ABSTRACT: This research is part of an ongoing project, BioREF (BioRefinery for sustainable Reliable Economical Fuel production from energy crops). BioREF is intended to develop, in a dynamic way, a benchmark for future integrated and sustainable bioenergy production systems that will contribute to enhance Denmark’s position in the bioenergy production. The objectives of the work described in this paper are to optimize the harvest and logistics for the transport of oilseed crops and suitable agricultural residues to production facilities and return the process residues for agricultural use as part of the overall biomass feedstock infrastructure. In this regard, the supply chain must comprise optimized steps of harvesting the crop, collecting residues, storing and transporting.

Keywords: biomass resources, logistics, sustainable use of biomass

1 INTRODUCTION

The interest in new and renewable energy has grown and will grow in the future. Biomass has been used for thousands of years as a source of energy and is today a major fuel source in terms of the quantities used worldwide. In fact, more people depend on biomass for energy world-wide than any other fuel [1].

The development and implementation of improved growing systems, for the purpose of biomass production for biorefinery utilization, is gaining attention due to the increasing demands for biofuels and a variety of biorefinery products. In order to have a successful shift from fossil fuels to renewable fuels, sustainable resources in larger scales are needed, particularly for the transport sector. Increasing needs of growth in living conditions in the new EU developing countries will cause higher energy demand. Such a tendency is common all over the world.

It might be expected that the plant species adapted for energy purposes have lower environmental pressure than food/feed crops, mostly due to the fact that they are grown for their energy content and not for their nutrients value. To be profitable for farmers, biofuels crops need lower levels of input and costs than conventional crops.

Beside biofuels, other products like amino acids, enzymes, and antibiotics can be produced from organic by-products via different processes. In the biorefinery concept, diverse renewable feedstock can be converted into fuels, food and feed, and other different chemical compounds that will be very important for the commercial success of introducing biofuels on the market.

Biofuels production from biomass is a key opportunity for agriculture, due to the possibility of valorizing the agricultural crop production devoted for this purpose. Biomass has to be retrieved in the efficient way from the field in order to keep the operation costs at reasonable level.

Biomass yield and its potential differ from country to country. However, a temperature above 5 °C, sufficient water supply in the root zone and top soils assure good growing conditions and efficient photosynthesis [2].

At present, however, producing electricity at power plants from biomass is far more expensive than from other more traditional sources such as coal and gas, partly as a result of the logistics costs involved in fuel supply.

The search for a process technological optimum and the elimination of weak points in process design require a description of the current conditions and dynamic precalculation which takes the interaction of the machines involved into account.

It is estimated that around three-fourths of the biomass which is used for production of food, feed, industrial round wood and traditional wood fuel is not fully exploited at some point in processing, harvesting and transport [2].

The transport sector accounts for approximately 30% of the total energy consumption; its dependency on fossil fuels is equal to 98%, which most of it originates from unstable parts of the world. Introducing energy from biomass would significantly increase energy independency of the EU-27 [2].

The objective of this paper is to gather the information needed in order to develop an optimization model of the supply chain for oilseed crops.

2 GENERAL ASPECTS OF THE SUPPLY CHAIN

The biomass supply chain is made up of a range of activities which include harvesting, baling, storing, drying and transport of the biomass both on the field and to the biorefinery, handling and transport of residues and by-products. The whole network operates in time and space coordinates so in order to estimate the logistics costs, a global view of the processes, which are strongly interlinked, is needed.

The main characteristics of the supply chain, that influence the logistics efficiency, are that the raw materials are produced over large geographical areas, have a limited availability window, and often are handled as very voluminous materials.

Biomass from oilseed crops has two different products: the seeds and the straw, so each of them has to be considered individually.

The most important is the seeds, resulting in an increased attention on the harvest, storage and drying of the seeds over the straw.

There is very little interest in the rapeseed straw in Denmark, mainly due to the differences between the density and the behavior of the bales when used for heating. Typically, the rapeseed straw is chopped and returned to the field.

Because of the current disadvantages of the straw, for this study, the supply chain of the bales will not be discussed, even if a different approach in harvesting and processing of the whole oilseed crops would result in...
more feasible operations.

In order to obtain a better biomass supply we need to have an optimum configuration of all the processes.

Further on, each step of the biomass supply chain will be presented with its technological features.

