DEVELOPMENT OF

A COMMON FRAMEWORK FOR A SUSTAINABLE AND CIRCULAR BIOECONOMY

Photo: Colourbox

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Abbreviations

approx.	Approximately
BioBIGG	Bioeconomy in the South Baltic Area: Biomass-based Innovation and Green Growth
ca.	Circa
DM	Dry matter
e.g.	Exempli gratia
eq.	Equivalent
EU	European Union
SBA	South Baltic Area
SME	Small and medium-sized enterprises
R&D	Research and development
R&I	Research and Innovation
ton	Metric tonne
WW	Wet weight

Executive summary

The issue of sustainable bioeconomy requires acceptance of the relevant definition for the proper deployment of significant unutilised potentials that might be technically and economically attractive. In the project, the closest to our understanding is the Nordic Council description of bioeconomy reading: "*An economy based on sustainable production ofbiomass with the overall objective of climate effect and reducing the use of fossil-based materials*". It is a broad definition enabling encompassing of most of the required issues for its implementation. In the light of the fact that civilization is rapidly increasing its numbers there must be necessary steps undertaken to modify the value-chains of biomass conversion in all aspects. Otherwise, in the remote future there will not be enough nutrition for everybody on the planet as well as the environment will not serve required conditions.

In the analysis presented in the report assumed have been the criteria for the common framework for a sustainable bioeconomy. These are: the cascading approach, use of waste, left-overs and residues and circularity. Cascading use of biomass increases resource efficiency and adds value to the biomass as well as increases the availability of raw materials. Along these themes collected have been the case studies related to cereal, wood, sugar, food waste and energy value chains.

In the report presented are cases of the biomass value chains in the respective South Baltic Area Countries. In all examples presented are the implemented technologies, material flows and management of resulting residues along with lessons learnt and future perspectives. In a few cases presented are up-cascading examples resulting in the increased value products. Examination of these cases will enable to transfer knowledge between South Baltic Area countries to improve the competiveness of technologies.

2 The common framework for a sustainable and circular bioeconomy

The complex and interconnected global challenges of climate change, food security, sustainable management of natural resources and eco-systems, and reducing dependence on non-renewable resources, force us towards a more sustainable production and consumption system that respects the ecological boundaries of our common planet[1]. At the same time, we need to modernise our industry and ensure the prosperity and health of the global population. To address these challenges we are unlocking the innovation potential of the bioeconomy[2].

We live in a world of limited resources. Global challenges like climate change, land and ecosystem degradation, coupled with a growing population, force us to seek new ways of producing and consuming that respect the ecological boundaries of our planet. At the same time, the need to achieve sustainability constitutes a strong incentive to modernise our industries and to reinforce unutilised potentials, that might be technically and economically attractive. For this reason, the processing chain should be lengthened, inventing a new application of today's waste so that it becomes a product. Global goal is to produce more valuable products and less leftovers. There is a need to answer a question: how to transform a big amount of low value by-products to small amount of high value products

The updated European Bioeconomy Strategy was launched in October 2018 and aims to accelerate the implementation of a sustainable European bioeconomy that will contribute both towards the fulfilment of the climate objectives in the Paris Agreement and the 2030 Agenda and its Sustainable Development Goals. In the updated Bioeconomy Strategy, bioeconomy is defined in the following way:

Sustainable and Circular bioeconomy
The bioeconomy covers all sectors and systems that rely on biological resources (animals, plants, micro-organisms and derived biomass, including organic waste), their functions and principles. It includes and interlinks: land and marine ecosystems and the services they provide; all primary production sectors that use and produce biological resources (agriculture, forestry, fisheries and aquaculture); and all economic and industrial sectors that use biological resources and processes to produce food, feed, bio-based products, energy and services.[1] To be successful, the European bioeconomy needs to have sustainability and circularity at its heart. This will drive the renewal of our industries, the modernisation of our primary production systems, the protection of the environment and will enhance biodiversity[3].

The objective of the BioBIGG project is to support implementation of production of biomass-based products and services in SMEs, based on residues and waste from bio-based value chains, in order to decrease pollution discharged in the South Baltic area. It will thereby help the increased use of innovative technologies and processes related to utilization of biomass-based residues and enable SMEs to develop innovative products that are both cost-efficient and

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[1] EU COMM, 2017: Bioeconomy development in EU regions
[2] EU COM 2018: A sustainable Bioeconomy for Europe: strengthening the connection between economy, society and the environment Updated Bioeconomy Strategy
[3] EU COM 2018: A sustainable Bioeconomy for Europe: strengthening the connection between economy, society and the environment Updated Bioeconomy Strategy

sustainable[4]. The project is thus already well in line with the aim and objectives of the 2018 Bioeconomy Strategy.

To support transition to a sustainable and circular bioeconomy a common framework has been developed, focusing on three simple principles that could be used as a guideline forevaluation of promising innovative biomass-based solution that are to be implemented or for evaluation of already exciting solutions.

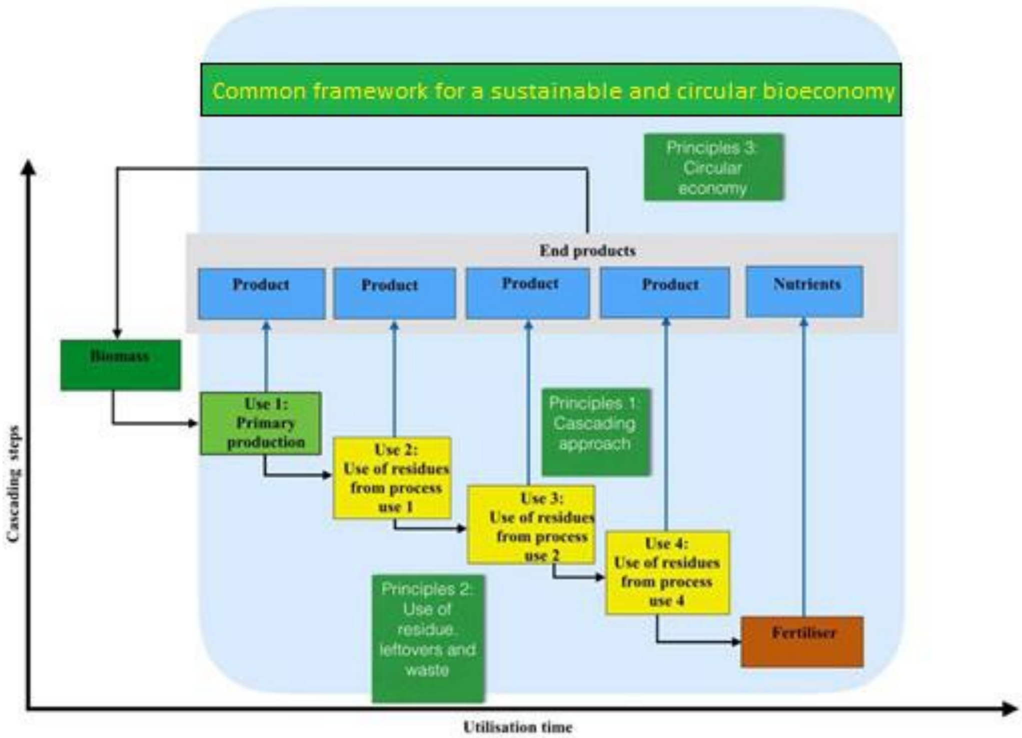
Principle 1. Cascading
The cascading approach prescribes the multi-purpose use of biomass through the whole value chain. High value products should first be obtained and then the low value residuals should be used for bioenergy, and nutrients used as biofertilisers. Cascading use of biomass increases resource efficiency and adds value to the biomass, as well as increasing the availability of raw materials.

Principle 2. Use of waste, leftovers and residues
There are two main reasons for starting the bioeconomy development by focusing on the biomass waste, leftovers and residues from agriculture and forestry:

a. There is a significant amount of residues available that might be both technically and economically attractive.

b. Arable land should be used for food production first, by initially focusing on waste, residues or leftovers the bioeconomy will not compete with food production or push loss of biodiversity.

Principle 3. Circular economy
The issue of circularity prescribes that: (a) All materials and nutrients should be recycled to the biosphere without harm, after the optimal balance between reuse, maintenance and cascading sequences; (b) All products should be designed with optimal durability and for reuse and recycling.



[4] BioBIGG application

3 Exemplary cases for a sustainable and circular bioeconomy

3.1 Introduction

The three principles mentioned above, namely the cascading approach, use of waste, left-overs and residues as well as a circular economy approach, are in our opinion fundamental to the concept of a sustainable bioeconomy. In this section of the deliverable, several examples of different biomass conversion chains, in different bioeconomy sectors, carried out at various sites in the participating countries, have been collected and analysed.

In most of the cases the three bioeconomy principles above (indicators) can be discerned, however the biomass conversion processes presented there are by no means complete and can still be modified to incorporate the principles of bioeconomy. In some cases similar biomass conversion chains are discussed which allow comparisons between different SBA countries and paths of execution of these types of production. One such example is sugar production from sugar beets, which is discussed on the basis of plants in Germany, Poland and Sweden. In that case it can be seen that the processes are very similar with a limited number of cascading opportunities. Similarities are also considered between beer brewing processes in Denmark and Poland.

Although the processes involved here are also very mature in that case the up-cascading opportunities are very limited. Of paramount importance is seeking such up-cascading opportunities in order to ensure development of prospective consumables in the form of nutrient components for up-cascading food production or the substrates of other products which will reduce the requirement for their supply from the present processes. An interesting example here is the production of collagen or gelatin from fish skin in fish processing factory or production of pectin from lemon peels. Collagen, gelatin and pectin are high value substrates for cosmetics and food production respectively.

3.2 SYSAV's pre-treatment plant for food waste – from waste to vehicle fuel and fertiliser

3.2.1 Mission and Vision

Sysav's pre-treatment plant for food waste came into service in 2009. In the pre-treatment plant, food waste is converted into a pumpable liquid, a slurry. The slurry is used as feedstock in biogas plants to produce two useful products – biogas and biodigestate. The biogas is upgraded to pure methane and used as vehicle fuel or injected into the natural gas grid, while the biodigestate replaces mineral and organic fertilizers in the growing of agricultural crops.

Sysav receives waste from households and businesses in southern Skåne (Scania). At Sysav a combination of methods are used to ensure that all types of waste from households and businesses are harnessed as resources in the best possible way. In addition to biological treatment, re-use and various forms of recycling, (energy recovery as power and heat from incineration, management of hazardous waste and landfill) are used.

Food waste accounts for almost half the weight of a standard household refuse bag. Food leftovers are also generated in restaurants, large-scale kitchens, grocery stores and the food industry. Sorting the waste and treating it biologically, in a biogas plant, will harness both the energy and the nutrients in the food waste.
This will reduce the use of fossil fuels and mineral fertilizers, thereby contributing to lower carbon dioxide emissions. Sysav's pre-treatment plant is a good example how food leftovers can be utilized for sustainable production of biomethane and biofertilizers in the circular economy.

Principle 1: Cascading approach
Promising opportunity for use of CO2 in the beverage industry or for methanation

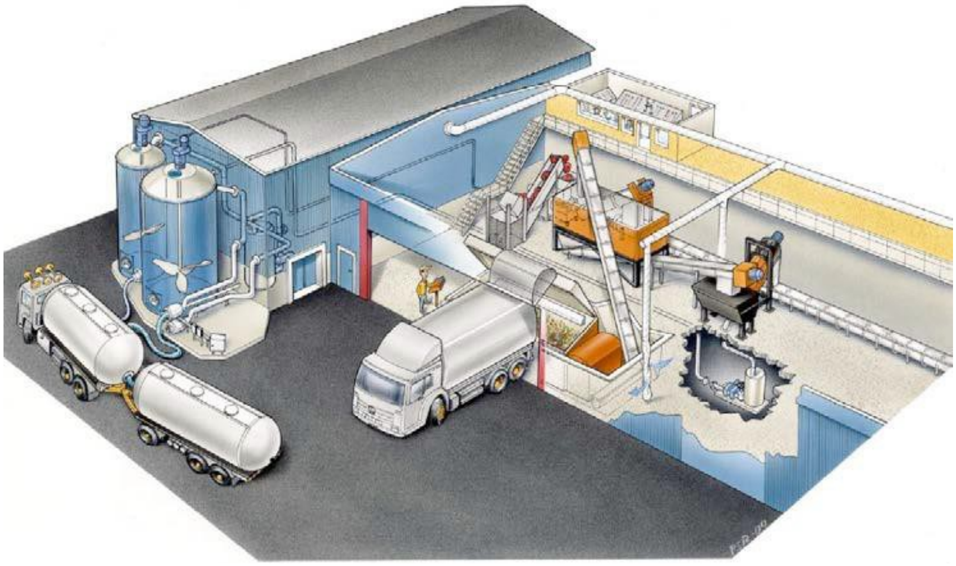
Principle 2: Use of residues, leftovers and waste
Use of food waste

Principle 3: Circular economy approach
Production of renewable energy and recycling nutrients

3.2.2 Technology description

At Sysav's pre-treatment plant 25.000-30.000 tons of food waste are processed every year. The biogas produced from the waste, used as transportation fuel, is equivalent to two million litres of petrol. The amount of liquid biodigestate produced in the biogas plant is approx. 25.000 m^3.

Households and businesses sort their food waste into special paper garbage bags which are placed in separate waste containers. Large-scale kitchens and restaurants can also use disposal grinders, e.g. under the sink, whereby the liquid food waste is collected in a tank. Shops and food producers can also leave food waste in their consumer packaging.



An effective pre-treatment of food waste is important to ensure that subsequent treatment in a biogas plant works well. The food waste is thus processed into a pumpable slurry. There is also a solid residual product in the form of combustible waste, which is used for energy recovery to power and heat Sysav's waste-to-energy plant.

Food waste from households, restaurants and large-scale kitchens is separated at source. The waste is tipped into a receiving bin and may only contain leftover food and the paper garbage bags it is placed in. Pre-packed food from industry and wholesale can also be received here.

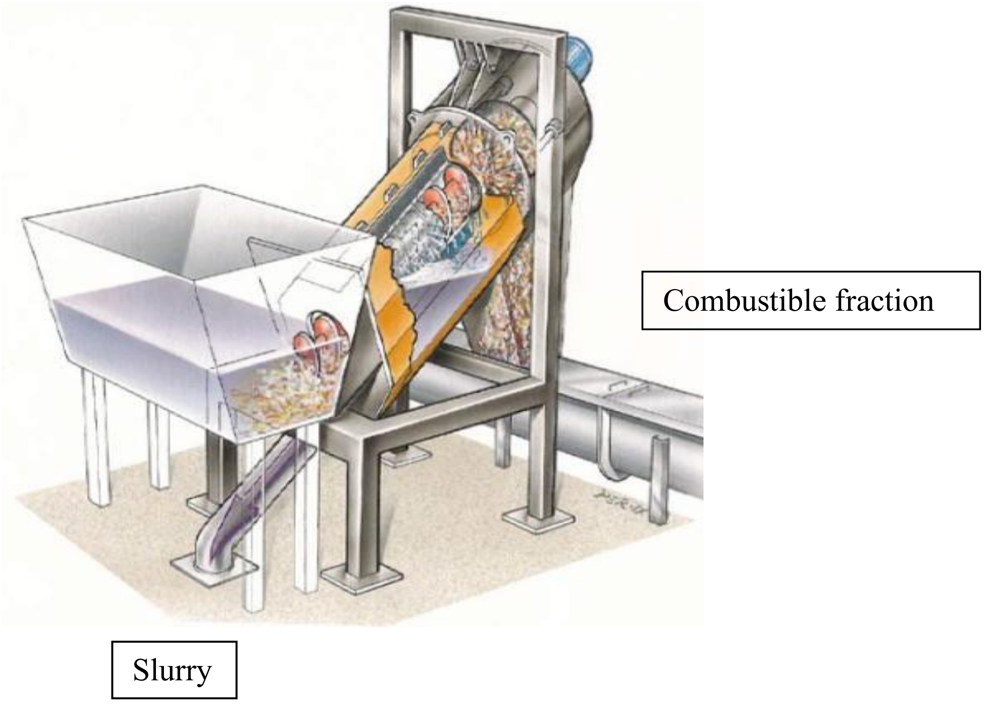
Main technologies used in the pre-treatment plant for food waste at Sysav

Line 1 - Reception of pumpable food waste
Design & planning: Purac & Sweco
Supplier: Purac
Receiving tank: 65 m^3
Agitators: Stamo, 3 propellers, 7,5 kW
Recirculation pump: Landia, cutting centrifugal pump, 150 m^3/h
Buffer tank: 200 m^3
Agitators: Stamo, 3 propellers, 15 kW
Recirculation pump: Landia, cutting centrifugal pump, 150 m^3/h

Line 2 - Pre-treatment of packaged liquid food waste on pallets
Supplier: OP system AB
Capacity: 2.000 tons per year
Pallet inverter: Nimo KG, SK 800 MK
Piston press: Pühler, MSV 500

Line 3 - Pre-treatment of source-separated food waste from households, etc.
Supplier: OP system AB
Capacity: 10.000 tons per year
Receiving bin: Havelberger H100-30, 30 m^3
Shredder: Doppstadt, DW 2060
Screw extruder: Doppstadt, DSP 20-5

In Line 3 the source-separated solid food waste is tipped into a receiving bin and then transported to a shredder. Here the food waste is shredded into small pieces. Then the finely shredded solid food waste is diluted in liquid in a mixing unit. The liquid used to dilute the solid food waste is primarily liquid food waste from Line 1 and 2.



In a screw extruder (Doppstadt, DSP 20-5) the diluted food waste is divided into a liquid fraction (slurry) for biogas production and a solid fraction for combustion for energy recovery as power and heat. The screw extruder presses the diluted waste and squeezes the liquid out through holes on the side of the extruder. The solid fraction is delivered to a conveyor for transporting to furnaces.

3.3 Unutilised biomass for production of biogas – Jordberg’s biogas plant

3.3.1 Mission and Vision

The vision is to use locally available biomass, currently not used for alternative purposes, to supply renewable energy and feedstock for chemical industry at the same time as the nutrients are recycled back to the soil.

The goal is to replace 20% of the dedicated agricultural crops used as substrate with unused silage bales. The biomass in these originate from agriculture, municipalities and the region, and thereby uses a biomass source that would otherwise only go to waste. Unused silage bales are an abundant resource but spread over large areas and diverse in their composition. The mission is to develop an efficient logistics system and a method for pre-treatment that makes high methane yields possible. The mission also includes further upgrading of the produced digestate by separating liquid and solid fractions to produce fertilizer and bio-oil.

Principle 1: Cascading approach
Use of straw for biogas production

Principle 2: Use of residues, leftovers and waste
Use of straw and food waste

Principle 3: Circular economy approach
Recirculation of nutrients to agricultural soil

3.3.2 Technology description

Unused biomass includes discarded silage for feed applications and ensiled grass from meadows, pasture and municipal grass land. This biomass is solid and pieces are too large to be feasible in conventional biogas plants. Much effort is therefore dedicated to the cutting or grinding of the biomass. Three different technologies have been evaluated for this purpose: Rotogrind, CutMaster and I-grind. At least 90% of the material must be cut to a chop length of <10 mm. Biogas is produced in a continuous mesophilic anaerobic digestion process. The biogas produced is upgraded and enriched with a small amount of propane before it is injected into the national natural gas grid. Digestate is sold as a fertilizer which is also approved for organic farming.

The use of unused silage as substrate for biogas production could be applied at any biogas plant that digests crops, waste and/or agricultural residues. The concept was previously tested in relation to the biogas plant in the Swedish municipality of Lidköping.

Jordberga’s biogas plant started operating in 2013 and today the plant has four employees. To include more difficult substrates, such as unused silage bales, may be more labour intensive than the current operation and thus more employment opportunities may be created. However, it is unclear whether these will be at the biogas plant itself or if they will be employed by entrepreneurs that take care of collection and logistics.
The annual production of biomethane at Jordberga is 11,7 MNm^3 and if 20% of this is replaced with unused silage bales that will correspond to 2,34 MNm^3 biomethane annually.

Bales of unused silage

Cutmaster, I-grind och Rotogrind, three options for cutting the unused silage in pieces of optimal size for anaerobic digestion at Jordberga Biogas Plant.

