AGROinLOG

INTEGRATED BIOMASS LOGISTICS CENTRES FOR THE AGRO-INDUSTRY

Basic analysis of targeted agricultural sectors

Country report Sweden

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ABBREVIATIONS

DDGS: Dried Distillers Grains with Solubles, by-product from ethanol production

DM: Dry Matter

LM: Lantmännen

PARTNERS SHORT NAMES

CIRCE: Fundación CIRCE

WFBR: Wageningen Food & Biobased Research

ZLC: Fundación Zaragoza Logistics Centre

CERTH: Ethniko Kentro Erevnas Kai Technologikis Anaptyxis

RISE: RISE Research Institutes of Sweden AB

CREA: Consiglio per la Ricerca in Agricoltura e L'analisi dell' Economia Agraria

APS: Agroindustrial Pascual Sanz S.L

NUTRIA: Anonymi Biomichaniki Etairia Typopiisis Kai Emporias Agrotikon

LANTMÄNNEN: Lantmännen Ekonomisk Forening

Processum: RISE Processum AB

SCO-OPS: Cooperativas Agro-Alimentarias de España. Sociedad Cooperativa

INASO: Institouto Agrotikis Kai Synetairistikis Oikonomias INASO PASEGES

AESA: Agriconsulting Europe S.A

UCAB: Association Ukrainian Agribusinessclub

UBFME: University of Belgrade. Faculty of Mechanical Engineer

EXECUTIVE SUMMARY

The specific objective of task 6.2 is to analyse the specific characteristics of various European agricultural sectors suitable for setting up an IBLC. This activity is a desk study that will target a limited number of six pre-identified high priority agricultural sectors with large expected synergies. The activity is a part of the AGROinLOG project "Demonstration of innovative integrated biomass logistics centres for the Agro-industry sector in Europe" (#727961) and is within the scope of the Task 6.2 "Basic analysis of targeted agricultural sectors". The results of this task will be used to achieve the goal with WP6 and the whole project, to establish a practical and theoretical framework for the development of new value chains in connection with Integrated Biomass Logistic Centres (IBLCs).

The following sectors of the Swedish agricultural industry are considered: the sugar industry, the vegetable oil extraction, the grain production and the feed and fodder. Each sector chapter consists of two parts: an overview and estimation of IBLC opportunities. The four sectors of the agricultural industry were selected primarily because they are existing large sectors in Sweden with large producing companies. The wine and olive oil mill sectors were not selected since the wine production is marginal in Sweden and there is no production of olives in Sweden. The methods used in the study have been interviews, literature reviews, compilations of market reports and statistical data.

In Sweden about 2 million tons of sugar beets are produced every year and that amount of sugar beets corresponds well to the amount of beets that Nordic Sugar Örtofta receives and processes. There is only one sugar factory and one sugar refinery in Sweden, situated in Örtofta and Arlöv. They are both owned by Nordic Sugar which is the only sugar producing company in Sweden. Örtofta is one of the largest and most efficient sugar-producing facilities in northern Europe with a yearly production of sugar of 382,000 tonnes/year. The sugar market was just deregulated, this can result in price falls and price pressure, but it can also lead to new markets and niches. Sweden produced around 2% of the total EU sugar production. The daily refinery capacity at Nordic Sugar Arlöv is around 1,000 tons raw sugar. Nordic Sugar Arlöv is a sugar refinery that is running all year round and Nordic Sugar Örtofta is a sugar factory that only runs part of the year during the production season from mid-September to mid-January. The sugar industry is a mature industry, historically a lot of resources have been put into research and development within the industry in Sweden. Nordic Sugar has become more and more involved in research projects the last couple of years, also in the Swedish part of Nordic Sugar, the projects they are involved in are focused on biobased products and processes, and the aim of the involvement from Nordic Sugar is to find a value chain increasement. They are involved in projects regarding biocommodities for bioplastic products. They are also involved in a project that will develop a value chain based on side streams from the sugar industry for the production of key basic chemicals. Examples of sector related residues from the sugar industry is sugar tops, which theoretically if all beet tops in Sweden were harvested amounts to around 80,000 tonnes dry matter. All biomass residues from the Arlöv and Örtofta refinery factories are utilized today. Just before the production season for sugar or just after the season there is a possibility to utilize some parts of the factory as the storage facilities and the drum drier. Some parts

of the production line are only adapted to the large flow of biomass, but some parts of the production line there are several smaller machines instead of one large.

In the last five years around 330,000 tonnes of oil crops were harvested in Sweden each year and the rapeseed crops are in a sharp rise. Most rape seed oils are hot pressed in Sweden, the rapeseed is pressed to oil at higher temperature, it is then refined, and more oil can then be extracted from the filter cake by use of solvents. AAK is the owner of the only largescale processing plant for oilseeds in Sweden. Total consumption of rapeseed oil for both food and technical purposes in Sweden is around 294,000 tonnes per year. The oil and fat industry in Sweden is a sector with high profit figures (the difference between the amount earned and the amount spent in buying, operating, or producing something). AAK had an economic turnover of approximately €650,000 in 2016. The production of rapeseeds in Sweden doesn't cover AAKs total need and therefore imported seeds are also used. The production of rapeseed oil and rapeseed meal at AAK Karlshamn is a year around production, there is no seasonal variation. The rapeseed oil and rapeseed meal industry is a mature industry. The vegetable oils is an agricultural product that is chemically most similar to mineral oils and therefore have a great potential as biological raw materials to replace the mineral oils in industries such as for biomaterials and chemicals. Example of a sector related residues from the vegetable oil industry are straw from oilseed crops in Sweden with around 740,000 tonnes per year. Only small amounts of biomass residual are produced in the vegetable oil production at AAK since the rape seed meal is utilized as well. Since there are no large amounts of biomass residues from the rape seed oil production and it is a year around production at the site there are no great opportunities for establishing a future IBLC at AAK Karlshamn. To become a supplier of biocommodities is not of interest for AAK Karlshamn. There is research projects investigating rapeseed straw used as raw materials in the manufacture of renewable plastic materials and to convert the press-cake from rapeseed to human food. The attitude of the industry is that they are not interested in becoming a supplier of biocommodities; this has a negative effect on the possibility to establishing a future IBLC in this sector.

The grain chain production raw material is crops wheat, barley, oats, rye and triticale. Annually in average, 5.5 million tonnes of grains are produced. The biggest crop in Sweden is winter wheat, which is produced in average 2.3 million tonnes per year or 41.8 % of total crop harvest. The three following crops are: barley, oats and spring wheat. The crops constitute to 49.7 % of total grain products. The most common grain crops occupy 999,940 ha of total 2,595,797 arable land excluding leys and pasture. The grain receiving plants are located at locations in high production areas, mainly southern Sweden to central Sweden. In total 60 % of the grain cultivated area is located in these regions. Processing products are mainly flour and groats, with the biggest quantities is 313,506 tonnes per year from wheat flour and 119,696 tonnes per year from mixed wheat and rye flour. Most processing facilities are utilized all year round, with lower production in grain driers from November to next year's harvesting period. The processing industry is actively researching in increasing value of side chains and residues. For example, husk residues from Järna mill are incinerated in boilers, where the steam is used for production and the heat is used for heating the house holdes in the local area. LM Agroetanol utilizes the CO_2 created by fermentation process of ethanol production to AGA industry commodities and the draff residues (the residual product in the production of ethanol from

cereals) is sold to the feed industry, mostly on export. The straw residues are estimated to 3.8 million tonnes per year, or 16 TWh per year, and the potentially usable amount for bio-energy is estimated to 3,600 GWh per year. A project is initiated in investigating possible uses of husk residues from oats for biobased furnishing and caskets. Researchers have found a way to produce polysaccharides from brans, possibly opening up for future use in biobased plastics like medicine capsules or protecting barriers around meat.

Feed and fodder consists of a mix of primary products of grain; mainly barley, wheat, oats, rape seed meal, beet pulps, molasses, peas, broad beans and grasses. Temporary grasses are produced in quantities of 4.9 million tonnes per year in leys and green crops are grown on 1,146,667 ha of arable land, in average 4.2 tonnes/ha. About 2,300,000 tonnes of grains are used as feed. The feed plants are mostly located at south to middle Sweden and also locally at animal production farms. The feed plants are utilized all year round with down time only for cleaning and maintenance. Grass are produced by the animal producers for their own animals need during summer period and to some extent bought in from the local area. Residues of primary products of grains are the same as in the grain sector. The innovation levels in this sector seems to be focused on reducing imported protein in the feed mix, and abandoned feeding plants have a history of being used for other productions. Biomass residues produced at feeding facilities are low to none and mostly reused in feed production. Grass production biomass residues consist of losses during harvest and transport and discarded amounts not suitable for feed. Potential benefits in IBLC are increased usage of today non-productive areas where grass is grown. If a decrease in animal production leads to an increased surplus capacity in the feed industry, this may also benefit IBLC. There are projects that are studying grass usage in larger extend than only feed, e.g. for biogas and to some extent ethanol production. The non-technical barriers are mainly potential competitiveness from feed industry, but a potential decrease in animal production may benefit bioenergy production. Barriers of grain production for feeds are considered to be the same as in the grain sector.

Interviews with representatives from the different industries showed that there are different levels of interest for the IBLC-concept in the different sectors. In Sweden, the sugar industry shows a large interest to utilize the industry in the time between productions of sugar. One possibility is to become a producer of biocommodities. The vegetable oil industry is not interested in becoming a producer of biocommodities, and their production is year around without large amounts of residues.

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1 INTRODUCTION

This report was written as a part of the AGROinLOG project "Demonstration of innovative integrated biomass logistics centres for the Agro-industry sector in Europe" (#727961) and is within the scope of the Task 6.2 "Basic analysis of targeted agricultural sectors". The report aims at providing an actual overview over the state of the sectors, as well as with respect to the IBLC related topics. The following sectors of the Swedish agricultural industry are considered: the grain production, the sugar industry, the feed and fodder and the vegetable oil extraction. Lantmännen was responsible for the parts on the grain production and the feed and fodder. RISE was responsible for the parts on the sugar industry and the vegetable oil extraction. Another goal is to determine, whether there is potential in all or in some of the selected sectors for an implementation of the IBLC concept. Each sector chapter effectively consists of two parts: an overview and estimation of IBLC opportunities.

The four sectors of the agricultural industry were selected primarily because they are existing large sectors in Sweden with large producing companies. The wine and olive oil mill sectors were not selected since the wine production is marginal in Sweden and there is no production of olives in Sweden.

The methods used in the study have been interviews, literature reviews, compilations of market reports and statistical data. One lesson is not to always trust the statistical data, sometimes the statistics differs from the practical reality in agriculture. In Sweden this was the case for the yearly production of biomass from pasture.

It has sometimes been difficult to get information from the companies with regard to their strict company confidentiality. But we would like to give a big thank you to all companies who generously shared all their information.

2 SUGAR INDUSTRY

2.1 Profile of the sugar industry sector

2.1.1 Production

All cultivation of sugar beets in Sweden is contracted by Nordic Sugar. In Sweden the majority of the sugar beets are grown in Skåne (the most southern county). The average area with sugar beets per year between 2012 and 2016 was 31,975 hectares, Table 1. During the first ten years of the 21st century, the number of beet growers in Sweden was reduced with 50% (Jordbruksverket, 2016). The cultivation area with sugar beets has also decreased during the same time period from around 60,000 hectares in 1999 to 2009. In 2015 the area with sugar beets was 19,465 hectares, a large decrease compared to 2014 with 34,401 hectares. A global surplus of sugar, combined with the new industry agreement, led to the reduction of sugar beet in 2015. In 2016 the area with sugar beets was almost back to normal again with 30 714 hectares. The standard harvest for sugar beets in Skåne was 64,547 kg/ha 2016 (17.8% sugar content) and slightly lower for other counties (Jordbruksverket & SCB, 2016). About 2 million tons of sugar beets are produced every year (Nordic Sugar, 2017).

Table 1. Area of sugar beets in Sweden in hectares (Jordbruksverket, 2012; 2013; 2014; 2015; 2016)

Area sugar beets, hectares						
Year	2012	2013	2014	2015	2016	Average 2012-2016
Area (ha)	39,046	36,250	34,401	19,465	30,714	31,975

The root of the beet contains 75% water, around 16-18% sugar, and 5% fiber (Nordzucker, 2017). The exact sugar content can vary depending on the cultivar and on the growing conditions.

The sugar production starts in the field with the sugar beets and ends with a diversity of products, including sugar products, feed products (molasses, beet pulp), sugar factory lime, stones, beet soil and water, see *Figure 1*. The sugar industry receives the sugar beets from the farmers and begins by the weighbridge on the industry site. The industry pays for the transports, by truck and tractor. Some products made in the factory are recirculated into the system as biogas, steam and water. As an example the biogas produced at the site is combusted and the heat is utilized in the process.

A refinery is an industry where the primary feedstock is raw sugar from sugar factories.