2.1 Harvesting

Considering its main characteristics, the biomass supply chain is different than other. It is important to plan the different activities from a total chain perspective, when regarding a single activity, rather than planning each activity individually. For instance, the best result in expensive storage or transport requirements [1].

For the production of biofuels, oilseed crops have a great advantage by using existing farm machinery with slight modifications.

The most common harvesting procedures are:

- Multi-pass harvesting, is a three or four step process. First, a combine harvests the grain and discharges the biomass in a windrow behind the combine. Second, a baler towed by a tractor picks up the windrow, packages the biomass in a bale, and discharges the bale when baler capacity is reached. Third, a tractor picks up the bales and hauls them field side. Crop residue biomass harvesting and collection in this manner is inadequate to meet the feedstock performance targets because it introduces a significant amount of dirt and rock contamination into the feedstock. In Denmark, the multi-pass harvesting involves a windrower that cuts the crop, then the layers dry on the field for approximately 14 days, and afterwards they are picked-up and threshed by a combine harvester.

- Single-pass harvesting, is a combination of a combine harvester – baler, resulting in simultaneous harvest of the grain and biomass. Whether the grain and biomass are separated in field or at field-side depends on the crop, its moisture content or end use. Straw baled directly results in a gain of up to 30% than baling off the ground, and retains quality due to less weather damage.

- Whole-crop harvesting, implies that the entire crop is cut and placed on windrows for field drying. The whole crop is then collected in a transport wagon and transported to store or the processing yard. The bales are unwrapped and fed through a stationary processor that performs all the functions of a normal combine. The straw is then re baled for transport to a site way from the yard.

2.2 Baling

There are different types of baling, mainly depending on the intended purpose of the straw: mini bales, round bales, mini-big bales or big bales. The most common types of bales are round bales or big bales. Round bales are mainly used in livestock feeding. Big bales are a standard in terms of combustion in CHP stations (combined heat and power) or at power plants.

2.3 Storage of oilseeds

If all year operation of the biorefinery is desired, there is a need of storing very large amounts of seeds for a significant period of time. However, storage facilities are needed either at the plant site or at intermediate points. Depending on the size of the plant, the storage capacity at the processing plants will be increased, resulting in shorter periods of on-farm storage.

Usually, seeds are stored in sealed bins or silos. Storage at low temperatures helps protect against increased free fatty acid (rancidity) levels due to broken seeds and the build-up of mites and moulds.

The oilseeds of rape are smaller compared to grains, and offer increased resistance to airflow for drying or cooling, so bulk depth should be reduced or fan capacity increased.

2.4 Drying

There are two different possibilities to dry the seeds: using hot air, the fastest way, depending on the moisture content and the type of dryer used can take up to two hours, or ambient air, which depending on the seed moisture content and the humidity and temperature of the ambient air may take 14 days, even if the seed bed depth is adapted correctly.

If during harvest the weather is relatively good, the moisture content (mc) of the seeds would be likely to vary between 10 to 12%. If the seeds are to be transported in a short period to the biorefinery and are below 12% mc, then no drying would be required. But if the agreement between the farmer and the plant is to deliver the seeds at a specified time, then the seeds need to be dried for safe storage. The optimum moisture content for safe storage is 7.5-8%.

For hot-air drying, research suggests temperatures of 70-80°C for up to 12.5% mc, and 60-70°C for above 12.5% mc in order to avoid rancidity [3].

Drying using ambient-air works very well when if the bed depth is reduced enabling an adequate airflow.

2.5 Transport

Biomass material may be transported in several different forms. The most appropriate transport option depends on the type of biomass, form, quantity, intended customer and distance to be traveled.

There are two steps of transport: from the field to the farm or temporary storage facility, and from the farm to the biorefinery. The first step can only be done by road transport, tractor with wagon or lorry, where for the second step other factors influence the choice of technology (e.g. amount of biomass, distance to be traveled, procedure of sending – if the biomass is sent as pellets, containers, etc).

When the biomass is provided by local suppliers, the main type of transport system is the road transport because it offers a great flexibility if relatively short distances need to be traveled [4].

For oilseeds, the form of the biomass can either be as a bulk or sealed in bins: bulk seeds can be transported with container and container lorry, tanker, grain or animal feed vehicle and walking floor trailer; sealed bins of seeds can be transported by flat bed trailers, tipper trailer or truck.

