on the market volume of pellets, see Fig. 23. The figure shows the average logistic costs in the area, excluding costs for raw materials and sales, for pellets delivered as bulk and for pellets in bags for 2005 and for the different scenarios in 2020. Compared with the market volume in 2005, the logistic costs in 2020 are reduced with 20-35 NOK/MWh (around 2,3-4€).

Figure 23: Logistic cost for pellets in the area, exclusive cost of biomass



Source: Energidata AS; Transportøkonomisk Institutt and KEMA consulting

4.2 Recommendations And Expectation

Logistics cost must be continuously controlled and the efficiency in the chains must be evaluated and improved. This is the responsibility of the market players. The four main approaches to increase efficiency are:

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

Efficient logistics chains are closely interlined with the organization or the structure of the bioenergy business sector. It is difficult to develop efficient chains if the sector consist of many small parties, each operating within only a small part of the chain. This might result in a logistics system which is not optimal, with too many transaction links and consequently high costs. On the other hand, too few players may lead to a lack of competition and monopoly tendencies. In order to harvest synergy effects, it is vital that the possibilities for combining bioenergy logistic chains with other chains, is looked for and exploited. This must be investigated for every element in the chains.
The authorities can hardly intervene in order to develop an efficient industry structure. This is the responsibility of the players in the market. However, the authorities ought to employ their means in a way that stimulate a wanted development. It is expected that developing of a marketplace for bioenergy will prove an important contribution to the development of efficient logistics chains.

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

The logistics chains cost structure has scale advantages for the production of wood chips and pellets. However, the scale advantages are small enough to be compensated by increased transport costs. Transport costs are highest for raw materials, so production should be situated as close to the raw materials as possible.
Location and size of a pellet production plant should be assessed with regard to local conditions in each case. A premise is that there are adequate sources of raw materials in reasonable vicinity. However, it is important to regard each production in relation to the bigger picture, in order to develop logistics systems which are efficient and robust with respect to possible market developments.

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

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

5 MAIN OVERVIEW THROUGH 3 CASES STUDY

This is essential, for customers of all sizes need to be confident with the supply of the right quantity of pellets when needed. At present, the pellet suppliers can be large, international businesses or small, local firms or farmers.

Production and Utilisation of pellets on a local or regional basis give a greater appeal of pellets' sustainability footprint. Due to the fact that pellet market is increasing rapidly, and a tough competition is setting up, it is planned that only distributors who can add value at their stage of the supply chain will succeed.

National distributors and possibly even Europe-wide distributors should serve the consumer market, ensuring supply and providing homogenized product quality and services. Some producer-distributors should concentrate on distribution, as they discover their core competence is in marketing and sales. Others should generate national sales networks and effective delivery systems and become large producers.

The future Pellet Market development is characterised as follow:

- Consumption of renewable pellets is estimated to reach 10 million tons in 2010
- Consumption will increase in all user groups
- In small-scale consumer market for heating, it is needed:
  - high quality fuel
  - low costs
  - turn-key installations
  - nation wide sales and services
  - more efficient production /distribution
- medium-scale customers (200 kW-2 MW) are more suitable for urban areas because they need low running costs
- Large-scale applications can be co firing. Actually due to the volume of biomass needed, high energy density fuel like pellets is preferable in order to limit the transportation costs.

The following paragraph will present, through case studies, an overview of 3 different logistic supply chains addressed to the three kind of consumers referenced below:

- Non industrial bulk; Sweden
- Non Industrial bags; Italy
- Industrial Bulk; Netherlands

The information is collected in order to be used for further logistic evaluation by University of Utrecht. A model for evaluation is developed and described in (Sikkema et. al. 2009), as well as the result of the evaluation.

5.1 Non Industrial Pellet Bulk: Sweden

5.1.1 Description of market

The non industrial pellet sector in Sweden is annually consuming over 1 million tonne pellets. Parts of this is begged pellets, either small bags 16-25 kg or big bags 500-1 000 kg. The bags are used in domestic installation. The remaining non industrial pellet is delivered as bulk. This is also a common system for residential pellet installation. In the middle scale pellet installations, like schools, dwellings, service centres etc. bulk is the only used system, as the volumes are too large to use bagged pellet. Also pellet boilers in small district heating are considered to be non industrial. The capacity range for this sector is 15 kW – 2 MW.