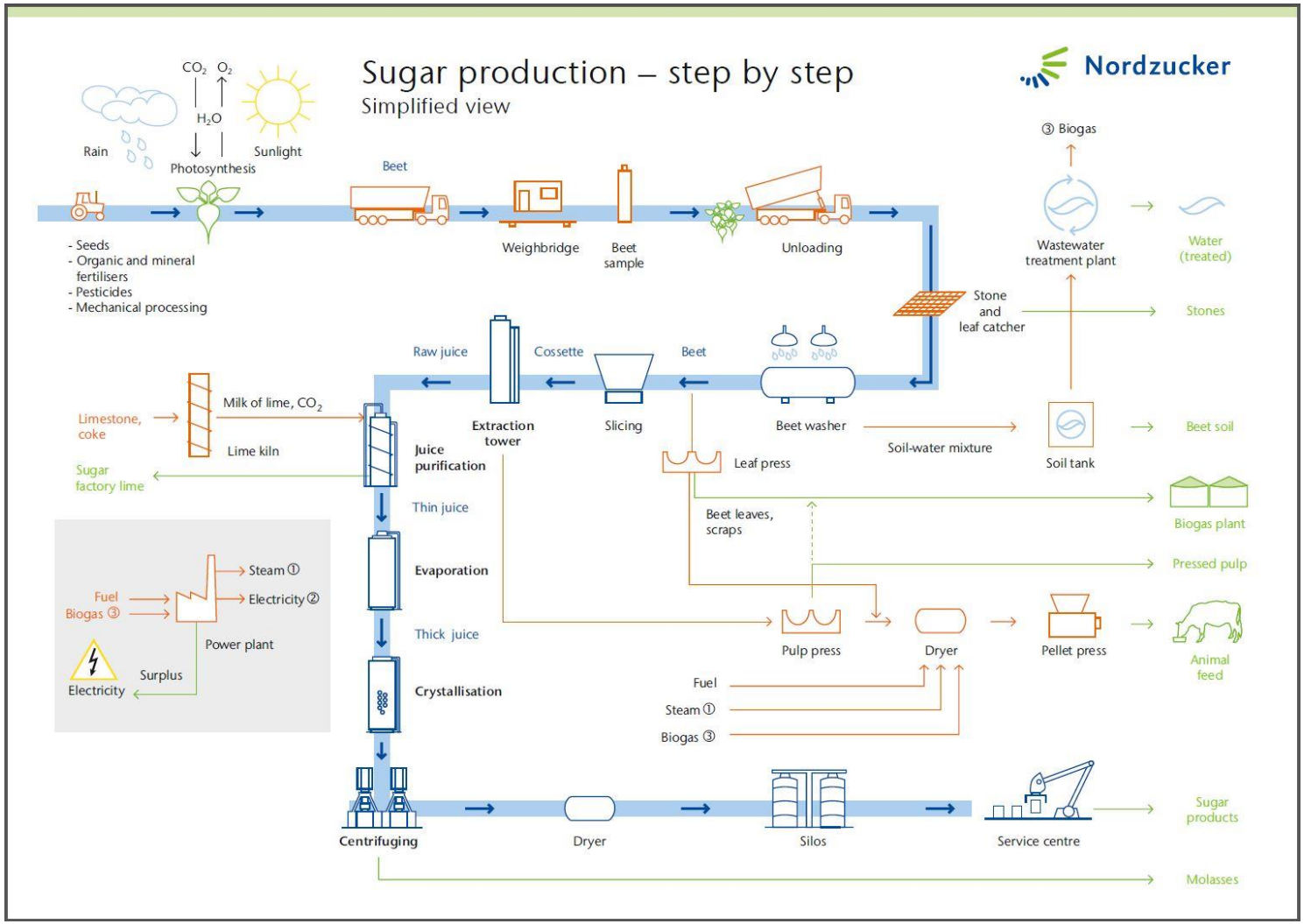

Figure 1 Sugar production – step by step. Source: Nordzucker (2017)

2.1.2 Volume of the sector

There is one sugar refinery, Arlöv, and one sugar factory, Örtofta, in Sweden, both owned by Nordic Sugar which is the only sugar producing company in Sweden, Figure 2. The refinery and factory is situated in the South of Sweden in Skåne.

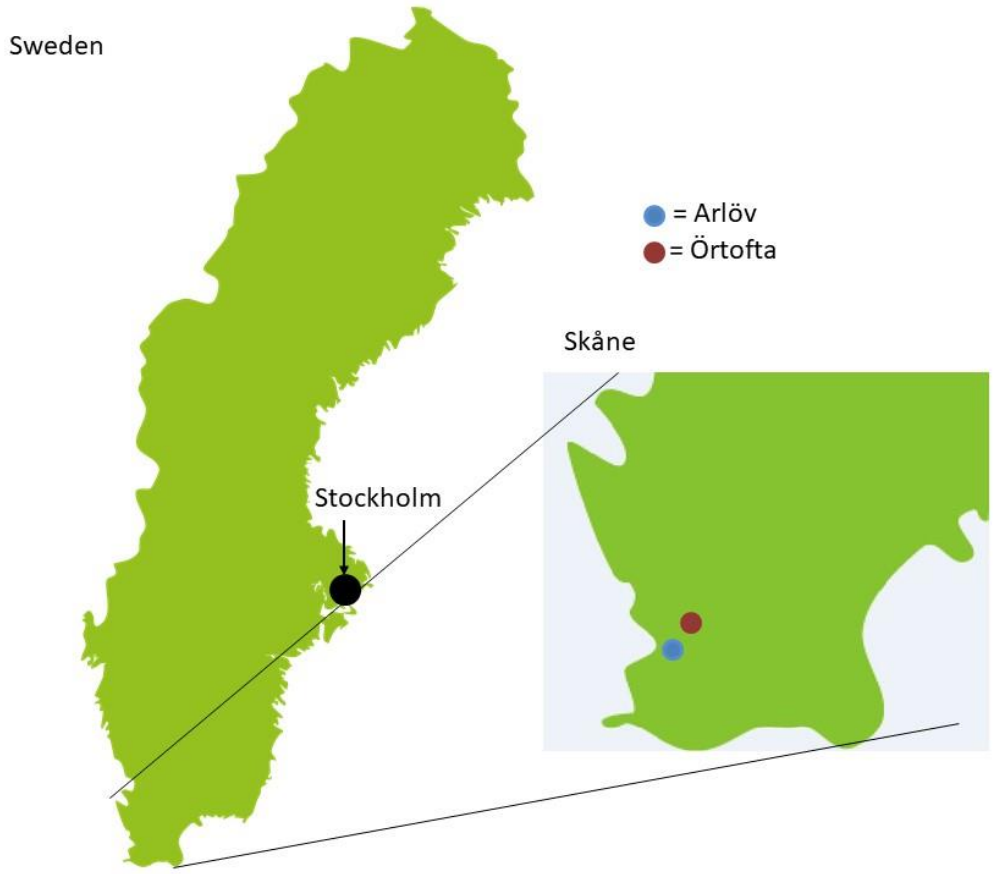

Figure 2 Map Örtofta and Arlöv in Skåne, Sweden

Since 2009, Nordic Sugar has been part of the German-based Nordzucker group, but has been manufacturing sugar for the Northern European market for more than 100 years. The sugar beets are locally produced, and some raw sugar is imported. Nordic Sugar has a total of 1,500 employees, of whom 330 work in Sweden. The employees at both Örtofta and Arlöv mostly work in production, such as machine operators, process operators and service engineers, where they work with electrical maintenance and automation or at the laboratory. Örtofta is one of the largest and most efficient sugar-producing facilities in northern Europe. The yearly production of sugar at Örtofta is 382,000 tonnes/year, Table 2. (Nordic Sugar, 2017)

Table 2 Yearly production in Örtofta. Source: Nordic Sugar (2017)

Yearly production Örtofta	
Products	Produced amount at Örtofta, tonnes/year
Sugar	382,000*
Molasses	58,000
Molassed sugar beet pellets (Betfor®)	74,000
HP-Pulp (HP-Massa®)	69,000

*One part is delivered to Arlöv

In Arlöv many different special products are manufactured for a wide range of applications, mainly for the food industry, Table 3. Some examples of special products are vanilla sugar, icing sugar, syrup, cube sugar, liquid sugar and nib sugar. They produce various sugar solutions which are developed in close cooperation with the customers and are delivered to daily basis to customers all over Sweden. About 80% of the products from Örtofta and Arlöv are sold to the industry market and about 20 % to customers.

Table 3. Yearly production in Arlöv. Source: Nordic Sugar (2017)

Yearly production Arlöv	
Products	Produced amount at Arlöv, tonnes/year
Sugar solution	146,000
Syrup	31,000
Cube sugar	7,800
Special products	11,000
Fractional sugar	23,000
Molasses	250

2.1.3 State of the sector

The EU sugar beet industry is preparing for one of the largest changes in its history which is the end of production quotas on 1 October 2017. When the EU regulation expires in 2017, it can mean that the sugar prices will fall within the EU with declining profits of sugar companies as a result. For the last 50 years the market for sugar beets has been regulated with quotas and minimum prices. EU production quotas and protective duties have been intended to prevent competition from imports of cheaper cane sugar cultivated outside the EU. This means that sugar prices in the EU today are almost twice as high as the world market price. A review shows that EU quotas and protection contributed to significantly increased profits for those companies in which sugar production is included. In just two years around 2013, for example, the operating results for the German Nordzucker increased from 78 million to 188 million euro (SVT, 2017).

In the summer of 2016 Nordic Sugar and the beet growers agreed upon a technical framework which will regulate the sugar beet production for the next four years. In autumn 2017 the market completely controls the demand for Swedish sugar, which means that the sugar production will compete with Europe in a new way.

For 30 years a factory in Köpingebro in Sweden has been producing fiber products from sugar beet intended for human consumption but in 2016 the factory was shut down. Examples of products produced in the factory were dietary fibre supplements made from sugar beet pulp. The reason behind the closing lies in the change of the human fiber market. (Nordicsugar, 2017)

The total sugar production from sugar beets has decreased with 38 % between 2011/12 and 2015/16 in Sweden, see Table 4. At the same time sugar consumption has remained relatively constant since the 1960s in the Nordic countries (Nordicsugar, 2017).

Table 4 Total sugar production from sugar beet in tonnes 2011/12-2015/16. Source: Comitesucre (2017)

Total sugar production from sugar beet, tonnes						
Country	2011/12	2012/13	2013/14	2014/15	2015/16	Average 2011/12-2015/16
Sweden	416,860	365,869	377,700	382,000	257,764	345,833

2.1.4 Typical size of the companies

Sweden produces approximately 2% of the total EU sugar production on a 5-year average 2011/2012-2015/2016 (Comitesucre, 2017). The length of the beet campaign at the sugar beet factory in Sweden was 118 days on average for 2011/12-2015/16 slightly above average for the 28 EU countries in
Table 5, 114 days.

The daily processing capacity at Nordic Sugar Örtofta is around 18,500 tons of beets. During the production season Nordic Sugar Örtofta receives and processes around 2 million tons of sugar beets. Every day 600 truckloads of beet are delivered. Around 1,500 beet growers sell their beets to the plant. Nordic Sugar Örtofta employs around 140 people, plus 70 seasonal workers during the production season. The daily refinery capacity at Nordic Sugar Arlöv is around 1,000 tons raw sugar, this sugar is delivered from Nordic Sugars beet sugar factory in Örtofta and some raw sugar is imported. Nordic Sugar Arlöv employs around 155 people. (Nordic Sugar, 2017)

Table 5. Number of sugar beet factories and daily beet slicing capacity by production year and length of the beet campaign Sweden, in total and average for the 28 EU countries. Source: Comitesucre (2017)

Sugar beet factories comparison different countries							
Country	Number of sugar beet factories and daily beet slicing capacity by production year, average 2011/12-2015/16						Length of the beet campaign, average 2011/12-2015/16
	< 5,000 tonnes	5,000-8,000 tonnes	8,000-12,000 tonnes	12,000-15,000 tonnes	>15,000 tonnes	Total	Days
Sweden	-	-	-	-	1	1	118
Total EU28	15	31	23	14	22	105	-
Average EU28	-	-	-	-	-	-	114

2.1.5 Distinctive facilities of the sector

Nordic Sugar Arlöv is a sugar refinery that is running all year round.

Nordic Sugar Örtofta is a sugar factory that only runs part of the year during the production season from mid-September to mid-January. The production period is linked to the cultivation season for sugar beet. During the production season the facility operates around the clock, seven days a week. During the time of year when there is no production on the site the key activities are focused on overhauling and maintaining the production equipment, installing any new facilities as well as on other improvement projects. According to Jensen and Dahlgren (pers. comm., 2017) at Nordic Sugar Örtofta, the non-production period could be shorter than it is today. There is no surplus on staff after the production season. But there might be a possibility that staff can be hired of the factory to do other things. This could for example create broader skills among the employees. In time this could

be possible just before the production season or just after the season. The process equipment is available from where the sugar beet enters the factory to the dryer. In the pre-treatment part of the factory there is great wear of the process equipment, so the reparation time cannot be that much shorted here. The storage facilities are utilized today but for a short period it could be used for other purposes.