For very large users of biomass, such as for a power station or a large scale transport biofuel production plant (particularly second generation), annual demand could be
around several hundred thousands to million tones, so if possible, ships are suitable for long distance bulk transport.

Railway is another possibility for transporting biomass, but it implies a more centralized system which at the moment is less efficient than road transport.

3 FACTORS INFLUENCING THE SUPPLY CHAIN

Because the biomass supply chain has so many variables (specific time and large area of harvest, all year need of biomass, etc.) it is important to have a good understanding of the main problems that can affect the optimal chain. These problems can be divided into three categories:

- Weather, has a great influence on the proper harvest of biomass because it can reduce the yield of the crop, affect the biomass quality, and burden the harvesting process by giving badly to no conditions of working on the field.
- The lack of resources, can make large scale biorefineries face real challenges since the need for biofuels is expected to increase in the years to come (see figure 1). There could be the case where a biorefinery can not get enough biomass in order to fill the orders of biofuels. There is a serious need for evaluating the total potential for energy crops in order to build and achieve enough resources to satisfy these needs. With the fast improvement of technology, both for means of converting biomass and the use of biofuels, it can be expected that at some point the need for biofuels will exceed the quantity of biomass produced.
- Communication issues, between biorefineries and suppliers can appear mostly due to lack of real-time knowledge on the status of the processes. This implies the use of a common database and information technologies that can keep both the suppliers and the users up to date. For example, if a biorefinery needs to buy large amounts of biomass from a foreign country, language problems may appear as well as means of transportation, place and time of delivery, and quality misunderstandings. The same type of problems may occur when the biorefinery is buying resources from a new supplier even though they are from the same country, all these resulting from a lean planning of the supply chain.

How can the influence of these factors be minimized to the level at which they don't affect the overall economical aspect of the process?

It is impossible to predict the weather in the long term, but it is possible to plan carefully the whole year round process of growing rapeseed in order to have less affect from the weather. This may mean the use of genetically modified rapeseed in order to increase the yield or generate safety measurements to avoid drastic changes to the harvest.

To avoid running out of raw materials, new policies for raising the attractivity of the business, and more efficient technology could be the answer.

When a company has such a high level of dependency with a series of other businesses, the communication is crucial for reaching required targets. Information sharing and real-time communication keeps the participants up-to-date with the latest changes and can provide today the difference between success and failure.

4 OPTIMIZATION TOOL

Biomass supply chain management involves coordinating and integrating activities and processes among different parties for the benefit of the entire supply chain. The integration of multiple functions in a global supply chain context is complex. Information technology (IT) systems have been recognized to facilitate the processes of supply chain management through integrated information sharing, process automation, and relationship management programs. The increasing use of Internet in a business-to-business context has further improved the supply chains through real time collaboration, 24/7 availability and access to worldwide markets [5], a very important aspect for obtaining a successful supply chain.

The use of available IT technologies aims at improving the entire biomass supply chain by information sharing between participants and avoiding bottlenecks.

While there is no doubt about the importance of information in the supply chain and about the fact that information technology (especially various software applications) can greatly reduce the costs, the strategic planning of this process and utilization of information is crucial. Information should be readily available to all parties in the supply chain and the business processes should be structured in a way to make full use of this information. Additionally, only sharing of information will not lead to improvements, but also coordination of activities is crucial [6]. Strategic utilization of the information is the most important part for the mobile supply chain.

Sharing of information can obviously be a problem since the companies involved in the supply chain may not be prepared to share their production data, especially when those companies are independent of each other [7]. Appropriate business processes are a prerequisite for the strategic utilization of information to assure everybody involved benefits the information [8]. Additionally, human factors have to be considered, decision-makers at various points in the supply chain are usually not making optimal decisions (due to the lack of information, company strategy or their personal hindrances) [8].
Mobile supply chain management integrates software applications with mobile devices (e.g. cell phones, personal digital assistants, pocket personal computers, personal computers) to give users the flexibility to operate in a wireless computing environment at any location. This enables users to take advantage of information systems linking business processes among different functions within the company and between companies at remote locations [9].

Real time information helps the participants to cope with changes of uncontrollable external factors affecting demand (e.g. prices, lack of resources, production halt, etc.) through real time measurement of demand.

