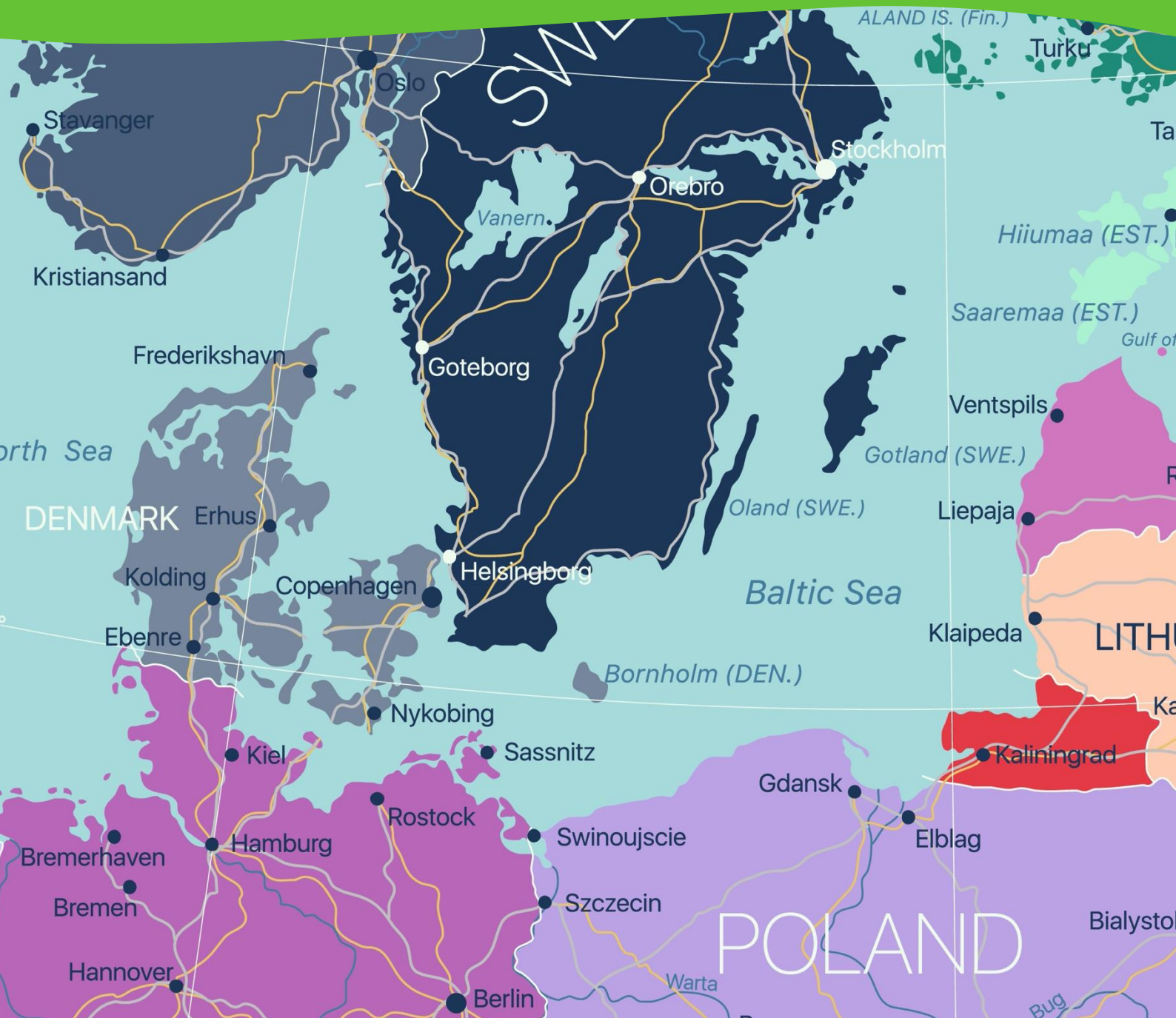
Implementation models for bio-based value chains in the South Baltic Region June 2021



Implementation models for agro-industrial value-chains and biomass-based production in the South Baltic Region

June 2021

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Executive summary

The regulatory, financial and technological difference between countries in the South Baltic Area calls for cross-border initiatives supporting knowledge transfer related to the development of a sustainable bioeconomy. This entails generic models on how to implement green technologies based on case-specific knowledge or operational settings. Such models can be used as a starting point for transposing technologies into new regional, national or international settings in the SBA.

The aim of this report is to introduce four cross-border implementation models within the agricultural and agro-industrial sectors. The models show how bioeconomy concepts developed in the BioBIGG project can be transferred from one SME to another, and likewise from one region to another. The selected concepts have been chosen by the project partners based on conducted pre-feasibility assessments, innovation programs and business cases (for more information visit the BioBIGG homepage: https://biobigg.ruc.dk)

Table of Contents

AGRICULTURAL SECTOR 1

Energetic use of paludi biomass in peatland-rich regions 3

AGRO-INDUSTRIAL SECTOR 11

Keratin hydrolysate production from poultry feathers 13

Cross-border implementation model: Bio-based plastic from potato starch 33

Leaf protein concentrate production from broccoli and kale leaves 42

Agricultural sector

ENERGETIC USE OF PALUDI BIOMASS IN PEATLAND-RICH REGIONS

Implementation Model: Energetic Use of Paludi Biomass in Peatland-rich Regions

At the 2015 World Climate Conference in Paris 197 countries committed to limiting global warming to well below 2 °C and preferably to 1.5 °C as well as to achieving greenhouse gas neutrality worldwide by the second half of the century. In Europe, greenhouse gas emissions are to be reduced by at least 40 percent by 2030 compared to 1990. Germany and many other EU-countries committed themselves to pursue greenhouse gas neutrality as a long-term goal by 2050[1]. One concept for efficiently reducing greenhouse gas emissions focuses on rewetting drained peatland and using the biomass (Paludi-biomass) for generating bioenergy[2]. It was already shown that biomass heating plants are able to produce energy for a regional heating network[3,4]; the plant "Agrotherm" in Malchin is an excellent example of an existing energy system that uses Paludi biomass to produce energy.

Achieving climate protection goals requires the reduction of gas emissions in many different ways. One way to achieve these goals is the large-scale use of rewetted peatlands to provide biomass for energy production. Not only in Germany, but in all regions rich in peatlands, areas could potentially be used for biomass productions. The current report therefore, will specify general criteria for implementing the described energy system with bioenergy from paludiculture to other regions. The basis is the innovation programme for the energetic use of Paludi biomass in Mecklenburg-Vorpommern.

Value chain

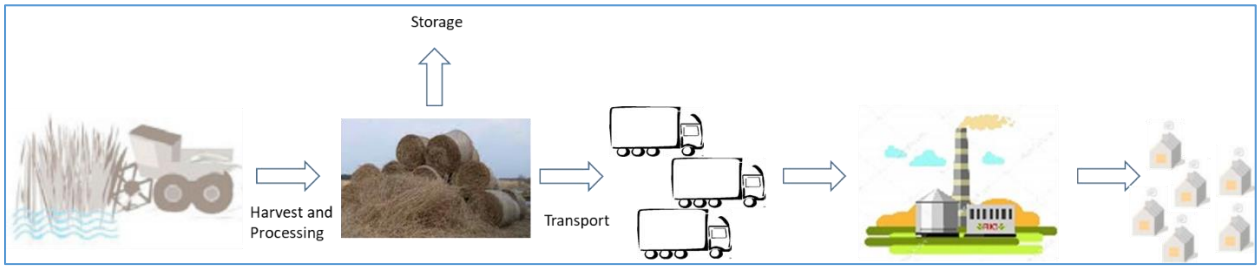

Fig.2: Value chain of energy production from Paludi biomass[5]

There are numerous possibilities to use different types of biomass for different energy systems. The choice of the technique always depends on the available raw materials. In this report, we only focus on regions rich of peatlands, resulting in Paludi biomass being the best option as a raw material for heat generation.

The following key factors must therefore be considered:

- Supply of peatland areas

[1] Bundesministerium für Umwelt (2019) Klimaschutzprogramm 2030 der Bundesregierung zur Umsetzung des Klimaschutzplans 2050
[2] Dahms, T. et al. (2017): Paludi-Pellets-Broschüre - Halmgutartige Festbrennstoffe aus nassen Mooren
[3] BioBIGG (2019): Development of a common framework for a sustainable and circular bioeconomy
[4] BioBIGG (2020): Business Case Model: Regional Energy Supply through Thermal Utilisation of Paludiculture Biomass in the District of Vorpommern-Rügen
[5] Already described in BioBIGG (2020): Innovation Programme: Energetic Use of Paludi Biomass in Mecklenburg-Vorpommern (MV)

- Amount of drained peatlands
- Amount of agriculturally used areas
- Management of the areas (intensity, organization)?
- Untapped biomass potentials

To evaluate the potential of the biomass, the following questions need to be answered:

- How much biomass can be generated (theoretical biomass potential)?
- How much biomass is needed? (depending on the demand of local (regenerative) energy)
- Which kind of biomass is most suitable?
- Is the biomass available for the whole year?
- How much biomass is available in a short time? What is the biomass potential in the region in the long term?

Although the biomass of peatlands can be used in biogas plants for straw-like biomass, this case is rarely found in practice so far. The factories are designed for biomass origins with good fodder quality; origins from wet peatlands are therefore suited only to a limited extent.

The heat energy demand is mainly dependent on the respective consumption structures and prices.

- Is the energy supply regional or global?
- Amount, size and location of the existing energy supply companies
- Acquisition of existing heating networks
- Calculation of the total regional energy production and demand (Kwh/a)

Energy price

Check-list of preconditions

Implementation of the concept of Agrotherm to other regions is only possible if specific preconditions are given. Some preconditions are unalterable, some are nice-to-have:

Necessary preconditions

The following preconditions are necessary and not negotiable:

Location

The requirements for a possible location are, on the one hand, the availability of suitable land (see “area potential”) and, on the other hand, the proximity to a company that supplies energy to a local network of end consumers.

Legal rights

It must be ensured that the area is not subject to legal requirements that prohibit the planned use (e.g. nature conservation, species protection). Although EU-wide laws regulate the use of land, legal rights can differ from country to country and must be checked beforehand.

All laws and regulations need to be checked regarding the transition from rewetted to wet and a change of the raw material. This concerns agriculture, the energy sector, and the interest of the part of the city/municipality[6] that is affected.

Remuneration of ecosystem services

Nowadays, the energetic use of biomass is hardly competitive with energy from fossil fuels. Without any support it is very likely that almost all existing power capacities will become economically unviable in the future with expiration of the subsidies within the framework of the renewable energy act[7]. To regain attractiveness for the transition from fossil to regenerative energy, compensation payments must be offered. This can be done on regional end EU-level in different ways:

- CO_2 compensation payments for every ton of CO_2 not emitted to the environment
- CO_2 tax for every ton of CO_2 emitted to the environment (Power plants based on fossil fuels have to pay -> higher costs -> bioenergy can be competitive)
- Funding programmes: rewetting of drained peatlands, cultivation of Paludi biomass,…
- Remuneration for adapting technique
- Remuneration of every MWh of produced bioenergy

After checking the relevant regional funding programmes, additional subsidies can be made accessible on a longer-term through influence on policy (changing directives and laws).

Optional preconditions

Some preconditions are optional: it is advantageous to have them, but alternative solutions are conceivable:

Ownership / attracting owners and farmers

Implementation is more straightforward if the area has only a few owners.

Owners of peatlands under consideration should be contacted in order to determine their interest in the realization of the project and to further specify existing options.

If the owners are not farmers, farmers in the surrounding area must be contacted and interviewed about their interest in cultivating and providing Paludi biomass. The interest in implementing paludiculture and establishing regional value chains must be evident. All actors must be involved from the beginning of planning.

Acceptance

Changing land and energy use will only play an essential role in energy system transformation if the technology is supported or at least tolerated by large sections of the population and social actors.