The technologies utilized at Nordic Sugar Örtofta are simple inorganic technologies which for example involve water, lime, carbonic acid and filtration processes. For example, high-pressure processes would not fit in (Jensen and Dahlgren, pers. comm., 2017). Temperatures around 150°C and 200°C are ok, but for example pyrolysis around 350°C would not work. Acid hydrolysis is also not ok because the process today is at a high pH.

In February 2018 Nordic Sugar spread the news in the media that they plan to discontinue operations in Arlöv and move all its production to the site in Örtofta (Skånska Dagbladet, 2018). It means a billion investment but also staff reduction. An efficiency study conducted by Nordic Sugar shows that there are substantial savings and efficiency improvements to be made if all the production is gathers by the plant in Örtofta.

2.1.6 Degree of innovation

Historically a lot of resources have been put into research and development within the sugar industry in Sweden. But today a lot of the research and development activities have been moved from Sweden to other countries such as Denmark and Germany. The sugar industry is a mature industry. Water treatment and biogas production are examples of techniques that have been developed as research and development projects and are now common technologies within the industry´s operations. Energy savings have always been in focus within research and development. A lot of focus has also been on utilization of residuals; development of dried fibres for human consumption and hard-pressed pulp as two examples. The usage of fossil fuels is high today; this is one of the biggest challenges for the sugar industry.

Örtofta has invested in lowering the environmental footprint by delivering all surplus heat from the sugar production to the local district heating network. This gives major environmental gains in terms of reduced carbon dioxide emissions of up to 8,500 tonnes a year. The amount of surplus heat delivered corresponds to the annual consumption of 3,000 single-family houses. Recently around 20 million euros were invested in a new steam dryer and a new boiler plant. This is a venture that reduces the factory's natural gas needs by 30 %. At the same time, they reduce CO_2 emissions by around 32,000 tonnes / year. (nordicsugar.se)

Nordic Sugar has become more and more involved in research projects the last couple of years, also in the Swedish organization. A lot of the research projects they are involved in is into biobased products and processes, and the aim of the involvement from Nordic Sugar is to find a value chain improvement.

There has been different smaller projects and pilot studies at Nordic Sugars sites in Denmark to use the dryer for different biomasses, for example alfalfa and wood chips, before the sugar beet

campaign (Jensen and Dahlgren, per. com., 2017). There has also been a study on producing pellets from other fibres than sugar beet fibres.

2.1.7 Miscellaneous

The European Committee of Sugar Manufacturers (CEFS) has initiated a life cycle assessment of European beet sugar production where a multiple of environmental aspects has been investigated (Spoerri and Kaegi, 2015a, b). For Örtofta Sugar factory a similar life cycle assessment was performed by (*Unpublished source*). In this the climate impact was assessed, as well as contribution to eutrophication. The latter was measured as phosphate emissions-equivalents in freshwater systems and as nitrate emissions–equivalents in marine water systems. Also, the non-renewable energy total use (NREU) was investigated. Results were presented with different allocation principles, and the following figures refer to unallocated result. For climate impact and phosphate emissions sugar beet cultivation and sugar production contributed with 50% each to the carbon footprint. For nitrate emission the contribution from the sugar beet cultivation was 90% of the total. For NREU 75% of the contribution came from the production.

2.2 Opportunities IBLC

2.2.1 Sector related residues

2.2.1.1 Biomass residues within the supplying agricultural sector

The average yield for sugar beet tops in Sweden is around 2.5 tonnes dry matter per hectare (Jordbruksverket, 2014). Today the majority of the sugar beet tops is left in the field and are ploughed into the soil. If all sugar beet tops in Sweden were harvested around 80,000 tonnes dry matter beet tops would be generated theoretically. Sugar beet tops have high water content at harvest, which makes them difficult to preserve as silage. It is therefore an advantage to use sugar beet tops as fresh material, for example as substrate (feedstock used for production of biogas) for biogas production. The material is mainly available at harvest in September to November. Different harvesting and transport chains for sugar beets and beet tops were theoretically evaluated in a study by Kreuger et al. (2014). In the most economically feasible harvest chain only 55% of the available beet tops was harvested to minimize machine waiting times. If around 55% of the sugar beet tops in Sweden were harvested around 44,000 tonnes dry matter beet tops would be generated.

2.2.1.2 Biomass residues from the agro-industry's processing operations

All biomass residues from the Arlöv and Örtofta refinery factories are utilized today, Table 6. Nordic Sugar doesn't want to use the word biomass residues; since they are all utilized today they see the residues as co-products.

The molassed sugar beet pellets consist of approx. 90% dried beet fibres and about 10% molasses. It can be stored for a long time without changing nutritional content. Molassed sugar beet pellets are used as feed material in the feed industry and as feed for feeding ruminants, horses, sheep and pigs. When fed to horses, the pellets must be soaked first. It can also be used as a silage agent. Molassed sugar beet pellets are manufactured during the beet campaign. The manufactured product is available throughout the year.

HP Pulp is primarily used as feed for ruminants and is an excellent complement to home-grown silage and grain. HP Pulp must be ensiled before use. All manufacturing and sales of HP Pulp is done during the beet campaign.

Molasses is used as feed material and as an individual feed for ruminants, horses and pigs. It is also a good binder for pelleting and binds dust. Molasses is also used as a silage agent and as a substrate in biotechnological production. Molasses is produced during the beet campaign in September - December. The product is available throughout the year.

The beet leaves and scraps are used as substrate to feed the biogas plant.

Table 6. Co-products from Arlöv and Örtofta. Source: Nordicsugar (2017)

Biomass residues from Arlöv and Örtofta	
Products from Arlöv and Örtofta	Produced amount, tonnes/year
Molassed sugar beet pellets (Betfor®)	74,000
HP-Pulp (HP-Massa®)	69,000
Molasses	58,250

2.2.2 Potential synergies & benefits

The time of year when there is no production on the sugar industry production site it may be possible to utilize the site for other types of production. But since the flow of material during the production season for sugar beet is so large it must be a large flow of material otherwise it will be hard to get a profitable production. In some parts of the production line there are several smaller machines instead of one large, there might be an opportunity to use only one of the smaller machines if it is a smaller material flow. There are several boilers in parallel and in the juice cleaning there are a number of filters running in parallel. The other parts of the production are large flows.

If Nordic Sugar can utilize the production site better for example with IBLC the profit will increase. An improved value chain can create conditions for Nordic Sugar Örtofta to be able to convince the farmers to continue to grow sugar beets (Jensen and Dahlgren, pers. comm., 2017). Even if the sugar price would fluctuate it would be possible to give a good price to the farmers for the sugar beets. Increased profitability can be a driving force towards to sugar beet growers to compensate for a lower sugar price.

One possibility is also to increase today's biogas production (only operating during the sugar producing period), by adding more biomass residuals. This will increase the volume of digestate. This can improve the economy by extracting phosphorus, nitrogen and potassium from the digestate, which allows for the design of new fertilizer products optimized for agriculture. Another opportunity

is to expand the production of pellets production of other material than sugar beet fibres in a pellet plant and protein drying in drum dryers prior to the sugar beet campaign.

2.2.3 Market developments

Nordzucker is a company that with many years' experience of campaigns lasting 120, 125, 130 days or longer or shorter, their maintenance and investment can be adapted to the campaign period that is needed depending on the new opportunities that arise. (Nordzucker, 2017)

Two examples of projects that Swedish Nordic Sugar is involved in are STEPS and Farm2Furan Furans of agricultural surplus. STEPS (Sustainable Plastics and Transition Pathways) is a research programme with a vision of a future society in which plastics are sustainably produced, used and recycled in a circular economy. Nordic sugars role in STEPS is to deliver biomass into the process of producing bioplastic. The sugar production will be viewed from a life cycle perspective. The purpose of the project Farm2Furan is to develop a value chain based on side streams from agriculture and food production to produce key basic chemicals in the context of the future biorefinery.

Nordic Sugar Örtofta is not interested in selling bioplastic products, but they are interested in utilizing their industry site to produce biocommodities for bioplastic products and to utilize their biomass residues for bioplastic production (Jensen and Dahlgren, pers. comm., 2017). For example Nordic Sugar is interested in using co-products from the sugar industry as the main raw materials for PLA (polylactic acid, biodegradable biomaterial) production in Sweden in a system based on industrial symbiosis. They have together with different actors applied for research funding for a project where all processing steps from raw material to a final prototype of a PLA-based product are included. PLA is a commercial product but there are great possibilities for innovation along the production chain.

Nordic Sugar are experts in their own markets, but they don´t know the bioplastic market for example (Jensen and Dahlgren, pers. comm., 2017). That is also one reason why they are involved in different research project with other industries, to network and create new businesses. Nordic Sugar have great knowledge in logistics and large flows with biomass, this is a valuable knowledge they can utilize to create new business with new partners.

2.2.4 Non-technical barriers

In an interview with Jensen and Dahlgren (pers. comm., 2017) they raised the issue that there is a misunderstanding regarding the first generation of bioplastics. In a period of about 10-15 years we should be able to base our production of bioplastics on the carbohydrates that are available now (for example in sugar beets). If we want to develop a compounding industry we have to do that. But today every resource is put into transforming raw material from the forest (non-available carbohydrate today) into bioplastics. If we do not utilize the available carbohydrates for bioplastics perhaps we will not have available bioplastics until 10-15 years. It is good that money is invested in raw materials from forest to bioplastics, but in parallel we should use existing available carbohydrates such as sugar beet. We could produce the first generation bioplastics and later on when the forest based bioplastics is available we just change the raw material and get the second generation bioplastics. By starting to produce the first generation bioplastics based on Swedish

arable crops as sugar beets a market is established and a demand is created. There is a prejudice barrier in the political system; it is a misunderstanding which causes the green shift to take much longer than it could have done. For example, we could get started with PLA from sugar beet

When a market is deregulated, as just happened to the sugar market, price falls and price pressure often occur. But at the same time a deregulation can also lead to new markets and niches, which will probably also occur in the sugar sector.

There are many uncertainties at the moment when it comes to the non-technical barriers in the sugar industry due to the end of production quotas on 1 October 2017. One possible scenario is a lower sugar price, with a result of a decrease in the number of growers. The strategy for Nordzucker in 2016 was “Shaping the transition”, due to the end of production quotas (Nordzucker, 2017). The Chairman of the Supervisory Board at Nordzucker thinks that Nordzucker is in a position of financial strength and is well prepared for the transition towards the new EU market without sugar quotas and minimum beet prices.

If the policy makers in Sweden would support the utilization of sugar and sugar beet pulp to produce a first generation of bioplastics and building blocks the beet area can be increased and the product value per hectare may increase in comparison with other countries. This would make it possible to keep a good price to the farmers and build a stable ground for the future production. The sugar production site would then be utilized in a more efficient way and the biobased products would reach the market faster. This technique will also be useful for second and third generation processes when they become available. (Jensen, pers. comm., 2017)

3 VEGETABLE OIL EXTRACTION

3.1 Profile of the vegetable oil extraction sector

3.1.1 Production

The average area with rapeseed per year between 2012 and 2016 was 102,537 hectares, see Table 7*Table 7*. The cultivation of winter rapeseed has doubled in recent years; the average area between 2012 and 2016 was 78,404 hectares. Half of the area is in Skåne (the most southern county in Sweden). In the same period the cultivation of spring rapeseed has decreased from 44,448 hectares in 2012 to 7,616 hectares in 2016. Stockholm, Uppsala and Västra Götaland are the counties in Sweden with the largest cultivated area of spring rape. The cultivation of turnip rape and linseed only constitutes a small part of the arable land in Sweden, but has been significant in the past in Sweden.

The standard harvest for winter rapeseed was 3,642 kg/ha in 2016 as average for Sweden. The corresponding number for spring rapeseed was 1,834 kg/ha (Jordbruksverket & SCB, 2016). In the last five years, an average of about 330,000 tonnes of oil crops was harvested in Sweden each year, see *Table 8*.

Table 7 Area of oil seed crops in Sweden in hectares. Source: Jordbruksverket, 2012; 2013; 2014; 2015; 2016

Area of oil seed crops in Sweden in hectares						
Crops	2012	2013	2014	2015	2016	2012-2016
Winter rapeseed	62,477	77,617	79,841	88,076	84,008	78,404
Spring rapeseed	44,448	49,284	14,734	4,584	7,616	24,133
Total rapeseed	106,925	126,901	94,575	92,660	91,624	102,537

Table 8 Calculated amount of oil seed crops in Sweden in tonnes. Source: Jordbruksverket, 2012; 2013; 2014; 2015; 2016

Calculated amount of oil seed crops in Sweden in tonnes						
Crops	2012	2013	2014	2015	2016	2012-2016
Winter rapeseed	222,369	288,509	290,405	318,147	304,295	284,745
Spring rapeseed	82,554	91,838	27,219	8,591	12,296	44,500
Total rapeseed	304,924	380,347	317,624	326,738	316,591	329,245

Oil is the main ingredient in rape seed; it is expressed as raw fat and amounts to about 45%. It also contains 55% raw protein and crude fibre. The rape seed that is cultivated today has a low content of erucic acid and glucosinolates. The moisture content, in the seed, must not exceed 9% in order to be stored.

