Business cases for bio-based value chains in the South Baltic Region June 2021

Business cases for agro-industrial value-chains and biomass-based production in the South Baltic Region

June 2021

Authors
Tyge Kjær, Rasmus Nør Hansen, Roskilde University, Denmark
Thomas Prade, William Newson, Faraz Muneer, Sven-Erik Svensson, Eva Johansson, Antonio Capezza, Swedish University of Agricultural Sciences (SLU), Sweden
Carl Jonson, Carl Jonson AB, Helena Tillborg, Tillborg Wolf Consulting AB
Valerie Sartorius, Lena Huck, Jennifer Nitzschke, Martin Behrens, Agency for Renewable Resources, Germany
Beate Cuypers, Max Mittenzwei, University of Greifswald, Germany
Dariusz Mikielewicz, Roksana Bochniak, Aleksandra Gołąbek, Paweł Dąbrowski, Teresa Żurek, Barbara Wojtasik, Grzegorz Rzepecki, Aleksandra Plit, Gdańsk University of Technology, Poland

Please cite the reports as: Prade, T., Newson, W., Huck, L., Muneer, F., Svensson, S., Johansson, E., Capezza, A., Bochniak, R., Gołąbek, A., Sartorius, V., Nitzschke, J., Behrens, M., Cuypers, B., Jonson, C., Tillborg, H., Dąbrowski, P., Kjær, T., Mikielewicz, D., Mittenzwei, M., Żurek, T., Wojtasik, B., Rzepecki, G., Plit, A., and Hansen, R., (2021). *Business cases for innovative agro-industrial value-chains and biomass-based production in the South Baltic Region* - BioBIGG

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 innovative agro-industrial value-chains and biomass-based production in SME's
Deliverable	D5.3 – Report on implementation of innovative value-chains in the participating regions.
Copyrights	All rights reserved to the partners in BioBIGG. Copyright © 2019 BioBIGG
Published by	BioBIGG

Executive summary

The implementation of new and sustainable bio-based value-chains presupposes document-tation of a potential profit generated by using a selected feedstock. This is a key driver for the mobilization of SME involvement and investments in the development of a sustainable bioeconomy. Initial financial assessments often contain a cost-benefit analysis related to the collection, processing and/or conversion of low-cost biological resources into higher value products in a cascading manner. This also indicates how financial considerations, energy-use and resource efficiency (i.e., marketable outputs) is interconnected via the bioeconomy.

The aim of this report is to evaluate the economic feasibility or marketable value of 16 bioeconomy concepts developed by the BioBIGG project (For more information see the reports: *Pre-feasibility assessments for innovative bio-based value chains in the South Baltic Region* on the homepage: https://biobigg.ruc.dk). The business cases are divided into four sectors: agriculture, forestry, agro-industrial and households. It is envisioned, that these cases are used to further support the financial justification of the concepts to relevant SMEs in the project regions.

Table of Contents

Agricultural sector

DIGITAL STRAW BALE MANAGEMENT IN DENMARK

COLOURBOX47342830

I. Authors note

This report (i.e., report 1) is part of three reports introducing a technological concept for an automated management of straw bales in large-scale supply chains.

Report 1 presents a pre-feasibility assessment of the technological concept. This entails an introduction to the technological concept based on best available technologies (see innovation program), followed by a preliminary cost-benefit analysis.

Report 2 presents a framework for an innovation program for the development of the technological concept from Technology Readiness Level 2 to TRL5. This entails a seed-money project and R&D-project.

Report 3 presents a potential business case for the commercialization of the technological concept in a supply chain. This entails value propositions on customer satisfaction and cost minimization effects related to the technology.

The reports have been written by Rasmus Nør Hansen, Roskilde University (Department of People and Technology) as part of the BioBIGG project under the Interreg South Baltic program 2014-2020.

II. Background information

The following paper will address how the technological concept can be converted into a business case. This is not a simple task compared to other bioeconomy concepts focusing on production processes for biological resources. The financial value of logistical concepts is more complex to define, as the concept cannot be directly related to production processes, output and revenue. Logistical value is instead defined by the ability to generate incremental optimizations to an operational and/or financial environment.

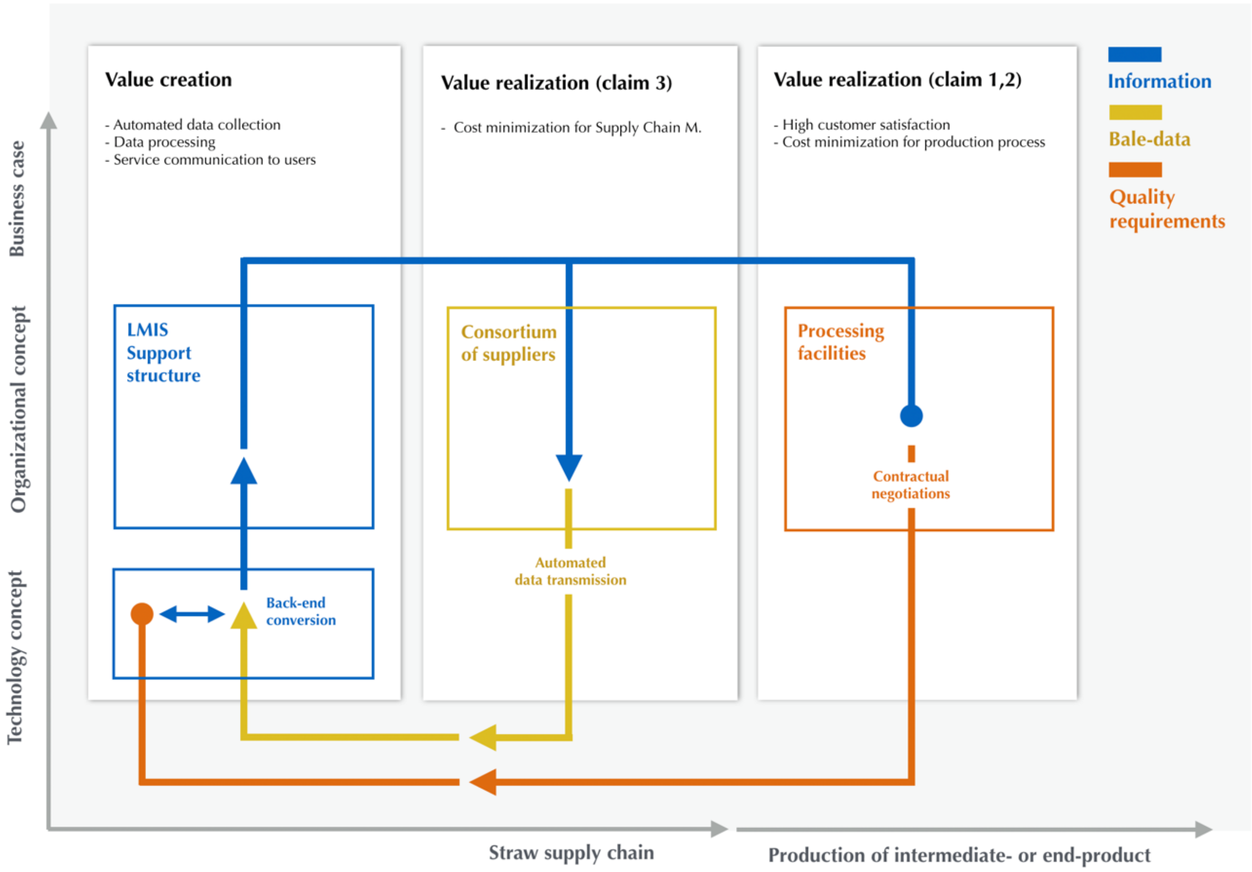
The total profit for a supplier is defined by revenues from selling straw and associated costs for meeting the demand. From this perspective, the LMIS can be viewed as a support structure for the development of a hybrid business strategy for suppliers, due to three claims:

- **First claim:** customers (i.e., processing facilities) will attach more value to identifiable bales delivered via the consortium, than undifferentiated bales delivered by multiple suppliers (i.e., increased revenue via the consortium).
- **Second claim:** processing facilities will favor consortium straw and related services over other feedstock sources delivering same goods, at a comparable or higher price.
- **Third claim:** systematic and automated management of bale-data reduces variable costs related to supply chain management (connected to claim 2).

This also shows how value creation and realization is asymmetrical; i.e., it is generated by the LMIS, but realized by suppliers and processing facilities. Or in other words; the support structure ‘doesn't convert agro-waste into valuable products within its internal boundaries’ (Donner et. al. 2020). The valuation is instead related to its ability to create value for another organizational structure.

An overview of the business strategy is presented in fig. 1 (see next page). Bale-data and quality requirements is converted into useful information (i.e., services) and, as a result, generates value for either a supplier, processing facility or both.

Figure 1: Converting the technology concept into a business case



1. Differentiation as a business strategy (claim 1,2)

The ability to stand-out in a generic supply market is a fundamental competitive advantage. This is referred to as a differentiation strategy (Porter, 1994). Within this framework, product development should not only be defined by the generic product (i.e., bales), but also by certain expected and unexpected features related to the product (i.e., material quality, delivery, supply stability, flow of information and so forth).

According to Levitt (1980) market suppliers 'seek competitive distinction via product features—some visually or measurably identifiable, some cosmetically implied, and some rhetorically claimed by reference to real or suggested hidden attributes that promise results or values different from those of competitors' products. But what they "sell" is the claimed distinction of their execution'(no page). The distinct value of the LMIS to the processing facilities, can be divided into four interconnected categories; High feedstock homogeneity, identifiable bales, supply chain transparency and Chain-of-Custody.

1.1. High feedstock homogeneity

Material quality refers to the value of the generic product and is currently defined by the incineration sector in relation to composition (moisture content), state (contamination), and dimension (form and size). Bale-loads are either rejected, partially rejected or approved at the processing gate by sampling 1-3 bales in accordance to these contractual requirements.

In a cascade-oriented supply market, contractual requirements will be more relative and dynamic. For example; low moisture content is a key variable in the production of biofibers (for composites) or incineration, as energy is needed to evaporate the moisture. In other instances, such as for biogas or chemical extraction processes, high moisture content will be less detrimental or even support the utilization purpose. Chemical composition or low contaminants might also be key variables for extracting building blocks or producing bio-composites, but less important when incinerating straw.

The distinct financial value of the LMIS (on material quality) is primarily related to automated sorting; i.e., optimization of supply/feedstock homogeneity in accordance to demand-side requirements (see pre-feasibility study for elaboration). A high feedstock homogeneity reduces production costs for processing facilities in relation to chemical-, water and/or energy usage. Processes will simple be more streamlined and interlinked with the desired input (i.e., sorted bales). As a result, this will also increase marketable output(s) and thereby revenue for processing facilities. Essentially, the service creates a double financial effect (i.e., cost reduction and increased revenue). The effect is of course relative to the process and material quality needed, but is especially expected to be useful for continuous biological and/or chemical treatment processes extracting (1) small amounts of high value components/building blocks from (2) large input quantities.

1.2. Identifiable bales

'On-the-spot' identification of bales is closely related to the abovementioned. Straw is to a high degree a generic product (in visual terms). This means that it is difficult for processing facilities to differentiate between approved bales when they are placed in a stack (i.e., the internal inventory). Moisture content of each bale can be sampled by a manual spear, but beyond this, material information is limited to sporadic personnel knowledge. RFID-filaments attached on bales thereby creates an opportunity for processing facilities to further the optimization of the production processes according to bale properties.

As already explained in the pre-feasibility study, the technological concept primarily focuses on simple sensory measurements (moisture and weight) and non-sensory data (baling time, straw type, location etc.). This should however only be viewed as the beginning of the commercial development related to data-driven product optimization.

The vision is to generate a linkage between bale properties and production data via the LMIS, in order to generate a more complex understanding of cause-and-effect for bale properties in relation to the commercial production output and/or production related bottlenecks. The output from certain high value processes can potentially be affected by several undiscovered interconnections to bale properties (composition), such as straw sort, location, baling time, moisture content, soil type and so forth. In order to establish these linkages, production data and historical bale-data needs to be processed via Machine Learning (ML) intergraded into the LMIS over time. Findings can thereafter be used for re-negotiations on contractual bale delivery in relation to existing or new quality requirements for processing facilities. From a more inter-organizational perspective, such a data-sharing processes will also intensify the collaboration between suppliers and the processing facilities.

1.3. Supply chain transparency

Supply chain transparency refers to the process of communicating material flows and quality in the supply chain before delivery (i.e., inventory on field, intermediate storage and reserves). Transparency should not be understood as absolute, but based on certain agreements between suppliers in the consortium and the processing facilities. Or in other words, each supplier has data-ownership over their own supply data in the LMIS. Limited transparency starts by creating an overview of the total supply from the consortium to a processing facility (i.e., each supplier's inventory data will be anonymized) and can be intensified to include differentiated supply data from each supplier, and so forth.

From the perspective of processing facilities, the overview can be used by personnel to adjust processes to expected variations in feedstock quality (within a certain degree) and to plan mitigation of supply shortages in a timely manner. Essentially, it is a question of response time. The near-real time overview creates a longer response time for processing facilities, whereas unexpected variations in feedstock can have a major impact on energy-, chemical or water-usage.

Collaborative supply security and timely information, also increases the competitiveness of straw towards other feedstock sources. In higher value markets, low-cost feedstocks will not necessarily create the highest demand. Accepting a higher feedstock price for a stable supply is often a financial trade-off for processing facilities (such as imported wood-pellets over local bales for incineration). timely information on supply and quality (via the LMIS) will thereby in itself become a valuation parameter.

1.4. Chain-of-Custody

Chain-of-Custody (i.e., CoC) refers to the documentation of a biological resource, as it moves through a supply chain. This often entails a systematic recording of sustainability data on origin, transportation and conversion of feedstocks to intermediary- or end-products. Data-sources are thereafter analyzed to verify certain criteria within a voluntary or non-voluntary certification scheme.

According to Nyström et. al. (2020) the demand for such processes is expected to increase over the coming years. For example, Langer et. al. (2017) conducted a systematic review on the effect of certification schemes on revenues for agricultural products. The findings showed an increase of 11% in revenues (via sales) of certified products investigated. This study was conducted on cases in low- to middle income countries, and is thereby not directly applicable for price-setting in DK, but nevertheless still indicates a positive conversion of certification schemes into a financial value.

The sustainability data needed for certifying straw is expected to be accessible via the systematic recording of bale-properties in the LMIS. Hereunder, origin of bales can be defined in accordance to field numbers. Transportation of bales can be defined in accordance to inventory overview and routes (i.e., distance between field numbers, intermediate storages and delivery location of Bale-IDs). These data-points can thereafter be interlinked by the processing facilities to their respective production data. This process entails a mass-balance approach (MB) to CoC-modeling, as bales are mixed and processed before output (i.e., untraceable in bale-form). MB can be defined as a methodology focusing on balancing inputs (i.e., bales) with outputs (i.e., intermediary or end-products). CoC and MB is thereby closely related to section 1.2.