Jordberga Biogas Plant outside Trelleborg (Skåne)

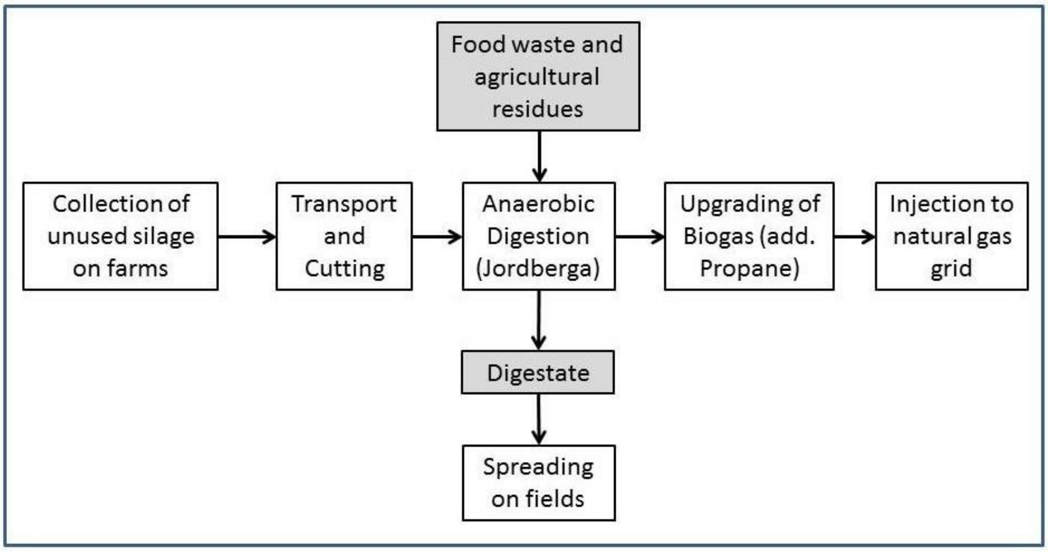
3.3.3 Investment and economy

Jordberga's biogas plant is a commercial plant operated by Gasum. Since they started operation in 2013 the turnover has increased and the results are improving even though the plant is still not profitable. The actual operational costs cannot be extracted from public sources. Unused silage is a cheap raw material but logistics and pre-treatment may be associated with high costs. Unused silage is spread on many farms and thus over a large geographic area. In a previous project the cost for delivery and disintegration (with a chipper) of the material were estimated to be 112-120 €/ton DM depending on whether intermediate storage of the material was assumed or not. Logistics should mainly be handled by entrepreneurs who will be the link between the farmers and the biogas plant.

3.3.4 Material flow

It can be assumed that 5% of ley crops grown and ensiled for feed purposes will be unused. In Skåne that corresponds to 44.839 bales with a total DM content of 12.106 tons DM. In addition to this 175 tons DM is assumed to be harvested and ensiled from meadow and municipal grass lands.

Jordberga is one of the largest biogas plants in Sweden. The annual production of methane is 5,95 MNm^3 and 20% of this (1,19 MNm^3/year or 3.268 Nm^3/day) should be produced from unused silage. The methane yield from unused silage is 281 Nm^3 CH_4/ton DM on average. The daily feed of unused silage will be 12 ton TS which corresponds to 35 bales. It is possible that the use of unused silage bales as substrate for biogas will increase the energy consumed in the biogas plant, mainly due to the more advanced pre-treatment and cutting of the material. However, the actual impact on the energy balance of the biogas produced still remains to be measured.



Flow chart for the process, unused silage to biogas and biofertilizer. Since this is a planned case there are not enough data to fill in the flow chart with actual numbers.

3.3.5 Estimated environmental and economic benefits

Unused silage bales can have different origins. One example is silage for feed that was produced in excess or that has been damaged and thus does not have sufficient quality for feeding purposes. It can also be biomass harvested from unused agricultural land or municipal grass areas used for other purposes than agriculture and from which cut grass has no current use. Since this biomass has no other use, biogas production should be beneficial. According to Gasum, the Jordberga biogas plant contributes savings of 28.000 ton CO_2 per year. Since part of the substrate in Jordberga is agricultural crops, this savings will not be possible to account for under the new version of EU Renewable Energy Directive (EU RED). Since unused silage is a waste material and does not compete for land with food production, the reduction of greenhouse gases emissions will be improved.

It is likely that transport and cutting of the unused silage will be performed by entrepreneurs and this could create new work opportunities. How many work opportunities that can be created will depend on the availability and demand for the service.

Since the biomass considered here does not have any further use than being a waste, new options for utilization will increase the resource efficiency considerably. The anaerobic digestion will provide not only the energy or chemical feedstock that is contained in the methane, but also organic fertilizer with further upgrading possibilities will be produced.

3.3.6 Lessons learned and recommendations

For more accurate results, more detailed tests are required.

The cost of disintegrating the silage bales can also be compared to the cost of the biogas plant for the purchase of cultivated crops as biogas substrates. Because the silage has a lower biogas yield than maize to be replaced, the number of silage bales must be greater than the amount of maize to be replaced.

The cost of purchasing bales and transport to the plant are the two largest costs in the system. How much the biogas plant is prepared to pay for the bales is highly dependent on the quality and methane potential. If the bale is of poor quality, it may be that a reception fee for receiving the bale may be equivalent to the cost of discarding of the bale.

3.3.7 The future

Using unused silage as substrate for biogas has been tested in Jordberga in a research project and the results look promising. Jordberga's biogas plant has to look for alternative substrates to adapt to EU RED and to increase profitability.

3.4 Suiker Unie GmbH&Co. KG

3.4.1 Mission and vision

The Anklam sugar factory was founded in 1883 and has more than 130 years of experience. In 2009, the Anklam sugar factory was acquired by the Dutch group Royal Cosun U. A. and has since then been known as Suiker Unie GmbH & Co. KG. The company deals with the entire production chain, from sugar beet growing to the packaging of sugar. Sustainability plays an important role in this process and is closely intertwined with the strategy of Suiker Unie. Since 2008, the factory also produces bioethanol and in 2013 it commissioned a biogas plant. Suiker Unie also strives to constantly optimize the production process and applies the concept of circular economy and cascading use through various sustainable solutions. More than 380 farms deliver their sugar beet from a total cultivation area of 19.300 hectares and the seeds are sourced exclusively from the factory.

Due to that, the beet cultivation area, which has already been increased by 50% since 2006, will continue to grow significantly until 2018 with approximately the same number of farms, which also contributes to the further development of the biomass source of sugar beets. Suiker Unie wants to achieve a position of leadership in optimal and sustainable ways adding value to all components and utilization pathways of the sugar beet and its products for its customers, growers and employees. It cooperates with its growers and partners to shape a better future. They do so by continuously improving local cultivation methods and processes for producing food and other useful products from sugar beets with specific concerns regarding people and the planet.

The case was evaluated in 2017 on the basis of 2016 data. It qualifies as an exemplary case of a sustainable bioeconomy, because it follows the concept of an integrated biorefinery, using 100% of the biomass and is also able to directly use the energy produced within the factory. It is therefore a prime example of circular economy.

Principle 1: Cascading approach
Promising opportunities for cascading of residues and by-products for production of bioplastic, animal feed, biogas, CO2, bio-ethanol and biofertilizers.

Principle 2: Use of residues leftovers and waste
Beet pulp and tails

Principle 3: Circular economy approach
Promising opportunity for for utilization of digestate from biogas production as fertilizer on agricultural soil.

3.4.2 Technology description

Suiker Unie produces not only white sugar, but also molasses, vinasse, press pulp, dry chip pellets, fertilizer from carbo chalk, bio-ethanol and bio-methane. It has an installed processing capacity of 12.00 tons sugar beets and 900 – 1.000 tons white sugar per day. Per year the factory produces 130.000 t white sugar, 20.000 tons molasses, 17.000 tons vinasse, 30.000 t dry chip pellets, 100.000 tons press pulp, 50.000 tons carbo chalk fertilizer, 75.000 m³ bio-ethanol and 11 million Nm³ bio-methane. There are 160 permanent employees working, usually around 28 campaign forces and 18 trainees. The production process can be divided into four steps:

1. The first section is before processing and is used for beet preparation, mainly by washing with water. Supported by various technical equipment, the beet, soil, stones, and other admixtures are separated and prepared for the following steps.
2. In the second step, extraction, the beets are cut into thin stripes, known as cossette. After that, they are transported to so-called diffusors, where the cell walls of the beet are broken down by water at approx. 70-72°C and the raw sugar beet juice is released by diffusion.
3. The juice so obtained is purified using lime, which is added to the sugar juice in the form of milk of lime. For this purpose, a lime-kiln for burning limestone is operated in the factory which processes 30.000 t limestone per year. The result is thin juice and the water is then evaporated to produce sugar syrup, the so called thick juice.
4. In the fourth and last step, controlled crystallization ("boiling") creates a mixture of pure sugar crystals and so-called mother liquor. Depending on the processing stage (A, B, C), the crystal suspension is either first homogenized and cooled, or it goes directly to centrifugation. The crystals separated there are in the form of pure white sugar, which has to be cooled and dried. In this way, about 40% of the total thick juice produced is processed directly into white sugar.

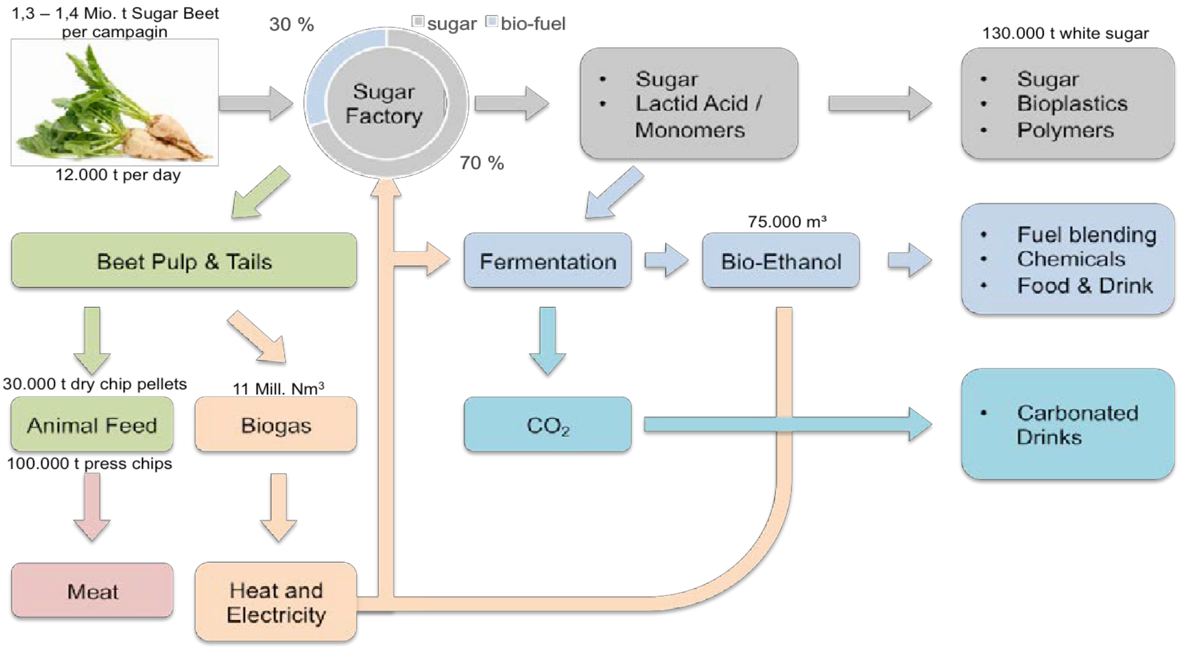
Since 2013, the surplus chips and other residual and waste materials have been fermentedinto raw biogas in the newly constructed biogas plant, which is operated all year round. This is treated with pressurized water scrubbing to create pure bio-methane of natural gas quality and fed directly into the natural gas network as green energy via a plant of Edis Netz GmbH. The bio-ethanol produced at the site is added to the fossil fuel as a renewable fuel supplement. With a daily capacity of 220m³, the bioethanol plant also operates year-round on the basis of fresh or stored thick juice. Bio-methane is used in the heating market and also as a fuel. Both products are certified according to the statutory sustainability requirements and meet the legal requirements for greenhouse gas reduction from 2017.

3.4.3 Investment and economy

Most of the information regarding investment and business is subject to trade secrecy and on this basis may not be disclosed. What can be revealed is that after the sugar factory was sold by the privatization agency to the former Danish company Danisco A/S following the era of the Cold War, the latter invested a total of 180 million euros in the site between 1992 and 1994, which created one of the most modern sugar factories in Europe in Anklam and also laid the foundations for future sustainable development.

3.4.4 Material flow

The Anklam sugar factory has an input of 1,3-1,4 million tons of sugar beet per year. It has an energy consumption of 40 million. Nm³ gas, 30.000 tons chalk and 2.500 tons coke. The connected boiler house serves as the energy centre of the factory and supplies electricity and steam. 96% energy efficiency is achieved due to cogeneration. This makes the operation particularly sustainable. The resulting wastewater is purified in a biological water treatment plant. This produces sewage gas, which is fed into the gas network together with the waste gas. Sugar beets contain more than 75% water and this is released as the condensate from evaporation during the production process. This water is reused to the greatest possible extent; e.g. for washing the sugar beets or hosing down the trucks, which transport beet pulp as their return load. Any remaining water is treated and filtered before being pumped back into the surface water. Suiker Unie has not used groundwater for starting up harvest activities since 2012. Tap water is only used for sanitation facilities. Each cubic metre of water which makes its way unnecessarily into the process has to be evaporated and this requires additional energy, so this must be avoided as far as possible.



3.4.5 Estimated environmental and economic benefits

Emissions of carbon dioxide (CO_2) and nitrogen oxides (NO_x) are unavoidable by-products of sugar production. These gases are among the products of combustion of the natural gas used for our steam boilers and pulp dryers. In addition, ammonia (NH_3) is released in a number of venting processes and when cooling the process water. Dust can also be generated when drying the pressed pulp and drying and cooling the sugar. Suiker Unie makes every possible effort to prevent or minimise emissions. For example, the burners in the boiler systems were modified in 2015 and 2016 in order to ensure compliance with the extremely strict regulations relating to NO_x.

Suiker Unie has set itself the target of reducing its Certified Financial Planner for sugar production by 40% in 2020 (compared with 1990). They have already achieved a reduction of more than 36% in 2016, so Suiker Unie is confident that it is well on the way to realising this objective.

Suiker Unie ensures a low carbon footprint through the optimal utilization of resources, residues, by-products and waste. Nevertheless, it continues to make every possible effort to achieve further increases in the sugar yield and further reductions in energy consumption in order to ultimately achieve an even lower footprint. Due to continuous enhancements of the process and implementation of new processes, additional jobs have been created over the years. In the biobased economy, the entire sugar beet plant is a source of biomass. This offers enormous opportunities for products other than sugar. Suiker Unie is already working on bioplastics produced from thick juice, fibres from beet pulp, protein from beet leaves and green gas from beet tops and tails.

As a supplier of biomass, Suiker Unie is at the beginning of the chain. They have already established a connection to various educational institutions and research facilities. Members of staff give guest lectures and Suiker Unie offers work placements and graduation assignments concerning the biobased economy.

The factory has already implemented numerous measures to further reduce noise and odour emissions by mid-September 2017 at the latest, in coordination with the State Office for Agriculture and Environment of Western Pomerania. The documents for the implementation of these measures are already available to the authority. All these projects precede the planned capacity expansion. These projects include among others:

- Construction of a noise barrier at the pre-wash drum
- Emission-reducing cover for a water-pond
- Construction of a noise barrier at the Vinasse concentration
- Optimization of the exhaust air system at the bio-ethanol plant
- Replacement of the air cooling system in the vertical mash of the sugar factory with a water cooling system

3.4.6 Lessons learned and recommendations

- The partnerships with universities, colleges and research institutes and their close cooperation have resulted in the development of innovative processes which can be easily integrated into the process from time to time (e.g. implementation of bio-methane, bio- ethanol and emission reduction technologies)
- From the initial phase and from the developed phase of the sugar factory, they had to continuously enhance the process based on the regulations as well as to withhold competitive ability.
- The sugar factory during the various operation phases has learnt to implement many innovative instruments to run various processes as smoothly as possible.
- The sugar factory has already implemented many processes and presently they are implementing the additional noise reduction from different processes.
- A present recommendation would be the further reduction of emissions, implementing modern technologies as implemented in partner factory branches**.**

3.4.7 The future

Currently the sugar factory is planning to implement additional noise reduction at various process steps and in future they would like to implement new technologies in the further reduction of emissions.

Apart from this, the sugar factory is also interested in the expansion or extension in the field of bio-plastic from the products directly available such as beet pulp, bio-ethanol, etc.
In addition, major investments were made in a sister factory in Vierverlaten in 2016 in order to condense ammonia out of the vapour produced in various processes, meaning that ammonia emissions to the outside air have been practically eliminated. The ammonia is condensed and removed from the process water via the water treatment plant. The effects of this investment are twofold: less odour emission and almost no ammonia is now emitted. It is assumed that these various improvements will also be made in Anklam.

3.5 Utilization of residues from production of pectin for production of biogas

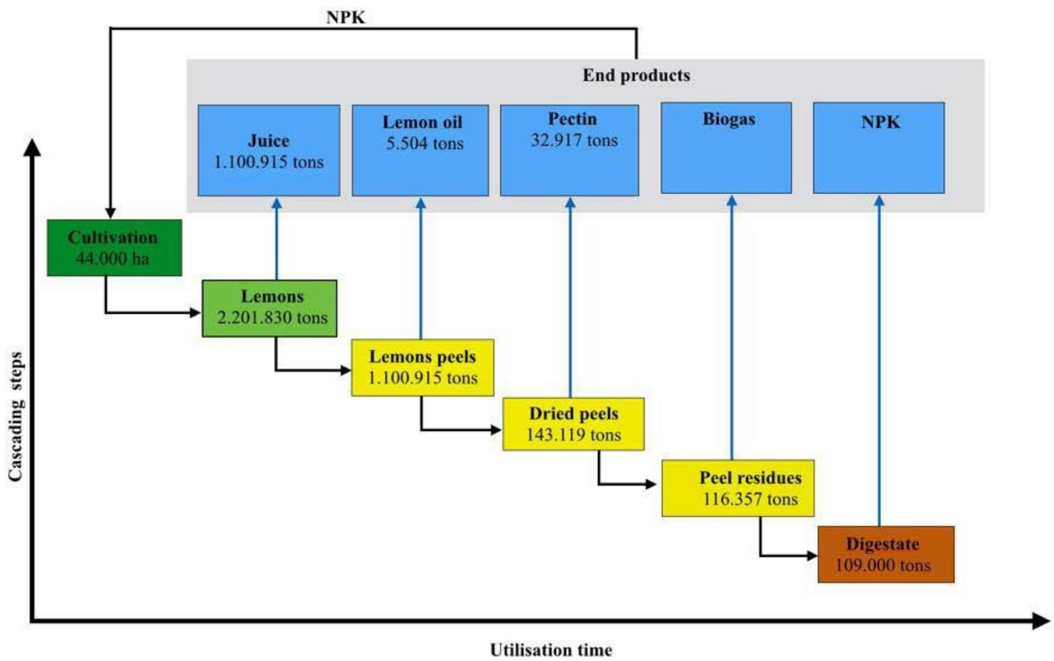
3.5.1 Mission and vision

The pectin factory in Lille Skensved is owned by CP Kelco and part of the C.M. Hubber Cooperation. The factory in Skensved was started in 1948 and today is the biggest pectin production factory in the world. The pectin products have several applications including improving texture and stability in food products and pharmaceutical and personal care applications. The production of pectin is based on dried citrus peel that is imported from South & Central America and Southern Europe. The dried peel is a residue from the production of juice and lemon oil. The factory in Lille Skensved receives around 143.000 tons of dried peels per year that is utilised to produce an estimated 33.000 tons of pectin. The main residue from the production process is the peel residues. The peel residues were previously used as cattle feed, but because of a decrease in the number of cattle farmers, the peel residues are today used as feedstock at Solrød Biogas, that was taken into operation in 2015.

Principle 1: Cascading approach
Utilization of lemon peels for production of pectin and residues from production of pectin for biogas production

Principle 2: Use of residues, leftovers and waste
Use of dried peel from the production of lemon oil and residues from the production of pectin

Principle 3: Circular economy approach Use of digestate from biogas plant on agricultural soil.