Landscape changes, restrictions for farmers, land-use changes, loss of conventionally used agricultural land and the products growing on it, reeking plants, rising lease prices, competition for land, failed subsidies, loss of biodiversity – just to name a few arguments which can result in a negative attitude of the population towards the transformation. For this reason, the public must be involved in the considerations at an early stage, and intensive educational work must be carried out.

Company

[6] Busse, S. et al. (2019) VoCo – Vorpommern Connect Meilensteinbericht 1, page 41
[7] Edel, M. et al. (2016) 1Integrated biomass policy frameworks GERMANY, page 7

The integration of biomass heating plants into already existing heating networks makes sense, since the cost for their establishment is then eliminated. The optimum sequence for establishing a Paludi heating plant is to look for suitable sites first, and then convince existing suppliers to convert their production (wholly or partly). This means at least an upgrade of their technology with adapted technique and, if necessary, a partial reconstruction of the factory. The willingness to do so will be greater if innovations are planned soon anyway (e.g. replacement of old machines).

Infrastructure / logistics

- *Transport routes*: The transport from the site, possibly via a storage site, to the recovery (heating plant) is an important factor influencing the costs because of the voluminous biomass. The transport costs depend on the distance and the technology used[8].
- *Storage facilities:* Because the biomass is not available continuously, but rather episodically, suitable storage facilities, at best directly beside the heating plant, must be constructed. At which times biomass can be harvested depends on the trafficability of the area and the plant species. A mixture of different plant species increases the time window in which biomass can be delivered.
- *Company size:* Heating plants with sizes of 800 - 1,500 kW and heat requirements of more than 2,500 MWh are particularly suitable for the energetic utilization of paludiculture biomass[9]. Smaller to medium-sized heating plants up to 1,000 kW can only be operated competitively if their capacity utilization is as high as possible (> 2,500 MWh) or if residues are used (raw material price near 0 €).

Long-term securities

Good arguments for changing to the use of Paludi biomass are securities. This includes not only long-term supply contracts but also financial guarantees for farmers and heat suppliers.

Collection of data from the region

To implement a regional bioenergy heating network, a region needs to be broadly analyzed to fully evaluate its potential. The first step is, consecutively, an analysis of existing structures.

Basic data collection[10]

- Survey of population and area data
- information on the economic situation of the region
- number of agricultural enterprises and distribution in the region

Area potential

The following factors determine site suitability[11]:

- *Wettability:* It must be analyzed whether the areas are hydrologically separated from neighboring areas or can be demarcated. Also, it must be determined whether the water

[8] Dahms, T. et al., (2017) Paludi-Pellets-Broschüre: Halmgutartige Festbrennstoffe aus nassen Mooren. Universität Greifswald, Greifswald.
[9] Schröder C, et al., (2017) Entwicklung einer klimagerechten regionalen Energieversorgung durch Paludikultur am Beispiel des Landkreises Vorpommern-Rügen. Abschlussbericht BMEL Modellvorhaben Land(auf)Schwung.
[10] Bohnet, S. (2012): DBFZ Report Nr. 23; Technisch-ökonomische Begleitforschung des Bundeswettbewerbes „Bioenergie-Regionen"; Endbericht Fördermaßnahme 2009-2012
[11] Busse, S. et al. (2019) VoCo – Vorpommern Connect Meilensteinbericht 1, page 9

supply is sufficient for rewetting or what kind of measures are required to maintain healthy/target water levels. A controllable water level is essential for crops.

- *Area size:* The areas of wet meadows should be at least 10 ha, preferably > 50 ha, whereby individual areas should not be too far apart. The total amount depends on the demand (e.g. heat demand). Cost-efficient use of machines can be ensured by inter-farm use if necessary.
- *Nutrient availability*: A nutrient supply via the inflowing water enables higher biomass yields and the cultivation of cattail, which has a steep nutrient requirement. However, water-saturated soils may not be fertilized according to the Fertiliser Ordinance.
- *Spatial distance:* Due to the high transport costs of energy biomass, only peatlands within a radius of 10 to 20 km from the recycling site are considered.
- *Biomass potential:* Soil, as well as plant potential and climate, influence the amount of biomass. The generated biomass must guarantee energy supply all year round.

Energy supply

Evaluations

Calculations

For the location analysis of Paludi biomass heating plants there is a calculation tool for different parameters on the following website:

https://www.moorwissen.de/de/paludikultur/tools/heizwerk.php[12]

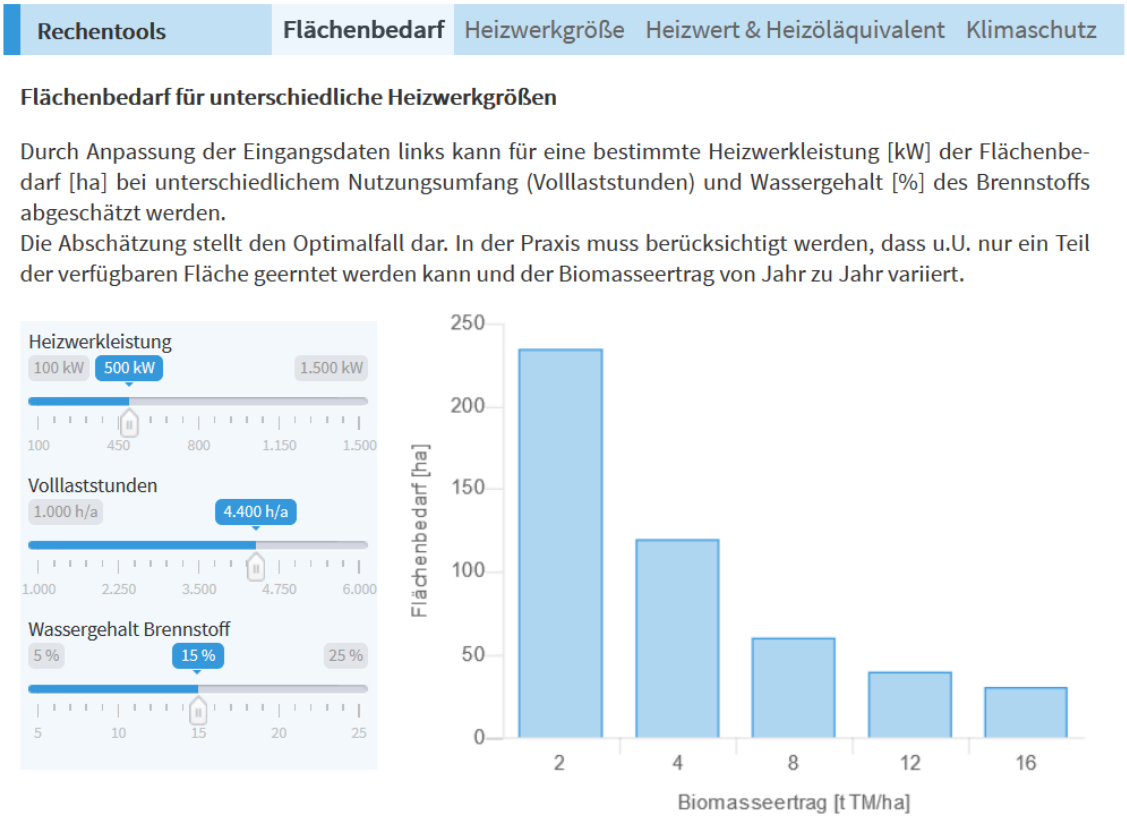

Fig. 3: Calculation tool with area requirement (Flächenbedarf) as an example

[12] Available only in German language

You can change heat output (Heizwerkleistung), full-load hours (Volllaststunden) or water content of the fuel (Wassergehalt Brennstoff). The biomass yield (Biomasseertrag) as a function of area requirement (Flächenbedarf) is then presented graphically. There is also the possibility to calculate with the parameters, heating plant size (Heizwerkgröße), heating value and fuel oil equivalent (Heizwert & Heizöläquivalent) and climate protection (Klimaschutz).

Connection to biomass heating plants

To kickstart paludiculture heating plants, existing heating networks are needed in order to distribute heat to the households. The connection of biomass heating plants to existing heating networks is useful because the costs for their establishment are then eliminated.

In regions where the heat demand is mainly generated from fossil fuels supplied by global supply chains, a Paludi biomass heating plant and its associated regional heating network can also be established. However, this might lead to higher investment costs, which must be compensated by a high gas price, cheap raw material, or public subsidies.

Calculation of greenhouse gas emissions and savings

The emission-reduction is one main reason for the transition from fossil fuels to regenerative energy. In order to convince the involved actors, saving CO_2 is a powerful argument for persuasion.

A second reason to calculate the emissions is the possible subsidies, which in some cases are dependent on the amount of savings.

Challenges

The following problems can arise and must be taken into account:

- possible price increases
- biomass in different quality
- risk of supply bottlenecks
- supply relationships with a large number of farmers -> complicated logistics

Financing

Administration

Because the new technique replaces the current one, there might be slightly higher administrative costs because of the additional effort in transportation logistics as well as the agreements with different biomass providers[13].

Calculation of the electricity price[14]

- investment costs / refinancing
- personnel costs
- raw material (harvesting costs are determined by the investment costs in the technology, its capacity utilization, and the realizable clout[15])
- transport costs
- storage costs

[13] Busse, S. et al. (2019) VoCo – Vorpommern Connect Meilensteinbericht 1, page 11
[14] See also BioBIGG (2020): Innovation Programme: Energetic Use of Paludi Biomass in Mecklenburg-Vorpommern (MV)
[15] Dahms, T. et al., (2017) Paludi-Pellets-Broschüre: Halmgutartige Festbrennstoffe aus nassen Mooren. Universität Greifswald, Greifswald.

- heat production costs
- arising quantities of ashes, as well as their removal
- Funding programmes
- Remuneration of ecosystem services

Summary

To partly replace fossil energy with energy from Paludi biomass on a larger scale, the following steps are necessary for implementation:

Analysis of the current situation

- Basic data collection[16]
- Existing heat supply system
- Area and biomass potential
- Legal rights

Implementation

- Adaption of the heating network (regional energy supply)
- Technical adaption of the heating plant/construction of a new heating plant
- Provision of biomass, which always guarantees sufficient energy supply in quantity and quality
- Biomass transport logistics
- Involving the public

In contrast to fossil fuels, the investment and operating costs of a biomass heating plant are higher. The competitiveness of a Paludi biomass heating plant is therefore difficult to achieve. Implementation is therefore easier with extended future subsidies.

[16] Bohnet, S. (2012): DBFZ Report Nr. 23; Technisch-ökonomische Begleitforschung des Bundeswettbewerbes „Bioenergie-Regionen“; Endbericht Fördermaßnahme 2009-2012

Agro-industrial sector

KERATIN HYDROLYSATE PRODUCTION FROM POULTRY FEATHERS

COLOURBOX33938251

09.10.2020

Implementation model

Keratin hydrolysate production from poultry feathers

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1 Introduction

Intensive development of the economy not only has a positive effect on improving the quality of life (access to modern technologies, ensuring energy security and access to food) but also may have a negative impact on the natural environment, where the deterioration conditions may also influence its quality. The use of raw materials according to a linear model of the economy (raw material is used to produce a product that, after fulfilling its role, is destined for landfill) has now led to an imbalance in the natural environment - resources are used too fast, which does not allow the natural environment to regenerate [1]. This way of using natural resources disturbs biodiversity and is not in line with the idea of "sustainable resource management", thanks to which it is possible to protect our planet and keep it in good condition for future generations [2]. Consider the above aspects, efforts were made to extend the value chains of raw materials, so their life cycle is longer. As a result, the demand for raw materials and the amount of waste deposited in landfills is reduced. Such a model is consistent with the idea of a circular economy, which task is to strive for the sustainable use of raw materials and responsible waste management. Therefore, more and more countries, regions, and enterprises are introducing solutions that are based on a cascading approach to materials, i.e., the use of various waste or post-process residues as raw materials in subsequent processes. However, it is worth noting that for the circular economy model to be developed in full the individual entities should cooperate, both when it is related to the exchange of products for the next processes, but these entities should also share knowledge and appropriate practices to enhance the mutual benefit. It should apply not only to individual enterprises in a given region, but such cooperation should take place on a cross-regional or even cross-border level.