Products from rapeseeds are oil (used for food purposes and for technical use) and rape cake and rape flour (used for animal feed to ruminants, pigs and chickens).

The vegetable oil is extracted by either cold pressing or hot pressing. The cold pressing of oil seeds means that the seed is crushed and the oil is mechanically pressed under low temperature. During

the hot pressing of rapeseed the oil is pressed at higher temperature, typically 90°C. The pressed oil is refined and more oil can then be extracted from the filter cake by use of solvents. Most rape seed oils are hot pressed in Sweden, a system overview of the process at AAK Karlshamn is presented in Figure 3.

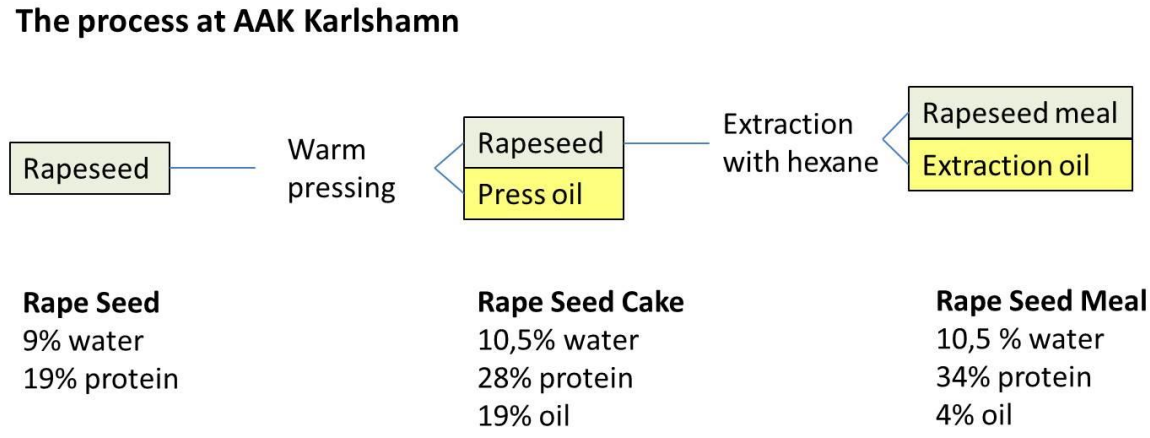

Figure 3 System overview of rapeseed pressing and extraction process at AAK Karlshamn. Source: Holmqvist pers. comm. (2017)

3.1.2 Volume of the sector

In Sweden the import of oil crops was higher than the export on average between 2012 and 2016, Table 9. In total, Sweden imported about 230,000 tonnes rapeseeds and vegetable oils and fats from rape seed per year (Fediol, 2017). The corresponding export was around 50,000 tonnes per year.

FEDIOL represents the European Vegetable Oil and Protein Meal Industry and produces statistics on the associated industry. The Swedish production of rapeseed constitutes only less than 2 % of the total production in EU, Table 9. The Swedish crushing of rapeseeds constitutes just above 1% of the total production in EU. The import of rapeseed oil, 200,000 tonnes, was higher than the Swedish production, 123,000 tonnes, on average between 2012 and 2016.

Total consumption of rapeseed oil for both food and technical purposes in Sweden was 294,000 tonnes per year on average between 2012-2016, Table 10. About the same amount of rapeseed meal is used in animal feed. One ton rapeseed gives approximately 0.4 ton rapeseed oil and 0.6 ton rapeseed flour.

Table 9 Production, import and crushing of oil seed in 2012-2016, in 1 000 tonnes. Source: Fediol (2017)

Production, import and crushing of oil seed in 2012-2016 in, 1 000 tonnes								
Crop	Production of oilseed		Imports of oilseed		Export of oilseed		Crushing of oilseed	
	Sweden	Total EU-28	Sweden	Total EU-28	Sweden	Total EU	Sweden	Total EU-28
Rapeseed	318	21,323	32	3,291	23	175	293	23,863

Table 10 Production, import, export and consumption of vegetable oils and fats in 2012-2016, in 1 000 tonnes. Source: Fediol (2017)

Production, import, export and consumption of vegetable oils and fats in 2012-2016, 1000 tonnes					
Crops	Production of crude vegetable oils and fats		Imports of vegetable oils and fats	Export of vegetable oils and fats	Consumption of vegetable oils and fats
	Sweden	Total EU-28	Sweden	Sweden	Sweden
Rapeseeds	123	10,203	200	29	294

AAK is a global company with around 20 production sites all over the world and around 3,000 employees. Their main business is food. AAK is organized in three business areas; Food Ingredients, Chocolate & Confectionery Fats and Technical Products & Feed. The cosmetics unit in Chocolate & Confectionery Fats is a growing business. The products from AAK are used as ingredients for the food industry (bakery, confectionery and dairy products), chemical industry, pharmaceutical industry, cosmetics, animal feed and environmentally-friendly lubricants (AAK, 2017). AAKs vision is to be the first choice for value-adding vegetable oil solutions. Almost all rapeseeds harvested in Sweden are delivered to AAK in Karlshamn, Figure 4.

Figure 4.Karlshamn´s location in Sweden

3.1.3 State of the sector

The rapeseed crop sector is in a sharp rise. Winter rapeseed is sometimes associated with some cultivation uncertainty, since it is important to establish the crop in field on time in the late summer.

Most of the food industry sectors follow the pattern of a declining staffing force. The number of employees was halved in the oil and fat industry sector in Sweden from 2008 to 2011, primarily in companies with more than 500 employees. This is partly due to the fact that some companies in the oil and fat industry started producing other things than oil and fat. At the same time the number of

companies in the fat and oil industry was 48 companies in both 2008 and 2011. The other food industry in Sweden, covering several of the processed agricultural products, on the other hand, grew in both the number of companies and in the number of employees during the period 2008 to 2011. (Jordbruksverket, 2012)

The oil and fat industry in Sweden is a sector with high profit figures (SCB, 2017). The neighbouring countries are Sweden's largest export markets. Denmark is the largest recipient country in terms of value, followed by Norway and then Finland.

The prerequisite for obtaining profitability in the rapeseed press process is based on the availability of both rapeseed oil and rapeseed press cake/rapeseed meal. The rapeseed press cake profit depends on the market price of rapeseed oil and vice versa. The need for rapeseed in compound feed is greater than can currently be produce in the country (Holmqvist, pers. comm., 2017). The great demand for the protein flour from rapeseed has during several years been the part that has affected the price of rape seed the most. Since 2007 there is a close connection between the price on vegetable oil and the price on fossil oil.

3.1.4 Typical size of the companies

The number of employees at AAK Sweden has not varied that much between December 2012 and December 2016, around 450 employees. The company had an economic turnover of approximately 650 000 Euro in 2016, an increase from December 2012 with around 63,000 Euro Table 11 (Allabolag, 2017). The profit went up from 2012 to 2013 and down 2014 and 2015, then up again 2016. Maybe there were large investments at AAK Sweden in 2015 that affected the profit of the year in 2015.

Table 11 Company facts on AAK. Source: Allabolag (2017)

	Company facts on AAK					
Facts	2012-12	2013-12	2014-12	2015-12	2016-12	2012-2016
Number of employees	456	440	448	454	451	450
Economic turnover (Euro)	589,980	586,251	631,960	627,105	652,905	617,640
Profit for the year (Euro)	20,331	42,434	34,667	13,796	51,110	32,468

AAK does not want to comment on the specific amount of rapeseed that is delivered to their production site in Karlshamn (Holmqvist, pers. comm., 2017). However, the production doesn't cover the company's total need and therefore imported seeds are also used.

Ecobränsle is a company that produce RME in their own factory in Karlshamn. In 2016 around 15,000 tonnes Swedish rapeseed oil was used for production of RME at Ecobränsle. From one ton rapeseed the RME yield is just below 100%, but in the process methanol is also added. In 2014 around 35,000 tonnes Swedish rapeseed oil was used for production of RME, in 2015 around 25,000 tonnes and 2016 only around 8,000-10,000 tonnes. The decline was due to a tax levied on RME in 2015. (Lorentzen, pers. comm., 2017)

Rapeseed oil is a large bulk product in the world market. Nevertheless, more and more Swedish farmers are investing in processing capacity for locally produced rapeseed oil. Here are examples of some locally pressed rapeseed oil: Nygård Gävleborg, Nyborg Stockholm, Julita Sörmland, Sänkdalen Östergötland, Stockuts Västra Götaland, Olivia Västra Götaland, Gunnarshög Skåne and SoilOil AB Skåne.

The Swedish company, Binol (www.binol.com), which has lubrication, engine and saw chain oils based on rapeseed oil. Binol was owned by AAK but was acquired by Quaker Chemical cooperation 2014.

3.1.5 Distinctive facilities of the sector

The production of rapeseed oil and rapeseed meal at AAK Karlshamn is a year around production. There is no seasonal variation. There are storage facilities at the site, but there is no possibility to store other materials in this facility since it is a year around production at the site.

Examples of type of machinery that is available on the site is a crusher, if capacity is fully utilized today or not is no information that AAK wants to reveal (Holmqvist, pers. comm., 2017). In the crusher the rapeseeds are mechanically pressed in expellers after a preheating step in indirectly heated conditioners. After the crusher the pressed cake will be further treated in the extractor (another example of machinery in the production process), since it might still content up to 19 % of oil).

AAK treats the meal further in a unique heat treatment process, which reduces the rumen digestibility without reducing the intestinal digestibility for ruminants. Very little soymeal is used for feeding bovines in Sweden today, much because of this process. (Holmqvist, pers. comm., 2017)

3.1.6 Degree of innovation

The rapeseed oil and rapeseed meal industry is a mature industry. As one example the production of fats and proteins for fodder is something that has arised from a need to take care of the residuals.

The vegetable oils is an agricultural product that is chemically most similar to mineral oils and therefore have a great potential as biological raw materials to replace the mineral oils in industries such as for biomaterials and chemicals. Already today vegetable oil is competing successfully with mineral oil in many technical applications. (Svenskraps, 2017)

The vegetable oil industry has put a lot of effort into delivering formulations with an improved nutritional profile to the food industry. Raw materials and innovative processes are in constant development with a clear cost impact. (Fediol, 2017)

3.2 Opportunities IBLC

3.2.1 Sector related residues

The total volume of straw from oilseed crops in Sweden is around 740,000 tonnes per year. This corresponds with 3.1 TWh in total energy production per year. The energy content in MWh per tonne dry matter is 5.0, with a water content of 16%. (Börjesson, 2016) There are a lot of nutrients in rape straw. From Swedish trials it was shown that winter rapeseed left 70 kilos of nitrogen per hectare as crop residues. The estimated content of phosphorus was 15 kilos and 340 kilos of potassium. (Svenskraps, 2017) A very small amount of rape seed straw is utilized in Sweden today, the most part is ploughed back into the soil. The utilization is as litter for animals.

Only small amounts of biomass residual are produced in the vegetable oil production at AAK since the rape seed meal is utilized as well. Small amounts of rape husks are separated from the rape seeds in the process at AAK Karlshamn. The specific amounts are nothing that AAK want to spread information about. Smaller amounts of bio oil are also produced. Both the rape husks and the bio oil are incinerated today. (Holmqvist, pers. comm., 2017)

The largest single import of oil crops consists of pressurized residues from vegetable oil production, so-called oil cakes and meal. About 400,000 tonnes of oil cakes and meal are imported annually to Sweden. (Jordbruksverket, 2017)

3.2.2 Potential synergies & benefits

Since there are no large amounts of biomass residues from the rape seed oil production and it is a year around production at the site there are no great opportunities for establishing a future IBLC at AAK Karlshamn. To become a supplier of biocommodities is not of interest for AAK Karlshamn (Holmqvist, pers. comm., 2017). AAK will not start producing rape seed press cake for food purposes, but it might be interesting for other non-food applications.

3.2.3 Market developments

At Lund University researchers are currently trying to convert the press-cake from rapeseed to human food, for an example as a protein substitute for meat. The press-cake from rapeseed contains around 30% protein, in comparison, meat contains 20 % protein. It also contains toxic substances such as glucosinolate. By using advanced membrane filtration methods, the researchers expect to extract these substances and then a whole new field of application opens up. In addition to the successful removal of the harmful substances, there is an off-flavour in the residual product which must be neutralized. (Lund University, 2017)

Rapeseed straw is not utilized to any significant extent in Sweden today. It contains macromolecules of the type lignin and hemicellulose which can be used as raw materials in the manufacture of renewable plastic materials. Researchers at KTH Royal Institute of Technology are working on developing a method for extracting the key elements from the rapeseed straw. The goal is to produce

a raw material and, based on it, create a renewable plastic that can be as good as oil-based plastics to eventually substitute the oil-based plastics. (KTH, 2017)

Rapeseed plants are flexible and can adapt to different uses. There is room for such development.