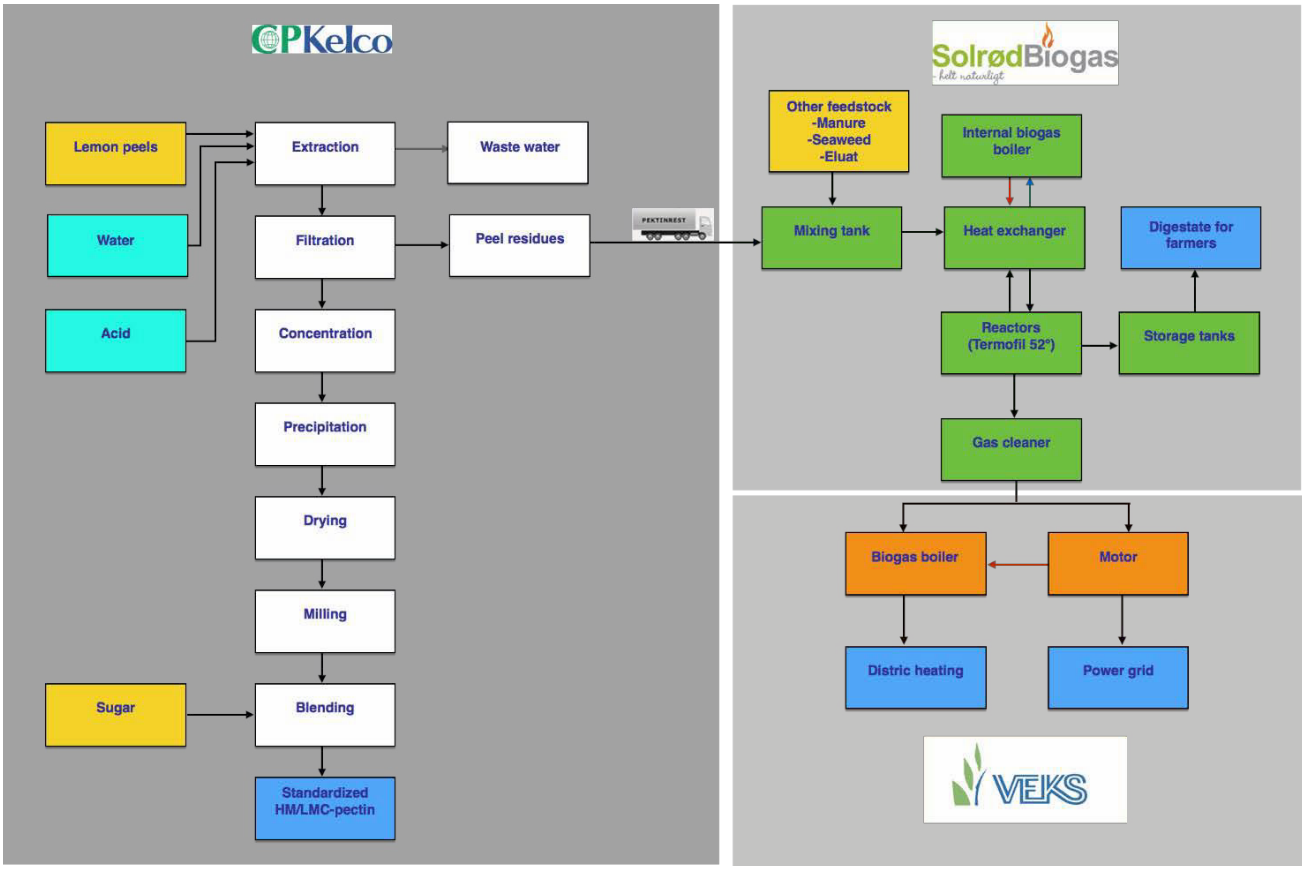
Delivery of peel residues at Solrød Biogas

3.5.2 Technology description

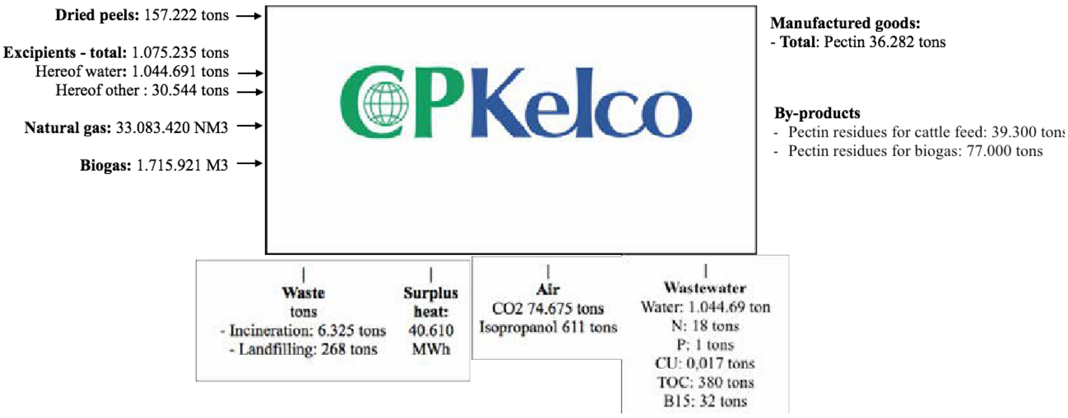
The use of dried peel for production of pectin and use of peel residues can been described as two steps in a cascade, both processes utilising residues as their raw material.

The manufacturing of pectin from the dried peel happens in a step by step process. The first step is washing of the dried peel in hot water together with a dilute mineral acid. The solid and liquids are afterward separated as effectively as possible through a repeated filtration where suspended cellulose pulp is added to help the process. The solid peel residues are finally pressed and stored until transported to Solrød Biogas. The clarified extract afterward undergoes a concentration and precipitation process before the final drying, milling and blending process takes place.

The peel residues are transported to Solrød Biogas by lorries where they are used as one of several feedstocks for the biogas production. Solrød Biogas has a treatment capacity of 200.000 tons per year. The biogas produced is used for CHP generation in a large gas engine. The power produced is sold to the grid and the heat is supplied to the local district heating system operated by Vestegnens Kraftvarmeselskab I/S (VEKS) that is owned by 12 municipalities in the Region Zealand and Capital Region. The digestate from the process is used as fertiliser for local farmers.



Input and output



3.5.3 Investment and economy

Cascading of biomass from CP Kelco to Solrød Biogas generates revenues and jobs that support the local economy. Also the implementation of Solrød Biogas has also meant that CP Kelco saves money that was previously spent on handling waste/residues.

Solrød Biogas (2016)
Plant Investment, DKK 85 million
Annual revenues/contribution margin DKK 14.659.000 DKK.
Local jobs: 14

CP Kelco (2016)
Plant investment, DKK 479 million
Annual revenues/contribution margin DKK 659.838.000 DKK (87 million €)
Local jobs: 364-385

3.5.4 Estimated environmental and economic benefits

The production of pectin is a good example of the potential within the bioeconomy for valorization of residues for the production of high value products. Also the cascading of residues have several environmental benefits:

- Production of renewable energy: 110 GWh per year
- Generation of 14 permanent local jobs
- Mitigation of climate effects: 40.100 CO_2 saving
- Production of digestate with nitrogen readily available for crops
- Reduction of leaching because of the improved fertiliser properties of digestate. N reduction: 62 tons/year and P reduction: 9 tons/year.
- The cascading of residues gives a more optimal use of arable land

3.5.5 The future

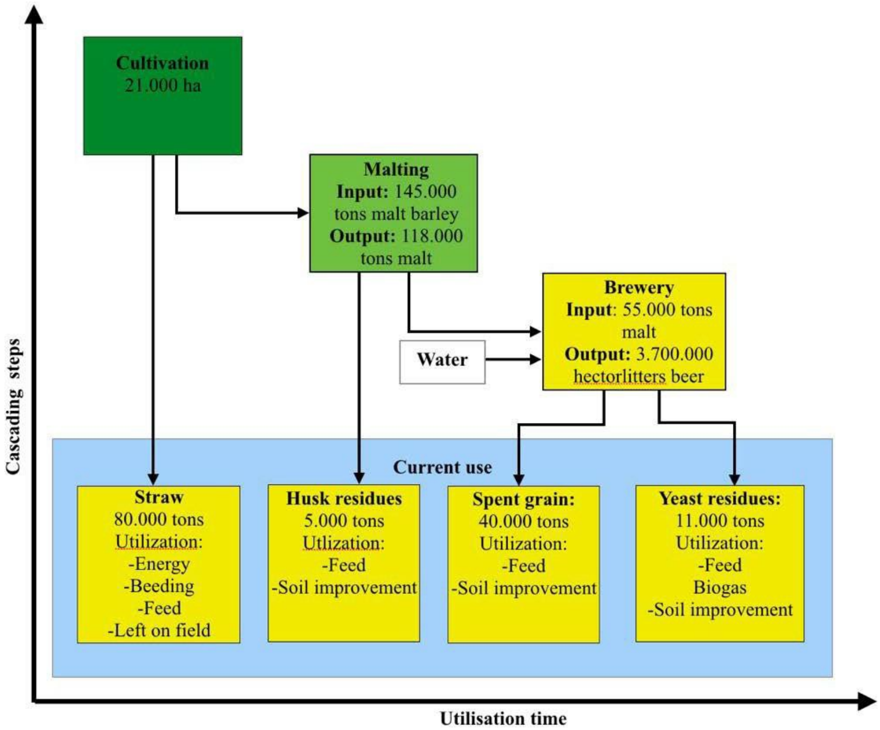
The production of pectin at the CP Kelco factory today results in 40.610 MWh of surplus heat. This surplus heat could in the future be utilised for production of district heating in nearby towns. The utilization has up until now been halted by rigid regulation, but is now expected to be implemented in the near future.

Pectin

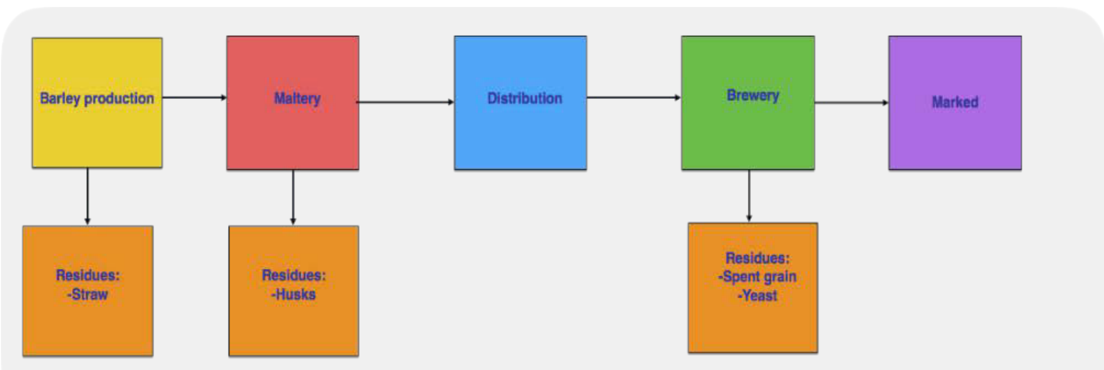
3.6 Finding the optimal use of residues from the brewery and malting industry in Region Zealand

3.6.1 Mission and vision

The production of beer generates a vast amount of residues. Faxe brewery owned by Royal Unibrew and Harboes Brewery in Region Zealand are no exception. The two companies yearly produce around 3.700.000 hecto litres of beer and generate around 40.000 tons ofspent grain. Also the company Viking Malt that produces malt from barley is located in the region. The company was previously owned by Calrsberg and named The Danish malting Group, but the company was bought in 2016 by the Finnish company Viking Malt.



Current cascading of biomass from the malting and brewery process.



Material flow

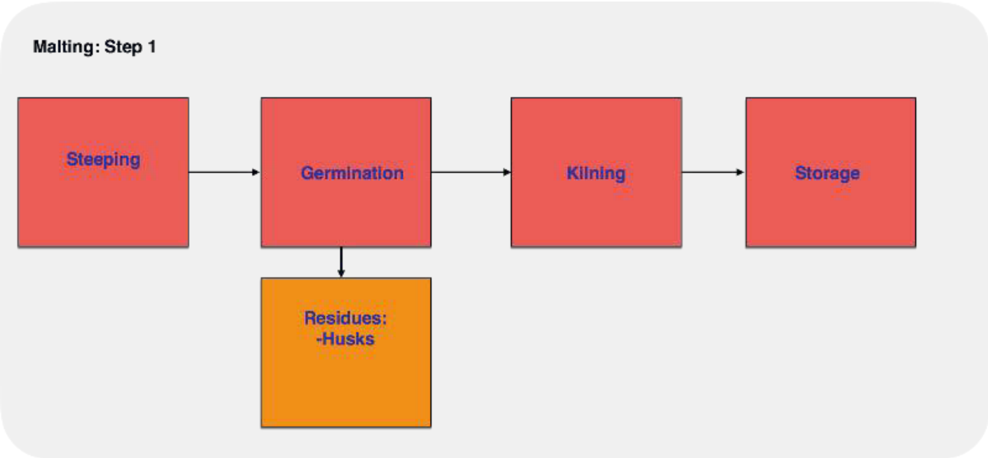
Principle 1: Cascading approach
Promising opportunity for separation of spent grain into a liquid and solid fraction. The solid fraction could then be used for meat substitution products and the liquid fraction for production of protein.

Principle 2: Use of waste, by-products and residues
Promising opportunity for more optimal use of spent grain and yeast residues

Principle 3: Circular economy approach
Left overs could be used for animal feed or production for biogas. The manure from livestock production could be utilised for biogas production and the digestate on agricultural soil.

3.6.2 Technology description

The first step in the malting process is steeping. Here the grain is washed and afterwards the moisture content is increased in the steeping tanks. The next step in the process is germination. The germination has already started in the steeping process and continues in the germination department. The germinating seed produces enzymes that are essential in the brewing process later on. The next part of the process is kilning. Kilning stops the modification process and makes the malt dry enough to be stored before being distributed to breweries.

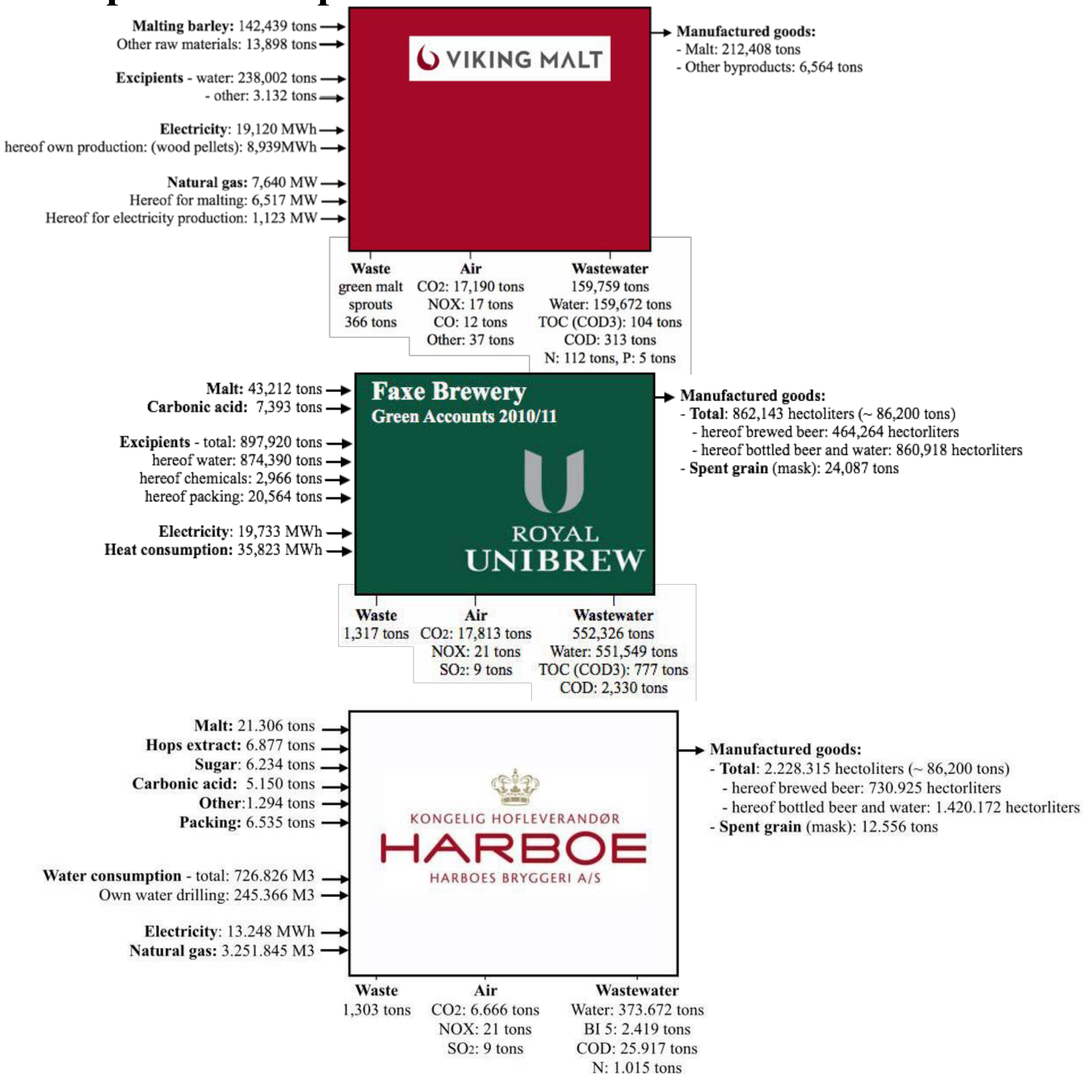


Malting process

The first step in the brewing process is milling. Here the different types of malt are crushed in order to break the grain kernels and extract fermentable sugars. The milled malt is then transferred to the mashing tanks, where it is mixed with hot water and enzymes break down the malt starch into sugars. Afterwards the product undergoes a filtration process where the solid spent grain is separated from the sweet liquid. The sweet liquid from the separation process is then sent to the boiler where the hops are added. The next step is the fermentation process that is started by adding yeast. After the fermentation, the beer is matured to develop its flavour. In the final step, the beer is tapped, carbonated and filtered.

Conventional brewery process

Input and output



3.6.3 Investment and economy

The brewing and malting industry play a central role in the local economy with around 888 employees in Region Zealand. The annual revenues/contribution margin has been increasing with 7,7% over a five-year interval. The annual revenues at Viking Malt has in the same interval between 71-100 million.

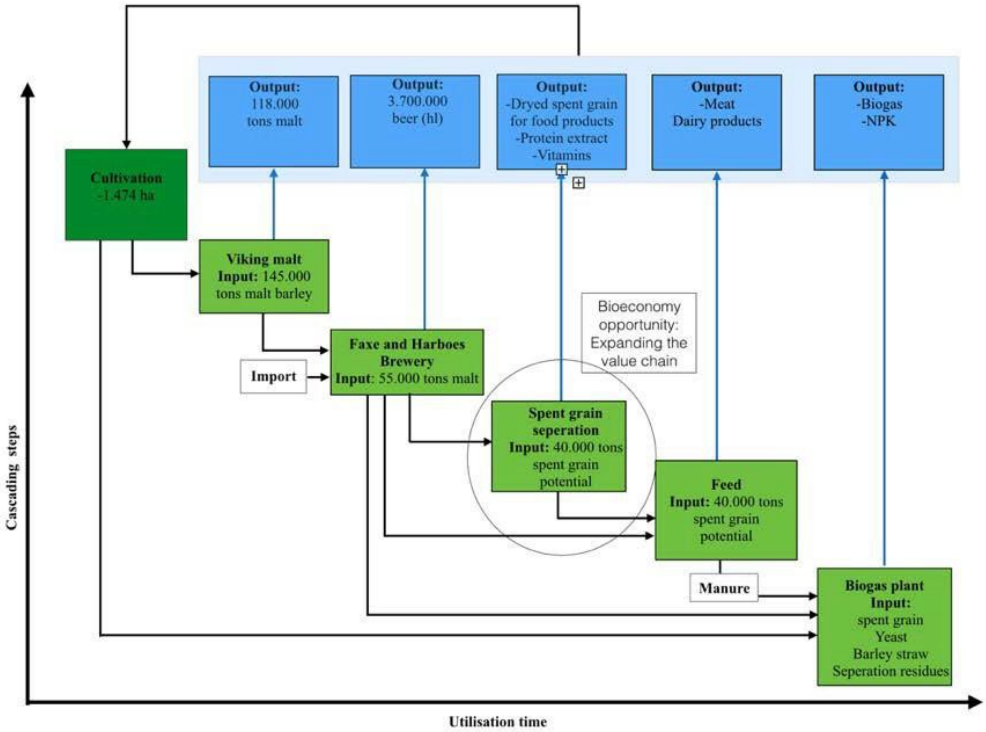
Viking Malt
investment, DKK 139 million DKK
Annual revenues/contribution margin DKK 90 million DKK.
Employees: 24

Faxe brewery
investment, DKK 849 million DKK
Annual revenues/Contribution margin DKK 1.693 billion DKK.
Employees: 888

Harboes brewery
investment, DKK 367 million DKK
Annual revenues/Contribution margin DKK 84 billion DKK.
Employees: 225

3.6.4 The future

In the future brewers spent grain that is generated during the brewery process could be separated into a liquid and solid fraction. The solid fraction following be used as filling material in food product and protein together with vitamins could be extracted from the liquid fraction. The residues from this separation process could then be utilized as feed or feedstock in a biogas plant together with the husks and yeasts.



Future cascade for malting and brewery residues

Pictures from the Company DACOFI that has specialized in the filtration of residues, including spent grain[5].

[5] http://www.dacofi.com/

3.7 Unused Biomass for Production of Alcohols and Biogas at Mełno Distillery and Biogas Plant

3.7.1 Mission and vision

The vision is to use locally available biomass (mainly bakery leftovers), to produce different kinds of alcohols (ethanol, propanol etc.) with simultaneous production of renewable energy and recycling of the nutrients back to the soil.

The biomass used in these processes originates from bakeries, hypermarkets, fruit and vegetable processing factories and factories that produce e.g. pizza bases. The used waste, if not processed in the factory, would otherwise only go to waste. Bakery or fruit leftovers are an abundant resource but spread over large areas. The mission of the case study is to develop an efficient logistics system and a method for collection of biomass and to transport it to the distillery. The mission also includes segregation of bakery products, fruit, vegetables leftovers from plastic bags, cardboard etc. and to develop the system of alcohol production with different substrates.

Principle 1: Cascading approach
Utilization of residues for the production of ethanol and propanol

Principle 2: Use of waste, by-products and residues
Use of bakery leftovers, fruit and vegetables

Principle 3: Circular economy approach
Recycling nutrients back to the soil and production of renewable energy.