It should also be mentioned, that the need for internal certification schemes was discussed by the DSA (Danish Straw Association) in 2020 and 2021, as a response to large incineration plant in DK favoring certified feedstocks (i.e., woody biomass) over non-certified feedstocks (DH, 2020). At the yearly DSA-meeting in 2020, the chairman proposed to clarify how to certify straw as a sustainable feedstock. This thereby indicates how the focus on bale-data is increasingly transformed into a competitive business strategy for differentiation.

2. Supply cost minimization as a business strategy (claim 3)

A cost minimization for a supplier has two purposes; (1) to increase profit margins by reducing costs or (2) to create the competitive advantage of reducing straw prices below competitors (i.e., cost leadership). The latter can be used as a strategy for protecting and increasing a given market share. It is not possible to conclude whether the effect of the LMIS would minimize costs below potential supply competitors in a feedstock market (i.e., straw by other sources, woody biomass, byproducts, residuals or biowaste).

However, certain assumptions can be made about how suppliers within the consortium will have reduced prospective costs compared to other suppliers (delivering the same goods and services). Cost minimizations generated by the system can be divided into the following sections: administrative costs, bale-rejection and substitution procurement.

2.1. Administrative costs

Administrative costs are defined by working hours spend on data-driven bale-management (i.e., documentation and usage of bale-data for logistical purposes) by suppliers, farm personnel, drivers and/or external consultants. Working time is thereby context-specific for each farm and difficult to quantify in general terms (consortium-level). If work is conducted by a supplier, cost should be quantified in relation to (other) economical farm activities not completed as a result of the bale-management. If work is conducted by employees, additional costs should also be assigned to hourly wages. In the following sub-analysis, costs are quantified in relation to farming personnel.

The cost minimization of the LMIS depends on what type of management system is substituted at the farm. This is essentially defined by the existing degree of automation. The administrative cost for an automated data-management of 5.000 tons/year (via the LMIS) is expected to be around 0,10 € pr. ton. The same process managed by a (dominantly) manual data-driven system can be estimated to be around 1,9 € pr. ton.

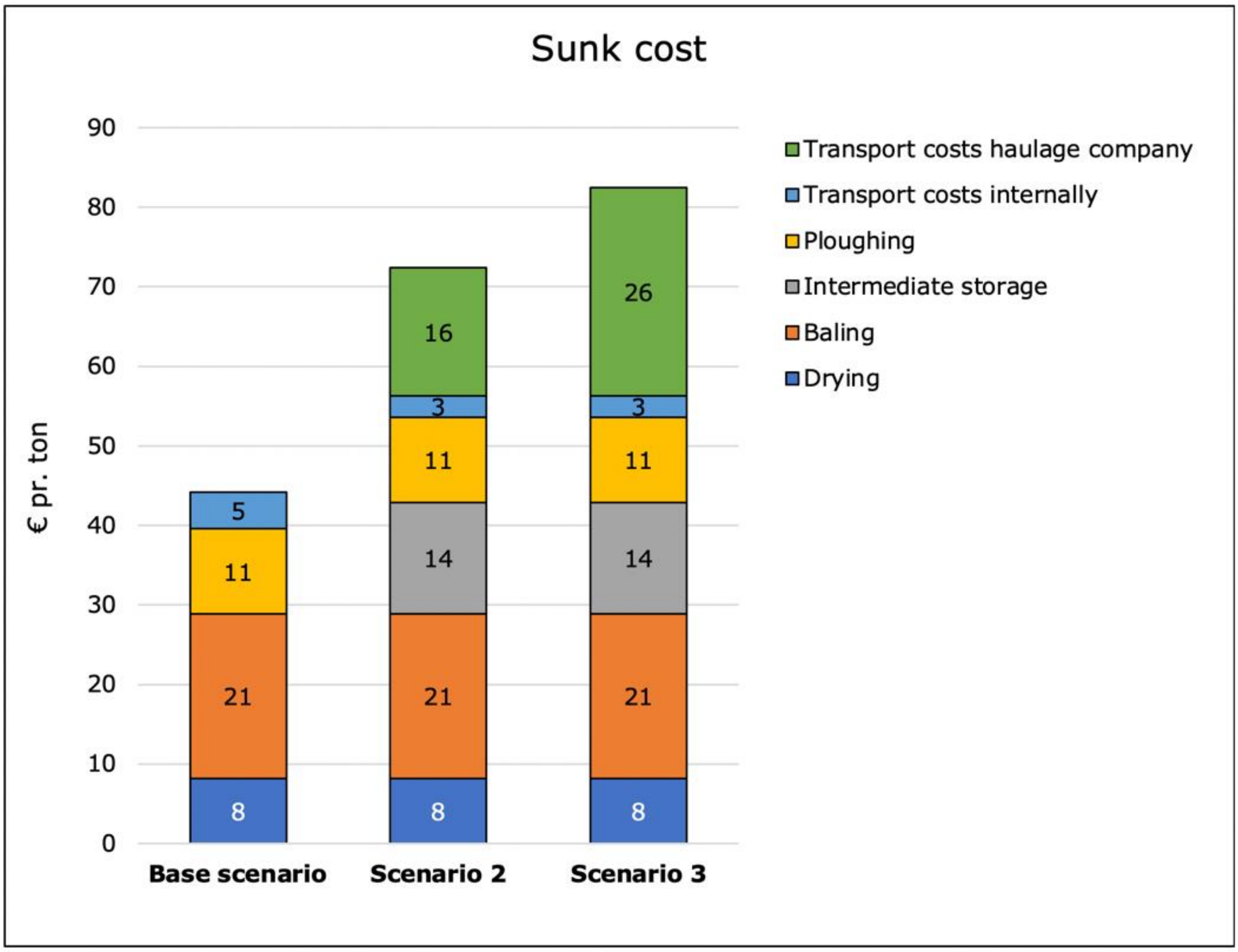
The biggest difference in time/costs is expected to be related to time spend by personnel on manually identifying bales for intermediate sorting (see pre-feasibility study for elaboration). This is estimated to take 303 hours, at an annual cost of 8.787 €. Identification by the LMIS is only estimated to take 13 hours for personnel, at an annual cost of 377 €. Calculations and assumptions are elaborated further in appendix 1. An automation process via the LMIS is assumed to have a considerable financial effect on bale-related administration within a cascade-oriented market.

2.2. Bale rejection

Bale rejection, via the LMIS, is conducted as an (on-field) pre-sorting process of identified bales with poor material quality (see pre-feasibility study for elaboration). Field rejected bales represent a material quality not accepted by any of the processing facilities related to the consortium. The bales should instead be used internally at the farm (ploughed, used for bedding and so forth)

Sunk costs, related to bale rejection, increase when bales move through the supply chain. The ability to mitigate costs by regulation the material flow in early stages of the supply chain thereby has a financial value. This can for example be quantified by calculating the difference in sunk costs between a field rejection and a rejection at the processing facility. In relation to this, three cost-scenarios have been calculated (see also appendix 2 – 4). The functional unit is 1 ton of rejectable straw. All sunk costs associated directly and indirectly to the functional unit are included.

Figure 2: Sunk costs for bale rejection through the supply chain



Base scenario: The straw (1 ton) is rejected as part of the field collection via the LMIS. The supplier leaves the bales on-field and returns to plough the straw before the next harvest operation. The distance between the farm and the field is 5 km. Scenario 2: the straw (1 ton) is transported to the farm, stored and delivered to a processing facility by a haulage company. However, the straw is rejected at the gate, returned to the farm and ploughed. The distance between intermediate storage and the processing facility is 20 km. Scenario 3: same conditions as in the second scenario. However, the entire bale-load is rejected at the gate (13 tons). The uncontaminated part of the load (12 tons) is transported by the haulage company to another lower value processing facility in the opposite direction of the farm. The additional distance is 10 km.

As figure 2 shows, additional sunk costs for scenario 2 and 3 is related to intermediate storage and external transport by the haulage company. The total sunk cost for the base scenario is 44 € pr. ton. The total sunk cost for the second and third scenario is 72 € and 82 € pr. ton. The on-field pre-sorting of bales (i.e., base scenario) would therefore reduce sunk costs respectively by 28 € and 38 €. The yearly membership fee is expected to be 3.807 €[1] for a supplier delivering an annual

[1] See pre-feasibility study (appendix 2b): member fees are 1.269 € pr. TCU * 3 balers = 3.807 € pr. year.

amount of 5.000 tons. The cost-saving would thereby cover membership fees at an on-field rejection rate of 2,7 % and 2,0 %.

2.3. Substitution procurement

Unforeseen supply shortage often increases supplier costs, as (substitution) bales needs to be procured via the spot-market. This market mechanism is expected to intensify for high value markets in a cascade-oriented supply system, as the delivery of the right amount, at the right time, will be a restrictive contractual obligation for most suppliers (compared to straw for incineration).

In periods of contractual shortages, spot-prices are expected to increase considerably and often above contractual prices, resulting in additional costs for suppliers with stock-outs. This can be exemplified in the following way: A supplier has over-estimated a future delivery of 5.000 tons and has not reacted quickly enough to mitigate stock-outs. The supplier therefore needs to procure 250 tons via the spot-market to cover a minimum contractual deliverance (i.e., 95 % of 5.000 tons). The average contractual price is between 90 € - 100 € pr. ton. However, the spot-price is 121 € pr. ton, resulting in an additional substitution cost of 5.250 € – 6.500 €[2].

Mitigating the risk of supply shortages can thereby be viewed as an indirect cost minimization strategy, which is operationalized through solid inventory management and data-driven stock projections. Within existing inventory systems, bales are sometimes measured by a weight sensor in the pressing chamber and manually transferred to the internal system at the farm. In other instances, stocks are based more on intuitive knowledge and delivery data from past seasons (i.e., historical data). Such inventory systems are expected to increase the risk of supply shortages in cascade-oriented supply markets due to limited systematic differentiation of quality and/or locational GPS data.

This can also be re-formulated; Inventory supply systems must autonomously distinguish between bales in terms of certain properties (i.e., weight, material quality and location) within the digital and physical world. This function is an integral part of the LMIS, as identified bales are digitally assigned to a location as secured, when transferred to an intermediate storage (see pre-feasibility study for elaboration). The autonomous data-collection creates a complete overview of quality categorized straw-reserves (collected in prior years), secured bales (upon collection) and historical bale-data. As a result, future supply shortages are minimized by data-driven inventory management and contractual projections on future supply. Shortages will of course still occur, but the risk is expected to be decreased considerably.

[2] 121 €/t – 100 €/t = 21 € * 250 t = 5.250 €
121 €/t – 95 €/t = 26 * 250 t = 6.500 €

3. Conclusion

The technological concept can be viewed as a support structure for the development of a hybrid business strategy - focusing on increased revenues and reduced supply chain costs for consortium suppliers. Optimizations are related to the asymmetrical processing and utilization of bale-data throughout the value chain via the LMIS. This systematic interconnection of suppliers and processing facilities, is expected to generate a strong market position and revenue stream for consortium suppliers.

In fig. 3 an overview of the perceived value of the concept is divided into a differentiation strategy and a cost-minimization strategy. The overview summarized how value is created by the technological concept/LMIS and realized by either processing facilities or suppliers.

Differentiation as a business strategy	
Processing facilities	
Business strategy: Consortium suppliers has a competitive advantage over other suppliers, as they deliver high quality bales in a very stable manner, while also offering key supply information to customers (i.e., processing facilities and end-users). This gives access to new high value supply markets, while also protecting and/or increasing market shares in existing supply markets (i.e., incineration, bedding, biogas etc.)	
Technology concept/LMIS	**Business case (value realization)**
Development of clustering algorithms: Sorting procedures integrated into supply chains	**High feedstock homogeneity:** Reduced production costs for energy, water and/or chemical usage for processing facilities
Development of attachment procedure for RFID-filaments in baler via supply roll: RFID-filament on binding material upon delivery	**Identifiable bales:** Increased marketable output due to accessible information on material input
Development of clustering algorithms: Inventory overview of bales in intermediate storage before delivery	**Supply chain transparency:** Reduced production costs related to unforeseen changes to input (amount or material quality)
Development of cloud-based data storage: Recorded data on bale-properties, location and transport	**Chain-of-Custody:** Increased revenue for intermediate- or end-product via sales, due to verifiable and certified feedstock use by facilities.

Supply cost minimization as a business strategy	
Straw suppliers in consortium	
Business strategy: Reduce supply chain management costs for consortium suppliers due to data-driven, near-real time and 'on-the-spot' accessible information related to material flows. This increases supply revenues, while also creating a competitive advantage for consortium suppliers in supply markets with high price-competition (i.e., prices can be reduced below competitors, due to reduced supply costs).	
Technology concept/LMIS	**Business case (value realization)**
Cloud-based data storage, clustering algorithms: Automated collection, processing and transmission of bale-data	**Automated administration of bale data:** Reduced administrative costs related to the management of bales for multiple processing facilities
Clustering algorithms: Sorting procedures in supply chain	**Reduced risk of bale rejection due to low relative material quality:** Reduced sunk costs related to management of rejected bales throughout the supply chain
Clustering algorithms: Inventory overview of bales for delivery and intermediate reserves.	**Reduced risk of bale substitution due to data-driven forecasting of bale production:** Reduced costs related to substitution procurement via volatile spot-markets

As shown above, the business case is expected to consist of multiple incremental optimizations throughout the value-chain. In the pre-feasibility study (report 1) it has been assumed that the LMIS can increase profit for a supplier by around 12€/ton as a result of this hybrid business strategy.

Appendix 1: Administrative time and cost

Administrative costs are calculated by assuming time needed for data-related management of 5.000 tons of bales in multi-purpose supply chains (five chains). These are only estimations for further discussion. The work is assumed executed by farm personnel.