One of the interesting cases worth deeper scrutiny in the context of introducing the circular economy relevant to the Polish South Baltic Area (SBA), is the use of waste from the poultry industry as raw materials for other processes. An example of such post-processing waste is poultry feathers, which, despite its valuable properties, is often incinerated or stored in landfills. Within their composition, there is 90% of keratin [3], which is a natural building component of human hair and nails, which makes it a product willingly used in the cosmetic industry (mainly in hair care products). Currently, keratin hydrolysate is most often produced from the sheep wool, and there are no companies that produce it from poultry feathers. Therefore, there is a niche on the market which, considering the amount of available raw material in the form of poultry feathers, could be filled by establishing a company or a production line for the production of keratin hydrolysate from them. Additionally, this idea seems to be attractive also from the still-developing cosmetics industry point of view and the demand for natural products, as well as the growing awareness of consumers regarding the sustainable use of raw materials.

The subject of this study is to assess the feasibility of implementing a solution based on the production of keratin hydrolysate from poultry feathers in the Polish South Baltic Area. During the considerations, the legal status in Poland regarding waste management was taken into account, the condition of the poultry industry in the Polish SBA was assessed, and potential locations, where a company producing keratin hydrolysate from poultry feathers could be established have been indicated. Moreover, the selection of key actors, whose role could decisively impact on the development of the proposed concept has been made. Additionally,

the potential opportunities related to the transfer of knowledge at the cross-border and international level are presented.

2 Legal framework

The production of keratin hydrolysate from poultry feathers, which are classified as post-process waste, is related to taking into account legal issues regarding waste management and the potential possibilities of their use for other purposes. It is connected with the so-called end-of-waste status, and its conditions are described in the Act on Waste [4]. According to Article 14 of this Act, individual types of waste cease to be such if they meet the following conditions after recovery or recycling [4]:

- the resulting object or substance is commonly used for specific purposes,
- there is a market or demand for such items or substances,
- the given object or substance meets the requirements related to its use for specific purposes,
- the resulting object or substance is not dangerous for human life, health, and the environment.

According to the Directive of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives [5], the term "recovery" is understood as operations which transform waste into usable materials, replacing raw materials that would otherwise have to be used to fulfill a given function or processes by which the waste is prepared to fulfill that function in a given facility or the wider economy. Recycling, on the other hand, refers to the recovery operations that transform waste into products that can be used for their primary or other purposes [5]. Recycling involves the reprocessing of organic material. It should be noted here that, according to the above documents, obtaining the end-of-waste status is resulted after the finish of the recovery or recycling process.

Waste after recovery or recycling should meet the requirements set by the European Union regulations [4]. The European end-of-waste legislation is set out in the above-mentioned Directive [5]. The document also states that if there are no specific end-of-waste procedures, each Member State may issue such a decision individually, notifying the European Commission [5]. In Poland, apart from the provision in the Waste Act (Article 14), no document would constitute the basis for describing the exact criteria related to the end-of-waste status process, therefore each reported case must be considered individually [6]. Also, it has not been stated anywhere what specific types of waste may lose their status, even though Article 14 of the Waste Act states that it refers to "individual types of waste."

Currently, in Poland, the end-of-waste status process is not specified or regulated by separate regulations - a positive decision regarding the end-of-waste status is associated with obtaining a permit for their processing or an integrated permit [6]. This is a major inconvenience for companies wishing to use waste for other purposes. There are also problems with administrative issues, which also complicate the process of end-of-waste status, which in turn may affect the reluctance of entrepreneurs to transform the economy towards a circular economy.

In Poland, the concept of the circular economy is still at an early stage, and various strategies are currently being introduced and developed to help in the pursuit of such a model. One of the documents that will be significant in the development of the circular economy is "Roadmap for transformation towards a circular economy" [7]. This document is intended to be a guide aimed at implementing the above-mentioned economic model in Poland. It contains a set of activities necessary to the transformation, including the period in which they should be carried out and information about departments responsible for a given task. Within the proposed activities, tasks related to biomass processing can be distinguished: inter alia, a review of the applicable regulations and the creation of uniform standards for biomass, analysis of the biomass supply potential at the national and regional level, and identification of priority in research, development, and innovation for the development of the bioeconomy in Poland [7]. Also, special attention will be paid to the cascading use of biomass - activities in this area will include, mainly, conducting an information campaign on the cascading use of biomass and products made of it, creating norms and standards for individual categories of products made of biomass and creating the concept of an information platform on the quantity, quality, place, and source of biomass [7]. The document also presents activities related to business aspects, indicating that the transformation towards a circular economy requires a change in the current business model, which will focus not only on delivering value to the customer but also on "closing the loop" [7]. The presented tasks in this area are related to the analysis of the possibility of introducing changes in the tax system that would encourage enterprises to take actions based on the circular economy model, developing proposals for changes in the public procurement law that would generate demand for products and services based on the circular economy. Also, the tasks describing the concept of the support (financial and educational support, as well as promoting at the stage of technology development and commercialization) enterprises working under the above idea [7]. The presented activities are crucial for circular economy development, and the fulfillment of individual tasks would allow for a faster transformation in this direction and would encourage entrepreneurs to invest in innovative solutions based on the use of biomass and extending the raw material processing chains. The described document and its assumptions are promising and could constitute the incentive for the implementation of the proposed project, i.e. the production of keratin hydrolysate from poultry feathers.

3 The poultry industry in the Polish South Baltic Area Region

According to EUROSTAT data, in 2018 about 70% of poultry meat production in the European Union came from six countries, including as much as 16.8% of thereof from Poland [8]. Poland is at the forefront of poultry producers in Europe - production for 2019 amounted to 3 596 297 tons [9]. The Polish South Baltic Area region consists of three voivodships, namely Pomeranian, West Pomeranian, and Warmia and Mazury ones. Figure 1 shows how poultry production developed in the Polish SBA region from 2012 to 2019 [9]. As can be seen, poultry production in individual voivodships fluctuates, and in 2019 there was a slight decrease in production for the Pomeranian and Warmia and Mazury voivodships compared to 2018 (838 tons for Pomeranian and 1 207 tons for Warmia and Mazury voivodeship). The production volume in the Pomeranian voivodeship has been approximately the same since 2014, while in the Warmia and Mazury voivodships in 2018 a production decrease of about 31 000 tons was

recorded. Since 2017, an increase in poultry production in the West Pomeranian voivodeship can be observed.

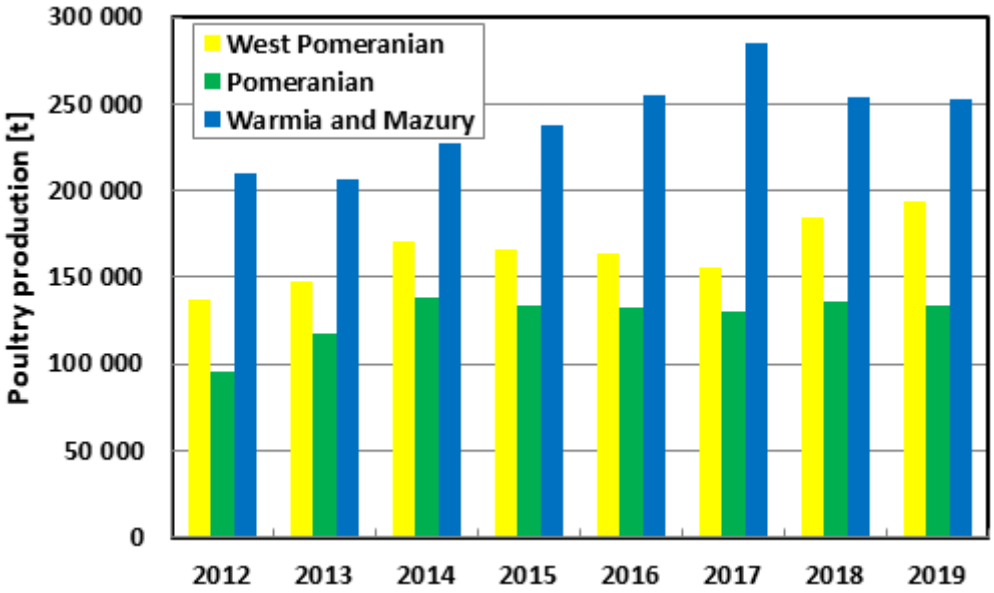

Fig. 1. Poultry production since 2012 in the Polish SBA region [9].

Table 1 contains data on poultry production for 2019 in the Polish SBA region and feather production (annual and daily), assuming, in line with literature sources, that feathers account for about 7% of the chicken weight [10].

Tab. 1. Poultry and feathers production in the Polish South Baltic Area region.

Voivodeship	Poultry production [t/a]	Annual feathers production [t/a]	Daily feathers production [t/d]
West Pomeranian	193 496	13 544	37
Pomeranian	133 972	9 378	26
Warmia and Mazury	252 599	17 682	48
Total	**580 067**	**40 604**	**111**

The values presented in Table 1 show the potential of using poultry feathers as a raw material in subsequent processes. Table 2 lists the significant poultry producers (slaughterhouses) in the Polish SBA region with their production capacities [11], while Figure 2 shows the distribution of these slaughterhouses in the Polish SBA region.

Tab. 2. The significant poultry meat producers in the Polish SBA region [11].

Voivodeship	Company name		Production volume
Pomeranian	1	Ubojnia Drobiu Mielewczyk	75 000 pieces/day
	2	Ubojnia Drobiu Gosz	5 000 pieces/hour

Voivodeship	Company name		Production volume
	3	Ubojnia Drobiu SZMIDTKE	70 000 pieces/week
	4	Ubojnia Drobiu HUBART	4 000 pieces/day
	5	DROBFUL Jolanta Fularczyk	10 000 pieces/week
	6	Ubojnia drobiu Przechlewo	No data
	7	Rzeźnia drobiu Jerzy Konkol	No data
West Pomeranian	8	Ubojnia Drobiu Drobimex	190 000 pieces/day
	9	Ubojnia Drobiu LINDROB	10 000 pieces/day
	10	Spółdzielcza Agrofirma Witkowo	25 000 pieces/day
Warmia and Mazury	11	Zakład drobiarski Lech Drób	220 tons/day
	12	Indykpol	70 740 tons/year
	13	Indyk Mazury	140 tons/day
	14	Ubojnia Drobiu Kondratowicz	20 000 pieces/day
	15	Ubojnia drobiu GÓRNI	No data
	16	Ubojnia drobiu Indor	No data

Fig. 2. Distribution of poultry slaughterhouses in the Polish SBA region.

Analyzing the capacities of presented companies, it can be noticed that these are the enterprises that can produce a significant amount of poultry meat per day or hour, which may indicate the use of advanced technologies by them. Additionally, these companies mostly export the produced meat to the global market, and therefore plants must comply with strict requirements and regulations during its production. Some of the above-mentioned entrepreneurship belong to the sector of family enterprises that have been developing their plants for years, passing them on to subsequent generations. As a result, these companies try to maintain their position on the market by applying best practices, employing employees from nearby areas, thus reducing

unemployment and implementing solutions that allow them to meet legal and environmental requirements related to the production of poultry meat.

4 The cosmetic industry in Poland

Since the proposed solution focuses on the production of keratin hydrolysate, which is classified as a cosmetic product, this chapter provides a short assessment of the condition of the cosmetics industry in Poland. The focus was put on skincare and personal hygiene products, which include hair care products that readily use keratin hydrolysate (mainly made from sheep's wool). In 2017, Poland was the sixth-largest cosmetics market in Europe [12]. The cosmetics market in Poland in 2019 generated revenues of over EUR 4 billion [13]. There is a growing trend in skincare and cosmetics for personal hygiene-related revenues (the cumulative annual CAGR growth in 2016-2019 was 4.7% for skincare cosmetics and 2.4% for personal hygiene cosmetics) [13]. In addition, Polish exports of cosmetics are growing every year (Fig. 3), and in 2019 skin beautification and care products accounted for as much as 43.6% of Polish exports [13]. The main importers of Polish cosmetics are Germany (15% of exported products), Russia (11.7%) and the United Kingdom (9.4%) [13].