Mobile technology and Internet are enabling users to connect to each other, to a computer server and database regardless of their geographical location which helps provides users with a better visibility and ubiquity of business processes to help reduce uncertainties of demand, forecasting and planning. For example, wireless technology can help to request information on a product in transit at any location without reaching a certain stage of the logistics.

Another advantage of the mobile supply chain is that it can have a personalized character. For instance, customizing and targeting specific information based on individual needs and circumstances. This means effective use of resources by filtering information to relevant users, but also enabling execution of multiple tasks at remote locations. Therefore, personalization in mobile supply chains changes the dynamics of the processes in terms of content and relational aspects such as trust and commitment [9].

4.1 Description

Most of the researches carried on optimized modeling of the biomass supply chains regard the ideal location and the size of a new biorefinery in terms of available resources and efficiency (e.g. BIOLOGICS – BIOMass LOGIsitic Computer Simulation, BIOLOCO – BIOMass Logistic Computer Optimization, both designed by The Department of Agricultural Engineering & Physics of the Wageningen Agricultural University, Netherlands), performances and costs estimation of bioenergy plants [10]. The fuel consumption, green house emissions and costs of the supply chain are also key elements of the models [11, 12, 13]. Models simulating the biomass flow from the field to the biorefinery [14, 15], are intended to estimate the efficiency and study the sustainability of bioenergies.

So far, the attention has focused either on farmers or biorefineries and too little on the aspects of the relations between them. It may happen that one optimized supply chain for a biorefinery may be unattractive to a certain farmer, and find himself discouraged to even grow the biomass, if a farmer has to travel a long distance to a particular plant and might not have the means to do so.

Given the unforeseeable character of the factors influencing the supply chain of biomass and the large number of human factors involved in this process it can be rather difficult to state which is the optimum chain. Also, companies tend to optimize their own performances disregarding the supply chain as a whole, resulting in a local optimization instead of global.

All this knowledge should be included in a system that can answer all the important aspects of logistics of biomass. This study tries to take a generalized view on the process, and intends to gather all the information needed for each stakeholder to be satisfied with its outcomes.

4.2 Key parameters

When talking about biomass supply chain all the stakeholders have to be considered as individuals. Because of the complexity of the biomass supply chain, each stakeholder (e.g. farmer, contractor, biorefinery) has different parameters. The tool should be able to provide optimal strategy, personalized on the individual needs, resulting in global optimization.

Farmers, biorefineries and contractors are the main actors of the process. Each will be regarded separately, with the interactive communication between one another. The key parameters of this model should be accordingly to the role of the participant.

The farmers hold one of the most important parts, providing the raw materials. This means optimum steps in harvesting, growing, storing and drying, which depend on the farmer’s possibilities to do them at the farm, and transporting the biomass to another participant. Each of these steps has again different inputs and outputs.

The harvest should have as inputs, besides the location of the field, its size and shape, the technology that the farmer has: the type of combine. The tool will therefore be able to calculate the optimum harvesting route in terms of fuel consumption, time efficiency, and workload, as well as to indicate the best harvesting interval for which the weather is favorable for the specific geographic position.

The inputs for the storage and drying regard beside the location of the farm and transport technology the farmer has, the available quantity and quality (the moisture content) and the possibility to store and dry at the farm. Depending on the requests, the result will consist in estimated prices for storing and/or drying, either at the farm or at another facility, the list of available locations that store and/or dry rapeseeds and transport routes to the selected locations. If only drying is needed, there will be an estimated time and cost for drying and a list of biorefineries or contractors and the maximum moisture content that is accepted.

For transporting the rapeseeds, the farmer has to insert his transport means, available quantity and quality of the seeds and the location of the farm. The outputs for the transport will consist of a maximum and minimum price with an estimated price for his crops’ characteristics, a list of all the biorefineries buying rapeseed at the moment, route planning for the given transport mean (e.g. tractors are not allowed on motorways), the time for the transport and the number of deliveries.

A very important part is processing the seeds into biofuels. The biorefinery thus has a series of steps like the distribution of the resulted products (biodiesel, crude oil, glycerin, rape-cake, etc.) to the clients, the storage of the rape and the storage of the resulted products, the pre-processing of the rapeseeds, and in some cases the transport from the farm or contractor to the biorefinery.