Labour cost pr. hour:		29 €/h		
Data-driven process (no LMIS):	**Method**	**Time used**	**Cost**	***Notes***
On-field data-collection:	Automated	1 h	29 €	[1]
Data transfer and processing - internal farm server:	Manual	8 h	232 €	[2]
Data communication to processing facilities (email):	Manual	13 h	377 €	[3]
Data-driven logistics information (bale identification):	Manual	303 h	8.787 €	[4]
Total administrative working time and cost:		325 h	9.425 €	
Data-driven process (LMIS):	**Method**	**Time used**	**Cost**	
On-field data-collection:	Automated	1 h	29 €	[1]
Data transfer and processing - internal farm server:	Automated	0 h	0 €	[5]
Data communication to processing facilities:	Automated	0 h	0 €	[6]
Data-driven logistics information (bale identification):	Automated	13 h	377 €	[7]
Total administrative working time and cost:		14 h	406 €	
	Cost minimization:		**9.019 €**	

Notes:
[1]: 32 days of on-field data management (turning tablet/LMIS on at start of baling operation.)
11 tons/h (bale capacity) * 14 h/day = 154 tons/day. 5000 tons/154 tons pr. day = 32 days
2 minutes starting up pr. day assumed. 2 min * 32 = 1 h.
[2]: Manual data transfer and assigning data in quality categories to server: 15 min pr. day
32 days * 15 min = 8 h.
[3]: Emails on inventory overview to processing facilities (daily updates) 4 min pr. day. pr. supply chain. Five supply chains. Estimated 20 days collection of bales. 20 days for delivery.
40 days * (4 min * 5 emails) = 10,6 h for inventory updating (i.e., intermediate, delivered etc.
[4]: 2 min. moisture spear (inserted 3 places on bale) and written on paper: 2 min. pr. bale
5000 tons/0,550 tons (bale weight) = 9.090 bales * 2 min = 303 h
[5]: automated process. No time by personnel
[6] automated process. No time by personnel.
[7]: Automated identification of bale upon pick-up and visual detection by driver: 5 s/bale
5 seconds pr. bale * 9090 bales = 13 hours

Appendix 2: Sunk cost analysis

Sunk costs related to bale rejection at different points in a supply chain

Material sunk costs	Base scenario	Scenario 2	Scenario 3	
Total amount of rejected straw:	**1 ton**	**1 ton**	**1 ton**	
Drying	8,2 €/ton	8,2 €/ton	8,2 €/ton	[1]
Baling	20,7 €/ton	20,7 €/ton	20,7 €/ton	[2]
Intermediate storage	0 €/ton	14 €/ton	14 €/ton	[3]
Ploughing	10,7 €/ton	10,7 €/ton	10,7 €/ton	[4]
Transport sunk costs				
Total km driven by supplier	5,0 km	5,0 km	5,0 km	
Total km driven by haulage company	0,0 km	20,0 km	40,0 km	
Total transport and handling time	0,0 min	15,6 min	22,3 min	[5]
Transport costs internally	4,6 €/ton	2,7 €/ton	2,7 €/ton	[6]
Transport costs haulage company	0,0 €/ton	16,1 €/ton	26,1 €/ton	[7]
Total sunk costs				
Total sunk costs:	**44 €/t**	**72,4 €/t**	**82,5 €/t**	

Notes:

[1 - 4]: Cost based on Dansk Landbrugsrådgivning estimate (2005) slightly adjusted due to personel comment by consultant at SEGES.

[5]: See transport analysis for haulage and farm personnel (supplier)

[6]: See transport anaysis for farm personnel (supplier)

[7]: See transport analysis for haulage company

Appendix 3: Transportation analysis (supplier)

Expected transport and loading costs for farming personnel employed by a supplier

Transport costs:			**Notes:**
Service cost pr. hour	29 €/h		[1]
Service cost pr. min	0,5 €/min		
Loading time pr. ton	2 min		
Transportation conditions:	**Base scenario**	**Scenario 2-3**	
Bale weight:	0 kg/bale	550 kg/bale	
Capacity on trailer - bales	0 bales	24 bales	
Capacity on trailer - amount	0 tons	13 tons	
Avg. speed of tractor	25 km/h	25 km/h	
Transportation time pr. load:			
Distance (A)	5 km	5 km	
Distance (B)	0 km	0 km	
Total distance (A+B)	5 km	5 km	
Transport time (A):	12 min	12 min	
Transport time (B):	0 min	0 min	
Total transport time (A+B):	12 min	12 min	
Total transport time - Functional unit	0 min	1 min	
Bale handling time - Functional unit			
Storage - unloading	0 min	2 min	
Storage - loading	0 min	2 min	
Total bale handling time:	0 min	4 min	
Total time:	0 min	5 min	
Fuel cost			
Fuel consumption	0,6 l/km	0,6 l/km	[2]
Fuel price - Diesel	1,5 €/l	1,5 €/l	[3]
Fuel cost	4,6 €/t	0,4 €/t	
Total sunk costs:	**4,6 €/t**	**2,7 €/t**	

Notes:

[1]: The labour cost is specified as 4.400 € month/(37h*4)= 29 €/h for farming personnel

[2]: Personal comment by supplier and farm machine provider at Farmas A/S

[3]: Fuel price based on average price of diesel for tractors

Appendix 4: Transportation analysis (Haulage co.)

Expected transport and loading costs for a haulage company employed by a supplier

Transport costs:			**Notes:**
Service cost pr. hour	90 €/h		[1]
Service cost pr. min	1,5 €/min		
Loading time pr. ton	2,0 min		
Transportation conditions:	**Scenario 2**	**Scenario 3**	
Bale weight:	550 kg/bale	550 kg/bale	
Capacity on trailer - bales	24 bales	24 bales	
Capacity on trailer - amount	13,2 tons	13,2 tons	
Avg. speed of truck	53,0 km/h	53,0 km/h	
Transportation time pr. load:			
Distance (A)	20,0 km	20,0 km	
Distance (B)	0,0 km	10,0 km	
Distance (B)	0,0 km	10,0 km	
Total distance (A+B):	20,0 km	40,0 km	
Transport time (A):	22,6 min	22,6 min	
Transport time (B):	0,0 min	22,6 min	
Total transport time (A+B):	22,6 min	45,3 min	
Total transport time contaminated bales	1,7 min	3,4 min	
Bale handling time - contaminated bales			
Storage - loading	2,0 min	2,0 min	
Storage - unloading	2,0 min	2,0 min	
Gate control	5,0 min	10,0 min	
Total bale handling time:	9,0 min	14,0 min	
Total time:	11 min	17 min	
Total sunk costs:	**16 €/t**	**26 €/t**	

Notes:

[1]: Service cost based on average hourly price of haulage company for square bale transport in DK

Bibliography

- Donner, M. Gohier, R. Vries, H. (2020). *A new circular business model typology for creating value from agro-waste*. Elsevier. Science of The Total Environment, Volume 716.
- Porter, M. (1980). *Competitive Strategy. Techniques for analyzing industries and competitors*. The Free Press.
- Levitt, T. (1980). Marketing Success Through Differentiation—of Anything. Harvard Business Review.
- Nyström, I. Andersson, E. Bjurefalk, T. (2020). Standards and certification schemes related to the mass balance approach. Applications in chemical industry. Johanneberg Science Park, CIT Industriell Energi AB.
- Langer, L. Oya, C. Schaefer, F. Skalidou, D. Mccosker, C. (2017). *Effects of certification schemes for agricultural production on socio-economic outcomes in low- and middle-income countries: a systematic review*. Wiley Online Library.
- DH (Danske Halmleverandører) Årsmøde (2020). *Generalforsamlinger, referat*

SALT MEADOWS - ORIGIN TO CATTLE BREEDING AND CRAFT CHEESE PRODUCTION

COLOURBOX3770008

15.09.2020

Business Case

Salt meadows – origin to cattle breeding and craft cheese production

Teresa Żurek

Barbara Wojtasik

Grzegorz Rzepecki

Aleksandra Plit

Paweł Dąbrowski

Dariusz Mikielewicz

1 Executive Summary

This Business Case was prepared on the basis of the report [1] in order to adapt its form and content to the needs of the project.

Salt meadows are special areas, most often located off sea or oceanic coasts, known as coastal salt flats, also found in inland areas as inland salt flats. A characteristic feature of these areas is their occurrence on saline (flowing or stagnant) waters. The coastal area in some sections has a specific character and groups of salt-loving vegetation. These areas are protected, but at the same time are places in many cases being part of private farms. An example of salt meadows is the nature reserve "Słone Łąki" (name in English Salt Meadows) in Władysławowo - located on the shore of the Puck Bay, at the base of the Hel Peninsula (Fig. 1). They constitute a low floodplain, resulting from storms in the bay's waters.

Fig. 1 The area of salt meadow in Władysławowo, Puck Bay, Northern Poland [1]

A serious threat to Władysławowo's salt meadows is the abandonment of extensive pasture management, which contributes to the expansion of reeds, changes in water relations (excessive desiccation can cause a decrease in salinity and the disappearance of salt-loving species, while an increase in water level will swamp the area and invasion of rush species in place of salt meadow communities. In addition, too intensive tourism and recreation can also contribute to the degradation of the salt meadows area [2].

Due to the monitoring of coastal salt flats [3], it is possible to develop a form of using these areas that would preserve their unique character and at the same time be used by the owners. This would lead to the designation of areas that, without loss of natural habitats, would form the basis of pro-health tourism focused on the health nature of staying in coastal salt areas.

2 Finance

The cheese market, especially the special recipe sector of dairy industry, is developing all around the world. In 2019 the global cheese market exceeded the value of 90 billion € [4]. As can be seen from predictions (Fig. 2) this share will steadily increase in next years. Hence it is a good time to invest in cheese, especially the high-quality, locally specific cheese. Study says that consumers are willing to pay extra 5% to 15% more for locally made cheese than for similar cheese found in a supermarket [5], which opens the doors to local entrepreneurs.

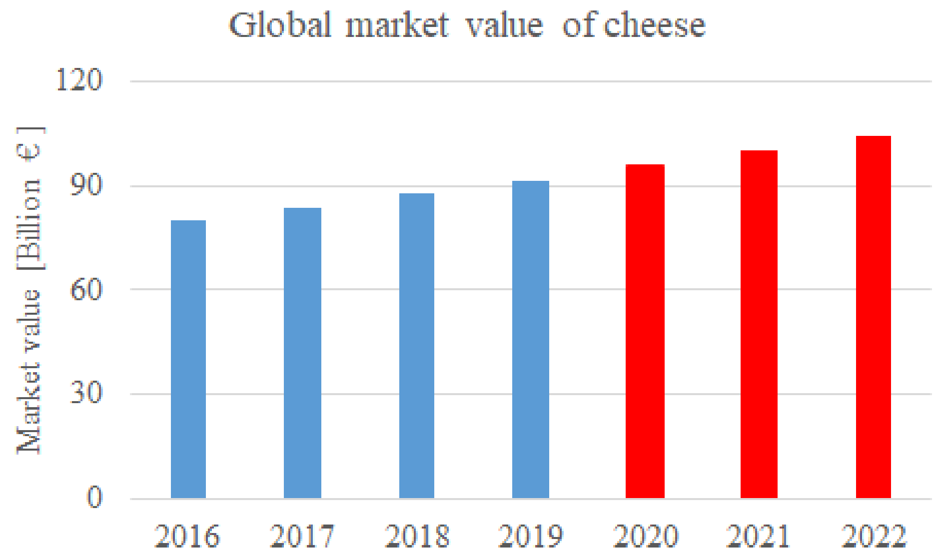


Fig. 2 The global market value of cheese. Blue bars show data, red bars show predictions [4]

The consumption of cheese in the entire European Union is significantly higher then anywhere in the world [5]. Europeans consume more cheese than citizens from USA, Russia or Brazil (Fig. 3). The annual consumption of cheese in the European Union is about 9 500 000 tonnes. The quality of that cheese is determining the consumption standards.

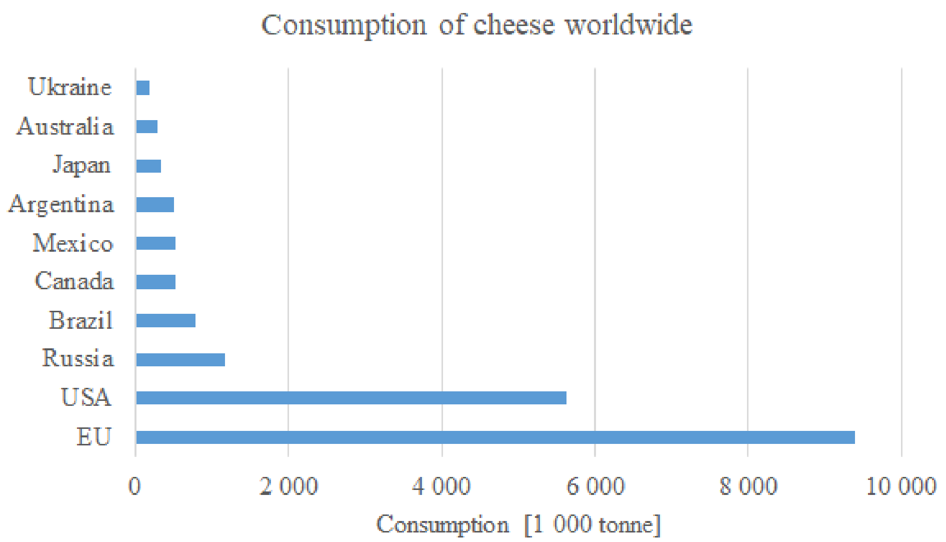


Fig. 3 Consumption of cheese worldwide in 2018 [5]

The cheese production in Poland is growing in a similar manner as the entire global market. In the last 10 years, the production grew by about 30% and now is more than 800 000 tonnes every year (Fig. 4).

Fig. 4 Cheese production in Poland in years 2008-2019 [6]

To make the small, local, high-quality cheese production lines possible there is a need to acquire some basic equipment and select the original source of milk supplies. In that respect the selection of appropriate cattle is very important. In the presented case the Highland type cattle is recommended for implementation in the region of Pomerania. Obviously the issue of development of appropriate housing for the cattle and their surrondings needs also to be established, neththeless the expenditure in that direction would not rather be different from the traditional cattle breeding.

Equipment required for production of cheese is also very well established as at the moment it is very trendy to produce the domestic products including cheese. The prices of cheese kettles range from approx. PLN 5 000 (1 117.50 €) for a boiler for 10 liters of milk to approx. PLN 98 000 (21 903.00 €) for 1 500 liters of milk. Milk centrifuge is an expense of PLN 2 099 (469.76 €) and the mini milk pasteurizer is about PLN 1 990 (444.54 €).

The price of one animal ranges from PLN 1 000 to approx. PLN 4 000 (223.80 to 895.20 €). Highland type cattle is very efficient in deliveries of milk. Milking is performed twice a day, giving about 8 liters of very fat milk. The most expensive investment in breeding Scottish cows is a fence, because they are very saltatory, so the fence must be sufficiently high and seasoning and dry aging cabinets for cheese maturing.

The example of the entire financial analysis of utilizing the selected salt meadows for cheese production with the use of Highland cattle's milk is shown in Table 1 and Table 2.