3.7.2 Technology description

Available biomass is a solid one and has to be milled, mashed, weakened and heated up before the fermentation process. Much effort is therefore dedicated to the processes of cutting, grinding and raising temperature of the biomass. Thus the excellent idea is to connect the distillery with the biogas plant, which is actually the case in the site considered. The waste from the fermentation process goes to the biogas plant while biogas is burned to meet the energy demand of the fermentation process.

Mełno Distillery and Biogas Plant started operating in 2012 and today the plant has 24 employees. The annual production of alcohol at Mełno is about 100.000 litres.

Heaps of bakery leftovers, beet pulp and onion peel

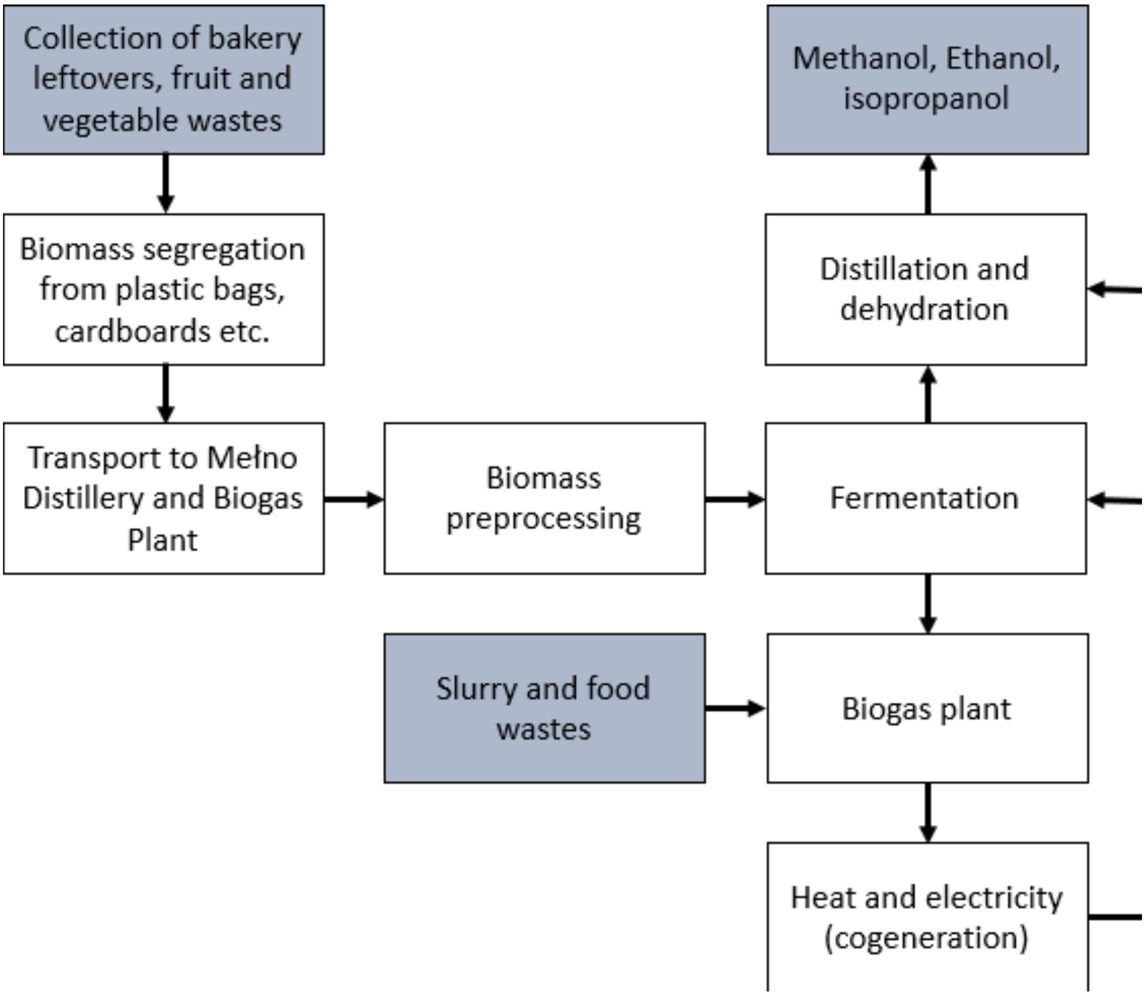
Four cogeneration 400 kWe units at Mełno Distillery and Biogas Plant.

Mełno Distillery and Biogas Plant, Poland

3.7.3 Investment and economy

Mełno Distillery and Biogas Plant is a commercial plant operated by Allter Power. Since the beginning of operation in 2012 the company turnover has increased and as a result the plant is profitable. The leftovers used in the distillation process are not expensive, very often obtained raw materials are for free, however their logistics and pre-treatment may involve high costs. Bakery, fruit and vegetables leftovers are collected from separate locations and thus over a large geographic area. Dedicated logistics and segregation are accomplished by external companies involved with collection and delivery of the distillation substrate to the plant. The average alcohol production cost is in the range 0,24-0,52 €.

3.7.4 Material flow



Flow chart for the process. Leftovers, waste to distillery and biogas plant.

3.7.5 Estimated environmental and economic benefits

Bakery leftovers, fruit and vegetables waste can be of different origins. One example is the product that was damaged or in excess of its sell-by date and thus cannot offer sufficient quality to be sold to customers. It can also be biomass (especially in fruit and vegetable processing factories) that remained after the particular processing. Since such biomass has no other use, the alcohol production with simultaneous biogas production represents an attractive option for its management.

In Mełno Distillery and Biogas Plant the transport and biomass segregation from plastics is performed by cooperating companies and this creates new job opportunities.

Since the biomass considered here does not have any further use than just being waste, new options for utilization will increase the resource efficiency considerably. The fermentation and distillation processes provide not only alcohol but also some organic fertilizer featuring further upgrading possibilities.

3.7.6 The future

The example of using bakery leftovers as well as fruit and vegetable waste as substrates for alcohol production with simultaneous biogas production has been satisfactorily accomplished in Mełno Plant. Increased production is now foreseen.

3.8 Production of sugar at Malbork Sugar Factory

3.8.1 Mission and vision

Malbork is located in Pomerania Region, close to the border with Warmia and Mazury. The factory was founded in 1880. In Poland there are 4 main sugar companies that are sharing the entire market. The largest one is the Krajowa Spółka Cukrowa S.A. (National Sugar Company Ltd) which has almost 40% share of the market. It has seven factories including one in Pomerania, in Malbork. In 2002, the Malbork sugar factory was taken over by the Polish group Krajowa Spółka Cukrowa S.A. and since then products have been sold under the Polski Cukier (Polish Sugar) brand. The company deals with the entire production chain, starting from sugar beet growing to the packaging of sugar including selling by-products such as molasses or beet pulp.

The factory itself is a very large plant, which is evidenced by the fact that it also has its own heat and power plant, which is used to prepare hot water and produce technological vapour, along with electricity. This is a coal-fired power station. Energy produced in this plant is used for the sugar factory purposes but a small surplus is sold to the city of Malbork. The factory also has its own sewage treatment plant and a technological water intake. Only water for sanitary purposes comes from the municipal water supply.

The last sugar season according to the old rules, with production limits imposed by the European Union on member states, was in 2016. On October 1, 2017 all the quotas were waived and the Malbork sugar factory became eligible to produce as much sugar as possible and sell as cheaply as possible in order to survive in the global, customer-oriented market.

Principle 1: Cascading approach
Promising opportunities for utilization of residues, leftovers and waste for production bioplastic, animal feed, biogas, CO2, bio-ethanol and biofertilizers.

Principle 2: Use of waste, by-products and residues
Beet pulp and tails

Principle 3: Circular economy approach
Promising opportunity for recycling nutrients from biogas production as fertilizer on agricultural soil.

3.8.2 Technology description

The Malbork sugar factory produces not only white sugar, but also molasses, fresh pulp, pressed pulp and dried pulp pellets. Production of white sugar amounts to about 900 tons per day. In the 2013/2014 sugar season over 560.000 tons of sugar beet were delivered from the local land to the factory. This is less than in the 2012/2013 season but more sugar was still produced, namely about 87.000 tons. In 2016/2017 the yields raised and the factory produced slightly less than 100.000 tons of white sugar from about 700.000 tons of sugar beets. In the latest year (2017/2018) the Malbork sugar factory acquired 706.602 tons of sugar beets which resulted in production of 101.873 tons of white sugar.

The average acreage from which beets are harvested amounts to over 10.000 ha. The average land yield is almost 70 tons per ha which gives an average of 11 tons of sugar per hectare. The sugar season lasts 110 to 130 days. The season starts in September and ends in January. The factory produces about 100.000 tons white sugar, 20.000 tons molasses and 480.000 tons beet pulp per annum. There are 170 permanent employees working and about 130 seasonal employees hired for the peak of the sugar season.

The contracted sugar beet without leaves is delivered to the sugar factory. Beets are washed and separated from soil, stones, and other admixtures. Soil management presents a huge problem for the company, which the company is seeking to help to solve in the next few years. Then, clean beets are stripped from their tails. Beet tails are used in a different process. Beets without tails are cut into small stripes, known as cossette. Cossette is about 80% of the mass delivered to factory (raw sugar beets). After adding water in a 1:1 ratio, the raw sugar beet juice is released by diffusion. In this process, called the juice extraction, the beet pulp is obtained. Raw juice is subjected to the filtration process where the result is the thin juice, while carbonation lime is a by-product. Thin juice is then boiled to evaporate water and thick juice is obtained. The last step is called centrifuging and here the white sugar is obtained. The very high-value by-product (molasses) is also obtained after adding water.

Heaps of sugar beet

Malbork sugar factory, Poland

3.8.3 Investment and economy

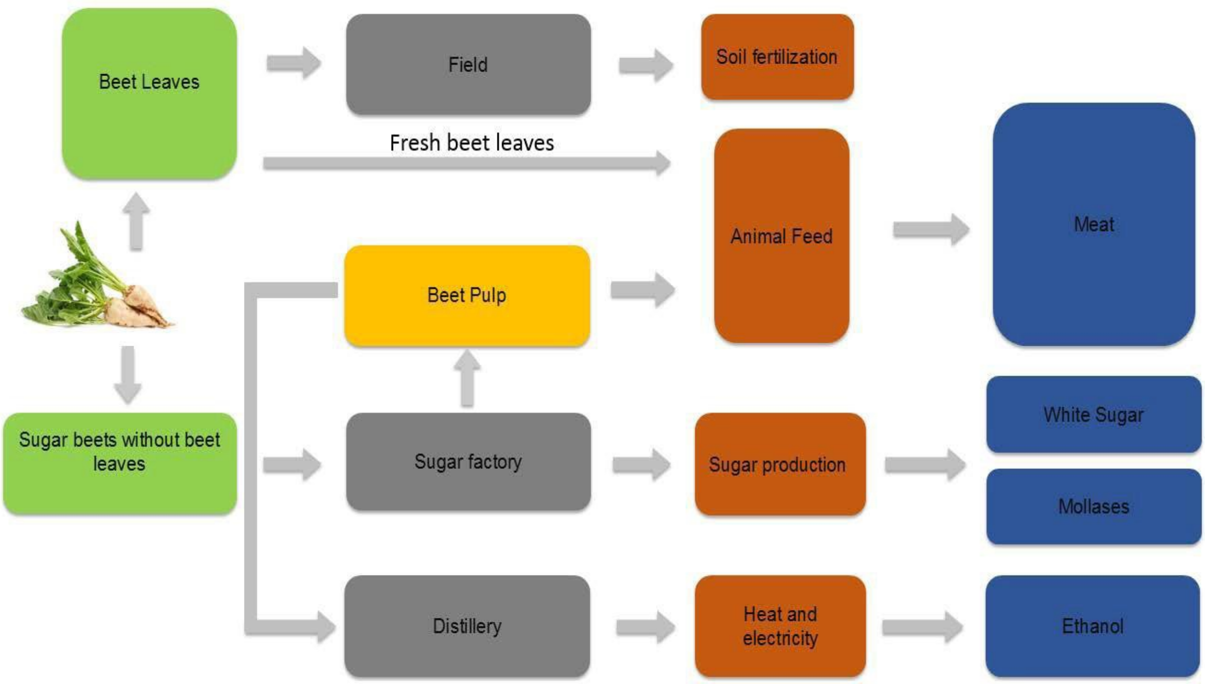
Most of the information regarding investment and business is subject to trade secrecy and may not be disclosed on that basis. The fact is that in recent years the turnover has increased and economic results are improving. The actual operational costs cannot be extracted from open sources. The Malbork sugar factory is trying to manage all waste and sell all by-products to increase profit. In 2013, the cost of repairs and investment activities before the sugar season amounted to approx. PLN 16 million (approx. € 4 million). In 2017 the plant realized following investments: construction of a new beet plant, reconstruction of the product plant, construction of a B continuous boiler, increased the filtration area and enlarged the wastewater treatment plant. The Krajowa Spółka Cukrowa S.A. has not revealed the real amount of expenditures, regarding it as a trade secret.

3.8.4 Material flow

Krajowa Spółka Cukrowa summarized the results of the sugar season 2017/2018. In all seven sugar factories, the company raised a total of over 6 million tons of sugar beet. In total, it produced over 900.000 tons of white sugar. The highest average yield was obtained in Kruszwica sugar factory - 73 tons/ha. Yields of over 70 tons per ha have also been reached by the Dobrzelin and Nakło Sugar Factories. In 2017, sugar beets were grown on an area of approx. 96 thousand ha, by about 15.800 farmers.

Malbork sugar factory has electricity consumption of 2,7 GWh and about 670 GJ of thermal energy. The connected boiler house serves as the energy centre of the factory and supplies electricity and steam. In 2013, the coal combustion installation consisting of two OSR-32/25 boilers and one OR-32/40 boiler was modernized. The modernization made on the OSR-32/25M boiler no. 2 resulted in an efficiency increase from 73% to 80% and power increase from 19,4 MW to 26,4 MW whereas in the case of boiler OR-32/40M No. 3 the efficiency improvement rose from 75% to 80% and power capacity increased from 23,3 MW to 28 MW. The wastewater is purified in a biological water treatment plant. The sewage treatment plant treats sugar wastewater of up to 80 m^3/h depending on the Chemical Oxygen Demand (COD) concentration of raw sewage in the front of the tank.

Sugar beets contain more than 75% water and this is released as the condensate from evaporation during the production process. This water is reused to the greatest possible extent; e.g. for washing the sugar beets or hosing down the trucks which transport beet pulp, as their return load. Any remaining water is treated and filtered before being pumped back into the surface water reservoirs.



Flow chart for the process.

3.8.5 Estimated environmental and economic benefits

All sugar industries produce a significant amount of air pollution and odours. The Malbork sugar factory is no exception. In 2014-2015, investments were made to minimize these inconveniences, including:

- implementing desilting and desalination of boiler waters - reducing the amount of coal burned and decreasing in the amount of pollution,
- installing inverters on devices (pumps, conveyors, etc.) - reducing electricity consumption, fossil fuel consumption and pollutant emissions,
- modernization of grates in industrial boilers - improving the coal combustion process,
- improving the efficiency of dust removal from cyclones in the pulp dryer,
- a programme of thermal insulation work on devices in order to reduce the fuel consumption as well as to improve the technological process.

An important action taken by the Malbork Sugar Plant was to reduce emissions ofodoriferous substances. For the neutralization of odours, the BIOSAN KZ200 preparation was used. The preparation is used in the technological process during the sugar season, when contaminants in the form of sludge from cleaning and washing sugar beets are directed to the settling tanks. Thanks to the use of the preparation, a good odour neutralization result has been obtained since 2010.

According to the data obtained from Krajowa Spółka Cukrowa S.A. in the years 2014-2015, investments were made to minimize noise around the Malbork sugar factory. The activities below have been accomplished:

- making an acoustic casing for the loading point of a lime kiln,
- execution of a new roof with insulation and new windows in the product building and the implementation of a new skylight,
- skimming of the inner surface of lime stone dispensers,
- works to increase the acoustic insulation of windows and doors,
- limiting the number of opened accommodation units in production rooms,
- installation of inverters on exhaust fans from the boiler room,
- installation of an acoustic silencer on the fan in the gas pumps building,
- assembly of acoustic blinds on the fan in the gas pumps building,
- repair of the roof and walls of the filtration building,
- execution of an air duct with a silencer for the fan after the sugar cooler,
- construction of sound absorbing screens around exhaust fans in the boiler room,
- refurbishment of the raw materials building,
- construction of sound absorbing screens for boiler room extractors,
- construction of sound absorbing screens near the entrance for trucks, on the lines of raw material evaluation and coach scales,
- replacement of windows.

Krajowa Spółka Cukrowa S.A. Malbork Sugar Plant has spent over PLN 2 million on the works related to the implementation of the above tasks. Since 2011, the factory is meeting the day and night noise standards.

During operation of the factory, by-products are created (previously regarded as waste), which include: pulp (PN-85/R-64808) - animal feed, rootlets and beet chips - sold for fodder, molasses (PN -76/R-64772) - used in the fermentation industry, defecosaturating lime (PN- 93/C-87007/02) - used in the fertilization of agricultural fields (defecosational lime is waste plant mass and solid sludges from cleaning and washing beets are subjected to process recovery of R3 and R11).

The Malbork sugar factory processing following wastes: waste used for fertilization and soil improvement, R14 - waste from cleaning and washing beets, limestone processing, ash-slag mixtures from the discharge of wet furnace waste, construction waste.

3.8.6 Lessons learned and recommendations

Malbork sugar factory should start cooperation with Universities, Research Centers or biological and chemical laboratories to find new solutions in the field of bio-plastic production from the products directly available, such as beet pulp, bio-ethanol or molasses. It seems that sugar beet leaves have big potential for new applications, especially when taking into account the volume of leaves which is about 70% of sugar beet roots. Leaves could be utilized in the chemical industry e.g. biopolymers.

A big issue for a sugar plant is rinsing water management. Presently water is taken into a sedimentation tank and mud is sent to landfill. This is a huge cost for factory. At the moment the plant is considering forcing the beet farmers to pay for that mud. An innovative idea is to dry the mud and sell it as a garden product or utilize mud as a flood barrier in areas threatened by floods.

Sugar factories should also make investments in order to condense ammonia out of the vapours produced in various processes, meaning that ammonia emissions to the outside air could be practically eliminated. Such activity has taken place in the Vierverlaten factory (Suiker Unie GmbH & Co. KG.). The effect of such operations was a significant reduction of odour emission and almost no ammonia emission to the environment.

3.8.7 The future

The Malbork sugar factory is in the process of implementing a quality control system for sugar beet already in the field. At the moment, the factory pays farmers for the sugar content in beet. In the future, thanks to this system, it may be that Malbork will pay for the amount of sugar produced from sugar beet. The system should improve the quality of beet grown resulting in greater efficiency, i.e. more sugar beet per hectare and even more sugar produced per hectare.

3.9 Groceries processing – Fruit and Vegetable Processing Plant at Kwidzyn

3.9.1 Mission and vision

Principle 1: Cascading approach
Promising opportunities for optimizing utilization of residues

Principle 2: Use of waste, by-products and residues
Promising opportunity for use of vegetable and fruit waste

Principle 3: Circular economy approach
Production of renewable energy and recycling of nutrients.

Kwidzyn is in the Pomerania Region, near the border with Kujawy and Pomerania as well as Warmia and Mazury regions at a distance of approx. 100 km from the seaports in Gdańsk and Gdynia. The Warmińskie Zakłady Przetwórstwa Owocowo-Warzywnego Kwidzyn (WZPOW Kwidzyn), can be translated as Warmia Fruit and Vegetable Processing Plant in Kwidzyn, and was founded in 1934. Over 50 years of the state-owned company's operation resulted in the establishment of a network of a high level regional cooperation and rose to the point of being the biggest agricultural and food processing company in this region. Since its foundation, the company has dealt with the production of tinned fruit and vegetables, and, more recently, wine. The enterprise processes the largest amount of green peas in Poland, which is its primary product in frozen and tinned ranges. The company is successively withdrawing from sales of tinned products to allow benefits of the fast development of the frozen product market. In 1998 the wine section of the company was sold. In 2005 the enterprise went into the portfolio of Pamapol S.A's ownership through their purchase of the majority stake. Currently Pamapol S.A. has 96,4% of shares in the company. As a result, the company has been restructuring its production potential, resulting in the implementation of modern machines and technologies on the site. The greatest asset of the company is the selection of raw material of the highest quality to be used in the production process. The vegetables processed in the plant are delivered by contractors whose cultivation area is exceeds 4.000 hectares. The farm land is monitored throughout the entire year beginning with the preparation of the ground, and the levels of fertilization and pesticides through laboratory analysis of the vegetable samples. WZPOW Kwidzyn ensures the highest quality of the raw material and delivers vegetables to manufacturers of food products for children and babies. The company has a Quality and Food Safety Policy, which states its mission:

- The main objective of the company is continuous improvement towards customers' requirements and expectations relating to specifications, standards and legislation.
- Another aim of the company is to increase the efficiency of production processes, by, amongst other things, implementing new technologies and improvements in the knowledge of processing.
- By undertaking such activities, the company takes full responsibility for the environment and the health safety of products.