The inputs for the distribution would consist of the location of the biorefinery, the available quantity of the products, transport means, packages, tanks, bottles, bags, etc., and the transporting system, by road, ship or railway. The tool should be able to offer the price range for each product type, a list of possible clients, with
locations and requirements (e.g. quality requirements, quantities, etc.), and the transport costs and duration.

Pre-processing is the step right before the actual process of producing biodiesel, and it involves drying the seeds to an even lower moisture content, usually below 6%. In the pre-processing step the purchase of the needed resources for the chemical process can also be included, resources such as catalysts, alcohol (methanol or ethanol), etc. The inputs will therefore consist of the list of resources needed for the chemical process and their quantity, the location of the biorefinery and estimated time of delivery, if the company has to meet a specific date. The tool will list the available sellers with their price ranges, the expenses of the transport and the delivery time.

The transport inputs will be considered only if the biorefinery wants to purchase rapeseed using its own means. The location of the biorefinery, the needed amount of rapeseed and the quality requirements regarding moisture content will be as inputs. The tool will list the farmers or contractors currently selling rapeseed and the quantity, the price ranges and the delivery time from the seller to the biorefinery.

The biomass supply chain might not always have the farmers and the biorefineries directly connected. This may occur due to the number of constraints that regards the quality of the rapeseeds. The long distance between the two parties may also result in the need of an intermediary, in order to reduce the costs and support the production of biofuels. Regardless the cause, a contractor will have an active role to help the continuous flow of the raw materials and to optimize his supply chain its transport system and the services they provide have to be considered.

Transport system for a contractor means from the farm to its facility or from its facility to a biorefinery. In cases, the location and the means of transport need to be added. Depending on the case, a list of accepted goods, prices or available goods are considered as inputs as well. The tool will show, based on the specific inputs, the transport routes to and from a given location, lists of biorefineries, farmers or other clients and available products.

The storage is a service a contractor may offer for a farmer that has no space for the rapeseeds. This means the contractor will have to introduce his location, the type of accepted products and the price for the service. In exchange, he will receive a list of farmers, biorefineries or clients that need storage, the available goods, the prices, and the duration of storage.

If a contractor wants to dry rapeseed, the location of the facility, the available drying technology and capacity, the type of accepted products and price ranges are important inputs in order to obtain the costs and time of drying, a list of farmers that need to dry rapeseed and price ranges.

4.3 Expected results

If weather is one factor that can not be changed, the lack of resources and communication issues can be solved by adopting a common database on all the areas involved.

Ideally, each user will have its own profile, so that each time they access the database there is no need to introduce again the same inputs like location, available technology, etc. Also by logging into the system, new changes in the area that concerns them will be shown.

Using this tool will help the participants to the biomass supply chain stay informed on all the changes regarding the entire aspect of the process, make better evaluation, organize and plan more efficiently their activities.

All the technology for making such a tool already exists, and is available on the market. With the help of Personal Computers networked through the Internet, the information can be transferred using satellite systems or cables, making the database available anytime and anywhere. This will allow the communication between partners to be continuous and up-to-date by sharing the knowledge.

5 CASE STUDY ON DENMARK

Denmark is situated in the northern part of EU and is one of the Nordic and Scandinavian countries. It is a small country with a population of 5.3 million inhabitants. Denmark is a flat country with rich agricultural land situated in a temperate climate.

Of the 4,308,000 ha, which present the total area of Denmark, 62 percent (2,679,000 ha) are cultivated. Danish agriculture is characterized by a wide variety of activities, among which cereals are the most important production, accounting for almost 55% of the total area. The main crops in Denmark are cereals, rapeseed and sugar beet making up for more than 87% of the total plant production (excl. grass) [16].

Rapeseed is the most common energy crop for biodiesel in Denmark, grown on 170,000 ha of which 70-80% is non-food (energy) crop. The soil and weather conditions are good for growing winter rape, resulting in an average yield of 3.5 tones [16] (3.8 – 4.5 tones of rapeseed yield is also common between danish farmers with 5 tones yield each six years) [19].

Pig farmers consider rapeseed a good crop due to its high need of N that can be provided through manure spreading. Rapeseed is a crop that can fit very well in existing rotational schemes. The pre-crop, for example, can influence the crop size. Due to early sowing time and the considerable need for nitrogen, grains are suitable as pre-crop. Rape leaves behind a rich soil of mineralized nitrogen providing good conditions for grains. It offers good coverage of the soil in winter, and limits the nitrogen run-off [17].