Table 1 Fixed costs planned to be implemented from January 1st to December 31st, 2021. Costs in Euro. [1]

	Mechelińskie Łąki reserve	Baka reserve	Sum of costs individual tasks
	Area 113.47 ha	Area 355.6 ha	
Establishing ownership rights (Land registers)	1 344	448	1 792
Coordinator - civil law contract	4 703	4 703	9 406
Botanical expert	1 612	2 083	3 695
Natural scientist expert	1 612	2 083	3 695
Spatial development plans - verification and possible corrections	403	403	806
Protection tasks - official legislation, constant monitoring	511	511	1 022
Introductory information and promotion	1 747	1 747	3 494

Promotion	1 344	1 344	2 688
Pasture fencing (quarters), including "electric shepherd"	5 598	11 197	16 795
Purchase of Highland cattle (Scottish cows) for an average amount of approx. PLN 2 500 each (10 and 20 cows, respectively)	5 598	11 197	16 795
Purchase or construction of a shelter to protect cows against snow and heat	448	896	1 344
Seasoning and dry aging cabinet	13 392	26 784	40 176
SUM expenses in individual Reserves	**38 312**	**63 396**	**101 708**

Table 2 Variable costs for staff (salaries) and operating costs (monthly)

	Mechelińskie Łąki reserve	Baka reserve	Sum of costs individual tasks
	Area 113.47 ha	Area 355.6 ha	
Support staff - office and task support	2 580	2 580	5 160
Cheese makers	1 500	3 000	4 500
Farmers (taking care of cows)	2 015	4 031	6 046
Electricity (cheese production and cheese maturing)	1 395	2 790	4 185
Water	500	1 000	1 500
SUM expenses in individual Reserves	**7 990**	**13 401**	**21 391**

The average amount of milk need for 1 kg of cheese is 10 liters. In the considered case, where the herd of cows consists of 10 or 20 Highland cattles, the annual amount of milk produced is 29 200 liters or 58 400 liters respectively. It gives almost 3 or 6 tonnes of high-quality salty cheese per year. The average price of 1 kg of high quality craft cheese may range from PLN 100 (22 €) to PLN 150 (33 €). It results in PLN 300 000 (about 67 000 €) to PLN 900 000 (about 200 000 €) of income every year, depending on the herd size and cheese price. The ROI parameter – Return of Investment was calculated as:

$$ROI = \frac{gross\,profit - expenses}{investment} \cdot 100\%$$

While the PBP – Payback period was calculated as:

$$PBP = \frac{1}{ROI} \cdot 100$$

Taking into account above formulas, it shows that a single household should be able to make a living of a farm and a cheese producing facilities with 20 cows and after about 1.7 years costs will be reimbursed.

3 Project Definition

The proposed business uniqueness is that the original Scottish cattle will be breeded in the specific environment. It will form a different way to use biomass obtained from areas covered with halophytes by grazing the Highland cattle there. Until now, these are only horses and traditional beef cattle. Sheeps are also grazed around the world, for example, on the French coast in Normandy, and the resulting product, namely lamb 'pré-salé lamb' is served as a delicacy. However, the information obtained from the Regional Directorate for Environmental Protection shows that grazing sheep on Polish salt meadows is inadvisable, because sheep graze the vegetation too low, and this would affect its disappearance in the current state of development of the areas covered by halophytes. Perhaps this could change in the next few years. Now, however, only the way horses and cattle gnaw vegetation is beneficial in these areas.

Fig. 5 Scottish Highland cattle [1]

As mentioned earlier the proposed novelty could be the breeding of Scottish Highland cattle, so far found very rarely in Poland (about 20 herds), rather as an attraction in agritourism farms. According to archaeologists, these cows have been living in nature since the 6th century. Their systemic breeding began only at the beginning of the 19th century in northern Scotland. Cows are characterized by high endurance to natural conditions, as well as low abrasiveness in feeding. It is not a thick layer of fat that protects them from the cold, but a thick, shaggy coat, which makes them have a marginal amount of casing fat compared to other cattle breeds; Scottish cows are also dairy cattle.

The worldwide popularity of Scottish cows in both hemispheres and the benefits of breeding them are evidenced by the Scottish cow breeding associations established since the 19th century in France, Scotland, Australia or even Canada and USA.

It is worth adding that the milk from Scottish cows grazed on brackish is many times more expensive than the milk of traditional cows. This is presented in detail in Appendix Costs.

3.1 Business Objective

The following reserves were selected for grazing dairy cattle: Mechelińskie Łąki and Beka. For a herd below 100 cattle the cheese producing activities should be executed onsite where the milk is collected. In such a way a local product can be developed. In case the cheese produces from that milk finds appreciation of the customers that the dedicated diary company should be sought. Such diary ought to rely its production on the ecological production. Two such diaries have been selected. In the vicinity of these reserves, Dairy Kosakowo was in operation from 1901, unfortunately, after its privatization in 1997, it was soon closed. The tradition of rearing dairy cows has remained however, and a local farmer is interested in the local community and in the village of Kosakowo grazing and milking of Scottish cattle. Therefore in Kosakowo, the milk of these cows would be obtained and preserved.

The distance between Mechelińskie Łąki reserve and Kosakowo village is about 5 km as can be seen in Fig. 6, so the logistics issues would be minimized. The distance from Kosakowo to Beka reserve is a bit logner (about 15 km) but still economically viable (Fig. 7).

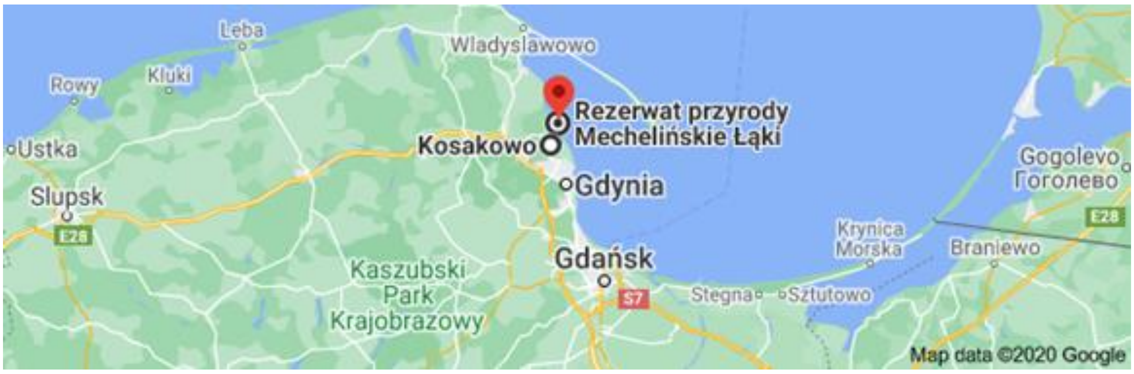


Fig. 6 The distance between Mechelińskie Łąki reserve and Kosakowo village [1]

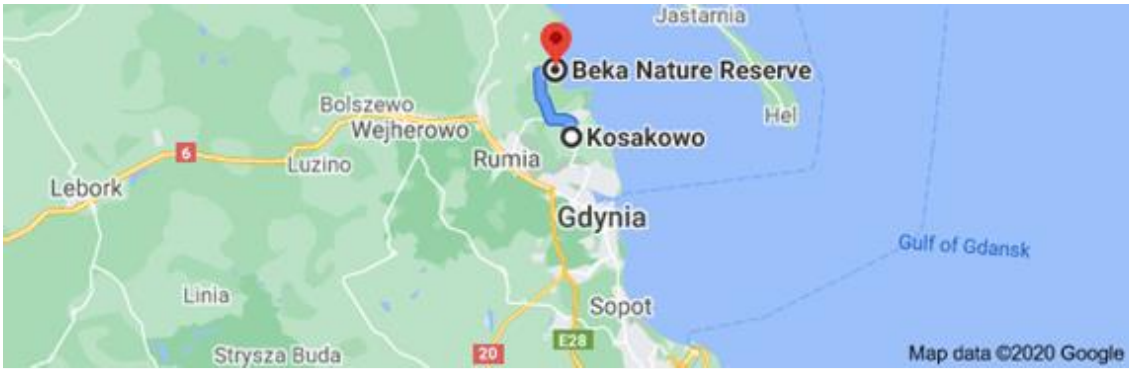


Fig. 7 The distance between Beka reserve and Kosakowo village [1]

Skarszewy Dairy, established in 1895, on the other hand would be an excellent location for cheese production. It is the company producing their products according to stringently high standards and does not replace milk fat with vegetable fats in the cheeses. Moreover, it does not use thickeners, fillers or any other artificial additives to dairy products. It produces dairy products utilising traditional methods, using the latest technology. In 2004, the Skarszewy Dairy's products qualified for trading in the EU. Such company would be an excellent location for production of an original cheese line from the original lawns. The milk collected in vicinity of Kosakowo would have to be transported to Skarszewy. The distance between Kosakowo and Skarszewy Dairy is about 70 km (Fig. 8).

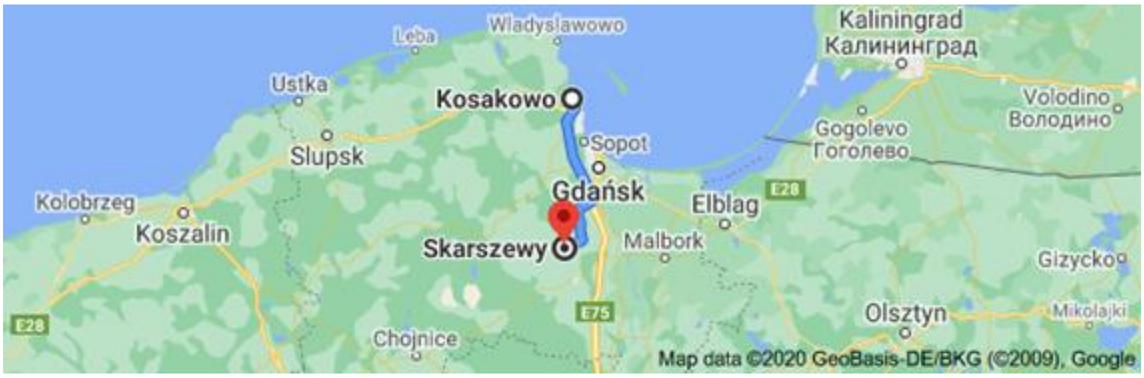


Fig. 8 The distance between Skarszewy Dairy and Kosakowo village [1]

The other possible for cooperation dairy company could be the District Dairy Cooperative "Maluta" in Nowy Dwór Gdański, which was established in 1963 - which of the five small pre-war diaries, located in the fertile areas of Żuławy, has a centuries-old tradition for cattle breeding and milk processing, especially for Dutch type cheeses. Maluta offers products with a natural composition, without fillers and milk fat substitutes. The distance from Kosakowo is about 80 km (Fig. 9).

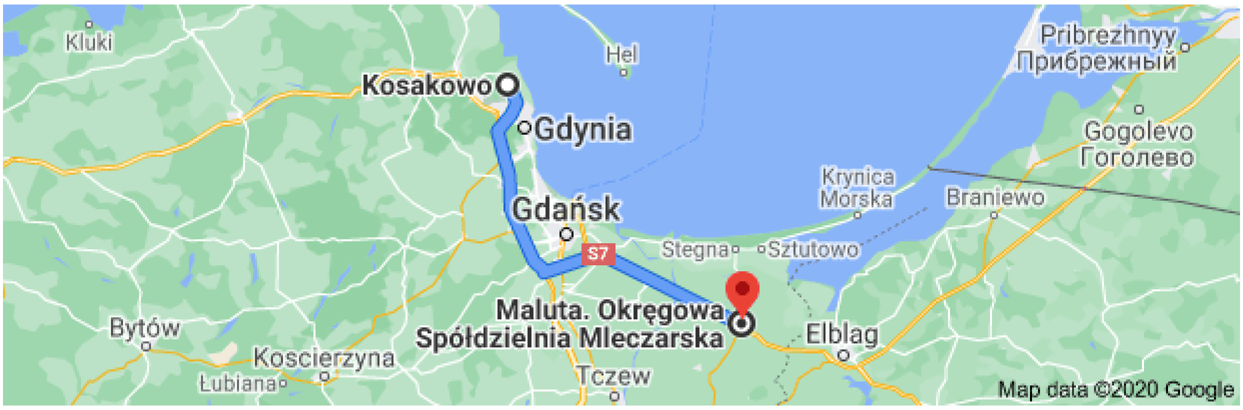


Fig. 9 The distance between Maluta Dairy and Kosakowo village [1]

Cheese-making has recently experienced a considerable development, as evidenced by small dairies (the so-called farm and craft layer) run by passionate cheese makers. The costs listed below relate to investments in a small dairy in the form of home-made or artisan cheese that can be implemented as an alternative offer emphasizing the usefulness of salt meadows instead of their disposal.

The cheese production process includes the following stages:

Stage I. Pre-treatment

Thermization - milk is heated to maintain its natural taste and aroma in a special stainless steel cheese kettle with a heating system that uses electricity, gas, oil, steam or hot water. An exemplary device for beginner cheese makers producing cheese from 20 to 150 l of milk is shown in Fig. 10.

Fig. 10 Mini Plevnik SKM cheese boiler with a 4 kW electric heater as a heat source [1]

Standardization - Some cheese makers alter the composition (e.g. fat, protein, etc.) of the cheese making milk. There are a variety of reasons standardization can be done. Many cheeses have regulations dictating the allowable limits of moisture and fat. In some cases, standardization is done to meet these regulatory standards. The composition of milk varies throughout the year and the cow will naturally produce milk with varying amounts of fat and protein month-to-month. The cheese maker can make up for this variation by standardizing the milk. One of the standardization is transport it to the centrifuge [7]. The example of milk centrifuge is shown in Fig. 11.

Fig. 11 Milk centrifuge [1]

Pasteurization – use to reduce pathogenic microbes to a non-hazardous level for health and to destroy harmful bacteria. There are 2 types of peasteurization techniques, namely High-

Temperature Short-Time (HTST) Pasteurization and Low-Temperature Long-Time (LTLT) Pasteurization. The first one is a pasteurization technique commonly used in large-scale cheese making facilities. This process is also called “continuous” pasteurization or sometimes “flash” pasteurization. The regulations prescribe that milk is heated to 72°C for 15 seconds. The machinery to accomplish this is very complex and expensive, which is why it isn’t seen in small-scale operations very often. The second one is a pasteurization technique commonly used in small-scale and artisanal operations. This process is also called “batch” pasteurization or “vat” pasteurization. The regulations dictate milk is heated to 63°C for 30 minutes. This process doesn’t use as complex of equipment as HTST pasteurization [7]. The example of mini pasteurizator for LTLT pasteurization is shown in Fig. 12.

Fig. 12 Mini pasteurizer MILKY FJ 15 [1]

Stage II: Leaven and rennet

Pasteurized milk is placed in a vat, leaven (cultured lactic acid bacteria cultures) is added, which causes the conversion of lactose into lactic acid, and rennet, which initiates the milk thickening process - the so-called cheese slurry. In the remaining stages, the resulting mass (curd) is separated from the whey (Stage III), pressed in cheese molds that give the planned shapes, placed in brine (Stage IV), and subjected to maturation and care at a temperature of 12-14°C (Step V).

In the context of the research and advanced tasks described above, the current level is defined as TRL 7 - System Adequacy Validated in Simulated Environment.