Most of the pellet suppliers are today offering bulk deliverance. Commonly the pellets are delivered directly from the storage by the production plant to the customer. More seldom external storages are used. The pellet is usually screened while it is loaded to the bulk truck. The truck has commonly several tanks, of for example 3 tonnes. This is the smallest amount that can be delivered to each customer. As these boilers normally are sensitive for fines, it is important that the in-blowing is made in a smooth way. The truck is either delivering to several small customers on a route that is as optimised as possible. The larger bulk installations may have storages large enough for the load of an entire truck, 35-40 tonne. Suppliers with several production and storage units, have possibilities to create route with return freight, and therefore are able to minimise empty transports.

5.1.2 Non Industrial Pellet In Bags, Italy

In this case study, consumers buy small bags at retailers' shops and use them in small scale heaters at home. A typical annual consumption is 5-6 tonnes. The size of the bags does vary between 15-25 kg. The quality requirement for this type of consumption is high, with low ash contents and low share of fines. It is either the consumer or the retailer who is performing the transport to the end consumer. The average transported volume is about 0.25 tonne, and the distances are relatively short. This market is typical for Italy, where about 450,000 tonnes of wood pellets are used for residential heating (Vivarelli and Ghezzi 2008).

The non industrial pellets for residential heating in Italy mainly, produced through small scale pellet producer, with average production at 25 000 tons of pellets per year. Other bigger producers also exist, with average production exceeding 40.000 tons/year and more dedicated to market of the big utilities

The logistical and economical evaluation has been developed on the basis of different studies in Austria (Thek and Obernberger 2004) and also on the data collection made by Italian project partner ETA Florence.

In general the pellet producer buy raw material already dried because of the energy costs in Italy that are very high. In this context it seems more economically interesting to buy dried material more expensive than the fresh one that will have to be dried on site.

Truck transport of raw material

The small scale pellet producers are generally already involved in wood sector and started pellet production from their own residues. For this reason the transport of raw material is limited. Obviously the actual capacity of production requires partial feeding from outside and mainly from neighbour countries like Slovenia, Austria, and Germany. We can estimate that around 25% of the feedstock is externally purchased according to the market study performed by ETA Florence.

Storage of raw material

The storage of raw material is obviously linked to the capacity of pellet production and also the seasonality of wood and pellet production.

In general we can consider there is only storage volume for some days at the saw mills and for some weeks at the pellet factories even if it could be better to have a 2/3 month storage capacity to front the market and seasonal evolution.

Transport to end consumer

In order to consider the average transport needed for delivery to end consumer, we have to consider some market characterisation.

- Destination of the pellets from pellet producer:
  24% is directly sold from producer to small private consumer
  68% is sold through retailers and big market centres for small private consumer
  8% is sold to the big consumers

- The area of market activity can also be characterised as follow:
  17% of pellets trades is performed at provincial level
  22% of pellets trades is performed at regional level
  61% of pellets trades is performed at national level

The question of distance from the small scale end consumer to retailer is calculated from the assumptions that the 44 retailers in Italy are evenly spread over the country of 300 000 km^2, and that each of the retailers are serving a circle. The average distance is 2/3 of the radius of the circle and an curve factor of 1,2 is used. This gives the average distance of 37 km.

5.1.3 Industrial Bulk, Netherlands

The Industrial bulk pellet chain is defined as consumers with an annual demand of 3,000 tonnes of pellets or more. The pellets is used in plants with electricity production. These large scale consumers with of pellets with less stringent quality standards, compared to the non industrial pellet volumes. In this case, the pellets are transported by wholesale merchants or international traders, operating between production plants and large scale consumers. This market type can be illustrated by the pellet market in the Netherlands, where about 650,000 tonnes of wood pellets are used for power production. The majority of these pellets are imported from Canada (Pelletsatlas 2008)

5.2 Collected data

Fig. 24: Raw material

▪		**Reference**
Form of residues (sawdust, shavings and / or bark)	Saw dust (Sweden) Mix saw dust shavings (Italy and Netherlands)	
Amount of residues (ton freshweight)	-	
Costs of residues for external buyers (€ / ton fw)	150 SEK/MWh, gives app. 70 SEK/ton fw (Sweden)	Swedish Energy Agency, 2008
Moisture content (in %; on wet basis)	55 % in Saw dust 15-20 % in shavings	
Average size of residues / particle distribution	1-2 mm (saw dust)	Swedish pellet actors
Dry matter loss per month if stored at sawmill (in %)	2,5-3 % (saw dust)	Swedish pellet actors