Another advantage of the rapeseed crop is that conventional machines can be used for harvesting. For the production of rape the soil management, sowing, fertilizing and weed and pest treatment are made with conventional “grain production” farm machinery [18].

In 2006, the number of farms in Denmark was of 47,000 with more than 5 ha of farm area. The average farm size is currently 57 ha, way above the EU-average. The smaller farms, extending to less than 30.0 ha constitute a significant proportion of the total number of farms (for more information visit www.statbank.dk/bdf).

The Danish farmers are single-pass harvesting without baling the rape. The procedure consists in combine harvesting the rapeseed by raising the cutting blades at the highest level possible in order to collect most of the seeds and obtain less moisture content. Currently there is little or no use of the rapeseed straw
and most of it is either chopped and ploughed back in the field or used for animal bedding.

Depending on the weather condition at harvest, the usual moisture content is between 9 and 12%. Usually the contractors that buy rapeseed accept until 9% without price reduction. Emmelev accepts up to 12% moisture content during harvest season and a maximum of 9% during the rest of the year [19].

Emmelev Molle A/S is the only biorefinery in Denmark producing biodiesel. It is situated on Funen island some 20km away from Odense, the third largest city in the country (see figure 1). Odense lies on the route between Copenhagen and Jutland, which gives access to Emmelev for ship transport, railway and road transport to all the country and making possible international relations with foreign companies.

![Figure 2: Map of Denmark](image)

Emmelev is buying rapeseed from Denmark, Germany, Latvia, Lithuania and Russia, processing 500 tones of seeds daily. The transport costs in average 10 € per tone, regardless its country of origin, which allows Emmelev to import rapeseed by ship through Odense’s harbour [19].

On an everyday basis, Emmelev deals with 15 lorries, having a storage space of 160,000 tones of rapeseed. For storing biodiesel they have 150 m³ tanks.

Apart from biodiesel, they produce glycerine that is sold to pharmacies in Germany, Finland, Sweden and Denmark. Glycerine is stored at 50°C and is transported in tanks.

Process residues such as rape-cake, very rich in proteins and used as animal food, is exported as pellets to Sweden and Norway. Emmelev conducts antibacterial treatments to meet Norways standards for the rape-cake [19].

For drying, Emmelev uses gas at approximately 60°C and the seeds are sent to the press directly. Each day, approximately 350 tones of rapeseed are dried (approximately 22 tones per hour of rape).

Emmelev Molle is the only producer of rapeseed oil methyl esters (RME or biodiesel) in Denmark. The production of biodiesel during 2007 was of 100 million litres and it is expected to be doubled during this year [19]. Due to the lack of national tax exemptions, most of this is exported to Sweden and Germany.

Winter rape can be produced through pesticide-free cultivation. In general pesticide-free cultivation of agricultural products results in a large overall yield loss (23% in average for corn), but according to Danish experience such cultivation is least affected for winter rape, with only 7 % yield loss. The energy content in the rape straw is a 4.5 times higher than the total gross energy consumption of growing the crop. It may be noted that, as an alternative to fodder, the energy content in the rape cakes may be used for energy production, either in a biogas plant or as fuel in combined heat and production plant or heat producing plants (source: http://www.inforse.org//europe/dieref/altfuels/biodiesel.htm#prop).

Given that most of the agricultural area lies in Jutland and the county with the highest number of farms is North Jutland (see Table I), the distance between a farm situated there and the biorefinery would be approximately 250 km. A distance far too big to travel considering both time and expenses, so the farmers prefer to sell the rapeseed to contractors from around their location.

Farmers from Jutland sell their rape to neighbouring contractors, like Brdr. Thorsen I/S or DLG, that further on sell to Germany or to the Danish production of vegetable oil for food consumption or industrial use (paint, crude oil for asphalt and concrete industry, etc.).