3.2 Benefits and Limitations

The implementation of the presented concept will allow to end the long-standing conflict between environmentalists defending the unique nature of salt meadows and the farmers who are obliged to care for their own land, that are also deprived of income due to the fact that parts of the property that has been owned for years, has been renamed to nature reserves of halophytes. Moreover, the implementation of the proposed concept will affect the intensive promotion of individual regions and highlight health-related importance of salt meadows.

An additional benefit of managing plants from salt meadows would be the reduction of biomass, which is often an environmental problem (waste). In the absence of a project related to the management of meadows, which leads to the abandonment of systematic mowing, there is a risk of the disappearance of salt meadows and their intensive growth through reed, biomass deposits in the shallow waters of the Bay of Puck, and this will ultimately contribute to the eutrophication of the Bay.

The summary of benefits and limitations can be found in Table 3.

Table 3 Summary of benefits and limitations associated with the production of salt meadows cheese from Scottish Highland cattle

Benefits	Limitations
• defending the unique nature of salt meadows • income for farmers • promotion of individual regions and highlighting health-related importance of salt meadows • reduction of biomass, which is often an environmental problem (waste) • lowering a risk of the disappearance of salt meadows and their intensive growth through reed • promotion of a not very well known in the country cattle type	• small, local production • Scottish Highland cattle is a breed of cows not very popular in Poland, which will require a lot of efford to breed • breeding cows on a salt meadows, which are reserve area can bring some ecological difficulties

3.3 Option Identification and Selection

The comparison of solutions regarding the salt meadows plants is shown in Table 4.

Table 4 Comparison of solutions regarding the salt meadows plants

Innovative solution/product	Conventional solution/product	Benefits of Innovative solution/product	Difficulties associated with innovative solution/product
Cheese from milk of Scottish Highland cattles pastured on the salt meadows	Cheese from milk of regular cow	Local product characterized with sophisticated taste that can be sold at higher price	Scottish Highland cattles are expensive
		Product that promotes local reserves where salt meadows grow	Small production that could be not economicaly feasible
		Scottish Highland cattles used for cheese production purposes are also a good attraction for tourists	

		It is very likely that the new cheese will have better nutritional/health benefits	

3.4 Market Assessment

Scottish cows are long-lived, have low nutritional requirements, graze lasts all year round, in winter they are fed with hay without the need to supplement it with silage, they are independent, do not require the breeder's help in terms of reproduction (no insemination is necessary) and calving. The price of one animal ranges from PLN 1 000 to approx. PLN 4 000 (223.80 to 895.20€). Milking is performed twice a day, giving about 8 liters of very fat milk. The most expensive investment in breeding Scottish cows is a fence, because they are quite saltatory, so it must be sufficiently high, despite the fact that these animals are massive and short: the cow is 105 cm at the withers and weighs around 400-450 kg; a bull is 120-130 cm and weighs up to 625 kg. There should also be a canopy in the meadow to protect the cows from rain and snow.
The initiative to use salt meadows as feed for dairy cattle was also interested in a dairy company, whose chief technologist declared to conduct research confirming that milk obtained from the milking of cows fed with salt can be the basis for the original dairy products, which over time would contribute to to the creation of a local product that would promote the Pomeranian region in this field.
A temporary obstacle to grazing dairy cattle is the low interest in this among farmers due to the inconvenience of milking, as the cattle would have to be led out of the meadows at an appropriate time. However, if the dairy plant is approved to use "milk from salt meadows", it is planned to conduct an information, promotion and incentive campaign to encourage farmers to graze dairy cattle on salt meadows and the associated systematic milking.
The proposed product, obtained from the specific milk of Scottish cows grazed on salt meadows, where chemical fertilization is not applied due to the applicable environmental protection regulations, is cheese, which could also be a regional product, e.g. protected by EU law with the status of a Protected Designation of Origin (PDO).

Table 5 The relationship of the proposed solution for the salt meadows development with individual factors.

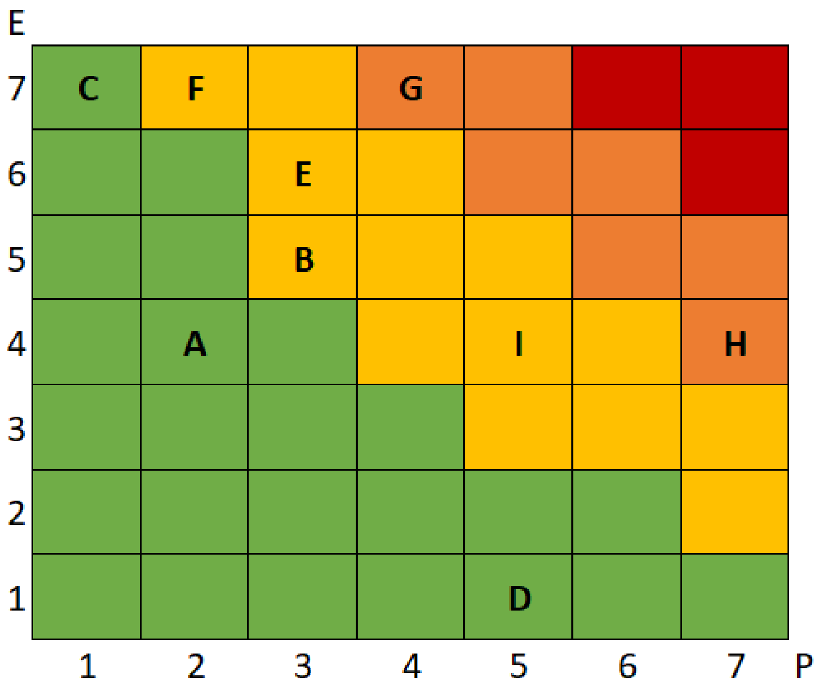
Economical	• new job places • farmers get source of income from an area that has been renamed to nature reserves of halophytes
Sociological	• promotion of individual regions and highlighting health-related importance of salt meadows
Legal	• there is a need to get permission of breeding cows in reserve area (salt meadows)
Environmental	• defending the unique nature of salt meadows • breeding a cows on a salt meadows, which are reserve area can bring some ecological difficulties

3.5 Risk Assessment

To determine the potential risk associated with the production of cheese from Highland cattles breed on salt meadows, a so-called Risk Map was made. It considers the risks associated with the adopted solution and allows determine what impact they will have on its development. The risk assessment took into account factors, that are decisive mainly at the initial stage of introducing the solution to the market, including the lack of proven technology in real conditions or the risk of lack of qualified employees.

RISK LEVEL „R"		PROBABILITY „P"		EFFECT „E"	
Name	**Scale**	**Name**	**Scale**	**Name**	**Scale**
Negligible	1-12	Very low	1	Insignificant	1
Noticeable	13-25	Small	2	Short	2
Monitoring necessary	26-38	Possible	3	Little	3
Immediate response	39-49	Big	4	Perceptible	4
		Threatening	5	Average	5
		Very dangerous	6	Significant	6
		Certain	7	Disastrous	7

RISK	P	E	R = P x E
A – consumers will not be interested in a produced cheese	2	4	8
B – a lack of farmers interested in Highland cattles breeding	3	5	15
C – introduction of legal regulations in reserves that will be unfavorable to the proposed production	1	7	7
D – a lack of financial support from governmental bodies at regional and state level	5	1	5
E – the product will not appear on the market due to a poor marketing strategy	3	6	18
F – tourists will be not interested in the considered regions	2	7	14
G – failure to obtain a permission for the breeding cattles in the reserves	4	7	28
H – Long duration of producing matured cheese, which results in delayed profits	7	4	28
I – The price will be too high for consumers	5	4	20



4 References

[1] Report „Management possibilities analysis of coastal salt meadows with the perspective of their innovative implementation resulting in development of bioeconomy in Poland" prepared by MSC Energoekspert Projektowanie i Doradztwo Techniczne Teresa Żurek

[2] https://npk.org.pl/ formy-ochrony -przyrody-1 /rezerwaty-przyrody-3/slone-laki/?ver=normal, date of view 25.03.2020

[3] http://siedliska.gios.gov.pl

[4] https://www.statista.com/statistics/602542/cheese-market-value-worldwide/

[5] https://agriculture.vermont.gov/sites/agriculture/files/documents/AgDevReports/Specialty%20Cheese%20Market%20Research%20Report.pdf

[6] https://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=tag00040&plugin=1

[7] https://www.cheesescience.org/

Forestry and biomass-related sectors

MATERIAL USE OF ALNUS GLUTINOSA FROM A REWETTED AND AFFORESTED AREA IN BRUDERSDORF AS CONSTRUCTION MATERIAL IN MECKLENBURG VORPOMMERN

COLOURBOX44507557

Business Case Model: Material use of *Alnus glutinosa* from a rewetted and afforested area in Brudersdorf as Construction Material in Mecklenburg Vorpommern (MV)

Introduction

The following report is based on a pre-feasibility study[1] and innovation program[2] which respectively describes the project concept for the business model and key factors to consider when structuring the business case model. It is therefore advised to read these two reports as well.

In Mecklenburg-Vorpommern, the alder (*Alnus glutinosa*) grows on an area of around 40,000 hectares, which accounts for 7% of the forest area[3]. One of the areas is located in the vicinity of Brudersdorf, town of Dargun in the district of Mecklenburg Lake District in MV. This area is predestinated for the development of a business case: The peatland is already rewetted and gives a relevant environment for the cultivation of alder trees.

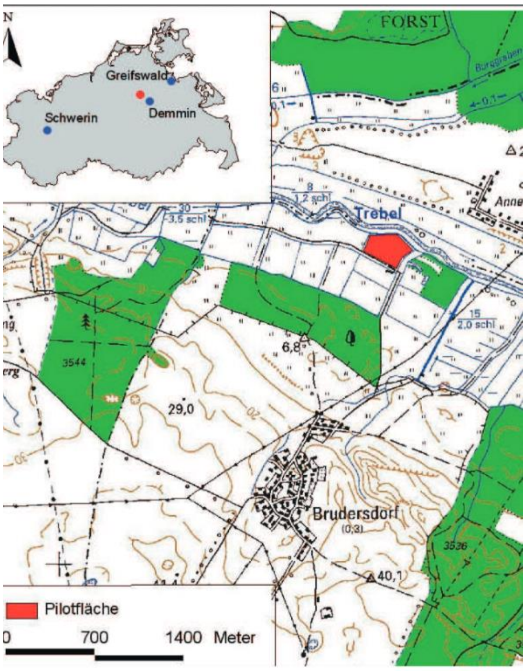


Fig. 1: Pilot area Brudersdorf; basis: geo basic data of the land survey authority (Landes-vermessungsamt) MV with permission of the University of Greifswald

Fig 2: Aerial view of the pilot area[4]

---

[1] BioBIGG (2019): Pre-feasibility study: Material use of *Alnus glutinosa* from Paludiculture as Construction Material in Mecklenburg- Vorpommern (MV)

[2] BioBIGG (2019): Innovation programme: Material use of *Alnus glutinosa* from Paludiculture as Construction Material in Mecklenburg-Vorpommern (MV)

[3] RÖHE, P.; SCHRÖDER, J. (2010): Grundlagen und Empfehlungen für eine nachhaltige Bewirtschaftung der Roterle in Mecklenburg-Vorpommern. Waldbesitzerverband für Mecklenburg-Vorpommern e.V.,

[4] Google maps: https://www.google.de/maps/place/Brudersdorf,+17159+Dargun/@53.9697848,12.8916296,526m/data=!3m1!1e3!4m5!3m4!1s0x47ab87a3071c922f:0xa251aeb323182f0!8m2!3d53.9527161!4d12.8786397

The peatland area is characterised by its near natural condition nowadays. The site had been completely drained in the 1970ies by poldering and equipped with a pumping station so far. In autumn 2002, in the frame of the project "Renaturierung von Niedermooren durch Schwarzerlenbestockung" ("Renaturation of fen by black alder stocking"), this 10 ha peatland in the Trebeltal[5] was afforested. Rewetting of the polder took place immediately afterwards. On average 2,500 alder tree plants were planted per hectare[6] with different planting techniques. After the end of the project period the test area in Brudersdorf remained untouched. In the meantime, the trees grew into a forest (see Fig. 3).

Fig. 3: Wet alder forest in Brudersdorf 2018[7] (Foto: Wendelin Wichtmann)

Current Situation

The cultivation of *Alnus* trees in MV and the use of their wood is described in the pre-feasibility study "Material use of *Alnus glutinosa* from Paludiculture as Construction Material in Mecklenburg Western Pommerania (MV)" and the innovation programme "Material use of *Alnus glutinosa* from Paludiculture as Construction Material in Mecklenburg Western Pommerania (MV)".

The state strategy in MV[8] approves for the consistent further development and implementation of procedures that are already practice-ready (such as alder cultivation). The area in Brudersdorf is now predestinated to develop a strategy for the further use of the alder forest.

---

[5] 50 km east of Rostock, Germany.
[6] Barthelmes et al. (2004): Zweiter Zwischenbericht zum Projekt Renaturierung von Niedermooren durch Schwarzerlenbestockung
[7] RÖHE, P.; SCHRÖDER, J. (2010):
Grundlagen und Empfehlungen für eine nachhaltige Bewirtschaftung der Roterle in Mecklenburg-Vorpommern. Waldbesitzerverband für Mecklenburg-Vorpommern e.V.
[8] report of the state strategy in MWP

The *Alnus* area was established in October 2002 and covers a total area of 10.41 hectares. "Only" approx. 6 ha represent the trial/ demonstration area. The experimental area was divided into three blocks (see Fig. 3), which are again subdivided into different sections representing different types of planting methods.

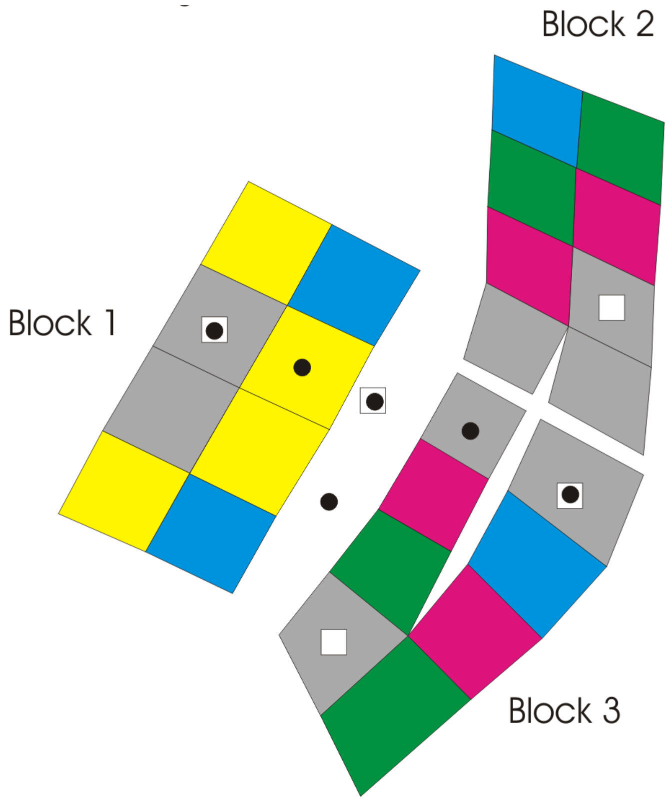


Fig. 4: Alnus pilot area Brudersdorf: Afforestation variants (modified according to[9])

The pilot area in Brudersdorf was afforested with different borders (flowerbeds) and different techniques (see Fig. 4). Overall, 5,048 seedlings were planted on 6 ha.