- All actions fulfil the Quality and Food Safety Policy, improve work organization and provide a training system.
- In order to achieve these objectives, the Quality Management System ISO 9001:2008 has been implemented, the HACCP system (based on the 7-rule Codex Alimentarius), GHP, GMP and the BRC v.6 and IFS v.5 standards, all of which guarantee the quality and safety of the manufactured products.
- The Company's management commits to compliance with labour law and respect for ethical principles

3.9.2 Technology description

The company operates in the vegetable and fruit processing industry and manufactures products in the following assortment groups: tinned vegetable (broad beans, peas, sweet corn etc.) salads side dishes and packaged frozen vegetables (spinach, broccoli, brussels sprouts, green peas etc.) or fruits (cherry, raspberry, strawberry etc.) and frozen vegetables in bulk.

The current production depends on the season, weather and current agricultural crops. The factory processes many kinds of vegetables and fruits but not all at the same time. The plant is able to store about 40.000 tons of final product which is about one year's production. In 2017 the factory bought 41.000 tons of vegetables from contracted farms mainly in Pomerania as well as Kujawy and Pomerania regions (80%) or Warmia and Mazury, Mazovia and Wielkopolskie voivodships. Production in 2017 focused on packaged frozen vegetables which amounted to 32.000 tons. The rest of the vegetables were used to produce 7.800 tons of tinned vegetables. Some frozen fruit capacity was also created (100 tons).

The technology implemented in the company is quite complex and complicated due to the multitude of processed vegetables and fruit, which are characterized by a variety of size, density, color, shape and other parameters. This complexity forces them to have many machines that operate for only 1 or 2 months a year.

Waste from the processing of products is transferred to the biogas plant (5.517 tons), because the people and organization are not entrepreneurs (4.986 tons). Unmanaged waste is transferred to specialized recipients for use, or to the landfill dump in Gilwie Mała. The daily waste caused by segregation and freezing processes is small and does not provide any problem. The main waste issue for the company is the by-product resulting from corn processing. When the company starts the corn season the corn-based waste is produced at a rate of 1.000 tons per week. Corn is delivered to the processing plant containing leaves and cobs. That creates a huge amount of low-density waste which is expensive to transport. Other non-bio-based waste is paper and foil. Foils are disposed of very cheaply, in fact just for the cost of transport.

Heaps of green peas (left – post-sorting waste, right – pre-production substrate)

Warmińskie Zakłady Przetwórstwa Owocowo-Warzywnego in Kwidzyn (left – 2004, right – 2009), Poland [http://www.warzywakwidzyn.pl/en/Home/About-Kwidzyn/The-Beginnings-of-WZPOW-Kwidzyn]

3.9.3 Investment and economy

The Kwidzyn company is a dynamic enterprise that is still growing and makes great efforts to be a modern and eco-friendly processing plant that produces high-quality products. The latest investments were implemented a few years ago.

In August 2016 WZPOW in Kwidzyn completed the task "Modernization of the dust collection system in the WZPOW in Kwidzyn boiler" implemented with co-financing by the Voivodship Fund for Environmental Protection and Water Management in Gdańsk, in the form of a loan of PLN 950.000 (approx. 221.000 €). The total cost of the task was PLN 1.212.000 (approx. 282.000 €).

The goal of the task was to achieve an ecological effect, i.e. reduction of air pollution. The objective of the task was achieved at 20.937 tons/year.
In June 2017 the company finished the project "Modernization of WZPOW in Kwidzyn freezing tunnel". The task was made feasible with the funding from the Voivodoship Fund for Environmental Protection and Water Management in Gdańsk in the form of a loan of PLN 1.800.000 (approx. 0,42 mln €). The total cost of modernization was PLN 2.335.383,50 (approx. 0,5 mln €).

The task was to modernize the installation of freezing tunnels where three pieces of REN-6 freezing tunnels were replaced with the one TZF-A5 tunnel featuring the following basic parameters:

- installed electric power = 269 kW,
- installed cooling capacity (cooling demand) = 1.420 kW,
- real capacity = 10,6 tons/h.

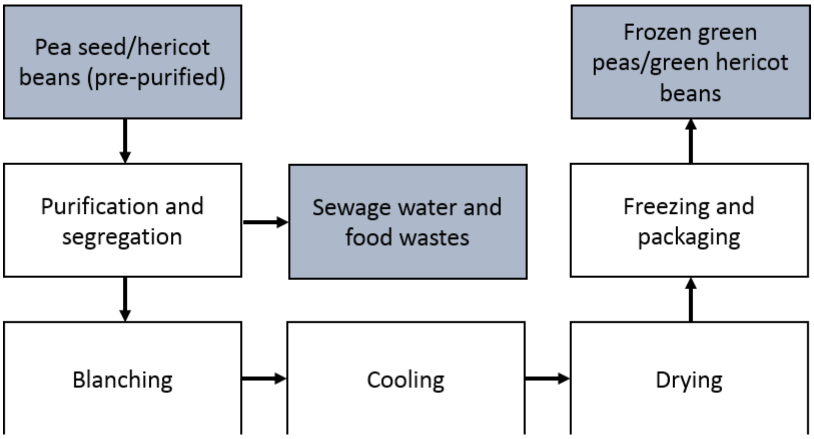
The aim of the above was to achieve the ecological effect, i.e. reduction of air pollution, by improving the energy efficiency of the installation and, as a consequence, reducing the load of the production process equivalent to CO_2 emissions to the atmosphere by 1999 of 922 tons/year.

Moreover, the company has purchased sorting machines that have a lot of modern optical systems, such as cameras and laser sensors that can be programmed for sorting products in respect to colour, shape and size.

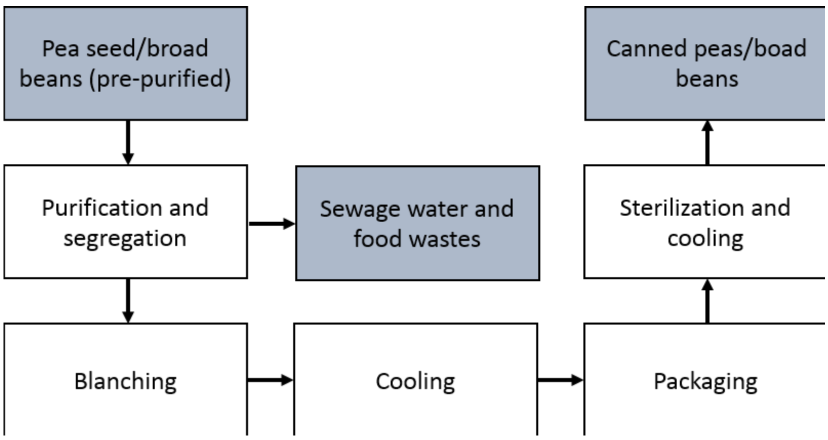
3.9.4 Material flow

The company has a demand for electricity capacity of 2,0 GW, which is used for the production of technological vapour, cooling capacity and hot water. The company does not feature its own source of energy, as all energy is purchased from outside. All waste water is going to a sewage treatment plant in the neighboring paper production company (International Paper Kwidzyn). This is a win-win situation because International Paper Kwidzyn releases mainly water containing chemical waste whereas WZPOW Kwidzyn releases mainly water with biological wastes. This mix results in a better water treatment in reactors.

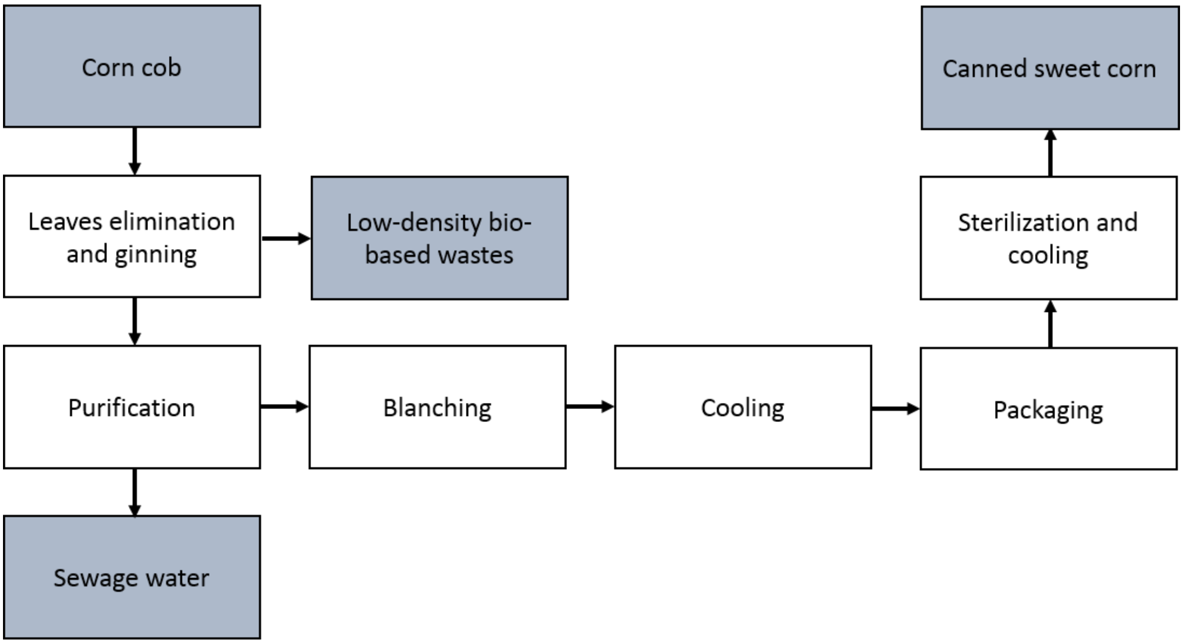
As said before, every sort of vegetable or fruit requires a different technological process. Despite that, every product needs to be purified (which results in sewage water), segregated (which results in food waste) and then blanched/cooled/dried/frozen, which result in energy usage. Below are flow charts for these processes.



Flow chart for the production of frozen green peas and frozen green hericot beans



Flow chart for the production of canned peas and canned broad beans



Flow chart for the production of canned sweet corn

3.9.5 Estimated environmental and economic benefits

The percentage share of operating costs in the company is as follows:

- raw material - 34%
- wages - 16%
- energy - 9%
- storage - 8%
- transport - 6%
- sale - 2%
- other - 25%

The price of products varies depending on the specific vegetable or fruit. Generally, it can be estimated in the range € 0,3 – € 0,7 per kilogram, e.g. 0,58 €/kg for carrot or onion, 0,65 €/kg for dish trimmings and 0,60 €/kg for green peas.

The company is still expanding. The annual business turnover is equal to 110 million PLN (approx. 25,5 mln €) in 2017. The estimated business turnover in 2018 is 140 million PLN (approx. 32,5 mln €). The expected turnover in 2019 will be 180 million PLN (approx. 42 million €).

The company has a large amount of bio-leftovers that can be utilized in different ways. The daily waste due to vegetables and fruit sorting is significant from the fertilizers perspective. The high-protein (green peas) and high-sugar (corn) content waste can be segregated and then used in up-cascading production.

3.9.6 Lessons learned and recommendations

The Kwidzyn company is a well-operating company that produces high-quality food products. The clients of the company are found all over the world. The largest recipient is South America (over 50% of selling share) but a lot of products are exported to Western Europe, Asia or even the Near East. The most recognized and praised Polish products are green peas and broccoli. A big issue for fruit and vegetable processing plants is management of by-products from corn, namely leaves and cobs. The problem is that this waste has a low density and the cost of transport is significant considering the price of waste. On the other hand, the amount of 1.000 tons per week of corn waste is a big opportunity. Corn-based by-products are characterized by a high sugar content and can be used for the production of higher value products (pharmaceuticals, food supplements).

The WZPOW in Kwidzyn should start cooperation with Universities, Research Centers or biological and chemical laboratories to find new solutions in the field of bio-plastics, food supplements or pharmaceuticals from the high value waste that contains a huge amount of protein (green peas by-products) and huge amount of sugar (sweet corn by-products). Itseems that sugar contained in waste from corn could be utilized for white sugar or alcohol production.

3.9.7 The future

The company is still growing. The best proof of this is the business turnover rising over the years. The WZPOW in Kwidzyn wants to buy new machines for food processing, especially more sorting lines that will reduce the waste from the sorting process. The company needs a solution for low-density waste from corn production which is costly and are not currently giving economic benefits. Especially when considering that this waste has a high sugar content and could be utilized in many beneficial ways.

3.10 Utilisation of residues at Craft Brewery – Bytów Browar Kaszubski

3.10.1 Mission and vision

Bytów is in the Pomerania Region about 90 km from Gdańsk. Bytów Browar Kaszubski was founded by two beer enthusiasts that restored the old brewery in Bytów in 2016. The symbolic opening of the brewery was on 26th January 2016 when the first bottle of light beer was filled. The company is the smallest manufacturer that brews beer in line with traditional recipe and all-natural ingredients. Since its foundation, the company deals with the production of classic beers, flavored beers and craft beers.

As a small company, Bytów Browar Kaszubski pays special attention to minimizing waste, energy consumption and re-using leftovers to maximize profits. It is in harmony with the spirit of bioeconomy, cascading approach and circularity.

As can be read at the website of the company, their mission is as follows: "Our main goal is to develop beer awareness by promoting tasty regional products created in harmony with nature."

Principle 1: Cascading approach
Promising opportunities for optimizing utilization of residues for production of protein and food products

Principle 2: Use of waste, by-products and residues
Promising opportunity for the use of spent grain and yeast residues

Principle 3: Circular economy approach
Production of renewable energy and recycling of nutrients.

3.10.2 Technology description

The company operates as a small, local brewery and manufactures products in the following assortment groups: classic beers (70% of annual turnover), flavoured beers (20% of annual turnover) and craft beers (10% of annual turnover) – in total 26 types of beer.
The main ingredients in brewery are water and barley malt (Pilsner type). The monthly raw material consumption in Bytów Browar Kaszubski is as follows:

- Hops – 140 kg
- Pilsner barley malt – 26.000 kg

From those raw materials the company is able to produce about 100 – 170 thousands 0,5 litres bottles of beer and some kegs. However, there are many factors that affect the natural processes of fermentation, filtration or maturation of beer, thereby affecting the total production. These are, among others, the thermal conditions of production or storage, air humidity or even weather. An interesting example is the finding that when there is a rain storm hundreds of kilometers away from the fermentation process, the yeast activity is slowed and the fermentation process lasts much longer.

The Bytów Browar Kaszubski has 2 owners that employ 16 manual workers and 3 managers which amounts to 21 employees. The brewery products are well known and appreciated in Poland, Europe and even in the United States of America. The amount of produced beer does not meet the demand on the products. Unfortunately, the company has limited development opportunities due to problems with the available land and limited financial possibilities.

The main waste from the brewery process is spent grain which must be dried and then can be given or sold to farmers. Farmers feed cattle with this by-product. Spent grain brings some issues, workload and financial expenditure. Since the spent grain is intended for farming purposes (cattle feeding), it must undergo periodic laboratory tests, which will confirm that it does not endanger the animals. This requires time and financial resources. Moreover, it has to be dried which requires energy and machines. At this moment, spent grain is not a very profitable by-product.


Spent grain


Bytów Browar Kaszubski; beer bottling line

3.10.3 Investment and economy

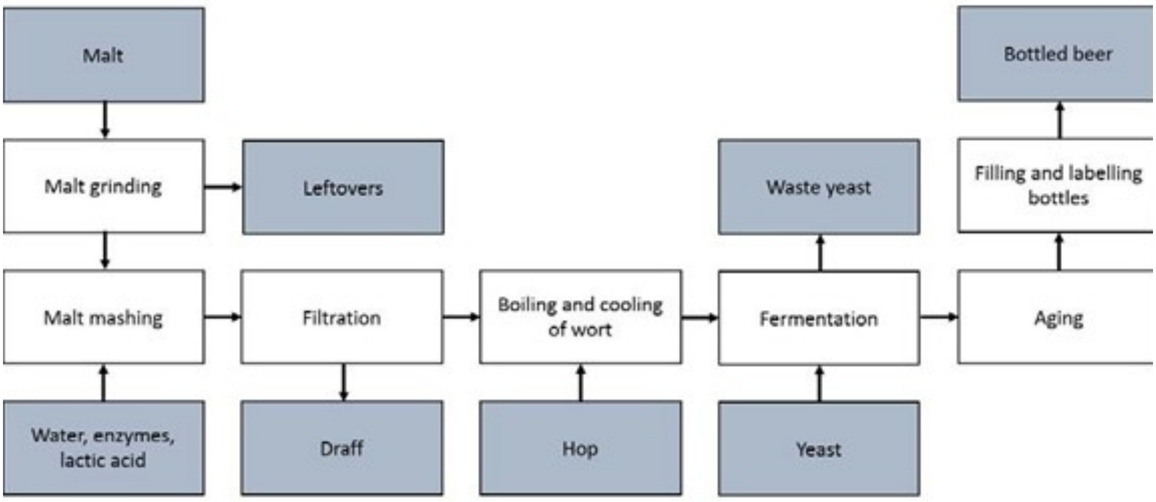
Bytów Browar Kaszubski is a small company that wants to expand and makes great efforts to be a modern and eco-friendly brewery that produces high-quality beers which are distinguished by their taste. However, the company has limited financial possibilities and land problems. Nevertheless, the owners have worked out a company development strategy and are planning some investments.

In the near future, the company wants to buy a new, bigger fermenter that will double the production. It will generate greater income and will allow them to make some more investments. The next idea is to design a new cooling installation. The old one does not meet the conditions required by the expanded fermenters. The cooling capacity for a new installation will be 70 kW. The last planned development will be a bigger magazine that will allow the production and storage of more bottles and, as a result, Bytów Browar Kaszubski will meet the demand on their products.

In addition, a new boiler room is planned in September/October 2018. At present there is no gas connection in the company. Boilers are running on thermal oil. The new boilers will be oil-supplied boilers with a possibility of conversion to gas. When the company is supplied with gas, the boilers will be switched to gas. The total cost of investment is 150.000 PLN (approx. €35.000). This solution will be more eco-friendly and will create some savings.

3.10.4 Material flow

The featured brewery uses about 66 tons of heating oil annually for energy purposes and has an electric energy consumption at the level of 14 MWh monthly, which is used for production of technological vapour, cooling capacity and hot water. The company does not possess their own source of energy, all energy is provided from outside. The required technological vapour's pressure is about 550 kPa. Steam generator has a power of 850 kW.
Bytów Browar Kaszubski obtains water from the municipal water supply system. This water is very ferruginous. Because of this, the company has their own water treatment station. Only treated water is used for beer production purposes. All waste water goes to the municipal sewage treatment plant. Sewage produced by the company does not contain very harmful substances or components such as heavy metals or chemicals and can be utilized in a standard way.
Below is the flow chart of the main products of the company.



Flow chart for the production of bottled beer

3.10.5 Estimated environmental and economic benefits

The percentage share of Bytów Browar Kaszubski operating costs is as follows:

- production - 67%
- transport - 23%
- sale - 5%
- other - 5%

The company has signed contracts with transport companies to deliver their products to recipients that are not in the region. Moreover, there are 2 sales representatives who look for new local markets. Some recipients come to collect ordered beer themselves.

The price of products varies a lot and depends on the kind of beer and ingredients that were used in the production. It can be estimated to be in the relatively wide range of € 0,5 – € 3,7 per bottle. Simple lager without any special flavour enhancing ingredients is at the lower end of the range shown above. On the other hand, dark stout in which coffee and almond flavours have been added that require special almond extract imported from London and a longer aging will cost significantly more.

The company is still expanding. The annual business turnover is not public but it can be estimated that the profit margin is at the level of 10% - 13%.
Bytów Browar Kaszubski has quite a small amount of bio-leftovers, mainly spent grain and some waste yeast, but it is not currently being used in a good way to make the most of economics and environmental benefits.

3.10.6 Lessons learned and recommendations

Bytów Browar Kaszubski is a local brewery that produces their beer with passion and in harmony with nature. The main market of the company are local shops, wholesalers and pubs, but the company also sells their product throughout Poland. Moreover, beers crafted in Bytów can be found in Netherlands, Israel or even in the United States of America. The demand is greater than the production of the brewery. For this reason, Bytów Browar Kaszubski wants to develop and invest money in new machines.

The main by-product in the company is spent grain. At this moment it is used for cattle feeding purposes. Spent grain contains about 77,7% water and because of that it needs to be dried which require a lot of energy to be spent for that purpose. Moreover, spent grain contains about 5,3% proteins. It should be considered whether this amount is reasonable to make some efforts to extract.

The brewery should start cooperating with Universities or Research Centers to find out if their wastes can be utilized in some ways.

3.10.7 The future

The company is small and is not able to make huge investments. However, the products of Bytów Browar Kaszubski have a good reputation and there are markets that want to buy their products. The investments that will be made in the next years will significantly raise production and income. The company needs a solution for spent grain which is sold very cheap for feeding purposes and at the moment is not contributing to the economic benefits of the company.

3.11 Residues management at Wood Processing Factory in Wiele

3.11.1 Mission and vision

The plan is to use mostly locally available wood biomass (mainly pine wood), to produce different kinds of products (elevation boards - 30% of production, wooden pegs – 15% of production, glued structural elements – 10% of production, wood pellets – 25% of production, garden products – 20% of production) with simultaneous renewable energy production for the purpose of production.