Fig. 25: Truck transport of raw material

		Reference
Form of residues	Saw dust (Sweden) 80 % saw dust 20 % Shavings (Italy) 49 % saw dust 51 % shavings (Netherlands)	Swedish pellet actors Thek and Obernberger 2004 Urbanowski 2005
Distance from sawmill to pellet plant	Approx. 65 km (Sweden)	Swedish pellet actors
Possibility to have return freight yes / no	No (Sweden)	Swedish pellet actors
Capacity of truck	140 m^3, 33 tonnes (Sweden)	Näslund 2006
Speed average (km/hr)	70 km/h	Näslund 2006
Km cost (in €/km) or (in € / ton km)	0,5 SEK/tonne, km (Sweden)	Swedish pellet actors
Load / unload speed (m3/hr)	20 min resp. 10 min for 33 tonne (Sweden)	Näslund 2006
Load / unload costs (€ / m3)	4,5 resp. 2,3 SEK/tonne (Sweden)	Näslund 2006
Fuel use (liter diesel per km)	0,5 l/km (Sweden)	Näslund 2006

Fig. 26: Storage of raw material

▪ Form of residues (sawdust, shavings and / or bark)	Saw dust (Sweden) Mix saw dust shavings (Italy and Netherlands)	
▪ Units of storage (#)	-	
▪ Average storage per month of quarter (m3) ➔ to be used for retention time (days)	Saw dust from pine get better pelletising properties after 2-3 months storage. Saw dust from spruce can be pelletised whithout storage. Commonly there are only storage volume for some days at the saw mills and for some weeks at the pellet factories. (Sweden)	Swedish pellet actors
▪ Storage costs per m3/tonne	-	
▪ Dry matter loss per month	2,5-3 % (saw dust, Sweden)	Swedish pellet actors

Fig. 27: Drying of raw material

Type of dryer	Rotating drum (most common) (Sweden)	Zakrisson 2002
Form of residues (sawdust, shavings and / or bark, wood chips)	Saw dust (Sweden) Mix saw dust shavings (Italy and Netherlands)	
Amount of drying installations (#)	1	
Drying costs per tonne		
Moisture content at the end	8-10 %	
▪ Use of electricity per tonne	30 kWh/tonne pellets (Sweden)	Zakrisson 2002
▪ Use of fossil fuels (& biofuels) per tonne	-	
▪ Use of heat (possibly to be distinguished between fossil fuel & biofuels)	520 kWh/tonne pellets (from biofuels), (Sweden)	Zakrisson 2002

Figures from a Swedish pellet producer with another type of dryer, where hot flue gases is blown into the hammermills, so both drying and milling is done simultaneously. The dryer do consume 20 000 tonne wood powder a year, equal to 100 GWh heat. This gives 630 kWh/tonne pellet.

A pellet mill using a steam dryer has the heat consumption 450 kWh/tonne pellet (from biofuels). The heat is reused after the dryer, either as 100 kWh electricity/tonne pellet or as 350 kWh district heat/tonne pellet.

Fig. 28: Sizing

		Reference
▪ Type of machinery relevant	Hammermill (Sweden)	Zakrisson 2002
▪ Av. particle size of model: after grinding	Approx. 0,5 mm(Sweden)	Swedish pellet actors
▪ Use of electricity (kWh) or fuels, related to av. particle size & volume (Bond Index)	21 kWh/tonne pellet (Sweden)	Zakrisson 2002

The pellet mill using the combined mill/dryer has the electricity consumption 22 kWh/tonne pellets for the hammer mill.

Fig. 29: Pelletising

		Reference
▪ Type of machinery relevant	Ring die pellet mill (Sweden)	Zakrisson 2002
▪ Use of electricity (kWh) or fuels, related to av. particle size & volume (Bond Index)	43 kWh/tonne pellet (Sweden)	Zakrisson 2002

Fig. 30: Storage at pellet plant

		Reference
▪ Type of pellets:	Wood pellets	
▪ Units of storage		
▪ Average storage & retention time	The storage capacity is 36 % of annual production capacity gives maximum 130 days ((Sweden)	Zakrisson 2002
▪ Storage costs per m3/tonne	28 SEK/tonne pellet (Sweden)	Zakrisson 2002
▪ Dry matter loss per month	No (Sweden)	
▪ Moisture content in the beginning and at the end	Similar, 6-8 % (Sweden)	
▪ Av. particle size	-	