Vegetable oil from oil crops has been used primarily in the food industry in the past, but the growing bioenergy market has been an important factor in rapidly rising prices and demand for vegetable oils.

3.2.4 Non-technical barriers

There are opposing views on whether crop based commodities should be used for biofuels and/or biochemicals. The pro side claims that it is a way to keep arable land in cultivation as well as in readiness to produce both fuels and food. Increased demand affects the farmers' decisions in the crop production. However, the pro-side claims that one positive side effect can be that the product, rapeseed oil, can be used as food for a major food crisis and temporarily replaced with fossil fuels. The opponents on the other hand claim that there will be a competition for the raw materials. They also state that the biofuel industries are very favored by todays EU regulations.

If there would be a possibility or a market opportunity to produce some kind of protein concentrate from rape seed for food purposes it would not be possible with today's legislation (Holmqvist, pers. comm., 2017). Only protein isolate is approved for food today, selling a rapeseed cake or concentrated protein product for food today is prohibited as long as the protein concentration is not at least 90%. The difference between concentrate and isolate is the content (concentration) of protein. In a concentrate the protein content is around 70% and in an isolate around 90%.

In the beginning of 2018 the European Parliament voted in favor of the Renewable Energy Directive (RED II). A key decision made in the voting was to remove biodiesel made from palm oil from the list of biofuels counting towards EU renewables targets from 2021. The rules endorsed by the EU are not final. The European Parliament, the executive European Commission and EU national governments must now negotiate a final draft of the legislation and vote to approve it in a so called trialogue.

The attitude of the industry is that they are not interested in becoming a supplier of biocommodities, this has a negative effect on the possibility to establishing a future IBLC in this sector.

4 GRAIN PRODUCTION

4.1 Grain production in Sweden

4.1.1 Production

4.1.1.1 Primary production

The primary grain processing chain production's main products are for human food consumption, animal fodder and industry applications like ethanol, biogas and alcohol beverage, Figure 5. The primary grain feedstocks are mainly wheat, barley, oats but also rye and triticale.

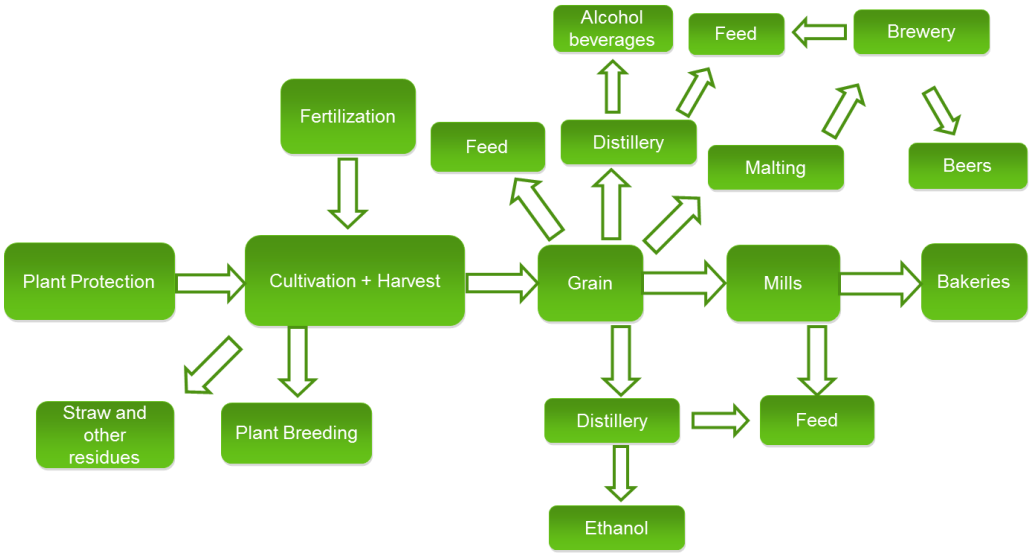

Figure 5. Schematic description of grain processing chain.

4.1.1.1 Processing industry production

For foods, mostly wheat and rye are used in flour production. For feeds, barley, oats, triticale and mixed grains are used as well as a large proportion of wheat. The by-products are bran and husks. The largest proportion of barley used in foods is brewing barley for the brewing industry with residues like malt grout pellets. A significant amount of wheat is used in ethanol production for biofuel and alcoholic beverages.

4.1.2 Volume of the sector

Table 12 shows, in average between 2012 and 2016, the total arable land (excluding pastureland) in Sweden was 2,595,797 ha and the total area used for the most common grains (see Table 12) were 999,940 ha. Wheat was the largest grain crop, sown on 412,185 ha or 41 % of total area with common grains. Slightly less than 80 % of the sown wheat was winter wheat. Barley is the second

largest grain crop and oats were the third. The sum of areas sown with remaining common grains were on average about 6.5 % of total area common grains (Jordbruksverket, 2017).

Table 12 Crop area for most common grain crops in Sweden (Jordbruksverket, 2017)

Crop area in Sweden (ha)						
	2012	2013	2014	2015	2016	Average
Total arable land excl leys and pasture	2,608,274	2,604,531	2,596,527	2,590,053	2,579,602	2,595,797
Total area with grains	1,000,240	984,491	1,034,378	991,776	988,815	1,011,307
Winter wheat	283,567	209,860	379,907	395,241	375,007	328,716
Spring wheat	84,804	116,353	75,282	64,710	76,192	83,468
Rye	22,027	25,127	27,130	23,649	16,650	22,917
Winter barley	9,131	13,701	13,357	15,699	19,179	14,213
Spring barley	364,687	378,867	321,924	311,779	308,154	337,082
Oats	196,240	200,581	164,895	168,055	180,869	182,128
Triticale	23,884	23,059	38,309	-	-	28,417
Mixed seed (grain)	15,900	16,943	13,574	12,643	12,764	14,365

Between 2012 and 2016, the total annual grain harvest was approximately 5.5 million tonnes, Table 13. The largest harvest obtained was winter wheat, averaging at 2.3 million tonnes, or 41.8 % of total grain harvest. The next three largest grain crops (spring barley, oats and spring wheat) were together averaging at 49.7 % of total grain harvest (see Table 12) (Jordbruksverket, 2017).

Table 13 Total harvest of different grain crops in Sweden. (Jordbruksverket, 2017)

Total harvest in Sweden (tonnes)						
	2012	2013	2014	2015	2016	Average
Total grain harvest	5,055,900	4,985,200	5,775,400	6,162,400	5,466,700	5,489,120
Winter wheat	1,933,800	1,319,000	2,750,800	2,984,800	2,502,100	2,298,100
Spring wheat	355,500	549,600	335,600	315,600	339,500	379,160
Rye	139,900	142,000	173,600	149,200	101,600	141,260
Winter barley	60,300	78,100	85,800	96,100	110,300	86,120
Spring barley	1,641,400	1,862,000	1,488,400	1,576,200	1,427,600	1,599,120
Oats	731,200	851,500	665,900	744,700	771,500	752,960
Winter triticale	140,400	111,700	226,400	231,300	148,700	171,700
Spring triticale	-	-	-	12,500	10,000	11,250
Mixed Seed	53,400	71,300	48,900	52,000	55,400	56,200

Grain is cultivated in most parts of Sweden, but the largest productions are in the counties of Skåne, Västra Götaland, Östergötland and Uppsala, all of which is in a range of south to middle of Sweden (see map in annex). In total 60 % of the grain cultivated area is located in these regions.

In average around 200 000 tonnes are used for seeds on the farm and 2,300,000 tonnes are used as fodder (Table 14). Approximately 745,000 tonnes are used by industries, e.g. Absolute Vodka and Agroetanol, where Agroetanol used most of that volume. In Table 14, the grain balance during 2010-2014 is presented for all grains and in Table 15 different examples of each grain is presented under 2013/2014. The data on consumption and fodder in Table 14 is uncertain and should be analysed with caution as remaining products are labelled as fodder for simplicity. The storage capacity does not include storage at the farms (Eklöf, 2014).

Table 14 Total grain balance July-June 2010/11-2013/14, 1000 tonnes (Eklöf, 2014)

Total grain balance July-June 2010/11-2013/14, 1000 tonnes					
	10/11	11/12	12/13	13/14 prel.	Average
Incoming supply	619	432	405	447	476
Harvest	4,280	4,630	5,056	4,980	4,737
Import	335	342	362	430	367
Total asset	5,234	5,469	5,846	5,857	5,602
Food	863	895	892	975	906
Industry	716	737	817	710	745
Seed	192	196	199	199	197
Fodder etc	2,046	2,346	2,416	2,440	2,312
Export	985	892	1,074	900	963
Total use	5,234	5,496	5,398	5,224	5,338
Outgoing stock	432	405	447	633	479

Table 15 Total cereal balance July-June 2013/14, 1000 tonnes (Eklöf, 2014)

Total cereal balance July-June 2013/14, 1000 tonnes						
	Wheat	Rye	Barley	Oat	Triticale	Other
Incoming supply	172	14	145	66	5	2
Harvest	2,289	140	1,702	731	140	53
Import	208	9	31	8	89	17
Total asset	2,669	163	1,902	805	234	72
Food	505	124	221	41	0	1
Industry	673	0	30	0	110	4
Seed	85	3	68	100	5	3
Fodder etc	837	0	970	389	102	53
Export	396	24	454	190	0	10
Total use	2,496	151	1,743	720	217	71
Outgoing stock	173	12	159	85	17	1

In average between 2010/11-2013/14, 360,000 tons of grains are imported into Sweden (Table 14) In 2013/14, primarily wheat followed by triticale were imported (Table 15). Higher quality wheat (higher protein levels for human consumption etc.) is usually imported in variable amounts depending on the quality of the Swedish harvest. Barley is imported when domestic barley is not of

sufficient quality for malting, among other reasons (Eklöf, 2014). How imports have varied with different grains between 2000 and 2013 is illustrated in Figure 6.

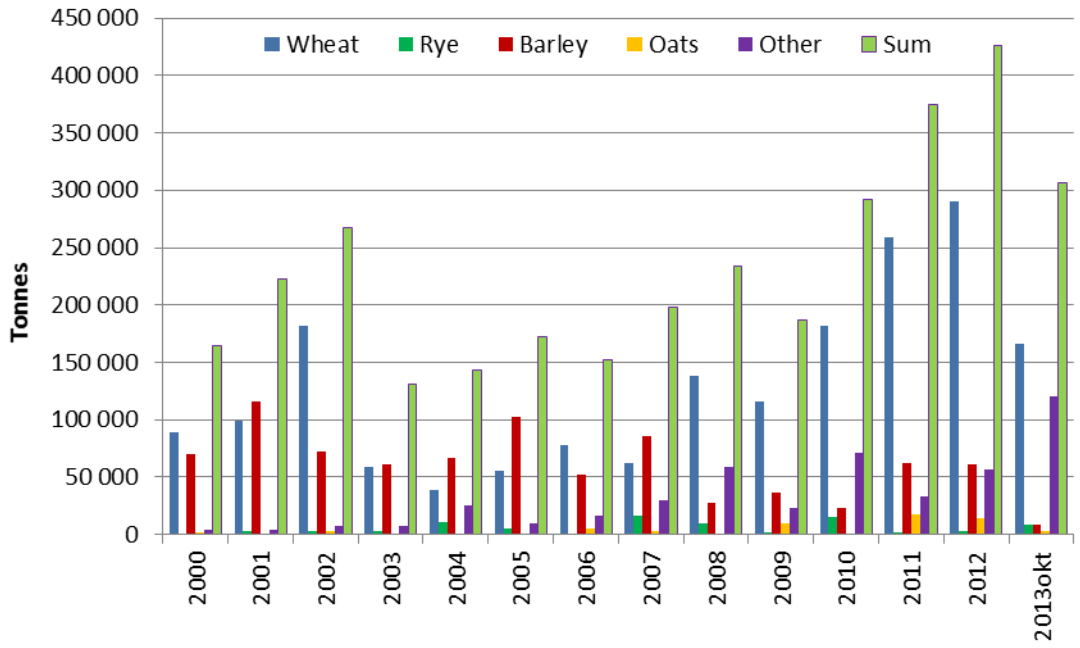

Figure 6 Import 2000-2013 (Eklöf, 2014)

As seen in Table 16, the average yield per hectare of the most common grains grown in Sweden is increasing over time, where the highest average was with winter wheat at 6,500 kg/ha (Jordbruksverket, 2017).

Table 16 Yield kg/ha for the most common grains in Sweden 2012-2016

Yield kg/ha for the most common grains in Sweden 2012-2016						
	2012	2013	2014	2015	2016	Average 2012-2016
Winter wheat	6,820	6,310	7,250	7,570	6,680	6,513
Spring wheat	4,290	4,800	4,530	5,000	4,540	4,428
Spring barley	4,560	4,980	4,710	5,200	4,760	4,570
Oat	3,820	4,370	4,170	4,610	4,450	4,094

Examples of end products of the grain chain industries are base products like flour, groats and flakes.