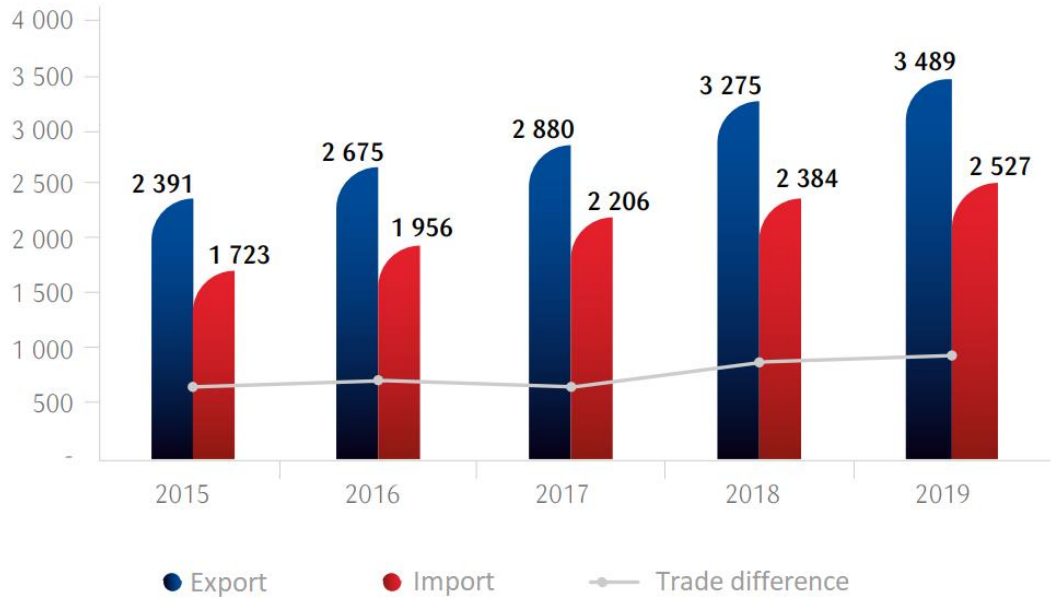

Fig. 3. Cosmetics industry in Poland – trade (million EUR) [13].

Poles in 2019 spent an average of EUR 24.8 on skincare cosmetics (the European average was EUR 33.7), and EUR 52.3 on personal hygiene products (the European average was EUR 21.4). The projected expenditure on these types of cosmetics (skincare together with personal hygiene products) in 2023 is to reach an average of EUR 87.8 (European average EUR 61.2) [13].

The above data shows that the cosmetics industry in Poland is constantly developing, and the products are appreciated by customers, including foreign consumers. This is good news when considering the idea of keratin hydrolysate production because there is a chance that there will be a demand for such a product.

5 The implementation model for keratin hydrolysate production in the Polish SBA region

In this chapter, an attempt has been made to select areas in the Polish SBA region that seem attractive due to the commencement of the production of keratin hydrolysate from poultry feathers. The arrangement of poultry slaughterhouses and the distance between them and cosmetic enterprises were taken into account. The focus was put on the factories producing cosmetics because they have access to modern technologies and equipment necessary for production, as well as qualified employees. Such companies mostly have their own research and development laboratories, as well as quality control laboratories, thanks to which it would be possible to research the production of keratin hydrolysate from poultry feathers - both in terms of its properties and improving the production process. Also, it was taken into account whether there are research centers in the area that could cooperate with cosmetic companies and slaughterhouses, looking for new methods of producing keratin hydrolysate or improving the existing ones (nowadays only in the laboratory scale), as well as developing new products containing the hydrolysate in their composition. Although there is currently no company in the Polish SBA region that would produce keratin hydrolysate from poultry feathers, and analyzing the distribution of individual plants, it can be concluded that there is a real potential for such a plant or production line.

Looking at the distribution of poultry slaughterhouses (shown in Figure 2), it is possible to indicate places of their concentration, which is beneficial for the proposed solution – plants producing keratin hydrolysate from poultry feathers could be established in areas where the distance to each of the adjacent slaughterhouses would be similar. Such a location of the plant would have a positive impact on ensuring continuity in the supply of raw material, and also, transport would not take place over long distances, which is important from an environmental and economical point of view. When analyzing the location of companies, four areas can be distinguished where poultry slaughterhouses are located at relatively short distances from each other. The analysis is shown in Figure 4 (numbering in accordance with Table 2). The first area, with as many as five slaughterhouses (marked with numbers 1, 2, 3, 5, 7), is located in the Pomeranian Voivodeship. The marked area is equal to approximately 194 km^2, and slaughterhouses 1, 3, 5, and 7 are separated from each other by a maximum of 11 km in a straight line, while slaughterhouse 2 is approximately 36 km from the furthest slaughterhouse (3). A plant producing keratin hydrolysate could be built in the middle of the marked area, ensuring proximity to raw material bases, but also it could be produced in existing cosmetic enterprises, which would, for example, launch a new production line. The map shows also existing larger cosmetics plants (green markers) that are located in the closest distance from the considered slaughterhouses. These companies are:

- Ziaja Ltd Zakład Produkcji Leków Sp. z o.o. – distant from the slaughterhouses by a maximum of 17 km in a straight line,
- Marion Sp. z o.o. – distant from the slaughterhouses by a maximum of 21 km in a straight line,
- WIBO Sp. z o.o. Sp. K. – about 15 km in a straight line from the slaughterhouses.

The mentioned above companies are Polish enterprises and have been operating on the market for about 30 years. They produce cosmetics that are popular in Poland, but also in Europe. They not only produce cosmetics in their own factories but also have their own research and development and quality control laboratories. Due to successful international sales, these companies are also very technologically advanced. Also, the map includes a university (Gdańsk University of Technology - red marker), which could carry out research and development projects with both slaughterhouses and cosmetics plants that would like to undertake the production of keratin hydrolysate from poultry feathers. The university educates specialists in, among others, chemistry and biotechnology who, after graduation, can find employment in the above-mentioned cosmetic establishments.

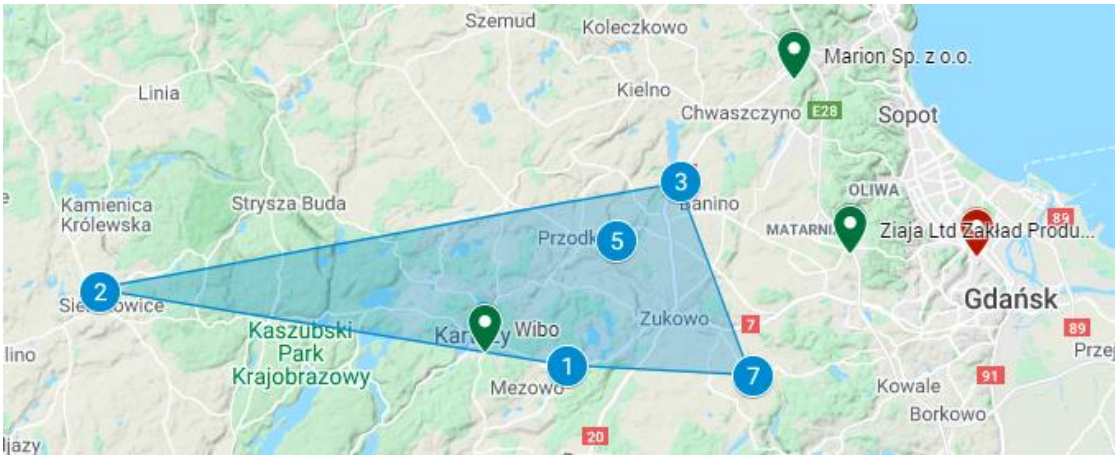

Fig. 4. Distribution of selected poultry slaughterhouses, cosmetics establishments and university in the Pomeranian Voivodeship.

The second selected area is located on the border of two voivodships between Pomeranian and West Pomeranian regions. There are two slaughterhouses, namely the HUBART Poultry Slaughterhouse (4) and the LINDROB Poultry Slaughterhouse (9), which are approximately 25 km apart in a straight line There are also three cosmetic companies in the vicinity of selected slaughterhouses:

- Pierre Rene Sp. z o.o. – distant from the slaughterhouse by a maximum of 33 km in a straight line,
- LOTON COSMETICS® – within a straight line distance of up to 30 km from a slaughterhouse.

LOTON COSMETICS specializes in the production of hair care cosmetics, which may be vital for the proposed solution, as the keratin hydrolysate is a product willingly used for these purposes. Pierre Rene is a company that follows global trends, and manufactures cosmetics are sold in about 35 countries around the world. There is no research center in the considered area that would educate specialists in the field of chemistry or biotechnology, but the Pomeranian University in Słupsk educates specialists in the field of biomonitoring and sustainable development, who could also cooperate on the use of slaughter feathers as a raw material for the production of hydrolysate keratin. Figure 5 shows the considered area with the marking of cosmetics plants (green marker) and university (red marker).

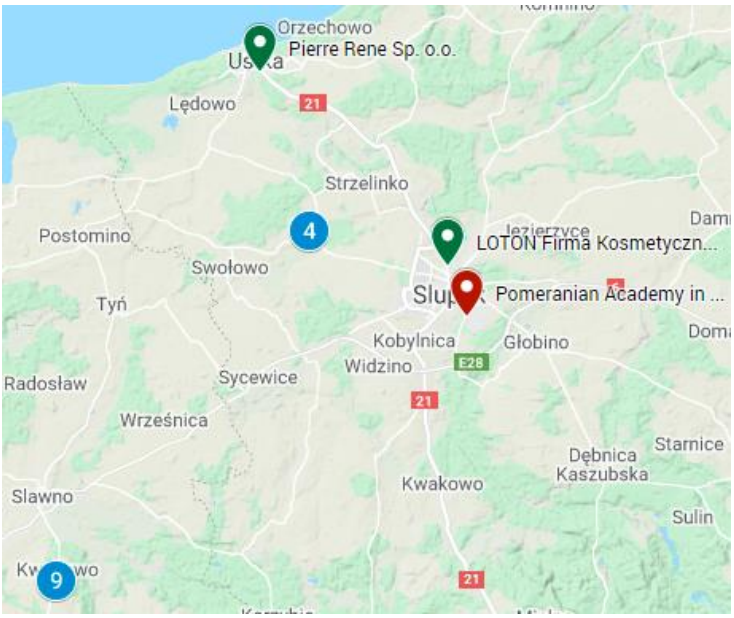

Fig 5. Location of selected poultry slaughterhouses, cosmetics establishments and university on the border of the Pomeranian and West Pomeranian Voivodships.

The third area that has been selected for the study includes two slaughterhouses in the West Pomeranian Voivodeship: Drobimex Slaughterhouse (8) and Spółdzielcza Agrofirma Witkowo (10), which are approximately 22 km apart in a straight line. When analyzing the production volume of these companies (around 215 000 pieces/day) it can be concluded that there is a high potential in terms of the amount of available raw material in the form of poultry feathers. Unfortunately, there are no large factories producing cosmetics near the slaughterhouse, only small units that would not be able to process large amounts of feathers. Consequently, a new plant should be built in this area to convert poultry feathers into keratin hydrolysate and sell it to those small companies. This area is attractive due to the volume of feather production, but also access to educated staff that could be employed in such a plant – the West Pomeranian University of Technology in Szczecin is located close to the slaughterhouses, as well as the University of Szczecin, which educates students in the field of biotechnology, chemistry, as well as environmental protection. Figure 6 shows a map with selected slaughterhouses and the marked universities (red markers).

Fig. 6. Distribution of selected poultry slaughterhouses and universities in the West Pomeranian Voivodeship.