Fig. 31: Transport to non industrial bulk consumers (Sweden)

		Reference
Average distance from pellet plant to small scale bulk consumers	One production unit companies: 110 km Companies with several production units can have much longer transports, but also higher rate of return freights.	Pellet actors
Possibility to have return freight yes / no	One production unit companies: 50 % Many production unit companies: up to 95 %	Pellet actors
Capacity of truck (m3)	63 m^3	Pellet actors
Capacity of truck (tonnes)	38 tonnes	Pellet actors
Speed average (km/hr)	70	Pellet actors
Km cost (in €/km) or (in € / ton km)	12 SEK/km	Pellet actors
Load / unload speed (m3/hr)	Approx.10 minutes each	Pellet actors
Load / unload costs (€ / m3)	-	
Fuel use (liter diesel per km)	0,4 l/km	Pellet actors

Fig. 32: Bagging and transport of small bags to non industrial consumer (Italy)

		Reference
Energy costs for bagging	4,8 kWh/tonne	Morbidelli and Pampanini, 2008
Additional labour costs	-	
Removing of fines before bagging	6,6 kWh/tonne	Morbidelli and Pampanini, 2008
▪ Average distance from pellet plant to retailer	200 km	Vivarelli and Ghezzi 2008
▪ Capacity of truck	24 tonnes	Vivarelli and Ghezzi 2008
▪ Transport distance from retailer to consumer in private cars	93 km	Vivarelli and Ghezzi 2008
▪ Average load	0,25 tonne	Vivarelli and Ghezzi 2008

Fig. 33: Transport of industrial bulk pellets from Canada to Netherlands

		Reference
Train transport distance from production plant to export harbour	781 km	Magelli 2006
Losses in handling and storage	1 %	Melin and Verkerk 2008
Ocean transport distance	16 500m km	Rotterdam Harbour 2008
Ocean transport load	40 000 tonnes	Rotterdam Harbour 2008
Losses during ocean transport	2 %	Rotterdam Harbour 2008
Inland river transport distance	100 km	Rotterdam Harbour 2008
Inland river transport load	4 000 tonnes	Rotterdam Harbour 2008

Fig. 34: Conversion of pellets into heat or electricity

Non Industrial bulk (Sweden)

		Reference
Type of combustion units	Pellet burners attached to boilers Pellet boilers Powder burners	Swedish pellet actors
Efficiency (%)	Pellet burners attached to boilers 70-85 % Pellet boilers 85-90 % Powder burners 90 %	Swedish pellet actors

Non Industrial pellet in bags (Italy)

		Reference
Type of combustion units	Pellet stowes	
Efficiency (%)	85 %	Forsberg 2000, Labouze and LeGuern 2005

Industrial bulk (Netherlands)

		Reference
Type of combustion units	Co-firing in power plants	
Efficiency (%)	40,1 % electricity	Romaijn 2008

CONCLUSION

Deployment of Bioenergy at large-scale and world-wide will require numerous international operations:

- Transfer of knowledge; technologies & know-how;
- Establishment of joint-ventures for a common business;
- Definition of recognised "International Standards" for different biofuels;
- Establishment of a wide infrastructure for international trade;
- Cooperation on education & training activities;
- Cooperation on R&D and demonstration projects;
- Implementation of commercial projects of common strategic interest;
- International financing.

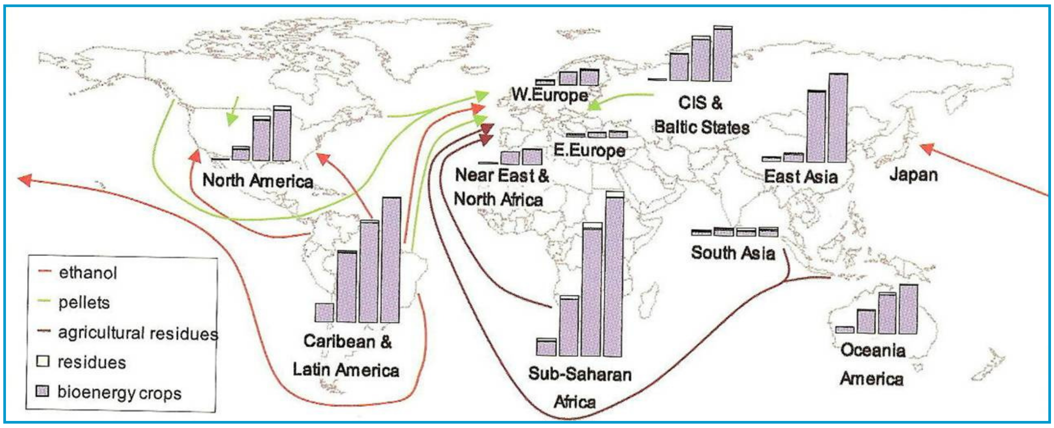
The availability of large amounts of Pellets at a reasonable price opened immediate or short-term market opportunities for wide sectorial summarised here below:

- Heat production (heating, processing steam) in competition with heavy-fuel oil and natural gas.
- High value "green-power" production by coal / pellets cofiring (considerable fast contribution equivalent to ~ 50,000 MWe capacity and 350 TWhe/y bioelectricity supply).
- Bio-H_2 production, by three-step process, competitive with H_2 derived by steam reforming of natural gas, especially if bio-H_2 saving 7 t CO2/t H_2 could get incentives
- Competitive co-production of Bio-methanol with Bio-ethanol (0.7 litre of biomethanol for each litre of bioethanol by synthesis of fermentation CO_2 with bio-H_2 from residues).
- Charcoal pellets for siderurgical use and high quality steels, in competition with coke.

Total estimated potential of agro-forestry residues for the E.U. -27 is evaluated to ~ 1,5 billion t (fresh) / y. At present most of these residues are not utilised for economic reasons (difficulty and expensive recovery, variability of feedstock, high volume / high cost of transport, etc.); although only ~ 20% should be left on the field for environmental reasons soil fertility conservation but always after composting to avoid GHG emissions. Although this is very large amount, biomass is dispersed on vast agriculture-forestry areas. The present lack of adequate technological instruments to facilitate the recovery and to reduce the high cost of logistics, makes economically at present difficult, the use of such energy resources, in particular of the large volume of residues, available at low cost. Anyway pelletisation seems necessary at least to limit the costs form production to distribution.

The considerable potential future demand of Pellets (in industrialised - developing Countries) as clean renewable energy resource for diversified sectorial markets (heat, power, transport) will stimulate the establishment and promotion of a significant infrastructure for "International trading & supply". In figure below a possible scheme of future trade-routes between continents is indicated.

Figure 35: Theoretical biomass potentials per region (see Smeets et al, 2004) and examples of current trade routes. Inter-European trade is not displayed for clarity.



Source: IEA Bioenergy Task 40: Sustainable International BioenergyTrade: securing an international supply and demand

In order to implement the better International trade, the establishment of a wide infrastructure is needed at the river sea-port, large storage facilities and a multimode transport system by:

- road-trucks (up to 20/30 t);
- train-container (up to 1,600 t);
- river-barges (up to 22,000 t);
- boat-container (up to 100,000 t).

Reliable and stable distribution systems are influenced by:

- Secure and reliable political framework, that is the basis for every investment decision in order to procure:
  - Adequate transport capacities and systems
  - Adequate storage facilities
  - Active storage holding of product that will be supplied if there is a real long term view of business
- Storage holding through market actions in the means of standard business processes, driven by the market, should be done.

Transport of pellets to the plants has to be considered as an important topic that presents several challenges for the future. The design and cost effectiveness of alternatives to road transport (i.e. railways) needs to be explored. Using pellets within a radius of more or less 100 km seems the most effective way of proceeding.

There are a number of opportunities to improve the mechanical systems associated with feedstock handling so that biomass resources can be used for a wider variety of applications. Improvements in feedstock analysis and preparation technologies as well as mechanical harvesting and storage practices should help lower the cost of production and delivery of biomass feedstock. Research is needed to advance existing technologies and processes in these areas as well as to develop new technologies. This research should enable the handling and storage of unique combinations of biomass feedstocks that are tailored for specific applications, without sacrificing the integrity of the feedstock.

Sophisticated transport systems are being developed to improve pellet quality and increase convenience. Pellet delivery systems are being modelled after the livestock feed industry using pneumatic tanker trucks. Gentle pellet loading, storage and transport systems are essential to minimize the amount of dust or fines generated during handling operations. Research continues to improve pellet durability to increase resistance to mechanical abrasion. Design of more efficient pellet storage, charging and combustion systems for domestic users is on-going, in order to optimise delivery of wood pellets to residential markets. One option is the development of pneumatic ash retrieval mechanisms on pellet delivery trucks to provide a 'one stop' fuel and waste removal service.