**Table I: Number of farms and agricultural area by region**

<table>
<thead>
<tr>
<th>County</th>
<th>Number of farms</th>
<th>Agricultural area</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Greater Copenhagen</td>
<td>3 101</td>
<td>121 164</td>
</tr>
<tr>
<td>West Zealand County</td>
<td>4 060</td>
<td>191 500</td>
</tr>
<tr>
<td>Storstrom County</td>
<td>3 119</td>
<td>244 820</td>
</tr>
<tr>
<td>Bronholm Municipality</td>
<td>571</td>
<td>35 534</td>
</tr>
<tr>
<td>Funen County</td>
<td>3 944</td>
<td>225 395</td>
</tr>
<tr>
<td>South Jutland County</td>
<td>3 889</td>
<td>281 322</td>
</tr>
<tr>
<td>Ribe County</td>
<td>3 400</td>
<td>198 319</td>
</tr>
<tr>
<td>Vejle County</td>
<td>3 378</td>
<td>180 348</td>
</tr>
<tr>
<td>Ringkobing County</td>
<td>4 595</td>
<td>300 075</td>
</tr>
<tr>
<td>Aarhus County</td>
<td>5 136</td>
<td>271 578</td>
</tr>
<tr>
<td>Viborg County</td>
<td>5 328</td>
<td>269 706</td>
</tr>
<tr>
<td><strong>North Jutland County</strong></td>
<td><strong>6 864</strong></td>
<td><strong>390 727</strong></td>
</tr>
</tbody>
</table>

Source: www.statbank.dk/bdf

If we would to take an example of a farmer around Aarhus, he would have to travel about 150 km, which including motorway would take him 1.40 hours for just one way (see figure 2). That is not at all convenient if the amount of rapeseed is not significant. And this would pretty much be the case since most of the farms have less than 30.0 ha. The law in Denmark specifies that tractors are not allowed on motorways, but concerning distance on national roads have no restriction.

This means that the contractor have to play an important role in transporting the rapeseed from the farmers and to the biorefinery.

For example, the same farmer from Jutland would access this database and would personalize his profile by adding the location of his farm, the size and shape of his farm, and specify the type of transportation he wishes to use.
fields and the type of combine harvester he has. He would then specify if he would want to bale the rapeseed straw or not. His storage facility and type of dryer he owns are also a requirement of the program so the farmer will say that he has storage for his rape but no drying facility. He will also have to introduce the distance from the field and to his farm along with what kind of transport he has, a tractor with one wagon for example. The program will then calculate when he should start harvesting, how he should plan his harvesting regarding his other crops as well as the shape of the field (e.g. what is the optimal turn for the harvester, how many turns, and so on, given the width of the combine and the technical specifications). Then the computer will tell him how much fuel, time and workload is needed for the harvest, as well as transporting the rape from the field and to his farm. After that, the farmer will introduce what amount of rapeseed he obtained from that particular harvest, the moisture content and what he wants to do with it. If the prices are very good and the seeds have good quality (moisture content of 9%), the farmer will be given a list of contractors that buy rapeseed, starting with the best option of price combined with distance to be traveled. But if his crop has moisture content higher than 9%, the farmer will have to dry the seeds. Given his location, the computer will show him which facilities dry rapeseed and for what price. Also the time needed for drying will be given. The farmer will then contact the facility he chose and transport his seeds there. After the seeds are dried he can sell the seeds and he will decide if he wants to store the seeds or sell it immediately consider the prices at that time. If the prices are good enough he will be given a list of contractors with prices and distance. Then he would know where he has to deliver his rapeseed, when, and if there are special requirements from the buyer (e.g. moisture content, amount). Like this, the farmer knows exactly his best deal adapted exactly on his possibilities. For his case, selling the crop to Emmelev would not be convenient given the big distance between and his transport machinery, tractor with wagon.

A common database means also the contractors will have or if it is better to wait until prices or the demand will change. This will be very helpful given the increased amount of rapeseed at harvest and the decrease after this period. At the moment, lists of turns for specific times of delivery are used, but this is common between small communities and it does not help the farmers that do not have the means to dry or store.

6 CONCLUSIONS

When a company has such a high degree of dependency with a series of other businesses, the communication is crucial for reaching required targets. Information sharing and real-time communication keeps the participants up-to-date with the latest changes and can provide today the difference for an optimal supply chain of biomass. Real-time information helps the participants of the biomass supply chain cope with changes of uncontrollable external factors affecting demand (e.g. prices, lack of resources, production halt) through real time measurement of demand. Information technology, with the help of Personal Computers networked through the Internet, will allow the communication between partners to be continuous and up-to-date by sharing the knowledge.

7 REFERENCES


[19] Personal communication, Thomas Jensen (Emmelev A/S); Stig Nyborg, Arne Kristensen, Jesper Rasmussen (Danish farmers).