Principle 1: Cascading approach
Production of particleboards, wood pellets and glued structural elements

Principle 2: Use of waste, by-products and residues
Use of saw dust, bark and word chips

Principle 3: Circular economy approach
Production of renewable energy and potential recycling of bio-ash and bark

The immediate company objective is to attain better wood sorting before the main production process. For this purpose, the company is planning to buy an X-ray scanner to analyze log structure during intake and the preliminary sorting process. The implementation of this should increase the quality of the main products, such as elevation boards, and enhance efficiency of production. The challenge is to separate unsuitable wood not only based on external shape but also on the internal structure of the material. The mission is also to produce heat and electricity in cogeneration using wood pellets.

3.11.2 Technology description

Wood trunks mostly from pine are used in the production process. The trunks are roughly sorted by a video system including optional human manual control. The sorted wood trunks are debarked, sawed, sorted and dried. At the end the preliminarily processed products again undergo sorting, packaging and are stored or delivered to customers. The trunks which do not show suitable quality are put in a wood chipper. The wood chips from the main production process and from the poor-quality wood are used in the production of glued structural elements and garden products. Other residuals such as:

- bark is used as garden products,
- wood dust is used in on-site pellet production.

The majority of pellets are burned in the plant boilers. At the moment, the factory produces hot water and steam which are used in the wood drying process. Moreover, a small amount of wood dust is used as a substrate in the production process of wood pulp and particleboard. The Wiele factory started operating in 1994 and today the plant has about 300 employees. The company's annual processing of wood is 150.000 m^3.


Wood and wood dust at Wiele Wood Factory


Cyclone dust collector at Wiele Wood Factory


Wiele Wood Factory, Poland

3.11.3 Investment and economy

The Wiele wood factory is a commercial company operated by Sylva Drewno which is an integral part of French concern Piveteau Bois. The company's annual turnover of wood is 150.000 m^3.
It is one of the biggest wood company in the Pomerania region. Annual business turnover is equal to 124 million PLN (approx. 30 million €).

The company is planning to purchase an X-ray scanner to analyze log structure during intake and the rough sorting process (estimated cost of € 0,5 million). In the next year Wiele wood factory will start to build a new cogeneration unit (estimated cost of €1 million). At this moment, the factory boilers produce about 12 MW of heat (hot water and steam).

3.11.4 Material flow

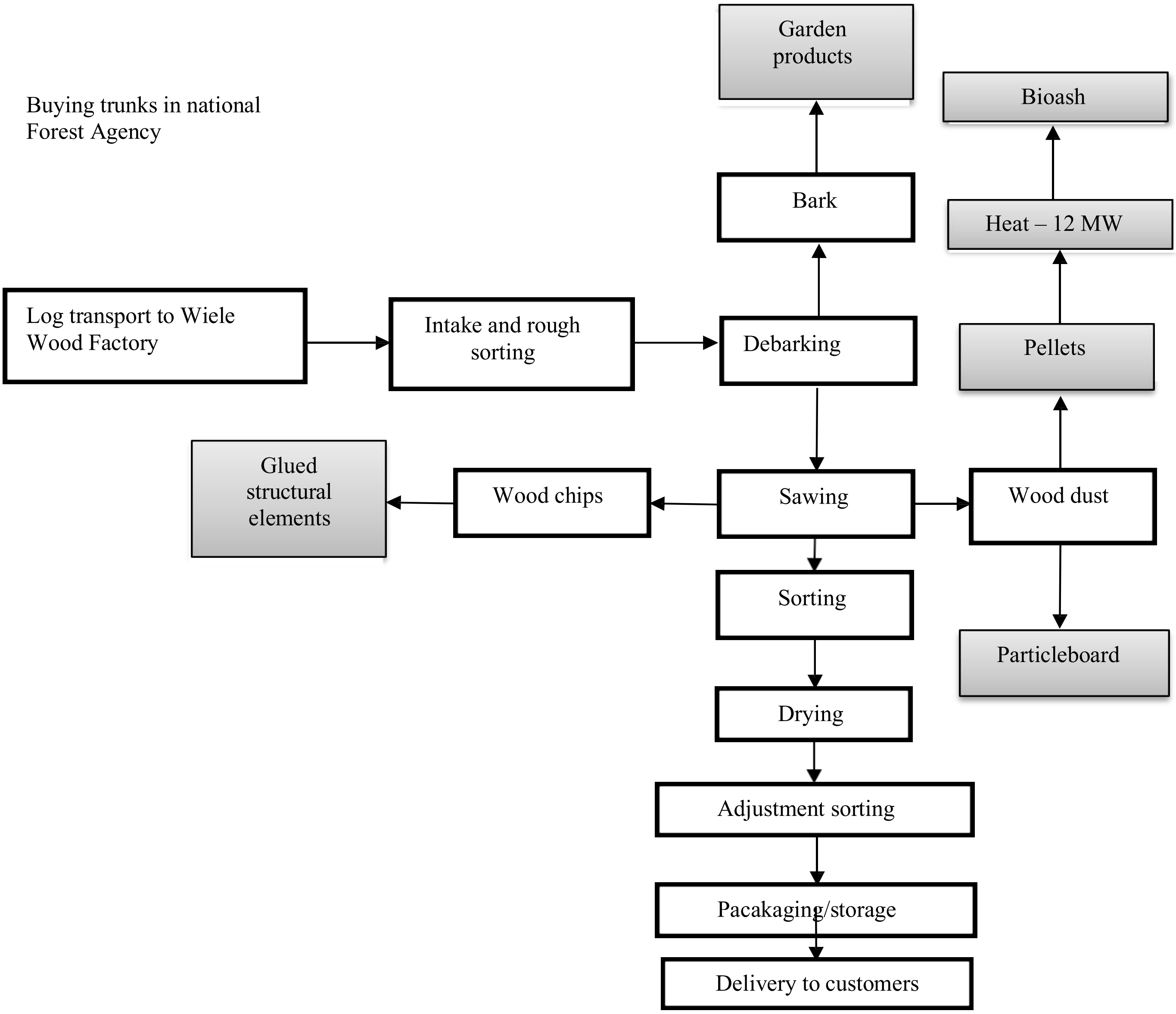
The Wiele wood factory is one of the biggest sawmills in Pomerania Region. The company's annual consumption of wood is 150.000 m^3 (75.000 t). The majority of wood (only the wood trunks) is bought from the National Forest Agency. The main company products are:

- Elevation boards – 30% of production
- Wooden pegs – 15% of production
- Glued structural elements – 10% of production
- Wood pellets – 25% of production
- Garden products – 20% of production

Most of pellets are burned in the plant boilers. Currently, the factory boilers produce about 12 MW of heat (hot water and steam).

Logging from the forest

Buying trunks in national Forest Agency



Flow chart for the process.

3.11.5 Estimated environmental and economic benefits

Environmental benefits:

- **Reduced energy** - wood products outperform concrete in overall carbon footprint reduction.
- **Less greenhouse gases emission** – wood manufacturing produces much less air and water pollution, lower volumes of solid waste and uses less ecological resources compared to other materials.
- **Carbon lock** - when wood is used as a building material, carbon absorbed by the tree as it grew is effectively locked away for many years.

Economic benefits:
The Wiele company is located close to the border between Pomerania and Kujawy in the Pomerania region. There is no other big companies in this area, except for the sawmill. Atthis moment, the company has 300 employees and cooperates with many other companies from the transport sector.

3.11.6 Lessons learned and recommendations

After the implementation of the cogeneration unit, the company will be energy independent. It could reduce production costs and increase energy efficiency as well as reduce the environmental impact of the company.

The implementation of an X-ray scanner to analyze log structure during intake and the rough sorting process should increase the quality of the main products.

3.11.7 The future

The Wiele wood company has to look at the increase of pellet heating value (now 19 MJ/kg). It could be used in the wood torrefaction process.

Bioash from the company could be sold to local farmers as fertilizers. According to EU regulations (EU 834/2007) wood ash can be used as fertilizers in ecological farms. Due to the fact that the number of ecological farms is constantly growing, it could be a large opportunity for the company.

3.12 Fish Processing and utilisation of residues at Limito S.A.

3.12.1 Mission and vision

At various stages of the industrial processing of fish, body parts of fish are separated, most commonly this is edible, so-called fish waste. This waste can either be a serious threat to the environment, if it is not disposed of properly, or can become a source of extra income, after converting it to valuable products. The types and properties of fish wastes at the place of their generation are very diverse and depend on the species, the initial form of the raw material, and the extent and method of processing. The main business of the Fish Processing Plant Limito S.A. in Grudziądz is the production of smoked fish products, in which the raw material is gutted salmon with heads, coming from aquaculture. Salmon is a relatively large fish, with an average weight of ca. 4 kg, and the individual weight of the processed salmon ranges between 2 and 6 kg. The value of this weight is important, because it determines the physical properties of the waste. According to the information received by the Limito company, the amount of raw fish material processed in the company is, on average, ca. 18 tons per day.

Principle 1: Cascading approach
Promising opportunity for the production of collagen and gelatin from fish skin

Principle 2: Use of waste, by-products and residues
Use of fish waste

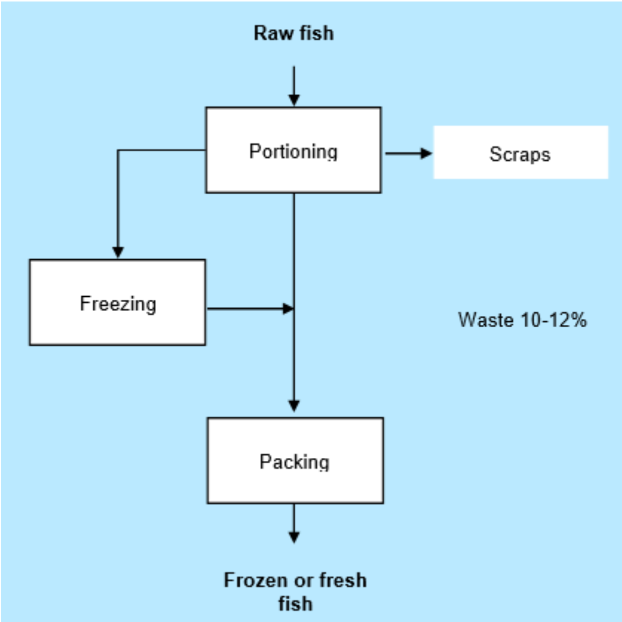
Principle 3: Circular economy approach
Production of renewable energy and promising opportunity for recycling of nutrients.

Products categories Limito S.A

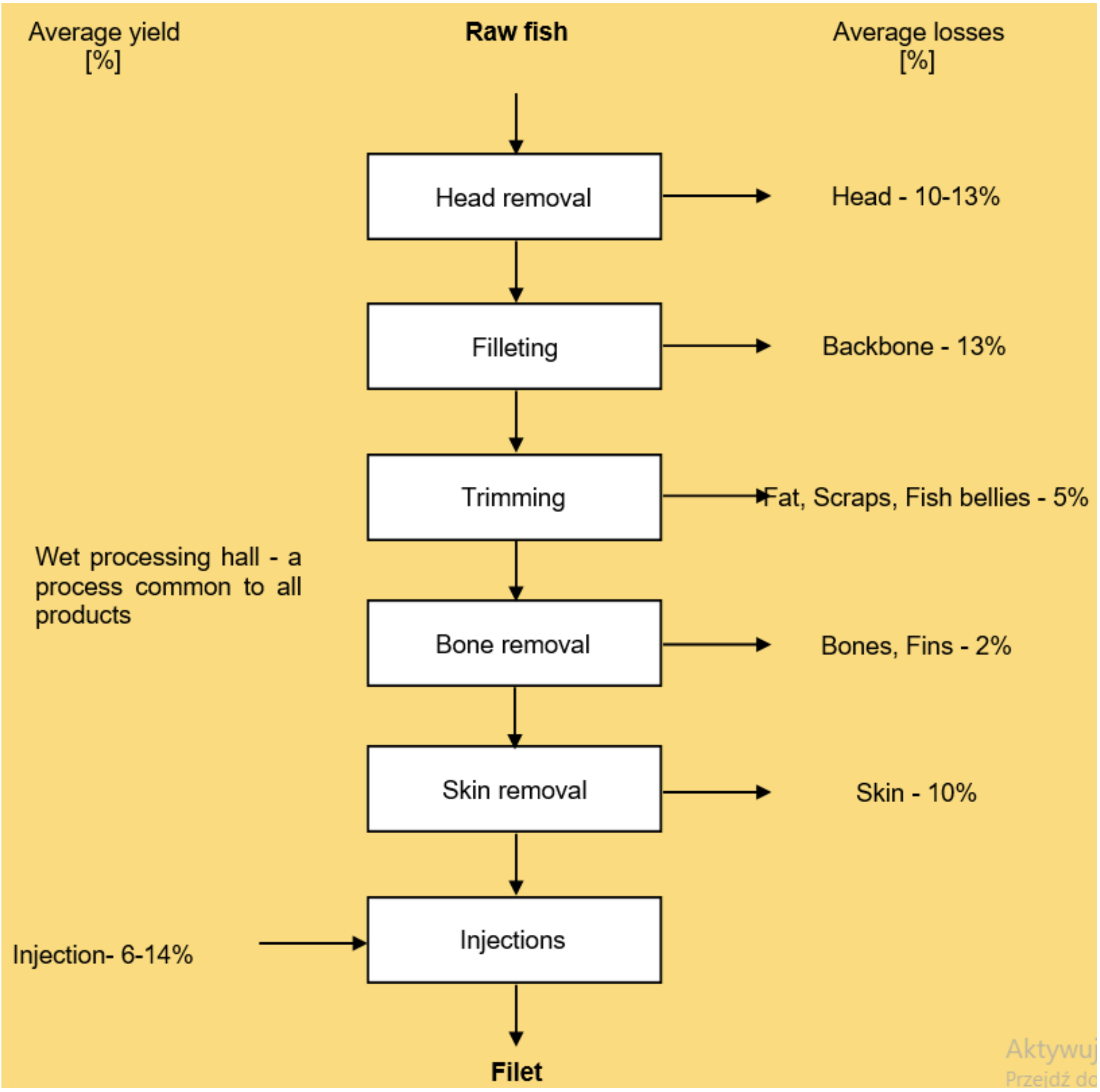
3.12.2 Technology description

The pretreatment of the raw material provided in the form of gutted fish with the heads attached involves removing the head of fresh fish or defrosting frozen fish, which are then reworked, i.e. removing heads, skins, filleting.

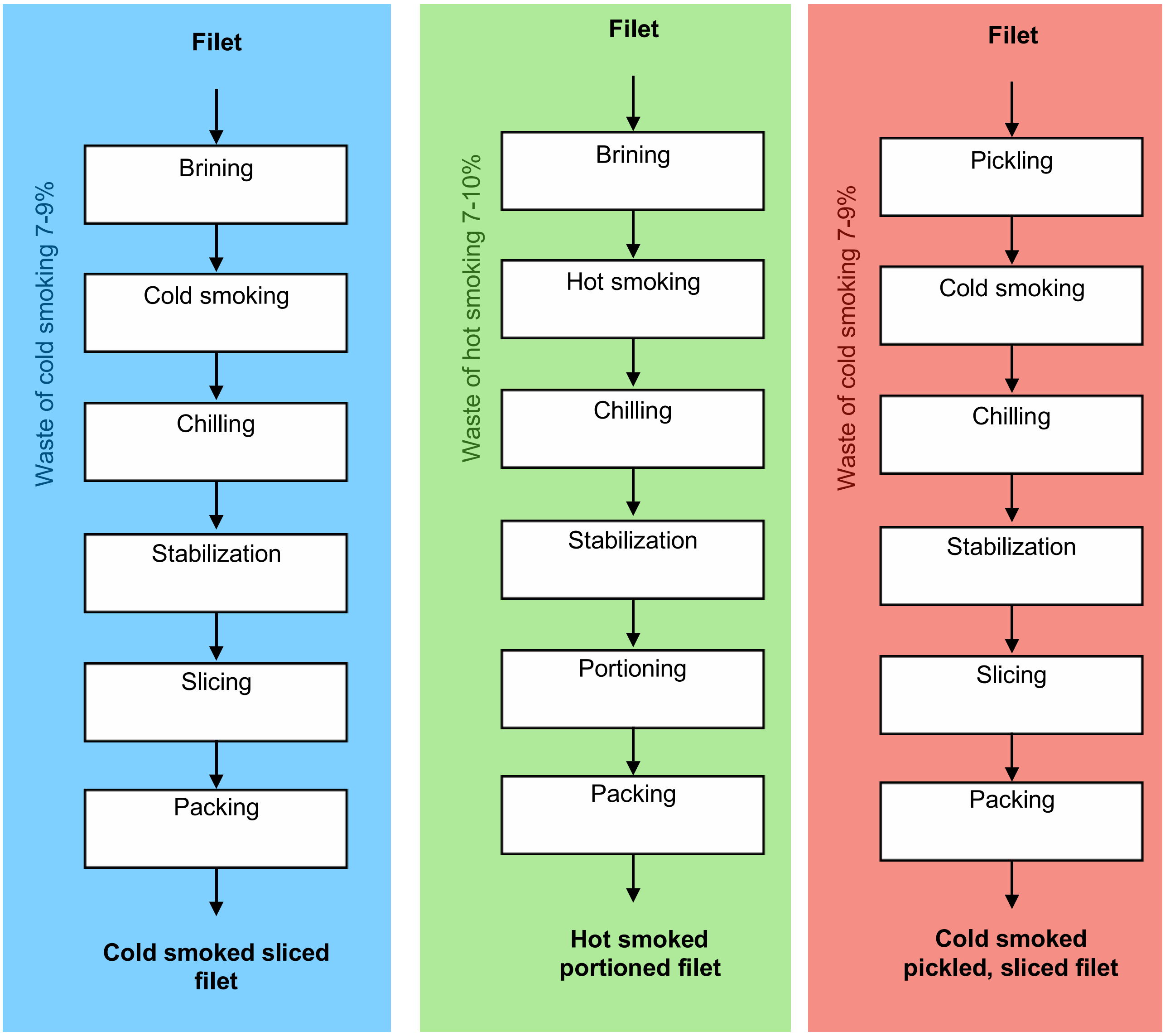
In the next step the half-product is processed into finished products in accordance with the following process.



The Limito S.A. Salmon processing - production of fresh and frozen fish.



The Limito S.A. Salmon processing - a process common to all products.



The Limito S.A Salmon processing – final processing

Machines, productivity and working staff

FILETING DEPARTMENT

MAREL filleting line with injecting machine FOMACO performance: to 21,9 tons per shift, 43,8 tons per two shifts

MAREL Portion Cutter	performance: to 6,20 tons per shift, 12,40 tons per two shifts
Multivac R245	performance: to 5,2 tons per shift, 10,4 tons per two shifts
Multivac T-700	performance: to 4,3 tons per shift, 8,60 tons per two shifts
Multivac R-535	performance: to 12 tons per day
Filleting machine FR9000	performance: 7,00 tons per shift
Slicing machine (GEBA SC250)	performance: to 1,4t per shift, 2,9 t per two shifts
Fillets freezing tunnel:	performance: 3,1 t per shift, 6,2 t per two shifts
portions:	performance:1,9 t per shift, 3,8 t per two shifts

SLICING DEPARTAMENT

Skinning machine MAJA performance: 6,5 tons per shift, 13 tons per two shifts
Skinning machine Uni Food V1558 performance: 8,2 tons per shift, 36 tons per two shifts 4
Slicing lines:
3 Sets of GEBA SC250
1 Set of Geba SC250 performance: 3,90 tons per shift, 7,80 tons per two shifts
3 Lines with Multivac R535 performance: 21.600 – 32.400 pcs.
3 Multivacs C-500 performance: 4,4 t per shift, 8,80 t per two shifts

Currently Slicing Department with working 2 lines has productivity between 2,5 - 6 t for one shift and 5 – 12 t in 2 shifts.

Staff - 34 workers

As a result of the pretreatment of gutted salmon, representing 100% of the initial material, 31-45% total waste is produced, which includes:

- heads: 11%
- backbones, with other parts of the carcass and adjacent to the backbone, remnants of fish muscle: 11%,
- raw skins, with scales and remnants of meat and fat remaining on the skins: 7,5-9,0%.

The data obtained from the *Limito* company shows that the percentage of this main waste in relation to the overall weight of the processed raw fish material is:

- heads: 11,0%
- backbones with remains of meat: 11,0%
- skins with a subcutaneous layer and other minor scraps: 7,5 – 9,0%.

In addition to the three main waste products, a small quantity of waste (salted and smoked) is formed during the portioning (trimming) of fish fillets for smoking as well as after their smoking, when slicing.

The post-production waste not categorized as Cat. 3 (Trimming - Fat, Scraps, Fish bellies), is sold to various types of plants producing salads, pastes, peppers and smoked meats. Products for reprocessing and human consumption account for up to 30% of the total amount of waste.

The Limito S.A. Salmon processing

3.12.3 Investment and economy

The Limito company was established in April 2004 in Grudziądz, and in a relatively short period of time has become one of the leading providers of Norwegian salmon and other fish on the Polish market. Today, the Limito company also successfully exports its products to countries in Europe, Asia and Australia. The estimated annual turnover of the company is ca. 200 million PLN. The company has 150 employees.