Storage presents some difficulties that need to be further studied and their solutions improved: dust and spore emissions, and the changes in biomass properties (changes in moisture content, energy value and dry matter content due to microbiological activity) need to be tackled in order to achieve a more stable, safer output. However, as mentioned above, the available solutions present constraints that need to be overcome: not all the vegetable biomass can be pelletised successfully; less mechanically stable biomasses are not usable for big and medium power plants, reducing the total benefits. Biomass drying can be done on the power plant site, since power plants are above all "heat rejecters". Why not explore the possibility of cogeneration to dry biomass for free? Nevertheless, this possibility could affect transportation costs, since the biomass resource would be humid.

Specific examples of research needs include:

- **Best Practices for Harvesting and Storage** – It is crucial to identify, develop, test and implement best practices for cost-effective and environmentally sound pre-treatment, collection, storage and transport of plant based biomass feedstock from agriculture and forestry. This should lead to improved plant residue recovery, improved handling and storage technologies/procedures and reduced environmental impacts.

- **Explore current and new types of logistics and network,** can be also one way to make transportation more efficient
  - Reducing biomass transport using regionally available biomass resources
  - Optimising transport logistics by choosing the best suitable systems (e.g. train, ship)
  - Evaluating transport innovations and review lessons learned in other industries and countries
  - Developing infrastructures for large-volume delivery of biomass to power plants

- **Improving storage, and setting up a storage strategy** is also necessary. Pre-treatment and storage systems must increase flexibility enabling the mixture of different kinds of biomass. At the plant level, improved systems monitoring and maintaining feedstock quality through the collection, storage and transportation phases of the product life cycle must be developed. It's also important to reconsider the storage systems avoiding additional storage steps between the locations of biomass production and the end-users plant and choosing optimal strategy for biomass fuel storage between:
  - Large storage for biomass fuels at the end user for long-term storage (pre-treatment and preparation of biomass fuels directly at the plant), or
  - Small storage capacities directly at the end user plant – just in time supply with an external storage for biomass fuels (pre-treatment and preparation of biomass fuels at the external storage)

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- "World Biomass Shipping study", presentation made by Doug Brad;ey, Climate Change Solutions during task 40 meeting in Brussels 28/01/2009
- "Verification of pellets supply chains", presentation made by François Ducarme, SGS during the Sustainable Energy Week, Brussels, February 9th, 2009
- "Biomass & Waste-to-Energy Investment Trends to-Energy Investment Trends" presentation made by Irmgard Herold, new energy Finanace during the 3rd Biomass Industry Day, Hamburg Germany, 1 July 2009
- "From innovation to operational assistance, Belgian approach GHG and certification scheme for biomass", Yves Ryckmans, LABORELEC, ELECTRABEL SUEZ, Biomass and Waste Competence Centre, 2008
- "Pellet distribution to heating plants and domestic consumers", Åke Andersson, SÅBI Pellets
- "Stable And Reliable Supply And Distribution Systems", presentation made by Marina Tcharnetsky, GEE Energy GmbH & Co. KG, during the AEBIOM Workshop in Brussels, 26 June 2008
- "From Visions and political Statements to substantial Activities Realizing the Potentials of Bio-energy Trade – how much, when and by whom?", Bo Hektor, May 28, 2008
- "Wood Pellets –best practice, market potential and perspectives", presentation made by Ing. Joachim FischerDeutscher EnergiePellet-Verbande.V.Tullastr. during the German-Finnish Workshop on Renewable Energy Technology in Jyväskylä, 25 may 2005
- "Recommendations for policies at EU level", presentation made by Jean-Marc Jossart Secretary General AEBIOM during the AEBIOM pellets workshop, Brussels, 26 June 2008
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Projects and websites:

- EUBIONET2: www.eubionet.net
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- BIOSOUTH: http://www.bio-south.com/
- NETBIOCOF: http://www.netbiocof.net/
- Biomass Energy Europe: www.eu-bee.info
- EUROSTAT: http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/
- Fachagentur Nachwachsende Rohstoffe : www.biomasse-info.net
- World Pellets Conference: www.pellets2002.com
- European Biomass Conference and Exhibition: http://www.conference-biomass.com/