The last selected area concerns the Warmia and Mazury Voivodeship and includes two poultry slaughterhouses: Indykpol (12) and Poultry Slaughterhouse Kondratowicz (14). These plants are only 4 km apart in a straight line. As in the case of the area in the West Pomeranian Voivodeship, there are no cosmetics plants nearby, but the potential amount of the raw material produced is so large that it is worth considering building a new plant that would process feathers into keratin hydrolysate. Near the slaughterhouses, there is the University of Warmia and Mazury, which specializes in natural sciences, including education in the field of biotechnology, therefore, the risk of a deficit of qualified staff is minimized. Additionally, the Warmia and Mazury voivodship is characterized by the highest unemployment rate in the country (8.8%) [14], so the creation of a new plant could reduce this number and contribute to the improvement of the economic situation in the voivodeship. Figure 7 shows a map with selected slaughterhouses and the university (red marker).

Fig. 7. Distribution of selected poultry slaughterhouses and university in the Warmia and Mazury Voivodeship.

Analyzing the above data, the most advantageous location for the production of keratin hydrolysate from poultry feathers, for the availability of the raw material, cosmetics establishments, and the research center, is the first proposal, i.e. the area located in the Pomeranian Voivodeship (Fig. 3). The advantage is that cosmetics companies are known by consumers, and therefore the possibilities of selling the obtained keratin hydrolysate increase - consumers are more likely to choose well-known and proven brands. Also, slaughterhouses located on the border of the Pomeranian and West Pomeranian voivodships are conveniently located - nearby there are cosmetics plants and a research center. The situation is different in the other two areas because there are no cosmetics plants in the vicinity, but the amount of raw material produced in both voivodships, the presence of research centers, and the high unemployment rate in the Warmia and Mazury voivodeship are promises for the proposed solution.

Due to the fact that currently there are no installations for the production of keratin hydrolysate from poultry feathers, and the production process, consisting of two-stage alkaline-enzymatic

hydrolysis [15], is only confirmed on a laboratory scale, cost estimation of the commercial enterprise is difficult. However, it should be taken into account that the process uses traditional chemical equipment (dryers, incubators, mixers, etc.), which is also used for the production of other cosmetics, therefore cosmetics establishments may have them, and the cost of purchasing additional equipment will be accordingly lower. The investment costs will vary depending on whether the entire feather processing plant is to be built, or if it is just another production line in a cosmetics plant. Each considered case is different and differs primarily in the amount of available raw material, which significantly affects the production volume and the costs associated with it. Nevertheless, taking into account that the proposed solution is based on the use of waste, the amount of which is significant, and the production of a valuable product, which is keratin hydrolysate, readily used in the cosmetic industry, considering the establishment of a plant or production line seems justified. If a given company develops technology for obtaining keratin hydrolysate from poultry feathers, it can start cooperation with other companies and share the know-how - thanks to this, it is possible to transfer a given solution between regions, and even cross-border.

6 Decision-makers, key actors and programs crucial for the implementation

Considering starting the production of keratin hydrolysate from poultry feathers in the Polish SBA region, one should also focus on selecting legal, administrative, and other institutions, as well as programs that could have an impact on the development of the project. Both national and regional units should be identified. However, it is worth focusing on the national scale at the beginning - decisions issued by state governing bodies have a decisive impact on the development of the economy in Poland. At this point, it is worth mentioning the ministries whose scope of duties may be related to the idea of producing keratin hydrolysate from poultry feathers, which is to be a solution consistent with the model of circular economy and the cascading use of raw materials.

One of the key actors is the Ministry of Development, Labor, and Technology, dealing with matters related to the national economy, which include issues regarding the competitiveness of the economy and its innovation [16]. One of the departments of this ministry is the Department of Innovation, which tasks are related to increasing the innovativeness and competitiveness of the economy, as well as related to the transformation towards a circular economy (including issues related to the environmental footprint and access to raw materials). Another department is the Department of Investment Development [17]. Its task is, inter alia, supporting investment processes, as well as carrying out works related to the Program for Supporting Investments of Major Importance for the Polish Economy for 2011-2030 [17]. This program supports investment projects which increase innovation and competitiveness of the Polish economy. As part of the project, it is possible to receive funding for large strategic projects as well as for medium-sized innovative projects. In line with the idea of the program, solutions based on modern technologies and related to conducting research and development activities [18] are particularly attractive. Investors planning to implement a production investment that results in an innovative product or process, which is a novelty on a national scale, may apply for a subsidy. The minimum investment expenditure must be PLN 7 million, and the minimum number of new jobs must be 20 [18]. Another department is the Department of Small and

Medium Enterprises [19]. Its tasks include, among others, supporting the development of entrepreneurship and developing programs and documents related to small and medium-sized enterprises.

Additionally, for the proposed solution, two entities subordinate to the Ministry of Development may be crucial – Special Economic Zones and Research and Development Centers [20, 21]. Special Economic Zones are entities that support and promote the development of new investments. Their tasks are also related to improving cooperation between enterprises, the local community, and social partners, as well as recommending entrepreneurs the best location for investments. Currently, there are 12 zones, in the Polish SBA there are the following:

- Pomeranian Special Economic Zone,
- Słupsk Special Economic Zone,
- Kostrzyn-Słubice Special Economic Zone,
- Warmia and Mazury Special Economic Zone.

The support provided by Special Economic Zones takes place within the framework of the Polish Investment Zone, which is an instrument that allows obtaining tax relief for the implementation of the new investment [22]. Support is specially granted to small and medium-sized enterprises and for the implementation of innovative projects. Additionally, the Polish Investment Zone facilitates cooperation with research units and supports the transfer of knowledge. On the other hand, the Research and Development Center is a status that can be granted to an enterprise that is not a research institute and which conducts research or development works. Obtaining such status entails the possibility of taking advantage of various exemptions, for example, a deduction allowance (deduction from the tax base of up to 150% of the tax-deductible costs incurred for research and development activities) or, for example, an exemption from the real estate tax [21].

The second crucial government unit is the Ministry of Funds and Regional Policy [23]. The task of this institution is to manage the European Fund's implementation system and to ensure regional development. Additionally, the ministry coordinates the implementation of the Strategy for Responsible Development, the aim of which is, among others, sustainable economic growth related to the development of innovative companies and small and medium-sized enterprises [24]. It is related to the improvement of cooperation between science and business and support for innovative entrepreneurs.

Support for innovative solutions that contribute to the sustainable economic development of the country is also provided by National Smart Specializations [25]. Their task is to focus investments in areas that ensure the economic development of the country and contribute to the transformation of the economy towards a competitive and efficient use of natural resources. One of the smart specializations is "Biotechnological and chemical processes, bioproducts and products of specialty chemistry and environmental engineering." This specialization is aimed at "Development of bioprocesses based on the use of biomass and waste from the agri-food, forestry, and herbal industries, obtaining substrates for the needs of various industries, including chemical, cosmetic, pharmaceutical, agricultural, textile, packaging, pulp and paper and the

production of other products" which is consistent with the idea of the proposed solution for the production of keratin hydrolysate from poultry feathers [25].

The Polish Agency for Enterprise Development and the Polish Development Fund [26, 27] are institutions whose goal is also the implementation of economic development programs, supporting small and medium-sized enterprises in their research and innovation activities. The first institution is involved in the implementation of national and international projects, financed from structural funds, the state budget, or programs of the European Commission. The agency participates in the implementation of the state policy in the field of entrepreneurship and innovation. The Polish Development Fund, in turn, brings together financial and advisory institutions that are to help enterprises, local governments, etc., in their pursuit of sustainable economic development of the country.

At the regional level, important institutions are Marshal's Offices, which, in cooperation with other units, implement plans included in regional development strategies. They cooperate, inter alia, with the Regional Development Agencies. In the Polish SBA region there are the following agencies:

- Pomeranian Development Agency S.A. (Gdańsk),
- Koszalin Regional Development Agency,
- Warmia and Mazury Regional Development Agency S.A. (Olsztyn),
- Pomeranian Regional Development Agency S.A. (Słupsk),
- Stargard Local Development Agency,
- Regional Development Agency S.A. in Koszalin.

The agency's task is to initiate, support and promote initiatives related to regional development. Their activity is based on supporting small and medium-sized enterprises, consulting in the field of marketing, law, etc., and the implementation of projects related to the development of entrepreneurship and innovation.

It is also worth mentioning the national and regional programs supporting the development of innovative solutions in the Polish SBA region. The first of the national programs is the Smart Growth program [28], financed by the European Regional Development Fund (EUR 8 613.9 million) and national resources (EUR 1 575.9 million). Under the project, the enterprises may receive support related to conducting research, development, and innovation activities (including support for investments in research and development infrastructure and support for technology transfer) and support for innovation in enterprises (including support for the implementation of research and development results and ensuring appropriate financial instruments) [28]. The second program is the Eastern Poland Program, whose task is to support the creation of start-ups and innovative products in several regions of Poland, including the Warmia and Mazury voivodeship [29]. The program is financed by the European Regional Development Fund (EUR 2 000 million) and national funds (EUR 353 million). One of the objectives of the program is to support the implementation of innovation by small and medium-sized enterprises that cooperate at the supra-regional level. The subsidy for such companies is up to PLN 20 million and can be allocated to various stages of the investment process aimed at introducing a new product or technology to the market.

Additionally, each voivodship has its regional programs consisting of Priority Axes. In the Pomeranian Voivodeship, attention could be paid to the priority axis related to the commercialization of knowledge (EUR 139 860 877) and the environment (EUR 120 909 938) [30]. EU funds allocated under the first axis can be used to conduct research and development projects aimed at introducing innovative products and services to the market, creating research and development teams, and exchanging experiences between enterprises. Under the environmental axis, funds can be used for projects related to waste management. The Regional Program for the Warmia and Mazury Voivodeship is also divided into axes, which focus on introducing innovative solutions in enterprises, creating modern research infrastructure and investment support for enterprises [31]. The second important axis is the natural environment, where the protection of biodiversity, improvement of waste management, recovery, and reuse are promoted. The European Union support for the priority axis related to the smart economy amounts to EUR 320 543 756, and the natural environment – EUR 105 215 193. A similar situation concerning the regional program is in the West Pomeranian Voivodeship, where one of the axes is also related to innovative economy and development of research activities (EUR 309 900 000), and another axis is aimed at environmental protection and adaptation to climate change (EUR 57 000 000) [32].

Analyzing the above information, it can be concluded that innovative solutions are particularly desirable in the Polish economy, and there is a good chance of obtaining various subsidies and financing investments, as a result of which a new product or technology will appear on the market. It is very optimistic when it comes to the production of keratin hydrolysate from poultry feathers, the production technology of which and the product itself may be a novelty not only on the Polish but also the international market.

7 International and cross-border cooperation

Production of keratin hydrolysate from poultry feathers could take place everywhere where there is instantaneous access to the raw material. Of additional benefit would be the acquisition of employees with appropriate education, but nowadays the distance from larger cities with higher education units makes that of the lesser importance, therefore it is worth considering the possibilities of knowledge transfer at the cross-border and international level, and also consider international cooperation. State government units again may be helpful in this - including the previously mentioned Ministry of Development, Labor and Technology, and the Ministry of Funds and Regional Policy. The duties of the first of these institutions cover economic cooperation with foreign countries and the promotion of the Polish economy abroad [16]. The department of innovation of this ministry deals with international cooperation in the field of innovation, technological and industrial policy. In turn, the Department of Investment Development deals with cooperation with institutions of the Polish and international financial and capital markets in the field of investment activities [17]. The Ministry of Funds and Regional Policy deals with promoting Poland and international cooperation, developing cooperation with Switzerland and EEA countries (Norway, Iceland, and Lichtenstein), and looking for new sources of investment financing, including under the Horizon 2020 program or the emerging InvestEU [23].

As a part of international cooperation, the Norwegian Financial Mechanism and the European Economic Area (EEA) Financial Mechanism were established, which are forms of foreign aid granted by EEA countries [33]. The main goal of the cooperation is to reduce economic and social differences between EEA countries and to strengthen relations between countries. It is worth noting that the largest financial support is foreseen for the areas of environment (EUR 140 million), research (EUR 110 million), and local development (EUR 100 million) [33]. InvestEU is a new program to replace the "Investment Plan for Europe (the so-called Juncker's Plan) [34]. The program aims to fill the investment gap and improve the level of investment. One of the pillars of the program is the InvestEU Fund - it aims to generate investments worth EUR 1 trillion. It is also important to create the InvestEU Portal which, like the European Investment Project Portal, is intended to enable potential investors to review investments from across Europe to assess their investment risk, ensuring that all potential investments are on one platform [35].