Due to the high water levels caused by the heavy rainfall event in summer 2011, more than two thirds of the alders have died on the area. Interestingly, the long water level above ground in the following spring led to a natural rejuvenation of the alder trees (see Tab. 1).

Tab. 1: Number of seedlings and percentage failure, after one growing season, time of recording: autumn 2003

Block	Year of Planting Plants / ha	After one Year Plants / ha	loss (%)
1	2,694	2,659	1,3
2	2,356	1,596	31
3	2,474	2,276	7,6

[9] Mirko Hübner (2013) Renaturierung von Niedermoorstandorten, Alnus-Pilotfläche Brudersdorf; Erlennaturverjüngung auf einer Erlenerstaufforstungsfläche aus dem Jahr 2001, die aufgrund der Starkniederschläge im Sommer 2011 zum Großteil abgestorben ist

An inventory was made in 2013 (see Fig. 5).

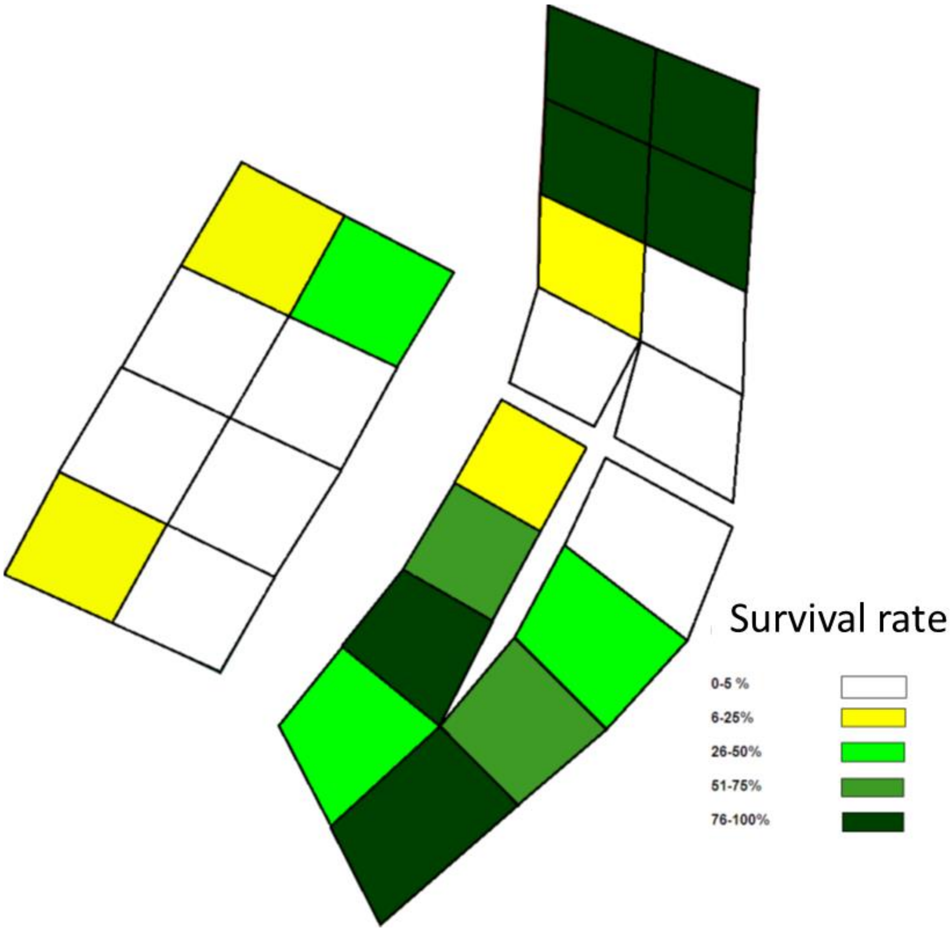


Fig. 5: Pilot Area Brudersdorf; survival rate of Alnus trees in the parcels (modified according to[10])

Due to the different planting techniques the survival rates in the different blocks and sections varies widely. The reasons and conclusions are not the subject of these investigations, only the present state of play is relevant.

[10] Mirko Hübner (2013) Renaturierung von Niedermoorstandorten, Alnus-Pilotfläche Brudersdorf; Erlennaturverjüngung auf einer Erlenerstaufforstungsfläche aus dem Jahr 2001, die aufgrund der Starkniederschläge im Sommer 2011 zum Großteil abgestorben ist

Tab. 2: Survival rate of the main alder population in 2013

Section Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
survived trees [%]	80	30	70	80	40	60	2	6	2	0	2	16	83	90	90	90	0	8	0	0	0	0	30	10
Block No.	3								2								1							
average survived trees [%]	46								46,6								6							

In the meantime, the trees were growing without notable losses.

Tab. 3: Current situation of the amount of alder trees in the test area[11]

Block	Section (0,25 ha each)	amount of seedlings / ha	amount of seedlings / Block	% survival	amount of survived trees / ha	amount of survived trees / Block
1	17-24	2694	5388	6	162	324
2	10-16	2356	4712	46,6	1097	2194
3	1-9	2474	4948	46	1138	2276
Sum		7524	15048		2397	4794

This is the current situation of the investigated area and thus the basis for its further concept and the calculation of the costs.

Ownership structure

In the present case, the business is not conducted by a company but through a foundation.

Foundations are allowed to generate money. It is important that guidelines of the charity must be followed. It is also possible to lease the ground to entrepreneurs for commercial use.

In general, foundations invest the capital transferred to it securely and profitably. The surpluses generated in this way are spent on the charitable purpose.

The ground in Brudersdorf is owned by the regional foundation "Stiftung Umwelt und Natur". It is planned that the foundation will manage the administrative work of the area and outsource all other activities to companies through contracts.

Alnus wood as source of biomass

Two parameters are new in the use of Alnus wood grown on wet areas:

- Alnus wood is not common in Germany. Common timber wood in Germany is from spruce (26%), pine (23%), beech (16%), oak (10%) and birch (4%)[12].
- It is difficult to drive in wood from rewetted areas. Special machines are necessary which rise the price

[11] Mirko Hübner (2013) Renaturierung von Niedermoorstandorten, Alnus-Pilotfläche Brudersdorf; Erlennaturverjüngung auf einer Erlenerstaufforstungsfläche aus dem Jahr 2001, die aufgrund der Starkniederschläge im Sommer 2011 zum Großteil abgestorben ist

[12] Bundesministerium für Ernährung und Landwirtschaft: Zahlen und Fakten zum Wald

Goal of the economic use of the alder forest is the production of non-energy high value added products. Alder forests in MV consist of trees of different age and wood quality. Without constant forest maintenance, a high amount of low-quality wood is obtained and only a small quantity of good quality wood can be harvested. The sale of low-quality wood from wet peatlands, on the contrary, is uneconomical (too low yields and high financial expenditure due to special harvesting technology). Therefore, a successful management can only take place if regular thinning and maintenance of the forest area is carried out immediately to achieve high timber prices with high-quality wood.

Timber from *Alnus* is fully suitable for veneering. By pickling it, it can be refined and used to imitate tropical woods. It's particularly suitable for imitating mahogany and ebony and can be used instead of cherry and walnut[13]. So, it can be used for all innovative building materials as well as for furniture.

Wood is a natural product. It was partly replaced step by step by synthetic products like plastic or concrete. Because these products are not sustainable nowadays customers begin to think about buying more natural products. Therefore the demand will (hopefully) continue to increase in the coming years. In addition, the regionally produced wood should replace tropic wood. Its harvest accelerates the degradation of tropical forests.

However, low quality wood is also obtained during forest care (removing unsuitable trees), which can be sold for energy use and revenues reduce the costs.

Existing enabling policies and economic factors

The afforestation of rewetted peatland with black alder is a forestry use but can be considered as ecological priority areas (greening), thus maintaining the eligibility of the land.

For private and municipal landowners the afforestation of rewetted peatland sites with black alder and the maintenance of young plants are eligible for funding on the basis of the GAK[14].

Business Model

The current utilization of Alder is primarily dominated by energetic use due to the woods low quality (compared to material purposes).

The aim of the present business model is thereby to structure the financial development of afforestation, so it supports a high-value timber production, on a specific paludi area (with older alder stocks). In order to reach this objective, a balanced age structure of the trees needs to be achieved through controlled forest interventions related to rejuvenation and maintenance of the existing growing stock.

Projected Expenditure and Revenues

A calculation of costs and revenues is highly speculative, because the harvest of trees planted today will only take place in the far future and the actual price development is difficult to predict. Orientation values for a calculation for alder management, however, are provided by today's prices.

Expenditure

Basis for calculating of the total costs:

1. administrative costs

---

[13] Pre-feasibility study: Alnus as construction material

[14] Richtlinie zur Förderung forstwirtschaftlicher Maßnahmen im Rahmen der Gemeinschaftsaufgabe Verbesserung der Agrarstruktur und des Küstenschutzes (2019), page 12

2. afforestation of the sections with great losses of trees: price for seedlings and work
3. Forest maintenance: Price per ha
4. Timber harvesting with classic equipment + additional costs for special harvesters

1. Administrative costs:

50 €/ha/a[15]: ***300 €/a***

2. Afforestation costs:

Afforestation is basically a very long-term investment decision. Only when the trees are harvested the majority of the income will flow back to the investor in the form of timber revenues. Economic risks are caused by natural losses such as insect infestation or the current weather situation as well as with inadequate stock management.

Brudersdorf has the advantage that the afforestation is about 20 years ago so that there are already trees in that age. Nearly the whole Block 1, where there's only one tree per 62 m², and some sections in block 2 and 3 with a high amount of losses, needs to be afforested. Normally afforestation will be only done after harvest and is not usual. But Brudersdorf is a test area where different techniques have been tested. Some techniques failed so that there was a high amount of loss of seedlings.

Tab. 4: Stand establishment costs for alder afforestation[16]

Amount of plants	3.000 – 3.500 / ha
Unit price of the plant	0,75 - 1,50 €/Plant
Planting	0,20 - 0,50 €/Plant

The following areas have to be afforested (see Tab. 2):

Block 1 except section 23 = 1.75 ha

Section 7, 9, 10, 11 = 1 ha

In sum an area of 2.75 ha must be afforested. This area is hereinafter referred to as the 'new' area, the area with old stock as the 'old' area.

Assuming 3,000 seedlings/ha, 1 €/plant + 0.4 € working time/plant

- 8,250 seedlings must be planted
- 3,300 € working time + 8,250 € for the plants
- ***11,550 €***

3. Forest Maintenance: Young growth and stock care

10 years after planting, a single, low-key procedure should be performed.

Costs: 250 € / ha[17]; ***1.500 €*** for the whole area (812,50 € + 687,50 €)

[15] Schäfer, A. & Joosten, H. (Hrsg.) (2005): Erlenaufforstung auf wiedervernässten Niedermooren : ALNUS-Leitfaden. Institut für Dauerhaft Umweltgerechte Entwicklung der Naturräume der Erde (DUENE) e.V., Greifswald, page 18

[16] Achim Schäfer 2020, Manuskript für UBA Projekt „Anreize für Paludikultur zur Umsetzung der Klimaschutzziele 2030 und 2050“

[17] Schäfer, A. & Joosten, H. (Hrsg.) (2005): Erlenaufforstung auf wiedervernässten Niedermooren : ALNUS-Leitfaden. Institut für Dauerhaft Umweltgerechte Entwicklung der Naturräume der Erde (DUENE) e.V., Greifswald, page 16

The best trunks are selected and should grow into valuable timber. These trees must be specifically promoted by taking away the nearest neighbouring trees. The costs for these interventions (which are partly eligible for aid) are approximately EUR 250 per hectare. The thinnings must be operated 3 additional times for the new, 2 times for the old area, until the wood is in such a high quality that it can be selled without loss.

The thinning of the 'old' 3,25 ha should be done immediately (costs: 812.50 €).

Assuming, that the 'old' area must only be thinned three times, the 'new' area 4 times, the costs will sum to 812,50 € x 3 + 687,50 € x 4 = ***5,187.50 €***

The next thinnings of the area later on are cost neutral (harvest costs are compensated by revenues, generated by removed low quality timber) and will not be considered in the calculation.

4. First timber harvest after 40 years, 2nd harvest after 60 years:

The total harvest costs are between 23 and 35 €/ solid cubic meters. This exceeds the costs of fully mechanized thinning in deciduous stands on non-wetted floors[18].

After 60 years of growth on average an amount of 348 m³ *Alnus* timber has grown on one hectare[19]. Minus bark loss and harvest loss of 10% each[20], 278,4 m³ is the timber yield after harvesting one hectare.

This means that after 40 years the 'old' area has an output of 278,4 m³ x 3,25 ha = 904,8 m³, assuming an average of trees of 28 m (28 m height x 0.45 cm diameter). 20 years later, the 'new' area give a yield of 278,4 m³ x 2,74 ha = 762,8 m³.

Harvest costs (assumption: 30 € /m³)

<u>'old' 3,25 m³ area:</u>

3,25 m³ x 278,4 m³ x 30 €= ***27,144 €***

2,75 m³ x 278,4 m³ x 30 € = ***22,968 €***

Revenues

<u>Basis for calculating of the total revenues</u>

1. Eligibilities
2. Harvest Revenues

1. Eligibility

Part of the afforestation costs are to be silvicultural measure eligible

Funding (the basis of the data is the currently valid "Guidelines for the Promotion of Forestry Measures" for MV of 10.02.2005)[21]:

- Rectification

  Planting material and planting for weather-related losses (more than 40 %): Up to 85 % of the eligible expenditure for improvements is eligible

---

[18] Röhe, P. Schröder, S. (2017): Paludikultur mit Anbau der Schwarzerle; Forstwirtschaft und Klimaschutz auf nassen Mooren; AFZ-Der Wald 23/2017

[19] Lockow, K.-W. (1998) Ertragstafel für die Roterle (*Alnus glutinosa* [L.] Gaertn.) im nordostdeutschen Tiefland

[20] https://de.wikipedia.org/wiki/Festmeter

[21] Summary in Alnus Leitfaden: Erlenaufforstung auf wiedervernässten Niedermooren (2005), page 19

Because of the high revenues the costs for weather-related losses will be neglected in the further calculation.

- Young growth and young stock care

  Improvement of structure and stability in young stands up to 10 m mean height

  The funding is available for up to two maintenance measures at EUR 220 per ha

  220 € x 6 ha x 2 times = ***2,640 €***

2. Harvest revenues

For alder timber with an average diameter > 40 cm you can get 100 – 150 €/m³ (solid cubic meters)[22].