3.12.4 Material flow

Based on the presented percentage breakdown of the three main types of waste in relation to the initial weight of the processed materials, it can be estimate that the amount of waste generated in this company is:

- heads: ca. 1,98 tons/day,
- backbones and attached waste: ca. 1,98 tons/day,
- skins with attached waste: ca. 1,35 – 1,62 tons/day.

The actual quantity of each type of waste arising in the Limito company may be different in different periods of time and may be different than estimated. However, this variability should not significantly affect the nature and importance of the issues arising from the need for the disposal or management of so large an amount of fish waste originating from one species of fish and generated in one company in terms of the fishing industry in Poland. According to the latest data obtained from the Limito company, segregated and separately collected waste is used in the following ways:

- heads: are frozen and sold to customers as a product intended for human consumption –the amount of heads sold for consumption purposes is small in relation to the total weight of this kind of wastes and is ca. 15%, (ca. 0,3 tons/day); the remaining amount of unprocessed heads is sold to external recipients together with other waste (heads, backbones, waste from separator, etc.), as a raw material for processing into fish-meal, animal feed, etc.
- backbones: after filleting fish from the parts of the backbone, a significant amount of meat can be manually recovered, approx. 10 - 12% of the total weight of this wastes (probably a similar amount of meat can be recovered using mechanical separation), meat recovered in this way is sold as a product for human consumption; part of the backbones is frozen in its entirety and is sold to customers as a product for human consumption – the amount of meat that is recovered from the backbone, frozen and then sold on to the consumer is variable and depends on the market demand. The demand reaches up to ca. 21% of the total weight of this waste, that is ca. 0,4 tons/day; the remaining quantity of untreated backbones is sold to external customers, with other waste, as a raw material for processing into fish-meal, animal feed, etc.
- skins: are not used in any way in the Limito company – all raw skins, separated after deskinning, ca. 1,5 tons, are sold to outside customers together with other waste as a raw material for processing into fish-meal, animal feed, etc.

The Limito company has a 2 MW power connection. The actual daily energy demand of the company is about 0,8 MW, of which 0,28 MW and 0,52 MW is used in the operation of technological lines and cooling systems, respectively. The company does not have its own energy sources. Production uses:

- electrical energy (used for the functioning of technological lines and cooling systems),

- cold water,
- natural gas.

Power supply

- Electricity:
  - Power supply 3,2 MW
  - Power installed 3 MW
  - High peak power use 2,02MW
  - Average use of power 0,8 MW
  - No alternative source of electricity
  - Guarantee of emergency power supply 0,24 MW
- Gas fuel:
  - Power installed 0,8 MW heat power
  - Average monthly use of gas power
  - waste heat from the cooling machinery is used to heat water
- Water and sewage:
  - Water for the production plant is supplied by the municipal system
  - Limito has no internal supply of water
  - Average water usage 6.500 m^3 per month
  - High peak usage is 10.000 m^3 of water per month

The waste Cat. 3 is transferred to fish meal. Companies receiving this waste are: Biovast-Latvia, Bioceval-Germany, TripleNine - Denmark, Agro Fish - Poland.
Currently, most of the wastes generated in the fish industry is transferred to the production of fishmeal.

After the delivery of the raw material (by-products from fish), it is ground and then pumped to a smelting unit. The raw material is heated by steam generated in a special LNG-powered boiler. The heating process takes place via direct or indirect (jacket) steam injection. Direct injection of steam allows the quick heating of the raw material with limited oxygen availability and with a minimum time for protein coagulation and oil melting. Then, the heated mass goes to the 2 or 3-phase decanter to separate the phases. Proper selection of the decanter ensures maximum separation efficiency within the distribution of all two phases (solid particles, sticky water + oil). The solid phase is transported to the dryer, where, after drying to fish meal, it contains about 10% of the water content. Fish meal is cooled and packed in big bags. The fat phase is taken to an intermediate tank from which it is pumped into a vertical separator in order to clarify the fish oil. During the oil clarification process, the separation of oil and sticky water occurs. The sticky water (rich in protein) is directed to the evaporation station system where, after the compaction process, it is pumped directly to the solid phase (from the decanter) and after mixing it is dried in a tumble dryer. The clarified oil is directed to the storage tanks. Optionally, fish oil can be bottled in 200-litre barrels.

Characteristics of commonly used installations:

I. Transport of raw material.

First, the raw material (hard and soft waste) from the silo is transported by means of a screw feeder (capacity approx. 10-25 tons/h and engine power about 5-10 kW) to the tank (capacity approx. 600 m^3). It is allowed to create a "cold" zone in a part of the building with a temperature of min. 0°C in the part of raw material receipt and its temporary storage.

II. Thermal treatment.

In the next stage, the raw material with two HM35 pumps (approx. 4-10 kW) is supplied to the cooker/stove type SFC 1110 (capacity approx. 10-20 tons/h, engine power approx. 7-11 kW), where it is subjected to a thermal treatment using steam.

III. Ironing / pressing / drying pulp / oil separation.

The overcooked raw material goes to a two-screw press type MS-56 F (engine power about 50-80 kW and efficiency correlated with the digester). The press squeezes all fluids (oil, water) from the given raw material under high pressure, and the resulting pulp is sent to the disk dryer HM 2555 type (drive power about 120-190 kW and capacity about 10-30 tons /h) where, using high temperatures, it is dried into meal. The liquid obtained goes to a tank equipped with a stirrer (with a capacity of about 17-35 m^3 and a power of approx. 2-6 kW), then from there to a decanter, which constantly separates the remaining solid material, which is added to the obtained pulp. The water and oil separated in this way go to the decanter and oil separator (capacity approx. 8-18 m^3/h and engine power about 25-40 kW). Depending on the raw material, only decanters can be used on the production line, without using the press.

IV. Cooling and grinding of the product.

The solid material - mostly fishmeal after drying, goes to the refrigerator CAC 1609 type (main engine power about 10-15 kW, fan motor 10-15 kW, capacity about 7.000-9.000 m^3 / h airflow) where it is cooled to about 20-25˚C. From the refrigerator the meal goes to the grinding section - hammer mill HM 630 type (power approx. 80-140 kW - and then to a silo for the finished product)

V. Oil separation stage II.

The liquid in the separator are separated into decoction and almost pure oil, pumped to the oil tank with a capacity of approx. 2-8 m^3. Next, the liquid goes to the next separator (capacity about 2-3 m^3 / h, power about 5-10 kW), which finally separates the remaining particles of the decoction from the clean oil. After this process, the oil goes to the silo for the finished product (oil silos should be able to contain about 75-500 tons).

VII. Inside the production hall, a system for utilizing odors that captures up to 98% of the compounds are used. They are based on a modern system of exhausts and ventilation finished with tanks, from which the odors are burned after condensation. The described installation has a target production capacity of about 70 tons of fishmeal a day and about 20 tons of fish oil per day, using raw fish material (fish waste) in the amount of about 300 tons per day. It is assumed that the raw material contains about:

- 18% dry mass;
- 7% fats;
- 75% water.

The obtained fishmeal contains about:

- 84% dry mass;
- 8% fats;
- 8% water

3.12.5 Estimated environmental and economic benefits

The fish industry produces a lot of pollutants in the form of sewage requiring purification. For this reason, fish processing plants carry out intensive investments towards the construction of their own sewage pretreatment systems and their own treatment plants. Sewage from production and washing processes (installations and vehicles transporting raw materials) will be sent to the factory sewage treatment plant in order to bring them to such a degree of purity that they meet legal requirements and requirements specified by the administrator of the

municipal sanitary sewage system.
In technological sewage the main type of contaminants are organic substances, i.e. proteins and fatty substances. They are the reason for a significant increase in sewage parameters suchas:

- BOD, COD;
- substances extracted with petroleum ether (oil impurities);
- total nitrogen
- phosphorus compounds.

To reduce the value of indicators of these pollutants, mechanical and physico-chemical methods are used in the process of pre-treatment and the treatment of technological wastewater:

- defatting flotation;
- sewage suction on mechanical sieves;
- coagulation;
- flocculation;
- pressure flotation.

3.12.6 Lessons learned and recommendations

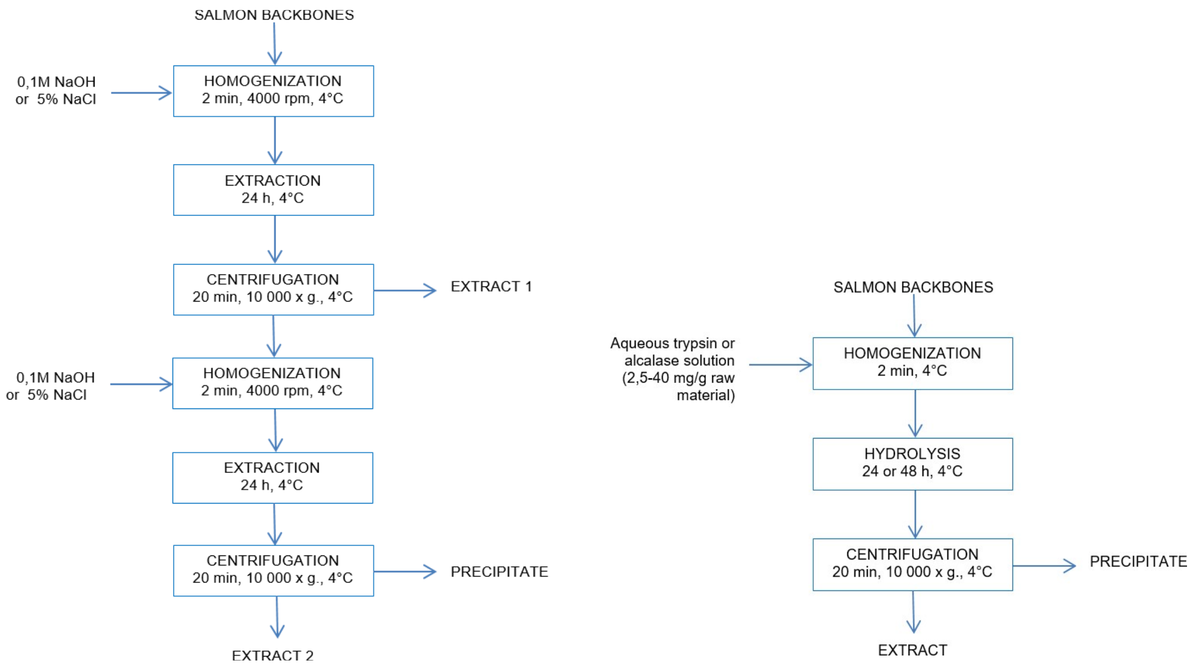
Fish processing enterprises should cooperate with scientific centers to diversify waste treatment technologies. The resulting waste can be used to produce collagen and fish gelatin. The first stage of the separation of collagen connective tissue is to remove the accompanying components, i.e. other proteins, glycosaminoglycans, lipids and mineral salts, which impair the physico-chemical properties of collagen. These three methods of collagen secretion are the most common:

- direct extraction of connective tissue with an organic acid;
- extraction of collagen with organic acid from connective raw materials after initial chemical treatment;
- extraction of collagen with organic acid from enzymatically processed material.

The direct extraction of collagen with an organic acid is only practical for connective tissue, in which the collagen is intermolecularly cross-linked with acid-labile bonds. Such properties have fish skin collagen. The most commonly used acids for extraction are solutions of acetic, glycolic or lactic acid. The temperature and time of action of acid solutions depends on the origin of the connective tissue.

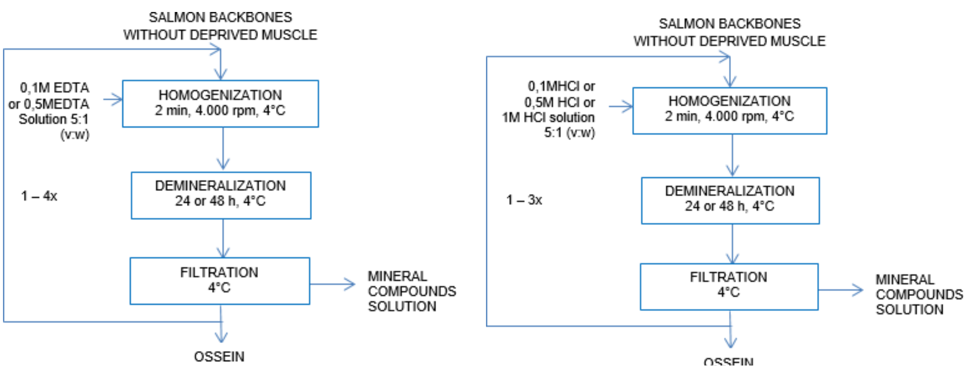
Heads, spines and skin obtained after fish filleting contain adherent muscle tissue, which is an unused source of muscle proteins. In order to obtain collagen, it is necessary to isolate these proteins by extraction with inorganic solvents or by carrying out enzymatic hydrolysis. The most conservative conditions for the secretion of collagen from connective tissues containing adherent muscle tissue create methods involving the extraction of non- connective tissue proteins using a salt solution. The most commonly used solvents are NaCl or NaOH solutions (see the figure below). Another method is the initial mechanical scraping of the muscles from the backbones. In addition to muscle protein, a bone crumb containing its residues is formed. For the separation of proteins from the backbones of the fish and from the bone crumb, enzymes of bacterial origin (alcalase 2,4 L, neutrase, protamex), animal - (trypsin) and vegetable (papain) can be used. The most commonly used is trypsin and alcalase. The efficiency of enzymatic hydrolysis depends among others on: the enzyme used, the type of waste to be treated, the time of incubation, the pH of the mixture and the temperature of the process.

a b



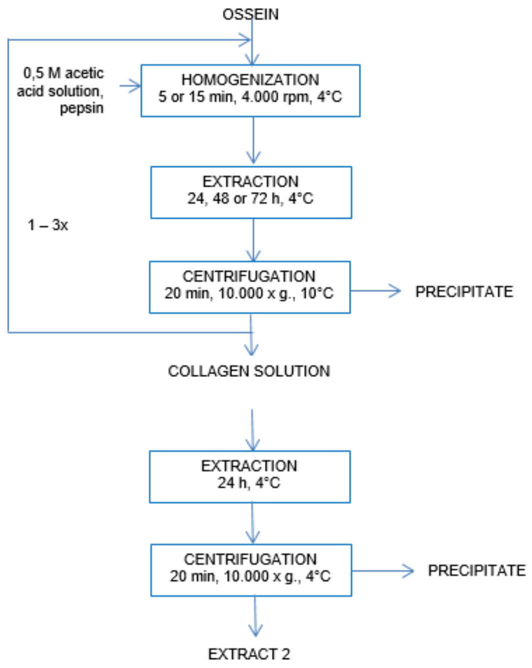
Obtaining collagen from hard waste – salmon backbones - deproteinization

Hard waste, such as fish heads or backbones, often requires additional chemical or enzymatic treatment leading to demineralization. The process is carried out using EDTA or HCl solutions as presented below. The product after drying is called ossein.



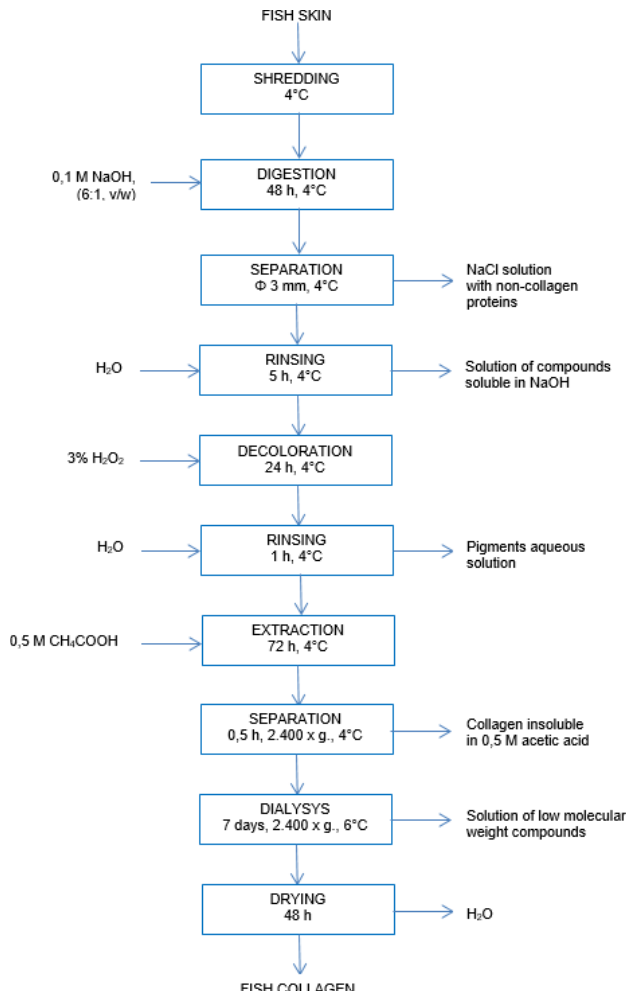
Obtaining collagen from hard waste – salmon backbones – demineralization

From ossein, it is possible to obtain collagen solutions by conducting extraction using diluted organic acids, as shown below:



Obtaining collagen solution from ossein

A much easier material from which it is possible to obtain collagen is soft waste such as fish skin. The efficient filleting process allows the minimization of the number of non- collagenous proteins, making the collagen in the skins much less cross-linked than in hard wastes. Collagen from fish skins can be obtained according to the scheme shown below:

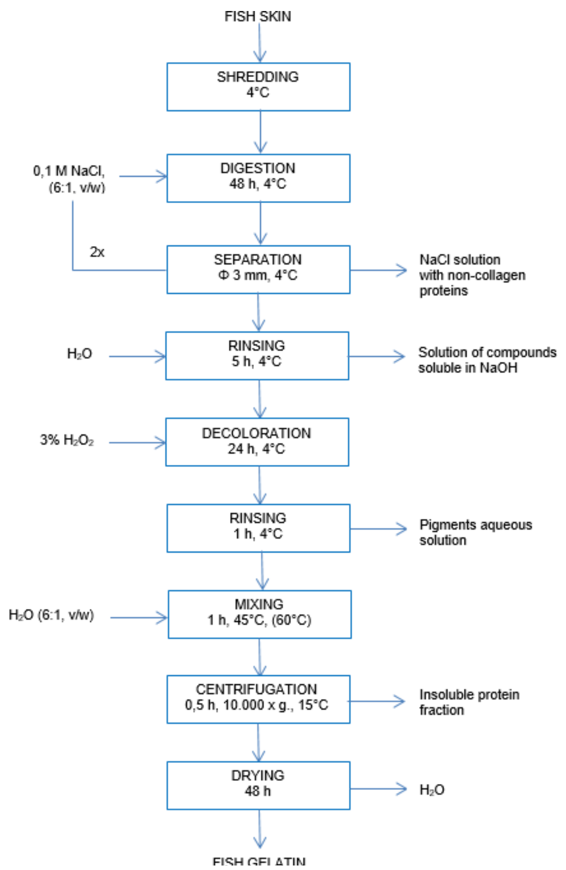


Schematic diagram of the process of obtaining collagen from fish skins.

After pre-removal of non-collagen proteins from connective tissue waste such as skin, head and backbone, fish gelatin can also be produced. The standard technology for obtaining gelatin is:

- Maceration of connective tissue waste in solutions (alkaline or acidic) from a few to several hours.
- Neutralisation of connective tissue waste.
- Washing of connective tissue waste multiple times with water (3 times or more) to remove salt formed during neutralisation.
- Thermolysis of collagen and multi-stage (at least 2 times) hot gelatin extraction (40 - 60 °C) with water (most preferably with distilled or deionized water). As a result of cooking, dirty, aqueous solutions of gelatin with a concentration of approx. 5% are obtained.
- Separation of gelatin solutions from solids through filtration or centrifugation.
- Compaction of gelatin solutions in vacuum evaporators to a concentration of 12 - 30%.
- Chilling and solidifying a thickened gelatin solution (gelation).
- Extrusion of solidified gelatin in the form of strands suitable for drying in air dryers.
- Drying of gelatin at a temperature of 30 ÷ 60 ° C.
- Grinding dried gelatin.

As it results from the presented technological process stages, the installation for the production of gelatin must cover a whole series of specialized devices that should be carefully designed, accurately selected and correctly assembled, in accordance with specific technological and production conditions and production scale. It is also possible to obtain fish gelatin from soft fish waste, such as skin, according to the scheme shown below:



Schematic diagram of the process of obtaining gelatin from fish skins.

3.12.7 The future

Limito S.A is currently focused on special products that will improve the company's market competitiveness in the future:

- The development of functional foods due to the increase in interest in pro-health food.
- Organic food development - the organic food market is growing at a rate of 10-15% per annum, and currently its value is estimated at approx. PLN 750 million, which is 0,3% of the entire food market. In Western Europe, the share of organic food in total sales ranges from 2 to 6%, which in the opinion of experts proves the potential development of the organic food market in Poland.
- The development of convenient food - the market of convenience food, especially ready-made frozen dishes.

The priority for innovation in Limito S.A. includes activities in the field of innovative technologies of production and waste management.