It is also worth paying attention to the Programs of the European Territorial Cooperation (ETC/Interreg) and the European Neighborhood Instrument [36]. ETC programs are divided into three types: cross-border cooperation programs (neighboring countries), transnational cooperation (European Union countries and not only), and interregional cooperation, which is to strengthen the regional development of the European Union through the dissemination of good practices, exchange of experience and expert knowledge. Poland currently participates in 7 cross-border programs, 2 transnational programs, and one interregional program [36]. In turn, the European Neighborhood Instrument is designed to create common prosperity in the European Union member states and partner countries. One of the areas of cooperation is a sustainable economy and economic development as well as integration with the EU internal market [36].

Additionally, the exchange of knowledge and experience at the cross-border and international level can take place through various types of clusters, networks, and organizations aimed at associating enterprises, investors, and decision-makers. An example of such an organization is ScanBalt® MTÜ [37], which brings together Northern European entities for cross-border cooperation in health and bioeconomy. The vision of the organization is primarily to promote innovation, improve cross-border cooperation, and reduce various barriers limiting it.

However, it should be noted that cross-border and international cooperation can also take place based on cooperation between companies that produce the same product. As a part of such cooperation, various training courses, exchanges of experts, and experience concerning, e.g. the production process could be organized. Additionally, innovative companies could share their knowledge by making their plants available to visitors. Entrepreneurs should remember that cooperation with other companies can bring benefits, and they should not be afraid of it, because the exchange of experiences can reduce the time spent on searching for solutions to various problems.

8 Conclusions

The transformation of the linear economy towards a circular economy requires entrepreneurs to take actions that will result in less waste production and the use of waste generated in

subsequent processes. By analyzing the potential associated with the production of feathers in the Polish SBA region, an attempt was made to determine the possibility of producing keratin hydrolysate from feathers. The location of poultry slaughterhouses, companies producing cosmetics, and research centers are favorable for the proposed solution, and although there is no such company operating in Poland at present, such a solution should be considered. Additionally, keratin hydrolysate is a cosmetic product that is often used in the production of cosmetics, mainly for hair care, so there is a good chance that consumers will be interested in it. Growing public awareness of the extension of raw material processing chains and sustainable economy may also have a positive impact on the development of the solution. The presented government units, institutions, and projects direct their activities towards the development of the circular economy and especially promote such investments, which may convince potential investors to be interested in the production of keratin hydrolysate from poultry feathers. The main problems associated with this production are the lack of proven technology on a scale larger than the laboratory and problems with end-of-waste status. However, if there was a suitable investor, and if there was cooperation between the scientific community and industry in this area, these problems could be minimized. Cross-border or international cooperation would also be an attractive solution, thanks to which it would be possible to develop the technology faster and find a potential investor.

To sum up, there are opportunities to implement the proposed solution in the Polish South Baltic Area, and thanks to cooperation between various institutions as well as enterprises and thanks to the exchange of knowledge, it would be possible to start the production of keratin hydrolysate from poultry feathers in other regions. It should also be noticed that significant amounts of poultry feathers are produced daily, and their disposal is currently a problem due to their properties (possible soil contamination during storage, odors), so action should be taken to eliminate this problem as much as possible.

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CROSS-BORDER IMPLEMENTATION MODEL: BIO-BASED PLASTIC FROM POTATO STARCH. THE CASE OF GERMANY AND POLAND

COLOURBOX26675650

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Deliverable: Deliverable 5.3: Cross-border implementation models and business case manuals for SMEs

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1 Introduction

This cross-border implementation model report aims to explore the use of potato starch for bio-based plastic. Building upon the findings of the pre-feasibility study[1] of the Polish BioBIGG partner, the Gdansk University of Technology, the report aims to address the strengths and weaknesses identified in the Polish case and compare it with the situation in Germany. Ultimately, the report seeks to review whether bio-based plastic from potato starch is a feasible model to be implemented in Germany.

Bio-based plastics are defined as plastics produced from renewable resources such as cellulose and starch. The term bioplastic is used in order to describe plastics that are either biodegradable, bio-based or both, hence being a broader category. Moreover, whilst the Polish study used the term potato "waste", this report will use the term "potato residue" instead. Waste is defined as "…any substance or object which the holder discards or intends or is required to discard…"[2], as potato peels etc. are not discarded when used to produce bio-based plastics the term *potato residue* is the most appropriate to use.

Firstly, bio-based and biodegradable plastics, including the use of potato starch for the production of bio-based plastics, will be discussed. Following the production of bio-based plastics in Poland will be analysed and the findings from the Polish pre-feasibility study will be discussed. Subsequently, the German starch and bio-based plastics industry will be examined. Then the case study and the implementation model will be presented. Lastly, the findings of the cross-border implementation model report will be concluded upon.

2 Growing Plastic: A Brief Introduction to Bio-based and Biodegradable Plastics

Plastics are organic polymers and one of the most durable and versatile materials, traditionally made from finite resources such as crude oil and coal[3]. At the end of the 1980s, plastics from renewable resources entered the market, which mostly were biodegradable; hence, the term "bioplastic" was synonymous with biodegradable.[4] Significantly, nowadays biodegradability does not determine whether something is characterized as a bio-based plastic or not, since some fossil-based plastics are biodegradable and some bio-based plastics are not. The European Bioplastics defines a bioplastic as either bio-based, biodegradable, or both.[5] The graph below illustrated the different properties of materials in the plastic family.

[1] Dr. Thielen, Michael (2020) "Bioplastics", https://mediathek.fnr.de/broschuren/fremdsprachige-publikationen/english-books/bioplastics.html

[2] Department for Environment, Food and Rural Affairs (2012) "Guidance on the legal definition of waste and its application A practical guide for businesses and other organisations", http://www.cldn.com/terms_cond_pdf/Other/pb13813a-waste-business-guide.pdf, last visited: 24.11.2020

[3] Plastics Europe, "What are Plastics", https://www.plasticseurope.org/en/about-plastics/what-are-plastics , last visited: 04.11.2020

[4] Dr. Thielen, Michael (2020) "Bioplastics", https://mediathek.fnr.de/broschuren/fremdsprachige-publikationen/english-books/bioplastics.html

[5] European Bioplastics, "What are bioplastics", https://www.european-bioplastics.org/market/ , last visited: 04.11.2020

Graph 1: Bio-based and Biodegradable Plastics[6]

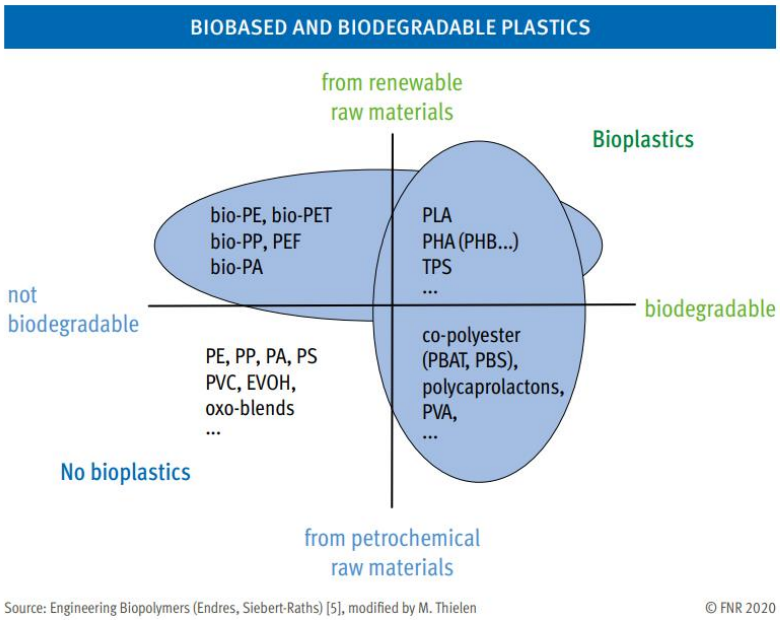

Fig. 1.1: Biobased and biodegradable plastics

In sum, biodegradable bio-based plastics are plastics that are both biodegradable and produced from renewable resources. Bio-based plastics can be produced from various different plant-based materials: Natural polymers (macromolecules that occur naturally in plants) and smaller molecules such as sugars, disaccharides and fatty acids.[7] The market share of bio-based polymers in the total global polymer and plastics market is 1% (3.8 million tons in 2019).[8]

Starch is a natural polymer and a polysaccharide found in plants.[9] Thermoplastic starch is produced by destructuring the starch grains; for this process to take place, the starch grains have to be subject to large amounts of mechanical energy and heat in the presence of softening-agents (plasticisers).[10] Worldwide 21, 3 % of bio-based plastics are made out of starch blends.[11] Potato starch can be used to produce a vast amount of different products: medication and supplements, bioplastics, biofuel, glue, paint, textiles.[12]

Quintessentially, this report argues that potato starch has a high potential for being used in bio-based plastics. Poland was selected, as it has a high potato production and a similar climate to Germany, hence the two countries can be compared.

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[6] Dr. Thielen, Michael (2020) "Bioplastics", Page 5, https://mediathek.fnr.de/broschuren/fremdsprachige-publikationen/english-books/bioplastics.html

[7] Dr. Thielen, Michael (2020) "Bioplastics", Page 8, https://mediathek.fnr.de/broschuren/fremdsprachige-publikationen/english-books/bioplastics.html

[8] Bioplastics Magazine, "The global bio-based polymer market in 2019 – A revised view", https://www.bioplasticsmagazine.com/en/news/meldungen/20200127-The-global-bio-based-polymer-market-in-2019-A-revised-view.php, last visited:24.11.2020

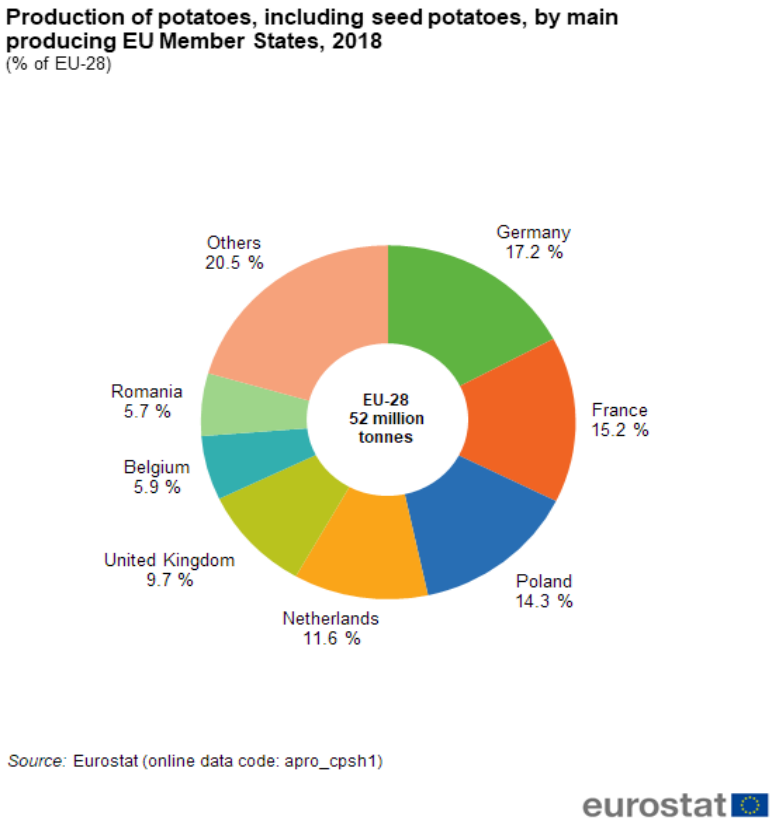
[9] Dr. Thielen, Michael (2020) "Bioplastics", Page 8, https://mediathek.fnr.de/broschuren/fremdsprachige-publikationen/english-books/bioplastics.html

[10] Ibid.