Table 17 shows grain chain industry's end products quantity in tonnes. The currently available data is from the period 2011-2015 (SCB, 2017).

Table 17 Deliveries from processed grains 2011-2015 in Sweden, tonnes (SCB, 2017)

Deliveries from processed grains 2011-2015 in Sweden, tonnes						
	2011	2012	2013	2014	2015	Average 2011-2015
Flour, grinded from regular wheat and spelt	335,323	326,887	264,821	260,930	379,566	313,506
Flour, grinded from mixed seeds of wheat and rye	106,061	122,077	121,059	114,627	134,654	119,696
Flour, grinded from barley	440	267	239	244	278	294
Flour, grinded from rye	0,0	48,163	50,456	49,786	52,418	40,165
Crushed groats and coarse flour incl. fine grouts from oats	4,084	75	16,557	18,785	25	7,905
Oats, processed to flakes	22,784	20,172	18,643	22,377	22,939	21,383

4.1.3 State of the sector

The largest number of farm enterprises is found in the area group 50.1-100 ha with 8,181 companies, followed by 30.1-50.0 ha with 7,458 companies, Table 18 (Jordbruksverket, 2017). Grain companies in Sweden have the follows the pattern fewer but bigger companies. In average, a farming company today has 43 ha arable land (Jordbruket i siffror, 2017) which is an increase of approximately 16 % from 2012 (Eklöf, 2014).

Table 18 Farm holdings in Sweden 2005-2016 (Jordbruksverket, 2017).

Farm enterprises in Sweden 2005-2016						
Size of holding	2005	2007	2010	2013	2016	Average 2005-2013
20,1-30,0 ha	7,583	7,122	6,603	6,022	5,413	6,549
30,1-50,0 ha	8,862	8,259	7,490	6,778	5,901	7,458
50,1-100,0 ha	9,569	8,957	8,205	7,368	6,807	8,181
100,1+ ha	6,099	6,165	6,456	6,605	6,690	6,403

4.1.4 Typical size of the companies

This section of the report focuses on the biggest companies in the sector. Lantmännen (LM) is a co-operative owned by approximately 25,000 Swedish farmers (in 2016). The corporate group is divided into several subdivisions. The division LM Lantbruk (LM Agriculture) is the core operation working with the primary production holdings, the farms, with selling commercial products (fertilizers, crop protection, etc.), seeds, animal fodder and more. As of 2017, the divisions Lantbruk and Maskin (Machine) is merged to one division. LM Lantbruk is also buying and selling the raw material (the grains). The number of employees at LM Lantbruk in 2016 was 766 (see Table 19), a decrease of 52 from previous year 2015. This division's economic turnover was €1.1 billion. LM Livsmedel (LM Food) is involved in the processing industry, producing, refining and developing grain-based products like flour, pasta, bread, breakfast products etc. This division's turnover 2016 was €1.46 billion with 6,610 employees (Lantmännen, 2016).

Svenska Foder is an agricultural company with a turnover of approximately €440 million and 329 employees. They are selling commercial products and raw material (grains) much like LM Lantbruk. The DLG-group owns 100 % of the shares in Svenska Foder.

Furthermore, there is a bigger group consisting of 18 private companies and co-operatives called Spannexgruppen (Spannex group). The organization acts as a whole sale dealer of products and raw material for the participating enterprises. The companies are Västerbotten Fodercentralen AB, Dalviks Kvarn AB, Värmlant AB, AB Johan Hansson, Fjällbacka Foder AB, Forsbecks AB, Buttle Foder & Spannmål, Varaslättens Lagerhus, AB Skene Valskvarn, Mörk och Söner HB, XL-Bygg Byggland Höör, Br Karlssons Foder AB, AB Hjalmar Möller, Karmegrens gårdsservice AB, Vallberga Lantmän, LT Lantmän, and Kristianstads Lagerhusförening (Spannex, 2018). Spannexgruppen has a turnover of approximately €300-400 million with approximately 400 employees over all the participating enterprises. Market share of each company within Spannexgruppen varies within the respective region and all companies are not working exclusively with grains and fodder (Von Sydow, pers.

comm., 2018). Swedish Agro is a subsidiary company to Danish Agro with a turnover of approximately €125 million and 137 employees.

Table 19 summarize the biggest companies in grain processing in Sweden.

Table 19 List of biggest companies regarding grain processing in Sweden

List of biggest companies regarding grain processing in Sweden		
Company	Turnover MEURO	Employees
Lantmännen Livsmedel[1]	1,460	6,610
Lantmännen Lantbruk[1]	1,119	766
Spannexgruppen[2]	300-400	400
Svenska Foder[3]	447	329
Swedish Agro[4]	125	137

Food & feed

The largest malting plant in Sweden is situated in Halmstad and has a production capacity of about 200,000 tonnes malt. A smaller proportion of barley and oats for food is composed of meals and flours which are grinded at the mills (Eklöf, 2014).

Ethanol

Presently in Sweden, fuel ethanol from grain is produced in a plant in Norrköping, LM Agroetanol, with a capacity of 230,000 m^3 ethanol per year. Ethanol production consumes about 600,000 tonnes grain per year, mostly wheat. The remains, besides draff, are carbon dioxide from the fermentation (Gundberg, 2017).

Milling

The milling industry in Sweden today is comprised of approximately ten production units which together have a turnover of approximately €151 million annually. The industry is effective with a low level of staffing. The economical margins are small but the processed quantities are very large. If the turnover in average is €100,000 per staff member, the equivalent figure in the milling industry is approximately ten times. (Svenska Kvarnföreningen, 2017). About 600 000 tonnes of grains are

[1] (Lantmännen, 2016)

[2] (Spannex, 2018)

[3] (Svenska Foder, 2017)

[4] (Swedish Agro, 2017)

grinded to flour for human consumption. The by-product is used mostly as animal feed (Svenska Kvarnföreningen, 2017).

4.1.5 Distinctive facilities of the sector

The two largest actors (Lantmännen and Svenska Foder) on the Swedish grain market have together close to 80 plants for grain delivery situated throughout Sweden. Most of them are strategically located near the main grain producing areas and there are fewer the further north in Sweden one come, see Figure 7 for location of Lantmännens 45 receiving plants (of which 25 have drying and storing capacity) in Sweden. In addition, there are 4 seed plants strategically placed near Eslöv, Skara, Skänninge and Klintehamn. Lantmännen has 2 breeding stations located at Svalöv and Lännäs. Lantmännen, in addition, has 3 research farms in Bjertorp, Nötcenter Viken and the Svalöv farm unit. Svenska Foder has its own facilities at around 30 other sites which includes feed factories, harbour facilities, seed plants, shops/storage terminals for receiving grains and sales/deliveries of animal feeds, seeds, fertilizers and chemical products Svenska Foder has seed plants in Kinne Kleva, Västergård and Bergsgården (outsourced operation). Seeds for Svenska Foder are produced by Skånefrö AB. Spannexgruppen has several facilities over the country, see figure 8 (Spannex, 2018).

During harvest period (normally July-October), the grain receiving facilities are utilized at 100 %, both storage and dryers. Usually, the dryers are not used between the beginnings of November to next year's harvest starts, but the storage silos are utilised as grain is received year round. The seed plants are used august to march at 100 %, then down to around 75 % of capacity (Jönsson, pers. comm., 2017).

Figure 7 Grain receiving plants for Lantmännen (Lantmännen, 2017).

Figure 8. Grain receiving plants and other grain facilities from enterprises collaborating under Spannexgruppen. (Spannex, 2018)

4.1.6 Degree of innovation

The level of innovation considering by-products/ side-streams can be considered as high. Many projects from Lantmännen are invested in using crop residues in alternative biobased products, but today most of the crop residues are used for feed, biogas industry or incineration (Pettersson, pers. comm., 2017). The sector is actively investigating in opportunities to increase the production effectiveness of its facilities.

There are many examples of already established benefits using raw material residues. For example, the oat mill in Järna is using the husk residues as burning material in their steam boiler in the process for oat groat production and excess steam and hot water are used as heating around Järna municipality. Not only does this reduce the factory CO_2 footprint, but it also reduces the transportation of residues to landfills and the transportation of fuel oil for the previous steam boiler which furthermore reduces the CO_2 footprint (Telge Nät AB, 2011; Ny Teknik, 2005).

During the ethanol production, a lot of CO_2 is produced which is utilized and refined in a nearby carbon dioxide plant in cooperation with AGA Gas AB (AGA, 2012).

LM Agroetanol has great experience in using the IBLC approach and is constantly working on increasing the added value of residues. All draff is used for fodder and the majority is exported. Not only is grain used as raw material but also food waste like expired bread and the like which was previously used mostly as animal fodder (Gundberg, pers. comm., 2017).

BIOAGRO Energy is a company located in Skåne in collaboration with Skånefrö AB and others. Their production is based on using dry biomass residues from agricultural production to create fuel pellets and district heating. The ashes can then be used as fertilizers (BIOAGRO Energy, 2018).

4.1.7 Miscellaneous

In a comparative study, two LCAs were established, where the first LCA compared three different scenarios in arable land use from a climate change perspective. The scenarios were cultivation of wheat used for production of bioethanol, carbon dioxide and DDGS (see abbreviation), cultivation of rapeseed used for production of RME, rapeseed meal and glycerine and fallow in the form of long-term grassland. The study concluded that the best use of arable land from a climate change perspective were cultivation of wheat for production of above-mentioned products. The second LCA compared the three protein feeds DDGS, rapeseed meal and imported soybean meal, where DDGS and rapeseed meal where to preferred instead of imported soybean meal from a climate change perspective (Karlsson & Sund, 2016)

4.2 Opportunities IBLC

4.2.1 Sector related residues

4.2.1.1 Sector related residues within the supplying agricultural sector

The biomass residues from primary grain production are mostly straw with smaller biomass components such as chaffs. The straw either stays on the fields and gets incorporated into the soil or is used for livestock bedding or feed. The availability in time of this biomass is limited due to the growing season, the harvesting period as well as the local storage capacity. Today, most of the straw residues are reintroduced to the soil to preserve soil humus content, but some are used as litter in animal production and a small part is used for incineration often in farm-level boilers and grain dryers.

Nutrient content in straw is estimated to 40 kg potassium, 4 kg phosphorus, 6 kg sulphur and 5 kg magnesium per hectare at a straw yield at 4 tonnes/ha (ATL, 2006). The amount of straw from gross grain production in Sweden is estimated to 3.8 million tonnes. Expressed as energy the straw is estimated to approximately 16 TWh per year. With consideration of ecological (leaving the straw to increase humus content etc) and techno-economic (harvest losses, limited harvest opportunities due to weather, straw as litter and fodder and more) Börjesson, 2016, estimates that the total, practical availability of straw is 3,600 GWh/year, and the regions with biggest available amount of straw lies in Skåne with 40 % (1,450 GWh/year) of total potential, followed by Östergötland and Uppsala (Uppland) with 15 % (500 GWh/year) each (Börjesson, 2016).

4.2.1.2 Sector related residues within the agro-industry's processing operations

Residues derived from the processing industry are mostly shell residues from milling and grinding of cereals and residues such as draff and marc from production of ethanol for industry/fuel, beer and other alcoholic beverages. Today the majority of these residues are used as animal fodder. The malt industry residue is approximately 13,000 tonnes malt sprout pellets, which today are used as raw material to fodder industry (Nowack, 2017). The draff from ethanol production is estimated to 190,000 tons per year (Gundberg, 2017). The biggest brewery in Sweden is Spendrups, and the company produces about 30,000 tonnes of marc per year (Spendrups, 2017).

Residues are produced during the cereal drying both at the local farms and at the silos from Lantmännen and other cereal buyers. The residues from Lantmännen's grain silos are estimated to 2,000 tonnes in the Skåne region and 9,000 tonnes in the middle of the country (Fredriksson, 2017). The deposits are used for incineration in Lantmännen's own facilities, other facilities and producing biogas. The volume from the local farms cereal dryers are much harder to estimate. Almost all of the residues that originate from grain drying are produced during harvest time and to somewhat extent the storage period directly after harvest time.

Comparing process industry's related residues to that of fodder and roughages, the logistics chain is easier to handle as the residues are already used for production today (Petterson, pers. comm., 2017).

4.2.2 Potential synergies & benefits

It is with each industry's core interest to maximize the production capacity of its facilities during the whole year. Therefore, many plants have few production dips, nowadays. Seed plants and grain receiving plants potentially have some surplus capacity, perhaps offering an interim storage of straw and other residues. There are examples of facilities moving its staff during high and lows in production, for example between seed facilities and grain receiving plants (Lööf, pers. comm., 2017). Many, and especially the bigger farms do not have the storage capacity to store their whole harvest and is therefore dependent on delivering some crop quantity during the harvest period.

It is also important to consider IBLC approach when planning for the location of future expansions of facilities and also adapt the building for different production and storage possibilities.