3.13 Challenges in Mushroom and compost production

3.13.1 Mission and vision

Użranki is in the Warmia and Mazury Region, near the city of Mrągowo and is 75 km from the capital of the region Olsztyn. This region is a land with a large amount of lakes and forests (about 30% of the area). Due to the high afforestation rate and low indicator of urbanization and industrialization, air in Mazury is very clean. It is known for producing good quality food. Pieczarki Mazurskie Fedor was established in 1988 as a family company. The company is the biggest of Poland's mushroom producers, which is its main product. The company consist of a few mushroom farms which cover a producing area of above 19.000 m^2. It should be noted that all production buildings are equipped with air conditioning systems which enable the control of mushroom growing parameters, such as temperature, humidity, air movement and carbon dioxide. It should also be emphasized that the mushroom farms use compost made in the company's own compost production facility which is also located on the production premises. All mushrooms are harvested by hand. After harvesting mushrooms go directly into a vacuum cooling chamber and are cooled to a temperature of 2°C. After three harvesting cycles all the mushroom growing chambers are thermally disinfected and the compost is replaced. The Pieczarki Mazurskie Fedor company works continuously over the year. The company has its own straw storage (area above 10.000 m^2) for the production of compost. The maximum amount of stored straw is about 100.000 tons, which is enough for two years of the company's production.

Principle 1: Cascading approach
Promising opportunity for the utilization of mushroom substrate for different uses

Principle 2: Use of waste, by-products and residues
Use of straw and wood pellets

Principle 3: Circular economy approach
Recycling of nutrients.

Straw bales storage

3.13.2 Technology description

The production of mushrooms is about 3.000 tons per year. Before sale, mushrooms are packed according to individual customers requirements or in the standard way:

- kg boxes loose
- box with tray 4 × 500 g
- box with tray 4 × 400 g
- box with tray 6 × 250 g

The mushrooms might also be sorted in different sizes:

- – 4 cm
- – 5 cm
- – 6 cm
- more than 6 cm “Riesen”

Waste from processing (spent mushroom substrate) is stored at the company field and sold to local farmers as a fertilizer. The company produces over 300 tons of spent mushroom substrate weekly.

Heaps of spent mushroom substrate

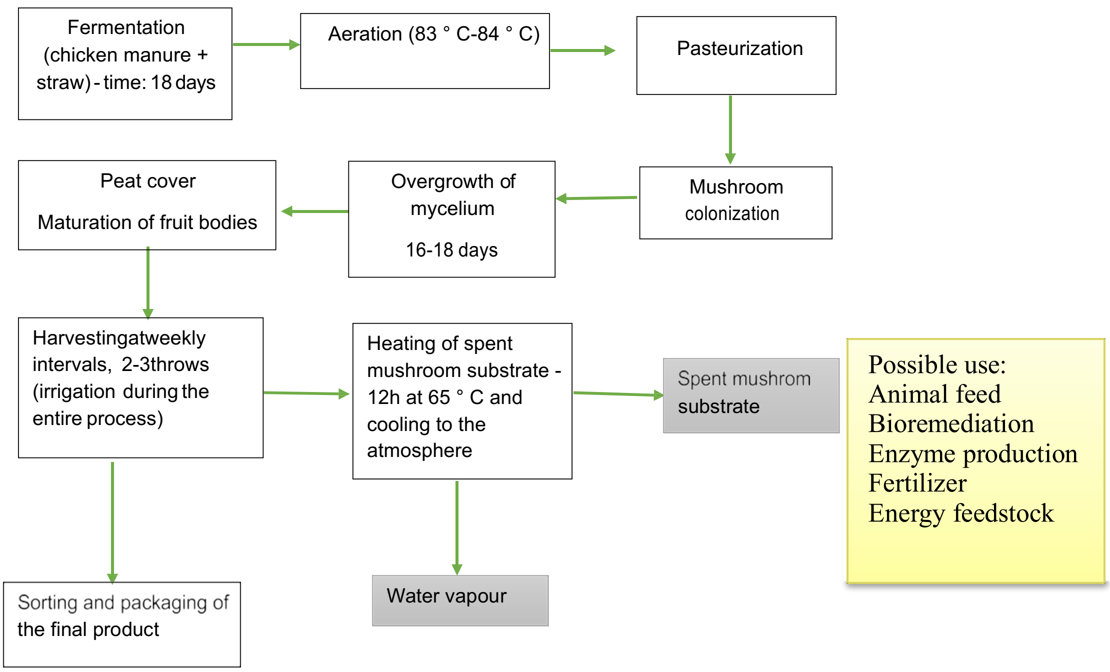
Pieczarki Mazurskie Fedor ,Poland [https://www.youtube.com/watch?v=LOtbrlHjRcU]

3.13.3 Investment and economy

Pieczarki Mazurskie Fedor in Użranki is a dynamic company that is still growing and makes great efforts to be a modern and eco-friendly processing plant that produces high-quality products.

3.13.4 Material flow

The company possesses their own source of heat, two boilers with a 500 kW performance each. The boilers are fired with wood pellets. One of the boilers is used to produce technological steam and the second one is used for hot water production. The company also needs electric energy to cool mushroom growing chambers and for the technological process of compost. Below are presented some flow charts for mushrooms.



Flow chart for the mushroom production

3.13.5 Estimated environmental and economic benefits

The price of products varies depending on the market. The main recipients of mushrooms are companies from western Europe: England, the Netherlands, Germany and France. Only 3% of the company's production is sold to the Polish market.

3.13.6 Lessons learned and recommendations

Pieczarki Mazurskie Fedor is a well-operating company that produces high-quality mushrooms. The clients of the company are all over the world. The largest recipient is England, but a lot of products are exported to Germany, the Netherlands and France.

A big issue for the company is the relatively high price of straw (40 Euro per ton) and low price of spent mushroom substrate (3 Euro per ton) which is used as a fertilizer. The company should start cooperating with Universities, Research Centers or biological and chemical laboratories to find new solutions in the field of bio-plastic, food supplements or pharmaceutics from the high value waste that contains huge amount of macronutrients (P_2O_5, K_2O, CaO, MgO, Na_2O, P, K, Ca). The next issue is to change the heat source used to a more environmentally friendly setup. One option is to install a waste heat recovery system from the chiller installation. The Company is also interested in using organic waste (spent mushroom substrate) partly as a fuel in the burning system. It is also a possibility to use spent mushroom substrate as a substrate in the biogas production process.

3.13.7 The future

The company needs to solve a problem with the growing use of electric and heating energy. It is especially important due to the fact that the price of electric energy in Poland is growing faster than in Western Europe. The new heating system should be installed. What is also needed is a waste heat recovery system from chillers as well as short term, storages of heat and cool. The possibility to use spent mushrooms substrate as a substrate in biogas production should also be considered.

3.14 The utilization of harvested, renewable wetland biomass for district heating – Agrotherm GmbH heat-only boiler station Malchin, Mecklenburg-Vorpommern

3.14.1 Mission and vision

The heat-only boiler station operated by Agrotherm GmbH in Schwinkendorf, near Malchin, Mecklenburg-Vorpommern is fired by bales of renewable wetland biomass. It went online in June 2014 and has a capacity of 800 KW that is fed into the local district heating network supplying 540 households, several office buildings, two schools and a kindergarten with heating and hot water.

The value chain around the Agrotherm heating plant is rooted in a set of techniques, principles, and land-use concepts for natural and rewetted wetlands, termed paludiculture. Conventional agriculture on wetlands requires draining the land which leads to degradation, compaction of soil and CO_2 emissions and other problems. Paludiculture, by contrast, involves adapting to the high water levels in peatland by growing plants (or raising livestock) adapted to high water levels, using machinery that is adapted to the soft ground, and developing uses and markets for thebiomass produced.

The plant was developed as a solution to a serious economic problem facing a cattle farmer following the rewetting of polders as part of a large-scale fenland restoration programme in the Peene river basin from 1992 onwards. Due to rising groundwater levels, the vegetation mix changed, with a higher share of more lignin rich species. Thus, the farmer's meadowland was no longer suitable for grazing for conventional cattle, threatening the financial viability of the farm. At the same time the restorationof fen meadowland habitats requires regular mowing to prevent colonization by shrubs.

As early as 2.000, contact with researchers from the University of Greifswald lead to the idea of utilizing the biomass material removed after mowing for energy production in order to provide a new line of business for the farmer and to ensure appropriate environmental management of the site. Between 2007 and 2009, funding from the German Federal Environmental Foundation for a research project allowed the clarification of various questions relating to material composition, fuel characterization, economic viability as well as the machinery needed for harvesting biomass from fen meadows.

Principle 1: Cascading approach
A promising opportunity for the utilization of additional uses for straw

Principle 2: Use of waste, by-products and residues
Use of straw

Principle 3: Circular economy approach
Recycling of bio-ash and green house savings from proper land management of wet lands

3.14.2 Technology description

The technology is adapted from the established technology for straw combustion. The technology used in the heating plant is similar to straw fuelled heating plants common in Denmark and the demonstration plant in Gülzow, Mecklenburg-Vorpommern. The modifications needed relate to the need to accommodate the inhomogeneity of wetland biomass bales and the fact that hay is longer than chopped straw.

Heat production in the plant can be broken down into the following steps:

1) Round bales of hay from fen meadows are taken from a storage shed with the capacity for several hundred bales and placed on two parallel conveyor belts with a capacity of 24 bales each using a frontloader. In winter the conveyor belts are loaded on a daily basis.

2) Bales are conveyed in two bale openers/shredders where the hay must be chopped in to pieces no longer than 15cm in length. Since the hay is comprised predominantly of reed canary grass and sedges, it is tougher than straw and cannot be shredded effectively using equipment designed for straw. The modified shredder contains 23 rotating discs, each with 6 serrated rather than straight cutting blades. This is twice as many blades as in straw shredders. Another modification not required for straw is a cage around the cutting chamber preventing the biomass from exiting the shredder before it is short enough for the subsequent process.

3) The chopped hay is transported to the boiler via a double screw conveyer. In conventional straw boiler setups, an airstream is used. However, this is not practicable with the mixed biomass material harvested in landscape management, which includes woody stalks that can become jammed leading to blockages.

4) In contrast to straw, the structure of hay means it is prone to clumping, it also consists of a variety of materials of different weights, which makes dosing more difficult. On the way to the furnace the hay passes through a weighing station to ensure that a sufficiently constant amount of biomass enters the furnace at each interval. This is a further difference to the process for straw fuelled boilers.

5) The hay is fed into the furnace of a modified Lin-ka HE 800 straw fuelled boiler by a stoker auger. For full combustion, the inhomogeneous material requires longer in the furnace than straw. Consequently, the grate in the furnace is longer than usual for straw fuelled systems. The ash is removed automatically.

The Agrotherm boiler station is equipped with a cyclone filter and fabric filter. Particulate and nitrogen oxide emissions are considerably lower than the levels permitted by German Federal law.

At maximum capacity 30 bales are burned a day. The capacity of the boiler was specifically chosen so that fuel needs could be met by local supplier without the need to purchase any additional hay from further afield. The plant can be run on wood chips if it is necessary to supplement the hay in case of a bad harvest due to wet weather conditions. A 25 m^3 hot water storage tank allows the boiler to run at maximum capacity at all times.

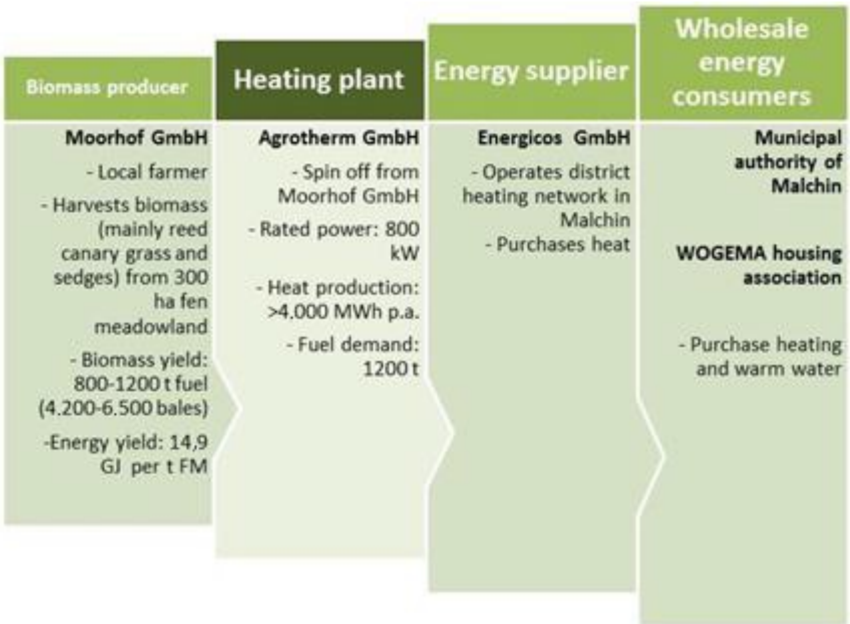
The plant is designed to meet the base load and average use in the district heating network. Peaks in demand, e.g. in particularly cold weather are backed up by gas boiler, owned by Energicos.

3.14.3 Investment and economy

Investment in the plant amounted to 640.000 Euros. EFRE funding for 30% (182.000 Euros) was secured for the project. Besides the investment in technical equipment this sum also includes the costs for the planning and approval process as well as an extension to an existing building. Agrotherm GmbH expects to amortize the investment costs in 15 years.

Agrotherm GmbH is contracted to supply 3,5 million kWh of heat to the local energy supplier, Energicos GmbH. The economic viability of the plant is derived from the fact that the biomass can be purchased at a low price due to cooperation with the producer, Moorhof GmbH, and transport costs are low due to the close proximity (12 km), whilst a price for the heat produced could be negotiated with Energicos GmbH that is at a similar level to the price of natural gas. The economic competitiveness of energy production from bales of wetland biomass in comparison to natural gas is not given in all cases. However, it is worth considering for smaller decentralized heating plants (800 kW), where operation at high, evenly distributed capacity >4.000 MWh/a is guaranteed, and the cost of biomass is low.

3.14.4 Material flow



The biomass feedstock for the heating plant is hay harvested from 300 hectares of fen meadowland by a local farmer, Moorhof GmbH. The land is owned by the farmer, who has long-term contracts with the agency responsible for restoring and managing the fens in the Peene river basin to mow the fen meadowland and remove the hay.

The hay produced consists predominantly of reed canary grass and sedges. The fen meadowland yields an average of 4,5 tons DM of reed canary grass and an average of 6 tons DM of sedges per hectare per annum.

Harvesting occurs annually in an approximately 10-week period between June and September, and is dependent on appropriately dry weather conditions. The water level must sink sufficiently (and naturally) for the ground to bear the weight of machinery for mowing and harvesting. To be suitable for combustion, the biomass must be able to dry to a moisture content level of 8-12%, equivalent to that of feeding hay.

The production of hay on fen meadow land is a multistage process that involves mowing, turning, windrowing, baling, and retrieval. Conventional grassland machinery can be used but, given the wetter ground, weight is a key consideration in the choice of the specific equipment deployed and some modifications are needed. The light-weight 160 horsepower tractor is fitted with extra-wide tires. The farmer produces round bales rather than rectangular bales because a round baler, even with the addition of a second wheel axle, weighs only 1,8 tons and is considerably lighter than a rectangular bale press. The additional costs for the farmer amount to 25.000 Euros. After retrieval the bales are stored in a shed on the farm and later delivered to the boiler station in batches.

A total of 4.200 - 6.500 round bales with a diameter of 120 cm and weighing between 185-200 kg DM are produced from 300 ha per year. The biomass yield is 800-1.200 tons of fuel. The energy yield is 14,9 GJ per t FM (15%). Each bale equates to approximately 85 litres of mineral heating oil.

The mineral content of reed canary grass and sedges are ca. 8% ca. 5% DM respectively. The ash left after combustion is rich in minerals and would be suitable for use as a fertilizer. However, the ash produced in the Agrotherm plant (290 m^3 p.a.) currently must be disposed of as waste despite its potential.

3.14.5 Estimated environmental and economic benefits

The use of renewable biomass from rewetted fen meadows in the Agrotherm heating plant reduces CO_2 emissions directly by replacing fossil fuels. The plant burns 800-1.200 tons of hay from fen meadowland annually. This corresponds to 2,9 – 3,8 GWh or between 290.000 and 380.000 litres of heating oil. The saving in greenhouse gas emissions from the Agrotherm plant amounts to 850 tons CO_2- eq. per annum.

By offering a successful example of a business case for renewable wetland biomass, the Agrotherm case contributes to increased acceptance of rewetting measures in areas with drained, degraded fens. In drained wetlands used for agriculture, the mineralization of peat releases CO_2 stored in the ground into the atmosphere. This form of land use is a key source of human-caused greenhouse gas emissions on a global scale. In Mecklenburg-Vorpommern, for example, drained wetlands are responsible for one third of greenhouse gas emissions. Rewetting of wetlands can reduce CO_2 emissions and mitigate climate change if managed correctly. The saving in greenhouse gas emissions from the rewetting measures on the 300 hectares managed by the farmer, Moorhof GmbH, is calculated at roughly 10.850 tons CO_2-eq. per hectare per annum.

Additional environmental benefits include a reduction of water pollution and eutrophication by reducing nutrient discharge. The conservation of an open, culturally shaped landscape not only promotes biodiversity through the restoration and management of habitats for rare species, it also has a positive impact on the local tourism industry.

The development of the Agrotherm plant has opened up a regional value chain for the use of renewable fen biomass as an energy source. This has enabled the farmer to pursue a new line of business and secure the future of the farm. It has also created two additional jobs in the local economy. The integration of the necessary regional value chain for a locally sourced, renewable bioenergy feedstock that grows on land unsuitable for food production allowed the energy supplier and wholesale consumers to reduce their reliance in fossil fuels. The project is a good example of how heat production can be organized locally and for local benefit. The use of fen meadow hay as the primary energy source also means that the costs of producing heat at the plant will no longer be determined by the price of fossil fuels, which is expected to rise in the long-term, leading to comparatively lower prices for heat for local consumers in the future

3.14.6 Lessons learned and recommendations

The Agrotherm plant can be seen as an exemplary case for a sustainable bioeconomy because it shows how the development of a value chain around the necessary harvesting of biomass from rewetted degraded peatland can contribute to local economic prosperity and decentralized, fossil-fuel-free energy production whilst producing a range of positive environmental effects. This is despite an unfavourable regulatory environment, where plants suitable for paludiculture are not classed as agricultural crops and are thus ineligible for CAP direct payments in Germany and where the provision of ecosystem services does not receive adequate financial compensation.

The successful development and operation of the plant is based on the cooperation between companies at various stages of the value chain: the biomass producer Moorhof GmbH, the plant operator Agrotherm, the energy supplier Energicos GmbH, and two wholesale heat consumers, the municipal authority of Malchin and WOGEMA, a local housing association. The conditions for realizing the plans for the heat-only boiler station were favourable because the district heating network already existed and the energy supplier needed a new source of heat to replace an old coal-fired boiler. Furthermore, due to the presence of an energy supplier that was willing to purchase all the heat produced, Agrotherm does not have to invest in acquiring and managing additional customers. It should be noted that due to the low density of the baled biomass, the financial and environmental benefits of the feedstock are diminished or even negated if it is transported over long distances.

Nonetheless, the Agrotherm plant can be seen as a model for farmers in other regions where wetland restoration is desirable and paludiculture could be adopted. In Mecklenburg-Vorpommern (ca. 1,6 million inhabitants) alone, if paludiculture was to be applied on just 20% of the area covered by wetlands or drained wetlands, the biomass produced could fire a further 200 similarly sized local heating plants supplying 150.000 households with locally produced heating from sustainable, locally produced biomass.

3.14.7 The future

Awareness of the environmental and economic potential of paludiculture is growing internationally and in the region. For instance, in 2017 the State Ministry of Agricuture and the Environment published a paper titled ‘Strategic Plan for the Implementation of Paludiculture on Agricultural Land in the State of Mecklenburg-Western Pomerania’. However, for the large-scale implementation of paludicuture in Germany and indeed other parts of Europe, it is necessary to revise the regulatory framework in order to support high numbers of farmers to adopt these new cultivation practices.

At present, transfer mechanisms used in agricultural policy such as the EU direct payments system, national support for organic farming and investment subsidies are misdirected as they encourage the persistence of the conventional practice of draining wetlands and, by doing so, prevent the adoption of alternative techniques suitable for wetland sites. Subsidies for bioenergy crops also promote the continued cultivation of crops like maize or rapeseed on drained wetlands despite the negative CO_2 balance. There is a lack of incentives and regulatory mechanisms to price in the high economic, social, and environmental costs of destroying the peat in wetlands. Furthermore, not all forms of paludiculture are currently accepted as agricultural activities and the eligibility for agricultural subsidies for farmers growing these plants is unclear.

A continued societal dialogue is needed to change the cultural mindset of people who for generations have been brought up with the idea that draining wetlands constitutes progress, as it brings land “into production”, while the public environmental goods produced by intact and appropriately managed wetlands have been discounted.

4 Conclusions

In the report presented are examples of various biomass value chains from the countries of the South Baltic Area. The focus was placed on the biomass value chains based on cereal, wood, sugar, food waste and bioenergy. Fifteen cases have been elaborated from such countries as Denmark, Germany, Poland and Sweden. All presented cases indicate that there is possible deployment of significant unutilised potentials, that might be technically and economically attractive. In subsequent workpackages there will be subsequent analyses focused on the nutrient values as well as bioenergy potentials of considered biomass value chains.