[11] FNR (2021) Basisdaten Biobasierte Produkte 2021, "Marktanteile der verschiedenen Biokunststoff-Typen", Page 10, Accessible via: https://fnr.de/fileadmin/allgemein/pdf/broschueren/basisdaten_biobasierte_produkte_2021_web.pdf

[12] Der Verband der Getreide-, Mühlen- und Stärkewirtschaft VGMS e.V., "VGMS Stärkeindustrie Stoffliche Nutzung", https://www.vgms.de/staerkeindustrie/stoffliche-nutzung/, last visited: 04.11.2020

Graph 2: A Pie chart showing the production of potatoes by main producing EU Member States in 2018[13]



3 Bio-based Plastics in Poland

The pre-feasibility study by the Gdansk University of Technology[14] outlined the bioplastic sector and use of potato residues a material for the production of bio-based plastics in Poland. The study highlights that whilst Poland is Europe's third largest potato producer, there are few companies that produce bio-based plastics, despite potato residues being the most feasible raw material for the bio-based plastic production in the South Baltic Sea Region.[15] The pre-feasibility study finds that the bio-based plastic production technology is underdeveloped and that there is a lack of knowledge about the production processes. Nevertheless, the authors argue that there is a high potential for using potato residues for the production of bio-based plastics as the demand for bio-based plastics is expected to increase in the future. Ultimately, the pre-feasibility study concludes that the bio-based plastic industry in Poland is at a very early stage and has a high potential of expanding in the future.

[13]Eurostats Statistics Explained (2018), "The EU potato sector - statistics on production, prices and trade", https://ec.europa.eu/eurostat/statistics-explained/index.php?title=The_EU_potato_sector_statistics_on_production,_prices_and_trade#Potato_production_in_the_EU_is_highly_concentrated.%20Eurostat,%202018, last visited: 05.11.2020

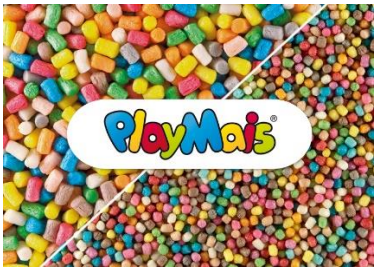
[14] Bochniak, Roksana, Gołąbek, Aleksandra and Mikielewicz, Dariusz (2020) "Prefeasibility study: Bio-plastics production from potato waste"

[15] Ibid.

4 Bio-based Plastics in Germany

In Germany, extensive research has been conducted on bio-based plastics and there are various companies that produce bio-based plastics. In 2018, 10% of the polymers used in the chemical industry in Germany was starch.[16] Germany is the largest producer of potatoes in the EU[17], hence there is a big supply of potato starch for the production of bio-based plastics. The most potatoes are being produced in the federal states of Lower Saxony and Bavaria.[18] Moreover, the required technology for breaking down the starch grains already exists, thus producing bio-based plastics from potato starch is feasible in Germany.

Bio-based plastics are primarily produced from corn starch, for instance the company Loick Biowertstoffe produces cushioning material and "Play Mais" toys that are 100% biodegradable. [19] FNR has a catalogue where different products made from renewable resources are listed, after going through the *Biokunststoffe* (bioplastics) category, it can be concluded that most products either use corn starch as the basis of the bio-based plastic or do not specify what kind of starch they are using.[20] Corn starch has a different crystal structure compared to potato starch; hence, depending on the product different kinds of starch are being used.[21] Moreover, whether or not potato or corn starch is being used depends on the availability of the renewable resource, for example if the bio-based plastic producer is located in an area with a high corn production it is likely that corn starch will be favoured over potato starch.[22]



[23]

Left: Cushioning material made from corn starch

Right: Toys made from corn starch

[16] FNR (2021) Basisdaten Biobasierte Produkte 2021, "Stoffliche Einsatzmengen nachwachsender Rohstoffe in der chemischen Industrie in Deutschland 2018", Page 8, Accessible via: https://fnr.de/fileadmin/allgemein/pdf/broschueren/basisdaten_biobasierte_produkte_2021_web.pdf

[17] Eurostat Statistics Explained, "The EU potato sector - statistics on production, prices and trade", https://ec.europa.eu/eurostat/statistics-explained/index.php?title=The_EU_potato_sector_-_statistics_on_production,_prices_and_trade#Potato_production_in_the_EU_is_highly_concentrated.%20Eurostat,%202018 , last visited : 05.11.2020

[18] Union der Deutschen Kartoffelwirtschaft e.V. (2020), "Kartoffel-Anbauflächen", https://unika-ev.de/index.php?option=com_content&view=article&id=86&Itemid=182#:~:text=Den%20gr%C3%B6%C3%9Ften%20Anteil%20an%20der%20deutschen%20Kartoffelanbaufl%C3%A4che%20halten,Kartoffeln%20an.%20Etwa%2020.300%20Kartoffelerzeuger%20bewirtschaften%20eine%20 , last visited: 10.11.2020

[19] https://www.loick-biowertstoffe.de/#Produkte

[20] https://datenbank.fnr.de/produkte/biowerkstoffe/biokunststoffe

[21] Phone Interview with Biotec employee, (12.12.2020), 14:19, interview conducted by author

[22] Ibid.

[23] https://www.loick-biowertstoffe.de/#Produkte

5 Case Study: Biotec

Biotec[24] is a German company that develops and produces sustainable bio-based plastics. Their thermoplastic materials are 100% biodegradable. For example, their thermoplastic material BIOPLAST 400 consist of potato starch and other bio-based polymers.[25] The material is particularly suitable for the production of foil. The company decided to use potato starch as they are located in a region, which grows large amounts of potatoes.[26] Moreover, as previously explained the chemical properties of potato starch can be more suitable for producing certain types of products. Biotec uses both the potato and potato residues, as there is a quality difference in the starch depending on what part of the potato is being used.[27]

Bio-based plastic bag made from BIOPLAST 400[28]

[24] Biotec, https://en.biotec.de/, last visited: 06.11.2020
[25] Biotec, BIOPLAST 400, https://www.biotec.de/bioplast/bioplast-400 , last visited: 12.11.2020
[26] Phone Interview with Biotec employee, (12.12.2020), 14:19, interview conducted by author
[27] Ibid.
[28] https://www.biotec.de/bioplast/bioplast-400

Table 1: Properties of BIOPLAST 400[29]

PROPERTIES

Parameter	Target value	Unit Test	Method
Pellet size	3.0	mm	Caliper gauge
Density	1.28	g/cm³	EN ISO 1183-1/A
Bulk density	800	kg/m³	EN ISO 60
MFR (190°C, 5 kg)	1.74	g/10 min	EN ISO 1133
Moisture content	< 0.3	weight-%	BIOTEC test directive

PROCESSING

BIOPLAST 400 was designed for use in blown film extrusion.

For further processing information, please refer to our specific guidelines.

MECHANICAL PROPERTIES OF BLOWN FILM* MADE OF BIOPLAST 400

Parameter	Typical value	Unit	Test Method
Tensile strength MD	25	MPa	EN ISO 527-3
Tensile strength TD	24	MPa	EN ISO 527-3
Elongation at break MD	350	%	EN ISO 527-3
Elongation at break TD	550	%	EN ISO 527-3

(*blow-up ratio: 3.5; die gap: 1.05 mm; die diameter: 60 mm; thickness: 20 µm)

The case study shows that potato starch can be used to commercially produce biodegradable bio-based plastics. If this starch is used from potato residues such as potato peels, which are not edible, an additional value chain is added.

Overall potato starch is mostly used in packaging, as that is where bio-based plastics are needed the most in order to replace conventional plastic. Whilst corn starch is mostly used to produce bio-based plastics, Biotec exemplifies that biodegradable bio-based plastics can also be made from potato starch. The determining factors being the availability of the type of starch and the type of product being produced.

6 Implementation Model

Potato starch can be used for biodegradable bio-based plastics both theoretically and practically. Currently, corn starch is preferred over potato starch as a renewable resource. As more and more research is being conducted, the prices for the starch modification is likely to decrease, making starch an even more suitable resource to use for the production of biodegradable bio-based plastics.

This report highlighted that potato starch can and is being used to produce biodegradable bio-based plastics in Germany. Available technology being the main factor, as Germany is able to commercially produce bio-based plastics from potato starch. In Mecklenburg-Western Pomerania, one of two federal states with access to the Baltic Sea, there were 12,400 hectares of potato acreage in 2018.[30] Whilst this is significantly smaller than the potato acreage in the federal states of Lower Saxony and Bavaria, this is still a relatively big compared to all other federal states. Research institutes such as the Fraunhofer Institute offer research that is very industry oriented, thus Germany is a driving force of innovation. Hence, the model is heavily reliant on affordable and readily available technology.

Reiterating, potato starch is a feasible renewable resource to be used for the production of biodegradable bio-based plastics in Germany.

[29] Biotec, BIOPLAST 400, http://www.biotec-group.de/BroschBioplast400_EN_Web.pdf , last visited: 12.11.2020

[30] Union der Deutschen Kartoffelwirtschaft e.V. (2020),"Kartoffelanbauflächen nach Bundesländern in 1,000 ha", https://unika-ev.de/unika/Statistiken/Flaeche_BL.pdf , last visited: 10.11.2020

7 Conclusion

In conclusion, this cross-border implementation model report discussed bio-based plastic made from potato starch in Poland and Germany. Firstly, biodegradable and bio-based plastics, as well as bio-based plastics produced from potato starch, were discussed. Importantly, biodegradable bio-based plastics are plastics produced from renewable resources. Secondly, the findings of the pre-feasibility study of the Gdansk University of Technology were outlined. Thirdly, the use of bio-based plastics in Germany and the case study of Biotec were presented, arguing that biodegradable bio-based plastic from potato starch is a feasible model to be implemented in Germany, as it has already been implemented at the commercial level.

LEAF PROTEIN CONCENTRATE PRODUCTION FROM BROCCOLI AND KALE LEAVES

COLOURBOX1065531

REPORT

IMPLEMENTATION MODEL – KALE AND BROCCOLI PROTEIN CONCENTRATES

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Project title	Bioeconomy in the South Baltic Area: Biomass- based Innovation and Green Growth. For information on the project please check https://biobigg.ruc.dk/
Project acronym	BioBIGG
Work Package	WP5 – Implementation of agro-industrial value chains and biobased production in SMEs.

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Implementation model: Kale and Broccoli protein concentrates

In this report, an implementation model for an innovation case is presented, both in general terms and applied to a specific case at SLU, Skåne, Sweden. The model can thus be used as a blueprint for innovation development in a certain region, e.g. in the South Baltic region, or for cross-regional collaboration.

The basics of the model are based on the Innovation Program and the significant steps required to initially carry out the concept and verification phase, respectively. The next phases, i.e. the development and commercialization phase, will be outlined together with the earlier involved external partners and by a company management and board. In the last section, organisations for innovation in specific projects and for more strategic innovation work, are proposed.

1. Manual for the initial phases of innovation

1.1 Manual for the concept phase

The concept phase main objectives are to verify the following[1]:

1. Is there a market? Is the market large enough to motivate investment in time and resources to put a product/solution on the market?

2. Does the idea/research result solve the market's needs faster, better, cheaper, safer, more environmentally friendly than existing alternatives?

3. Is there any obstacle, patent / license that prevents further development of the idea?

4. Is it possible to make money on the idea?

The kale and broccoli case should initially evaluate which side streams can be of the greatest importance in order to identify a long-term profitable business model. Due to the project's many potential side streams and its possible need for further processing steps, several different potential markets and products need to be included in this initial mapping. From previous experience[2] it is suggested that the kale & broccoli case will not be profitable just by extracting proteins. Instead a circular and bio-based business model needs to be evaluated including a number of side-streams and potential products from these streams.

Hence, to meet the main objectives in the concept phase, a technical analysis and a market analysis should be performed and from this a risk estimation for the future project made. To fund the initial analysis, public or university support organisations and innovation bodies can be helpful. At SLU, funding for these steps could be received through the Innovation office, SLU Holding.

[1] The steps refer to the innovation model in ”Fokus Affärsutveckling” by Innovationsbron (Swedish only).