As most of the residues are already used today in some way other than landfills, the main focus in the IBLC approach is to further increase the added value of these by-products, both in the process industry and in the primary production. There are several examples of production focus in already established facilities.

It is also important to look at the synergy between companies both inside as well as outside the grain sector. For example, LM Agroetanol recently started cooperation with truck manufacturing company Scania, with the intent of delivering total solution for heavy transports to reduce emissions (Jordbruksaktuellt, 2016).

4.2.3 Market developments

Lantmännen is involved in a recently started project regarding developing bio composite material from oat husks used for furniture and coffins (Andersson, 2017). This can increase the added value of these residues even more than earlier mentioned and this could be a new market for LM.

Today, wheat bran is mostly used as animal fodder and to some degree as fibre addition in human food. A research team at Royal Institute of Technology (KTH) has found a way to extract polysaccharides from pollards, opening up for several, more environment-friendly fields of applications with bio-plastics like medicine capsules and protecting plastic layers around meat (ATL, 2017).

Lantmännen is involved in a project called Farm2Furan with the purpose to develop a value chain for production of chemicals within a frame for a future bio refinery based on agricultural raw materials and residues like husks, straw and brans (Moldin, 2017).

4.2.4 Non-technical barriers

Looking forward in time, there are several factors that play a role in the supplies of crop residues. Therefore, there are many uncertainties in the estimates in future potential for bio-production purposes. For example, the area of land for growing crops may decrease, yield levels, changes in the amount of straw relative kernels (straw/kernel-quota), other fields of applications and more (Börjesson, 2016). In Hjerpe et Al. (2012) model studying has shown that a decrease in farmland area by 30 % and maintaining the same production levels by 2050 is possible.

The volume of straw is determined by the amount of cereals produced which in turn is determined by the price. The prices for cereals are mainly influenced by global market prices and therefore dependent on variation from countries with larger influence. The type of crop that is produced is therefore to some extent controlled from a market demand standpoint. As the sort of crop varies, so does the amount of straw, which in itself adds fluctuations in the amount of straw available for processing. The weather plays a significant role as well on the management and storage of straw.

The EU has formed a burden-sharing policy, the Renewable Energy Directive (RED)5, where 20 % of total energy needs to be produced from renewables and 10 % of transport fuel comes from renewable sources by 2020. Due to a recent proposal, the total energy produced from renewables should be 35 % by 2030 but also a reform on which crops that are classified as renewables. This proposal may have an influence on primary crop production to biofuels, but also has the potential to benefit the production from grain sector residues.

[5] https://ec.europa.eu/energy/en/topics/renewable-energy/renewable-energy-directive

5 FEED AND FODDER SECTOR

5.1 Profile of the feed and fodder sector

5.1.1 Production

Feeds and fodder for animals in Sweden derives from grains, green crops, protein crops, leys, and residues from different industries. The biggest proportion of feed are grains and mainly barley, wheat and oats. Protein crops are peas, broad beans, imported soybeans and rapeseed meal. Residues from sugar and vegetable oil production are also important feeds for fibre and fats and ethanol production residues are rich in proteins. Green crops are crops that are prematurely harvested and silaged (whole crop silage). Fodder mixtures are divided into two groups: complete feed and complementary feed. Complete feed must cover the animal's complete nutrient need and complementary feeds are premixes, concentrates and feed supplements (Jordbruksverket, 2017).

5.1.2 Volume of the sector

5.1.2.1 Volumes from the primary production

Leys and green crops comprise the largest group of crops in Sweden and were cultivated on 37% of agricultural land between 2010 and 2016 (Table 20). The average annual harvest of temporary grasses is 4.9 million tonnes. Looking at yield levels, here are some uncertainties about the statistics. Between 2010 and 2016, in average yield per hectare of temporary grasses is estimated to be 5,670 kg/ha, calculated as weight in hay, assuming 83.5% dry matter (DM),

(Jordbruksverket, 2017). These numbers includes all ley production in Sweden, but focusing on more high-intensity production in southern and middle Sweden, the yields are much higher. Trial material compiled and used in report 445 by Tidåker et.al, 2016 shows yield levels at 10,000 kg DM/ha with two harvests and 11,200 kg DM/ha with three harvests, effectively doubling the yield from the national average.

Table 20 Use of arable land 2010-2016 (Jordbruksverket, 2016)

Use of arable land 2010-2016 (ha)				
	2010	2015	2016	Average 2010-2016
Pasture and green crops	1,194,700	1,137,900	1,107,400	1,146,667
Sum total arable land incl ley and meadows	3,085,400	3,039,900	3,031,500	3,052,267

Table 21 Temporary grasses total harvest and yield (83.5 % DM) in Sweden (Jordbruksverket, 2017).

Temporary grasses total harvest in Sweden						
	2012	2013	2014	2015	2016	Average 2012-2016
Yield, kg/ha	5,320	4,960	5,950	6,240	5,880	5,670
Total harvest, tonnes	4,751,500	4,532,500	5,224,900	5,382,200	4,733,700	4,924,960

Protein crops grown and used as fodder in Sweden are peas and broad bean. In Table 22, yield per hectare and total harvest between 2012 and 2016 are presented (Jordbruksverket, 2017). The number of companies with animal production is presented in Table 23.

Table 22 Yields and total harvest of peas and broad beans 2012-2016 in Sweden (Jordbruksverket, 2017)

Yields and total harvest of peas and broad beans 2012-2016						
		2012	2013	2014	2015	2016
Yield, kg per hectare	Peas	2,730	3,340	3,220	3,710	3,680
	Broad beans	3,240	3,510	3,240	3,960	3,520
Total harvest, tonnes	Peas	35,100	40,800	46,500	83,100	92,700
	Broad beans	58,200	61,300	61,100	99,100	103,900

Table 23 Number of companies with animal production (Jordbruksverket, 2017)

Number of companies with animal production						
	2012	2013	2014	2015	2016	Average 2012-2016
Cows	16,314	15,712	15,035	14,624	14,221	15,181
Cattle	19,561	18,962	18,210	17,581	17,046	18,272
Sheep	9,263	8,869	8,951	9,110	8,724	8,983
Pigs	1,113	1,281	1,282	1,228	1,252	1,231
Poultry	4,766	5,020	4,898	3,920	3,484	4,418
Horses	N/A	16,595	N/A	N/A	15,358	15,977

The dairy cow population at present in Sweden is approximately 330,000 cows
Table 24). Daily consumption per cow is on average about 10 kg silage (DM basis) and 5-6 kg DM silage for young stock (Eriksson, 2017).

In Table 24, a number of animals is presented between 2012 and 2016 (Jordbruksverket, 2017). For convenience, certain animal groups are grouped together. Other cattle include cows for breeding calves, heifers, bulls, steers calves under 1 year of age, sheep includes lambs, rams and ewes, pigs

includes boars and sows for breeding, slaughter pigs over 20 kg and piglets under 20 kg, poultry includes both for slaughter and egg production. All animal groups except other cattle and poultry show a decline in numbers in the presented time period. Poultry shows some increase and other cattle are almost unchanged. Due to the recent crisis in dairy cow production, one can argue that an amount of dairy cows has been moved to other production and affecting the numbers.

Table 24 Number of animals in Sweden 2012-2016 (Jordbruksverket, 2017)

Number of animals in Sweden 2012-2016						
	2012	2013	2014	2015	2016	Average 2012-2016
Dairy cows	347,969	344,021	344,339	339,823	330,833	341,397
Other cattle	1,152,324	1,152,505	1,148,780	1,140,235	1,158,791	1,150,527
Sheep	610,534	576,769	588,757	594,753	578,174	589,797
Pigs	1,363,364	1,398,875	1,377,530	1,356,027	1,354,286	1,370,016
Poultry	14,760,985	16,540,365	16,173,528	17,856,775	18,752,274	16,816,785

5.1.2.1 Volume of the processing industry

There is a substantial amount of grains used in feed production as well. As mentioned in the grain sector chapter, an average of 2,300,000 tons grains are used and processed as fodder (Table 13). Grains mainly used in feed processing are barley, wheat and oats.

Lantmännen's 7 feed mills in Sweden are located in: Åhus, Falkenberg, Lidköping, Klintehamn, Kimstad, Västerås and Holmsund (Figure 8), all situated close to harbours. Feeds, feed supplements and additives are produced here for dairy and beef cattle, pig, poultry, reindeer, sheep and horses. These 7 units produce about 1.1 million tonnes of feed yearly. This is composed of 430,000 tonnes grain and 700,000 tonnes other feed materials, including feeds in organic farms and oil plants (Lantmännen, 2017).

Figure 8 Lantmännens feed mills in Sweden (Lantmännen, 2017)

5.1.3 State of the sector

The number of animal farms has been steadily decreasing (Table 23) and so has the number of animals

Table 24) (Jordbruksverket, 2017). Land use for grass production has been maintained by the usage of horses when cattle numbers have decreased. Sweden has a very high status of animal welfare legislature which is unique. The regulations influence production forms in Sweden. All farm animal groups, pig, poultry and not least dairy cows, have undergone crises during the last fifteen years which has greatly affected production. Smaller units have been forced into closing and larger operations with modern housing have been established (Hermansson, pers. comm., 2017).

In Sweden animal production is often associated with on-farm crop production. On-farm produced grain that is sufficient to cover all or part of the farm's feed requirements offsets the effects of price surges in the grain market, at least in the short term. Those animal producers that are most directly affected by increases in grain prices are those buying complete feeds and those producing their own grain but are in areas which have not supported normal harvests and need to complement with more grain than normally (Lööf, pers. comm., 2017).

Grass producers without animals have specialized in horse feeds amongst others. These operations are often close to the segment such as for example around the district Mälaren (Stockholm area and west of Stockholm) where much of the horse husbandry is situated. (Andersson, pers. comm., 2017).

5.1.4 Typical size of the companies

The two largest companies for feed production in the market are Lantmännen and Svenska foder. Lantmännen produces 900,000 tonnes feed of which half of the raw material is from grains (Szabó, pers, comm., 2017). The latest feed factory in Sweden was built in Kalmar, which produces about 270,000 ton yearly. In this feed factory about 400 different feed recipes are produced, which in practice means that recipes and production change every hour. Another example of a factor is Lantmännen's feed factory in Holmsund (north of Sweden) which processes about 30,000 tonnes of grain in feed production (Hermansson, pers. comm., 2017). The feed produced in Holmsund is shipped by bulk tanker as far north as to northern Norrbotten and even to Finland. One of Lantmännen's largest customer group are reindeer herders who often need to complement their feeding to the reindeers during the winter months. (Thomas Ruuth, pers. comm., 2017) A third example of factories is Svenska Foder's feed mill in Åhus (southern Sweden). Svenska Foder's yearly production is around 500,000 tons feed for cattle, pig, horse and sheep, corresponding to 25 % of the total market. Other producers are Swedish Agro, approximately 200,000 tons or 10 %, and Vallberga Lantmän, approximately 100,000 tons, or 5%. The remaining 15 % is divided between KLF, Johan Hansson, Teknosan, Västerbotten Fodercentral AB and more, including a large number of local feed mills.

5.1.5 Distinctive facilities of the sector

In perspective of idle time and surplus capacity, the fodder factories in LM have an even production a yearly basis with no seasonal highs or lows. The work schedule is 4 to 5 shifts per day with an idle time of around 20-30 hours per week dedicated to cleaning the factories (Jönsson, pers. comm., 2017).

Lately, the prices for feed grains have generally been low and this has helped maintain animal production ventures, which are struggling. The price for feed grains is steered by developments in the global grain market and how the harvest is for Sweden (Jeppsson, pers. comm., 2017). New types of grains have been developed, which can be used both for mills and feeds. Previously feed grains had a much greater yield. Due to seed development, this difference is no longer decisive which leads to a more diverse market benefitting producers who have a surplus over their own production needs and can sell on the general market.

5.1.6 Degree of innovation

Innovations are being made in limiting the need of import of protein crops in feed production. Between 2007 and 2009 around 240,000 tonnes of soy were imported to Sweden. From a time period perspective over ten years there has been a reduction from 300,000 tonnes. About 40 % of imported soy is used in feed production for cattle, about 40 % for poultry and 10-15 % for pigs. Remaining part is other animals like horses, cats and dogs (SLU, 2017). Alternative resources to protein are draff from ethanol production, soy beet pulp, rapeseed meal and pulses like peas and broad bean. Draff is an excellent protein source in feed mixing, but the quality of draff is too uneven for Swedish feed industry (Gundberg, pers. comm., 2017). Studies have shown that domestic-grown

rapeseed meal can replace soybean meal while maintain or increase milk yield in dairy cows (Gidlund H., 2017).

Innovation in grass as feed is mainly focused to decrease the need for protein supplements production and therefore also decreasing the need of imported protein. Animal advisers are actively working with farmers to increase the usage of grass to dairy cows e.g. increasing digestibility of roughage to decrease the need of supplementary feed.