With an assumed price of 100 €/m³:

278,4 m³ x 100 € = 27,840 € / ha

For the 6 ha alder forest, **167,040 €** can be generated, one part after 40, the other after 60 years.

<u>The 'old' 3,25 m³ area can be harvested after 40 years:</u>

3,25 m³ x 278,4 m³ x 100 € = ***90,480 €***

<u>The 'new' 2,75m³ area can be harvested after 60 years:</u>

2,75 m³ area x 278,4 m³ x 100 € = ***76,560 €***

Financial viability

In order to produce timber on the 6 hectare in Brudersdorf a sum of 85,149.50 Euro at nominal value has to be invested. Of this sum, 2,640 Euro will have been refinanced through silvicultural subsidies at nominal value (see Tab. 5+6).

The break-even is reached in the 40th year after the first harvest: The net income in this year is 36,938.50 Euro (see Tab. 6). Although in the following 20 years the further investment sum up to 6,000 Euro (300 € x 20 years) without revenues, the total net income remains positive until the 2nd harvest generates the next income.

Two real value scenarios have been calculated, where inflation is assumed at 2% and 1% per annum respectively. In both cases the break-even point is reached after 60 years. The projected costs after this time are in all cases lower than the projected revenues from subsidies and timber sales (see Tab. 5).

[22] Utschig, H. Waldwachstumskundliche Charakterisierung der Schwarzerle (*Alnus glutinosa* (L.) GAERTNER) am Beispiel der Wuchsreihe Wasserburg 642

Tab. 5: Net profit after 60 years

	Net income / 6 ha			Net income / ha		
	Nominal Value	Real value (adjusted for Inflation at 2% p.a.)	Real value (adjusted for Inflation at 1% p.a.)	Nominal Value	Real value (adjusted for Inflation at 2% p.a.)	Real value (adjusted for Inflation at 1% p.a.)
Expenditure	*85.149,50 €*	*33.344,32 €*	*47.216,73 €*	14.191,58 €	5.557,39 €	7.869,46 €
Administration	18.300,00 €	10.625,97 €	13.749,45 €	3.050,00 €	1.770,99 €	2.291,57 €
Afforestation	11.550,00 €	11.550,00 €	11.550,00 €	1.925,00 €	1.925,00 €	1.925,00 €
Young growth care	5.187,50 €	4.334,15 €	4.734,18 €	864,58 €	722,36 €	789,03 €
Timber Harvesting	50.112,00 €	6.834,20 €	17.183,11 €	8.352,00 €	1.139,03 €	2.863,85 €
Income	*169.680,00 €*	*65.403,70 €*	*104.880,65 €*	28.280,00 €	10.900,62 €	17.480,11 €
Timber revenues	167.040,00 €	63.107,64 €	102.418,88 €	27.840,00 €	10.517,94 €	17.069,81 €
Subsidies young stock care	2.640,00 €	2.296,06 €	2.461,77 €	440,00 €	382,68 €	410,30 €
Balance	**84.530,50 €**	**32.059,38 €**	**57.663,92 €**	**14.088,42 €**	**5.343,23 €**	**9.610,65 €**
Balance / a	**1.408,84 €**	**534,32 €**	**961,07 €**	**234,81 €**	**89,05 €**	**160,18 €**

Net profit of the 6 ha Alnus forest in Brudersdorf (see Tab. 6)

84,530.50 € is the net profit in 60 years at the nominal value,
1,408.84 € is the net profit per year.

On average, every year in a 60-year-schedule a benefit of 1,409 € can be generated for the 6 ha area in Brudersdorf at nominal value. But it needs 40 years after the first revenue from harvesting can be entered on the credit site, with an input of 56,181.50 €.

Perspective

The area in Brudersdorf belongs to a foundation. At the moment you don't get much return when the foundation money is invested. Therefore, it is a preferable business model to invest in forest care. 56,181 € must be invested during the first 40 years. You get the return on investment after this time and additionally more money in year 60.

In the meantime you can re-afforest the harvested area and the procedure can be repeated.

For the operation of the business, a network of different stakeholders is necessary. Experts in forest management (e.g. Landesforst MV) offer free consultations, experts in paludiculture (e.g. University of Greifswald, Succow-Stiftung, DUENE, Greifswald Mire Centre) have a lot of scientific application-oriented publications which can be downloaded for free[23]. It is recommended to ask for forestry consulting before forest care measures starts[24]. All work concerning the forest care and the timber harvest should be processed by an expert. Further important contacts must be established with the timber purchasers. In our case it is the wood raw trade and sawmills.

[23] https://www.moorwissen.de/de/publikationen/publikationen.php#artikel
[24] Schäfer, A. & Joosten, H. (Hrsg.) (2005): Erlenaufforstung auf wiedervernässten Niedermooren : ALNUS-Leitfaden. Institut für Dauerhaft Umweltgerechte Entwicklung der Naturräume der Erde (DUENE) e.V., Greifswald

The foundation will take over the management and will outsource all activities concerning forest care, harvest and transport to the customer.

The foundation does not need the contact to the final consumer. Because the amount of produced wood is low in comparison to the total amount of produced wood in the region it is sufficient if one or two larger local sawmills are contacted. Processing of alder wood is similar to processing of other wood species and so it might be no problem if alder wood is added to the product portfolio of an existing company. Some years ago the sawmill “Pollmeier”[25] showed interest and would produce solid panels from this wood.

[25] https://www.pollmeier.com/de/Unternehmen/standorte/Malchow#gref

Tab. 6: Calculation of costs and revenues (some columns have been hidden)

Costs																								
Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	40	60	Sum
Administration	300,00 €	300,00 €	300,00 €	300,00 €	300,00 €	300,00 €	300,00 €	300,00 €	300,00 €	300,00 €	300,00 €	300,00 €	300,00 €	300,00 €	300,00 €	300,00 €	300,00 €	300,00 €	300,00 €	300,00 €	300,00 €	300,00 €	300,00 €	18.300,00 €
Planting	11.550,00 €																							11.550,00 €
Young Growth Care	812,50 €								687,50 €															1.500,00 €
Young Stock Care					812,50 €				812,50 €				687,50 €				687,50 €				687,50 €			3.687,50 €
Harvest																						27.144,00 €	22.968,00 €	50.112,00 €
Sum	12.662,50 €	300,00 €	300,00 €	300,00 €	1.112,50 €	300,00 €	300,00 €	300,00 €	1.800,00 €	300,00 €	300,00 €	300,00 €	987,50 €	300,00 €	300,00 €	300,00 €	987,50 €	300,00 €	300,00 €	300,00 €	987,50 €	27.444,00 €	23.268,00 €	85.149,50 €
Revenues																								
Harvest income																						90.480,00 €	76.560,00 €	167.040,00 €
Eligibility for Young Stock Care					1.320,00 €						1.320,00 €													2.640,00 €
Sum	0,00 €	0,00 €	0,00 €	0,00 €	1.320,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	1.320,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	90.480,00 €	76.560,00 €	169.680,00 €
Net income	-12.662,50 €	-300,00 €	-300,00 €	-300,00 €	207,50 €	-300,00 €	-300,00 €	-300,00 €	-1.800,00 €	-300,00 €	1.020,00 €	-300,00 €	-987,50 €	-300,00 €	-300,00 €	-300,00 €	-987,50 €	-300,00 €	-300,00 €	-300,00 €	-987,50 €	63.036,00 €	53.292,00 €	84.530,50 €
Break even											**-15.335,00 €**										**-20.397,50 €**	**36.938,50 €**		
3,25 ha older tree population																								
2,75 ha new afforested area																								

REWETTING AND AFFORESTATION OF A DRAINED PEATLAND AND ITS USE FOR PALUDICULTURE WITH ALNUS GLUTINOSA IN MECKLENBURG-VORPOMMERN

COLOURBOX44507557

Business Case Manual: Rewetting and Afforestation of a Drained Peatland and its Use for Paludiculture with *Alnus glutinosa* in Mecklenburg-Vorpommern (MV)

Introduction

Achieving the climate protection goals (Paris climate protection agreement) necessitates limiting man-made global warming to significantly below 2°C compared to pre-industrial levels.

At present, it appears that the "2 degree target" will probably be very difficult or impossible to achieve. For this reason, biogenic carbon reservoirs - and thus also peatlands - are increasingly coming to the attention of the public[1].Peatland rewetting is the most cost efficient land use based greenhouse gas emissions abatement measure, e.g. in Germany[2]. This means changing the path of unsustainable agriculture in peatlands. They could be rewetted on a large scale and alternative forms of land use introduced on a step by step basis.

One alternative form of land use is the settlement of forest. In a pre-feasibility study[3], prepared within the BioBIGG[4] project, the possibility of cultivation of alder (*Alnus glutinosa*) trees in MV under wet or semi-wet conditions and the use of its wood has been shown. Further investigations[5] evaluated the possibility of a financially feasible *Alnus* production in rewetted peatlands for high value usage of *Alnus* wood in MV. During the search for suitable areas, a small rewetted region could be identified, which was already covered with alders and on the basis of which a business model for the use of its wood was developed[6].

In the current report an additional business case has been developed, which goes one step further: Not only the cultivation of trees on wet sites, but also the previous rewetting of a drained peatland has been investigated. The effect is a substantial CO_2- saving by binding the gas in the soil as well as in the alder wood.

Area Potential of Peatlands

Currently 165,880 ha (57%) of the peatlands in Mecklenburg-Vorpommern are used for agricultural purposes. Near-natural peatlands, rewetted peatlands without use as well as ditches and zero use take up 77,022 ha. 52,000 ha of peatland in MV are without economic use[7] (Fig. 1).

---

[1] MLUV (Ministry of Agriculture, Environment and Consumer Protection) (2009): Konzept zum Schutz und zur Nutzung der Moore. Fortschreibung des Konzeptes zur Bestandssicherung und zur Entwicklung der Moore; https://www.lung.mv-regierung.de/dateien/moorschutzkonzept_2009.pdf

[2] Röder, N. et al. (2015): Evaluation of landuse based greenhouse gas abatement measures in Germany. Ecological Economics, 117:193-202

[3] BioBIGG (2019): Pre-feasibility study: Material use of *Alnus glutinosa* from Paludiculture as Construction Material in Mecklenburg- Vorpommern (MV)

[4] BioBIGG: Bioeconomy in the South Baltic Area: Biomass-based Innovation and Green Growth

[5] BioBIGG (2019): Innovation programme: Material use of *Alnus glutinosa* from Paludiculture as Construction Material in Mecklenburg-Vorpommern (MV)

[6] Business Case Model: Material use of Alnus glutinosa from a rewetted and afforested area in Brudersdorf as Construction Material in Mecklenburg Vorpommern (MV)

[7] LM M-V (2017) Umsetzung von Paludikultur auf landwirtschaftlich genutzten Flächen in M-V. Fachstrategie zur Umsetzung der nutzungsbezogenen Vorschläge des Moorschutzkonzeptes. Ministerium für Landwirtschaft und Umwelt M-V, Schwerin, page 9.

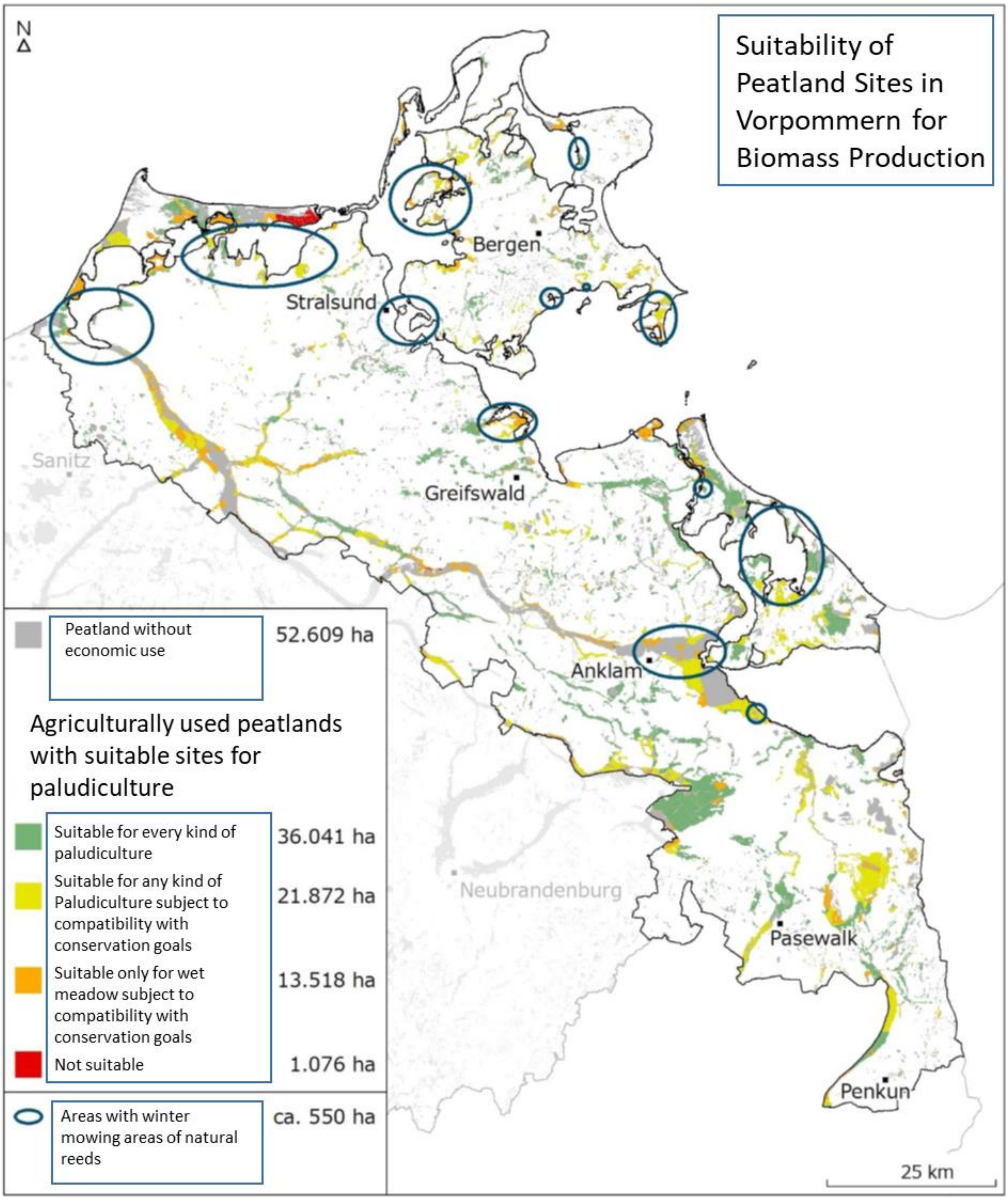


***Fig. 1: Area potential for biomass production on rewetted peatlands in Vorpommern*[8]**

Suitable areas for rewetting and afforestation of peatlands with alder must meet the following criteria:

- Spatial distance to processing sites: prevention of high transport costs

---

[8] VoCo – Vorpommern Connect Meilensteinbericht 1 (2019), page 55; LM M-V (2017) Umsetzung von Paludikultur auf landwirtschaftlich genutzten Flächen in M-V. Fachstrategie zur Umsetzung der nutzungsbezogenen Vorschläge des Moorschutzkonzeptes. Ministerium für Landwirtschaft und Umwelt M-V, Schwerin.