[2] See PlantProteinFactory.se

The market analysis has to be done with the regional conditions in mind, e.g. the supposed market and production facilities. One should study the existing markets; the size, pricing and which players currently are in operation, to find potential competitors and/or partners.

The first step in the technical analysis is a news review (patent novelty search). It is performed to identify potential patent barriers and opportunities, respectively. The degree of maturity in the future process technology is important to consider. If the process technology is already well established, the risk is lower. If the process technology is new, unreliable and poorly optimized, the risk is higher.

After the technical analysis and market mapping, it is possible to get a rough estimate of the risk in the project, if there is a business potential, what are the main obstacles to resolve and what strengths future products can have in comparison with today's solutions.

A further result of the concept phase is a list of potential SME-actors that could be interested in investing both time and money in a future verification project. Potential actors appear in the "Patent novelty search", from both innovators and owners of patents, and in the market mapping. The list of potential collaboration actors is helpful when setting up an organisation for innovation, see next section.

1.2 Manual for the verification phase

When the technical analysis and market mapping have shown a business potential and market need, identified potential risks and attracted SME-actors to be involved, it is time to enter the verification process. This process is included in the first phase of the Innovation program "Concept/verification" in Fig. 1). Its main objectives are the following:

1) **Identify potential products**, make prototypes and let the SME-market actors evaluate future potential products.
2) **Evaluate different business models** and recommend the most suitable business model for the case.
3) **Identify potential process** related costs and potential future prizing.
4) **Identify potential distributors** and try to receive a "Letter of intent" for further collaboration and market launch.
5) **Specify potential large-scale production** facility and future investment need.
6) **Identify potential patentable** process- and product related inventions to strengthen the business case.

If the verification process is successful, it will result in an Investment memorandum for future investors. The purpose is to propose a path forward to build a business, and to offer an opportunity to be part of the journey as partners/owners. The Investment memorandum should at first be offered to the partners within the project team and second to the Investment board (see Fig. 1) and external SME´s.

2. Set up an organization for innovation

2.1 For the specific project

The analysis and work in the concept and verification phases are driven by a project team, led by an appointed project manager. The team should involve researchers with insight in the research results, the technical aspects and with an interest in commercialisation. It is possible to include external actors to cover the need for market understanding and entrepreneurial drive already in the initial phase. Innovation support organisations can be helpful discussion partners in the formation of a winning team.

Due to the complexity of the kale & broccoli protein concentrate business model it is important to involve many perspectives, hence several different SME- actors early in the verification process. In the Innovation program for kale & broccoli protein concentrates we have mapped some regional actors that could be involved (see Fig. 3). To be able to transfer knowledge to other regions, the different roles have been specified as a guide to find regional partners. When contacting potential partners, it is recommended to create a proposal including IPR status and market analysis, and a draft of how a possible verification project should be carried out.

2.2 For strategic research and innovation

2.2.1 The visionary and strategic

For future successful innovation programs and for successful cross-border implementation, we recommend the establishment of boards with a long-term and holistic approach to research and innovation in the region, linked to the university – so called “Visionary board” (VB). The majority of the members of the VB should consist of SME-actors from several different market segments and countries, along with participants from the university. Several different VBs may be required to set clear visions and goals linked to specific market challenges. For example, one can either establish a VB focusing on "circular and bio-based business models" or e.g. "future animal feed", "plant-based cosmetic ingredients" and "plant-based meat". The clearer and more well-defined the VB's mission are, the greater the likelihood of a successful innovation program and involvement of external SME- actors will be. The VB will create a “pull-effect” through the future Innovation programs.

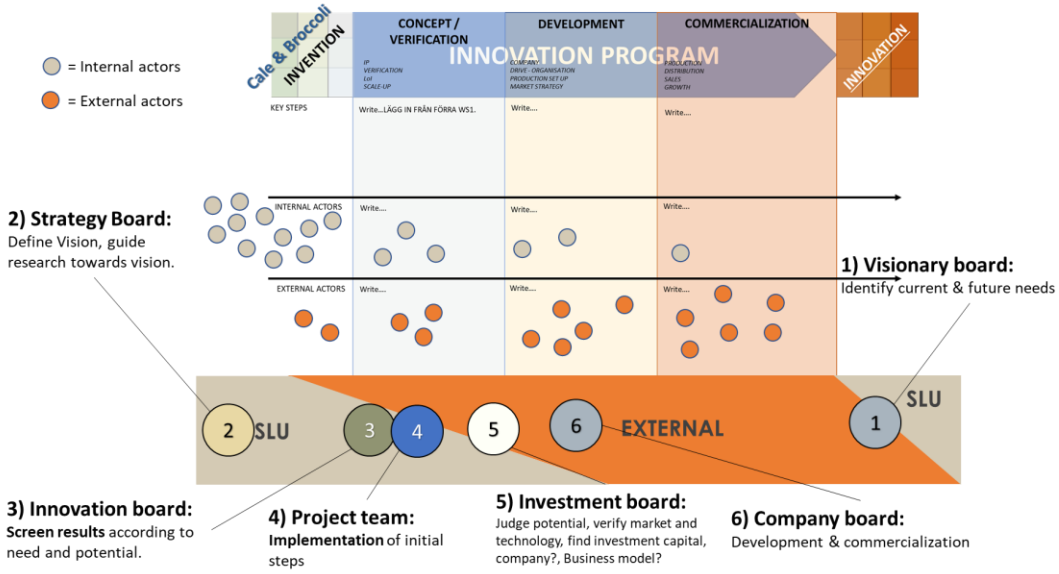

Figure 1. Schematic picture of the innovation organisation; teams, boards and their constitution of internal and external actors

Fig. 1 shows an example of the relations between the VB and the "Strategy board" and how other boards and teams are connected. Initially, external actors (SMEs, the orange dots) are identified for all different phases and secondly the respective boards are established. The grey dots represent internal actors at SLU. The share of external actors will increase in sequences of commercialization and establishment of company.

The "Strategy board" should include external representatives. Its task is to propose research and innovation strategies that meet both the future needs of new circular and bio-based solutions and the academic requirements for publications and skills-enhancing activities such as Licentiate and Doctorial examinations. As described above, the future needs are proposed by the VB, e.g. using back-casting according to the ABCD-method[3]. Fig. 2 describes a proposed implementation model for research and innovation strategy, that consider both “research to research” and “research to business” paths, to increase the level of utilized research results[4]. A key tollgate is the “Innovation board” with the purpose to choose the path for the research results – should they be published or used for building research capacity “research to research” or do they have potential for new innovation “research to business”?

[3] See report Innovation Program for Kale and Broccoli protein concentrates and references therein.

[4] See report ”Business Model Manual – Example 4; Research-based consultants”

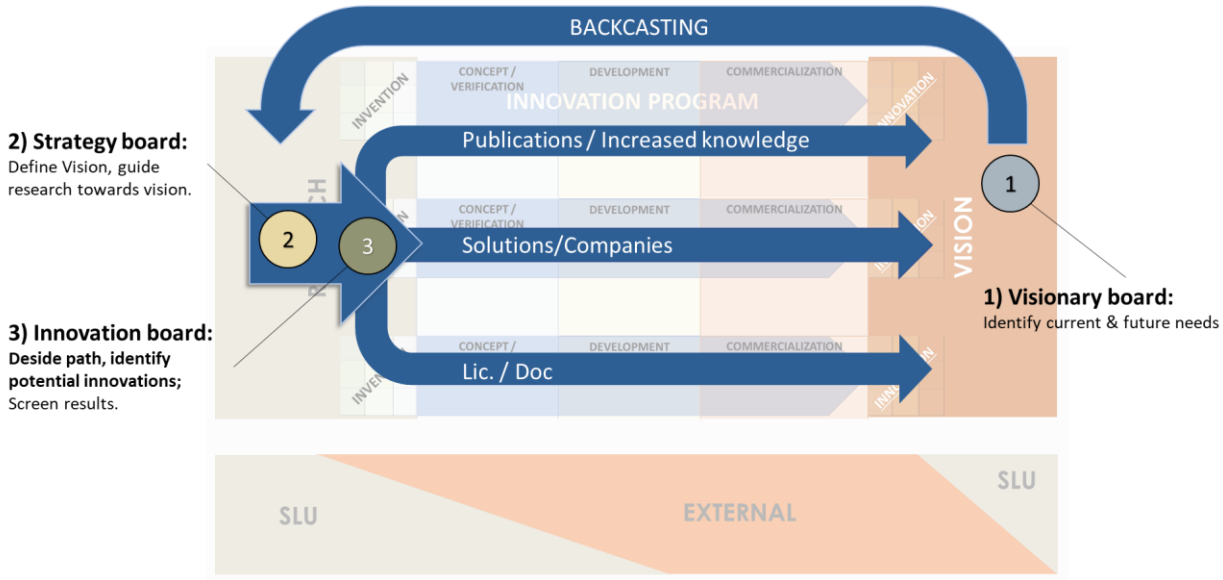

Figure 2. The strategic research and innovation paths

By implementing an organisation for research *and* innovation, the sustainable business solutions will be implemented more quickly, and it will increase knowledge and hence number of publications that will benefit society.

2.2.2 Action plan for strategi research and innovation organisation

For successful implementation, increased cooperation between the countries in the South Baltic region and active involvement from SMEs in innovation projects, we recommend the following action plan:

1. Identify potential external SMEs in the South Baltic region and their future needs.
2. Establish a Visionary board with a well-defined vision to create current and future market needs.
3. Establish a Strategy board within the academia.
4. Establish an investment board for future project funding.
5. Use the back-casting method in the Visionary board to visualise current and future needs. Set strategies and goals for research-based organisation[5] (Research to business) within the Strategy board, and screen potential research projects according to the defined goals and strategies.
6. Establish an Innovation board with the purpose to screen innovation and business potential of the achieved research results. The Innovation board should have at least 50% external members and represent market needs (SMEs), venture capital (usually public organizations like the Innovation office SLU Holding) as well as academia.
7. Research results are screened by the Innovation board according to the manual of the concept phase (see Sec. 1.1.). If the research results fulfil the objectives according to the concept phase check list the Innovation board should set up a project team and the research results enters the innovation program. The next steps for the project are according to the verification phase manual (Sec. 1.2).

[5] Ibid.

8. The project leader should recurrently report the project progress to the Innovation board as well as an Investment board to prepare for possible establishment of a company and future funding needs.

In Fig. 3 below is shown how an organization and process for the potential Kale and broccoli protein concentrate innovation program could look like.

ORGANIZATION for Innovation				
CURRENT SITUATION	**CONCEPT/ VERIFICATION**	**DEVELOPMENT**	**COMMERCI-ALIZATION**	**VISION**
Strategy Board: Define Vision, guide research towards vision. **Potential members:** Faculty: Department: Research group: External Academia: Research funding organizations:	**Innovation board:** Screen results according to need and potential. **Potential members:** - SLU - Manufacturing process companies (SME) - End-product producers/ distributors (SME) - Potential funding organizations. **Example:** SLU Department, SLU Holding, Tetra Pak, Alfa Laval, Lantmännen, Food Hills, Food for Progress, Ineko-gruppen, Gasum, Region Skåne, Vinnova.	**Investment board:** Judge potential, verify market and technology, find investment capital. **Potential members:** Innovation office, SLU Public funding companies Private funding companies SME-partners within the project team **Example:** SLU Holding Almi, Vinnova, RISE Connect Sverige, Venture capital funds SME-partners Gasum Tetra Pak IKEA	**Company board:** Development & commercialization **Potential members:** Project team Future owners of established company (SME).	**Visionary board:** Identify current & future needs, set overall visions and goals: **Potential members:** - Academia (SLU) - Manufacturing process companies (SME) - End-product producers/ distributors (SME) - trend & market analysing firms.
	Project team: Implementation of initial steps. **Potential members:** - Researchers at SLU - Project leader - Process- & technical expertise (SME). - Product development expertise (SME). - Market and sales expertise (SME). - IPR consultant - Business advisor			

Figure 3. Steps and actors in the innovation process for the case Kale and Broccoli protein concentrates.