5.2 Opportunities IBLC

5.2.1 Sector related residues

Residues produced from primary production (mainly grains) can be considered as the same as for the grain chain sector. Also, residues sugar industry and vegetable oils in form of molasses, sugar beet fibres, HP Pulps, rape seed meals and cakes (see sugar industry and vegetable oil sectors).

The amount of by-products from grain processing industry facilities from LM is considered low, around 2 %, which is stored at the factories and then reused in the fodder production (Jönsson, pers. comm., 2017).

Residues from leys in primary production are mainly in form of losses during harvest, storage and transport between storage to feeding platform. During harvest of leys, the DM losses is estimated to be between 3-10 % with silage roughages and 17-30 % with hay (Grovfoderverktyget, 2017).

Residues derived from other processing industries like ethanol or malt production (see grain sector) are today already used as feed.

5.2.2 Potential synergies/benefits

An upcoming project where RISE JoL (formerly JTI) will investigate the profitability of using discarded silage bales for biogas production. The same company is looking into combining traditional cultivation system with energy crops to increase profitability of the farms (JTI, 2017).

There is some amount of area in Sweden that cannot be used for traditional grain crops but could be suitable for leys. Today, some locations in Sweden have crop producing farms with fields that has low to no production (farrows and meadows). With increased value of products of these unused fields, there is a potential that the biomass availability would increase without affecting any other production areas. Consequently, increasing the profitability for the primary producers and availability of biomass for IBLC.

By using leys as a break crop in the crop rotation on farms, several benefits will emerge and increase crop production profitability in the long round. From a climate perspective, growing ley for biogas production is positive in several factors by increasing coal assimilation and reducing the use of fossil fuels (Tidåker *et. al,* 2016) and therefore has a positive effect on environment.

If the number of animals continues to decrease, consequently the demand for feed and also raw material for feed production will decrease. One can speculate that as animal numbers are decreasing, the surplus capacity in feed plant may increase, opening up for future IBLC use. Previously abandoned fodder plants has been successfully utilitized for other applications for example, Gyllebo Gödning is today using a feed plant for producing organic fertilizers (Lööf, pers. comm., 2017).

Morover, by offering different depositions for feed grain if animal production is decreasing, the primary production can continue. For example, the ethanol production has kept the need for producing feed grains (Eklöf, 2014).

5.2.3 Market developments

Just as straw from grains, grasses could broaden the choice material available for lignocellulosic ethanol processing and other bio applications. Research is ongoing but for the moment no official reports are published.

Grasses and whole crop silages are used as fodder, but there is potential in these products as a bio gas substrate. Today, most of the bio gas industry uses sewage sludge, food waste and manure as substrates. But studies have shown a net energy (energy exchange minus energy usage in production) of 28 MWh/ha for grass and 33 MWh/ha from wheat whole crop silage (Prade *et.al.*, 2015).

5.2.4 Non-technical barriers

Many by-products from other industries are already being used in feed production. One can argue that there is competitiveness in the market presently which may be a barrier for future biomass uses. One can speculate however, with a future surplus capacity of feed grains, the availability of biomass is increasing with a potentially decreasing animal production. Other non-technical barriers of primary production of feed grain are the same as in the grain sector.

6 SUMMARY ANALYSIS OF THE COUNTRY

Table 25. Summary Sugar industry sector.

Sector Sugar industry	
	Profile
Production	• About 2 million tons of sugar beets are produced every year in Sweden, the majority is cultivated in the southern part. • The sugar production starts in the field with the sugar beets and ends with a diversity of products, including sugar products, feed products (molasses, beet pulp), sugar factory lime, stones, beet soil and water.
Volume of the sector	• There is one sugar refinery, Arlöv, and one sugar factory, Örtofta, in Sweden, both owned by Nordic Sugar which is the only sugar producing company in Sweden. • Örtofta is one of the largest and most efficient sugar-producing facilities in northern Europe with a yearly production of sugar of 382,000 tonnes/year.
State of the sector	• For the last 50 years the market for sugar beets has been regulated with quotas and minimum prices, in October 2017 the EU regulation expired. • In autumn 2017 the market completely controls the demand for Swedish sugar, which means that the sugar production will compete with Europe in a new way.
Typical size of the companies	• Sweden produces around 2% of the total EU sugar production on a 5 year average 2011/2012-2015/2016 • During the production season Nordic Sugar Örtofta receives and processes around 2 million tons of sugar beets and the daily refinery capacity at Nordic Sugar Arlöv is around 1,000 tons raw sugar.
Distinctive facilities of the sector	• Nordic Sugar Arlöv is a sugar refinery that is running all year round and Nordic Sugar Örtofta is a sugar factory that only runs part of the year during the production season from mid-September to mid-January. • Just before the production season or just after the season there is a possibility to utilize some parts of the factory as the storage facilities and the drum drier.

Degree of innovation	• The sugar industry is a mature industry, historically a lot of resources have been put into research and development within the sugar industry in Sweden. • Nordic Sugar has become more and more involved in research projects the last couple of years, also in the Swedish organization, the projects is in into biobased products and processes, and the aim of the involvement from Nordic Sugar is to find a value chain increasement.
Miscellaneous	• For Örtofta Sugar factory a life cycle assessment of the beet sugar production was recently performed where a multiple of environmental aspects has been investigated.
	Opportunities for IBLCs
Sector related residues	• If all sugar beet tops in Sweden were harvested around 80,000 tonnes dry matter beet tops would be generated theoretically • All biomass residues from the Arlöv and Örtofta refinery factories are utilized today.
Potential synergies & benefits	• The time of year when there is no production on the sugar industry production site it may be possible to utilize the site for other types of production. • Some parts of the production line are only adapted to the large flow of biomass, but in some parts of the production line there are several smaller machines instead of one large.
Market developments	• Nordic Sugar Örtofta are involved in projects regarding bioplastics, they are interested in utilizing their industry site to produce biocommodities for bioplastic products and to utilize their biomass residues for bioplastic production. • They are also involved in a project that will develop a value chain based on side streams from the sugar industry for the production of key basic chemicals in the context of the future biorefinery.
Non-technical barriers	• When a market is deregulated, as just happened to the sugar market, price falls and price pressure often occur, but it can also lead to new markets and niches, which will probably also occur in the sugar sector.

Table 26. Summary Vegetable oil extraction sector.

Sector Vegetable oil extraction	
	Profile
Production	• In the last five years, an average of about 330,000 tonnes of oil crops was harvested in Sweden each year. • Most rape seed oils are hot pressed in Sweden, the rapeseed is pressed to oil at higher temperature, it is then refined and more oil can then be extracted from the filter cake by use of solvents.
Volume of the sector	• AAK is the owner of the only large-scale processing plant for oilseeds in Sweden. • Total consumption of rapeseed oil for both food and technical purposes in Sweden was 294,000 tonnes per year on average between 2012-2016.
State of the sector	• The rapeseed crop is in a sharp rise. • The oil and fat industry in Sweden is a sector with high profit figures.
Typical size of the companies	• AAK had an economic turnover of approximately 650,000 Euro in 2016. • The production of rapeseeds in Sweden doesn't cover AAKs total need and therefore imported seeds are also used.
Distinctive facilities of the sector	• The production of rapeseed oil and rapeseed meal at AAK Karlshamn is a year around production, there is no seasonal variation.
Degree of innovation	• The rapeseed oil and rapeseed meal industry is a mature industry. • The vegetable oils are an agricultural product that is chemically most similar to mineral oils and therefore have a great potential as biological raw material to replace the mineral oils in industries such as for biomaterials and chemicals.
	Opportunities for IBLCs
Sector related residues	• The total volume of straw from oilseed crops in Sweden is around 740,000 tonnes per year. • Only small amounts of biomass residual are produced in the vegetable oil production at AAK since the rape seed meal is utilized as well.
Potential synergies & benefits	• Since there are no large amounts of biomass residues from the rape seed oil production and it is a year around production at the site

	there are no great opportunities for establishing a future IBLC at AAK Karlshamn. • To become a supplier of biocommodities is not of interest for AAK Karlshamn.
Market developments	• There are research projects investigating rapeseed straw used as raw materials in the manufacture of renewable plastic materials and to convert the press-cake from rapeseed to human food.
Non-technical barriers	• The attitude of the industry is that they are not interested in becoming a supplier of biocommodities; this has a negative effect on the possibility to establish a future IBLC in this sector.
Sector Grain	
	Profile
Production	• Primary production is grains where the mostly common grown crops are wheat, barley and oats • Process production are mostly flour and animal feeds
Volume of the sector	• In average, 5.5 million tonnes of grains are produced where most commons grains are grown on 1 million hectares. • Around 300,000 tonnes of wheat flour are produced and 120,000 tonnes of wheat flour mixed with rye. About 2.3 million tonnes of grains are used as feed
State of the sector	• The number of farm companies is decreasing but each farm is getting bigger • The average land used by each farm is 43 ha, an increase of around 16 % since 2012
Typical size of the companies	• The biggest agricultural company is Lantmännen which is owned by 25,000 members, followed by Svenska Foder.
Distinctive facilities of the sector	• The two biggest companies have together around 80 receiving plants, where 45 is Lantmännen's and 30 is Svenska Foder's. • The facilities high production period is during harvest, but the storage silos are receiving grains all year round.
Degree of innovation	• Lantmännen has a history of investing and developing residue usage mostly by increasing the added value of side chains in processing production

	• One example is the usage of oat husks from groat production for incineration in boilers, where excess energy is used to heat the local house holdings
Miscellaneous	• A study using LCA shows that cultivation of wheat for production of ethanol and by-products were better fitted usage from a climate change perspective than cultivation and production of rape seed for RME production.
	Opportunities for IBLCs
Sector related residues	• Straw from gross grain production is estimated to 3.8 million tonnes per year, or 16 TWh/year. The practical potential usage for bioenergy from straw were estimated to 3,600 GWh/year • Residues from drying were around 9,000 tonnes from Lantmännens receiving facilities in the middle of Sweden
Potential synergies & benefits	• There is some surplus capacity at seed plants and receiving facilities and personnel are moved between production facilities • Benefits can be made by increasing the added value further from residues and side chains. There is already today synergies between facilities in and outside this sector
Market developments	• Projects are researching the use of bran and husks in production of biobased furniture and other bioplastics.
Non-technical barriers	• There are many uncertainties while estimating potential bioenergy potential, for example changes in straw/kernel-quota and decreasing land used for growing crops • Recent proposals in EU-regulations points that primary crops used in production of bioenergy should not be classified as renewable. This may open for future usage of residues in these productions

Table 27. Summary sector Fodder

Sector fodder	
	Profile
Production	• Feed and fodder consists of mixes of different crops like barley, wheat and oats, whole crop silages, protein crops like rape seed, peas and broad beans, and grass as roughages
Volume of the sector	• Temporary grasses are produced in quantities of 4.9 million tonnes per year in average, and leys and green crops are grown on 1.1 million h/year

State of the sector	• About 2.3 million tonnes of grains are used as feed • The number of animal farms is decreasing, and all animal groups except poultry are decreasing in number of animals
Typical size of the companies	• Lantmännen produces 900,000 tonnes of feed yearly where about half is from grains. Svenska Foder produces 500,000 tonnes of feed
Distinctive facilities of the sector	• The fodder factories seem to be in production all year round with little down time. • Previously, focus in specialized feed grains has grown on farms with animal production, usually locking in the usage of these crops to only feed. Nowadays, it is possible to maintain high yields of crops used in other applications like human consumption, which opens up sales market for the farmer in other areas than just feed
Degree of innovation	• There seems to be a focus on research in using domesticly grown protein crops to decrease the need of import. • Focus on increased grass proportion for dairy cows to decrease the need of grains and other crops as supplement
Miscellaneous	
	Opportunities for IBLCs
Sector related residues	• Residues from grain productions are the same as in grain sector. There are no biomass residues from feed production as the by-products are being reused • Grass production residues are losses during harvest and transportation between storage and feeding place. Losses in DM varies between 3-30 %
Potential synergies & benefits	• Using grass as break crop in grain dominant production may benefit grain production and profitability on farm level in the long run • If number of animals and animal producers continue to decrease, there is potential of using grass and feed crops for other applications, for example in the bioenergy industry
Market developments	• Studies are showing that grasses have potential of being used in production of biogas, ethanol and other bio applications.
Non-technical barriers	• The non-technical barriers of feed grains are the same as mentioned in the grain sector

- There may be competition from feed industry using feed products in the bioenergy production, but biomass availability may increase if the need for feed to animals decreases

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8 ANNEX A: COUNTY MAP OF SWEDEN

County	Letter
Blekinge county	K
Dalarnas county	W
Gotlands county	I
Gävleborgs county	X
Hallands county	N
Jämtlands county	Z
Jönköpings county	F
Kalmar county	H
Kronobergs county	G
Norrbottens county	BD
Skåne county	M
Stockholms county	AB
Södermanlands county	D
Uppsala county	C
Värmlands county	S
Västerbottens county	AC
Västernorrlands county	Y
Västmanlands county	U
Västra Götalands county	O
Örebro county	T
Östergötlands county	E