- Ownership structure: Implementation is easier if the area has fewer owners and / or the ownership is in public hands (role model function, interest in establishing regional value chains, in some cases project partners).
- Area size: The area should be big enough, so that the effort is worthwhile with regard to the use of the equipment. The area should connected. If this is not possible, individual parts of the land should not be too far apart (cost-efficient use of machinery).
- Semi-wet locations are particularly suitable for forestry use[9]. The peat body can be preserved, the CO_2 balance is positive and the alder cultivation can be operated economically.

A small area (6 ha) in Brudersdorf was already assessed for its economic viability[10]. It could be shown that the timber can be produced economically. Because of the higher harvesting costs the focus should be on high value wood, which achieves a good price. One important parameter which influences the harvesting costs, and therefore the break-even, is the passability of the soil. The water content in the soil and the right harvest time therefore plays a crucial role and determines the amount of use of special machines. On semi-wet sites (e.g. water stage 4+) equipment of the conventional grassland management machinery can be used. Wet locations (water stage 5+/6+) require a special technology. Semi-wet locations have just those conditions where alder trees show a satisfactory growth.

An area to be rewetted consists of different soil structures and different height profiles. A rise in the water level will have the effect that the flooded area will have different water levels. The investigated area preferably should have a high amount of semi-wet and a less amount of wet soil to maximize the yield of high-value wood and minimize the use of high-priced machinery.

However, one disadvantage is the long time until the first harvest and therefore until the first net income is reached. A second disadvantage is the irregular income only in years of harvest.

The business case in Brudersdorf forms the basis for this report. In the present business case, strategies for minimizing the disadvantages and additionally different financing instruments are examined.

- Bigger area: Thurbruch at the island of Usedom (60 ha)
- Rewetting of drained peatland gives an additional surplus on climate protection
- Stepwise afforestation (e.g. 1 ha per year) followed by stepwise harvesting and re-planting
- Financing the lag-phase with CO_2 compensation payments

Description of the Region Thurbruch[11]

The entire investigated area covers 2,716 ha (see Fig. 2), of which 788 ha (29%) have protected status. 1,544 ha are grassland, 41 ha are arable land, 637 ha are water bodies (Gothensee, Kachliner See, peat bog) and 811 ha are shore areas and unused peatland areas. In addition, there are 290 ha of forests and woodland[12] (see Fig. 3).

---

[9] GMC: Flyer Schwarz-Erle (*Alnus glutinosa*); Forstwirtschaft auf nassen Standorten
[10] BioBIGG (2020): Material use of *Alnus glutinosa* from a rewetted and afforested area in Brudersdorf as Construction Material in Mecklenburg Western Pommerania (MV)
[11] Hohlbein, M. (2013): Potenziale für Paludikultur im Thurbruch (Usedom) (Diplomarbeit)
[12] LUNG-MV (Landesamt für Umwelt, Naturschutz und Geologie Mecklenburg-Vorpommern) (1991/2003): Biotop- und Naturschutzkartierung, Güstrow

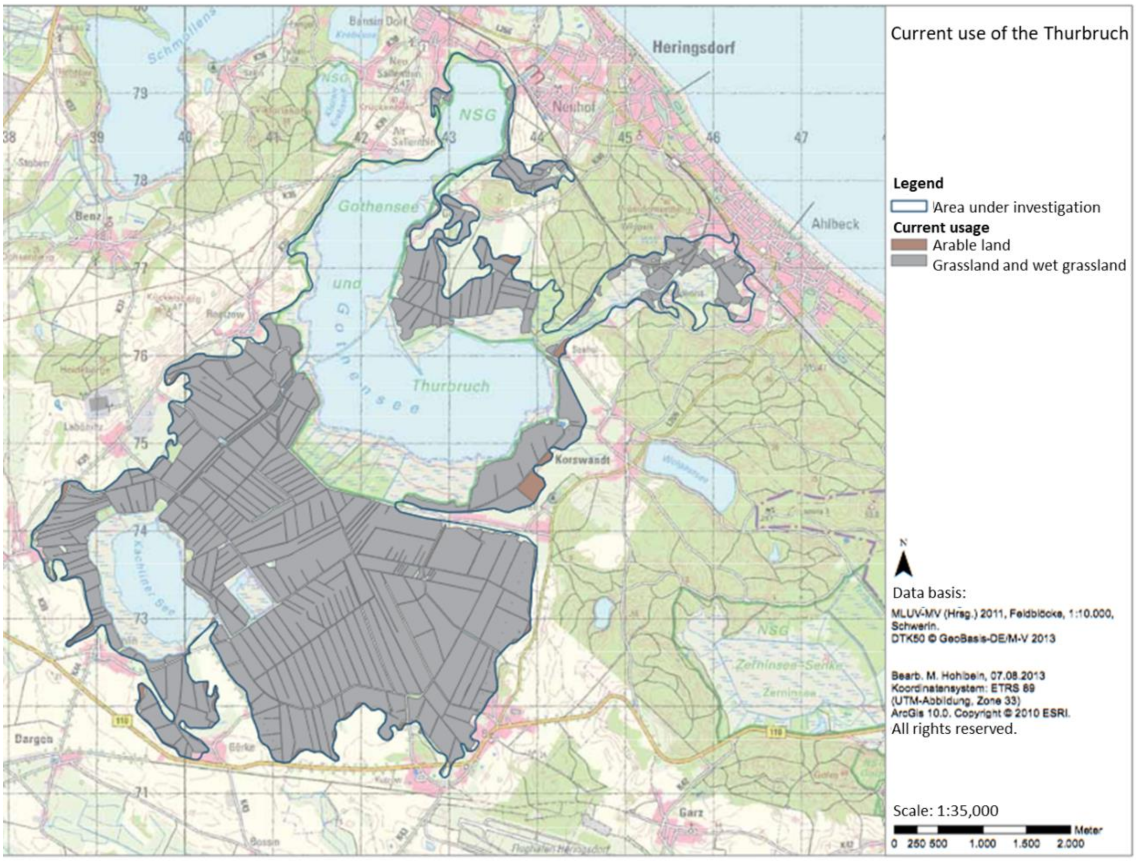


Fig 2: Present use of the Thurbruch[13]

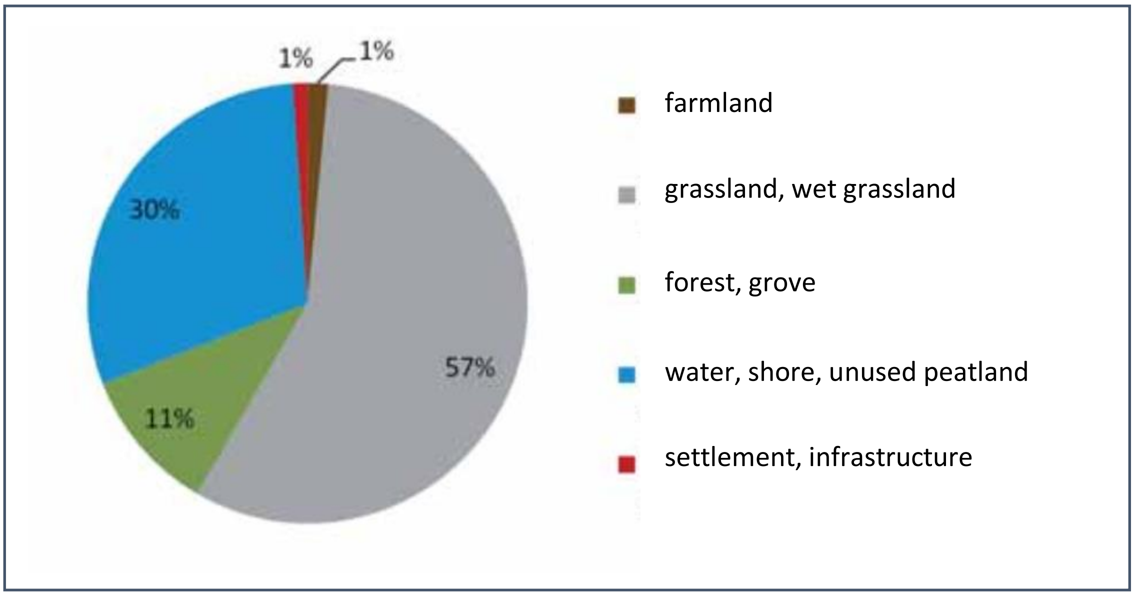


Fig. 3: Current use of the entire area[12]

More than half of the area in the Thurbruch is currently used for agriculture, mainly for extensive livestock farming and the production of green fodder. These areas are managed by 12 farmers[14]. The

[13] Hohlbein, M. (2013): Potenziale für Paludikultur im Thurbruch (Usedom) (Diplomarbeit)
[14] Hohlbein, M. (2013): Potenziale für Paludikultur im Thurbruch (Usedom) (Diplomarbeit)

farms are usually small (80-150 ha), only a few farms have areas up to 450 ha. Mostly suckler cows are kept, but revenues are also generated from dairy farming. For the current land use, all areas were drained in the past, and its continual pumping is necessary to keep the water level at a sufficiently low level. The water is pumped via a drainage network and four pumping stations into the Gothensee, at higher water levels the water is channeled further into the Baltic Sea.

Business Model

In this study we consider two business models (BC I and BC II) for silviculture on rewetted peatland. They are very similar: The basic model is the same in BC I and BC II and differ only in the kind of afforestation.

First, we will consider a basic scenario in which the business case for the production of alder (*Alnus glutinosa)* for timber on rewetted peatland is presented. This will show that the cultivation of alder for timber alone can be economically viable under certain circumstances. It is however a long-term investment and requires a significant amount of capital. We will also examine an alternative model, in which an afforestation regime, that combines the production of alder and willow (*Salix*), allows regular biomass harvesting and income generation before the alder trees have matured. The second part of the study discusses scenarios for financing the lag-phase until the first harvest of alder through additional revenues from CO_2-compensation instruments.

Basic scenario: cultivation of *Alnus glutinosa* for timber

The company "Bogwood GmbH" has been set up with the aim of producing high quality, high-value timber for furniture and other uses from *Alnus glutinosa* (black alder) on rewetted peatland on the Island of Usedom in north-eastern Germany.

Selecting the right site in terms of size and location is crucial for the viability of the endeavor both economically and in terms of local acceptance of rewetting. Whilst it would be technical possible for the company to rent or purchase an area of 600 ha of drained peatland from the different owners and manage the rewetting, afforestation, care and harvest of this site, the direct socio-economic effects of a land-use transformation on such a scale in this setting would be negative. With the conversion of agricultural land to forestry, farmers will be displaced and lose their previous source of income. Farming on the remaining land may no longer be viable and farms will cut jobs or even cease to exist. Large-scale rewetting for forestry may however be feasible in other regions or at a later date under a changed regulatory and policy environment. But for the Thurbruch on the island of Usedom, we will assume that Bogwood GmbH will rewet and afforest a site of 60 ha. The specific site was chosen to fulfill the following requirements:

- Predominantly grassland; as little arable land as possible
- The farmers are not dependent on the land (e.g. not suitable for farming, farming as a sideline, farming has become/is becoming too expensive because of the costs for regular drainage)
- Each farmer should have to rent / sell only a small part of his/her land

In order to find an appropriate site and to negotiate with the land owners, Bogwood GmbH cooperated with scientists at the University of Greifswald, where peatland research groups have long-standing experience with rewetting of drained peatland. Example is the rewetting of the *Polder Kieve*[15] (which was financed in the frame of a research project).

The company has to calculate the following costs:

- farmers must be payed annually for their loss of revenue (or the area will be purchased)
- costs for rewetting, afforestation, forest care and harvest for 60 ha

The company can expect revenues from the following activities:

- Timber sales
- Afforestation
- Forest care

The company will have a first active period: The owners must be convinced to sell or rent land for silviculture subsidies, grant applications must be written and the entire 60 hectares must be rewetted. There will then be a lag phase, as the areas will only be afforested gradually.

Rewetting

Normally, rewetting generates planning and construction costs. As there are many existing water-technical facilities in Thurbruch, no relevant construction costs will be generated. The water levels can be adjusted by the existing pumping stations and weirs. The rewetting costs are therefore at the lower cost limit[16].
The water level should be adjusted so that the proportion of land on which paludiculture biomass can be obtained is as large as possible and create good conditions for an optimal growth of the trees. This is intended to prevent the further decomposition of the peatland soil on the largest possible area.

Afforestation BC I

The afforestation is planned to be stepwise: every year one hectare. If the timber is harvested after 60 years, there is a yearly regular income after this time. Every year one ha can be harvested followed by reafforestation.

Afforestation BC II

In this case, a double-cut (zweihiebige) afforestation, as described by the National Forest (Landesforst)[17], with a combination of *Alnus* and *Salix* (willow) is planned. The basic principle is a stepwise afforestation of 5 ha every 5 years with alders. The remaining area will be afforested with willows. Willows are fast-growing tree species that are particularly capable of developing rods. The aim is to use this stocking to produce wood biomass in short-rotation. For this purpose, the trees are repeatedly harvested in a rotation period of 5 years, i.e. they are cut down close to the base as in coppice management. Since the regrowth potential decreases with the age of the stocking, a production period of about 20 to 30 years can be expected depending on the frequency of the total harvest.

[15] https://www.moorfutures.de/projekte/polder-kieve-mecklenburg-vorpommern/
[16] Hohlbein, M. (2013): Potenziale für Paludikultur im Thurbruch (Usedom) (Diplomarbeit)
[17] Ministerium für Landwirtschaft und Umwelt Mecklenburg-Vorpommern (2017): Zweihiebige Erstaufforstungen – Integration von Kurzumtriebsbestockungen in Erstaufforstungen

The procedure is as follows: At the time t=0, 5 ha rewetted peatland are afforested with alders and 55 ha are afforested with willows. After 5 years all willows will be harvested. 5 ha will be cleared (removal of all willow roots) and afforested with alders. The willows on the remaining area (50 ha) sprout again. After 10 years the procedure will be repeated so that we have 15 ha planted with alders, 45 ha with willows. This process will be repeated in total 6 times. In year 30 the remaining 30 ha willow area will be harvested, all roots removed and re-planting is repeated with new willow seedlings. The procedure will be continued until year 60.

Tab. 1: Planting and harvesting procedure (in ha)

year	t=0	5	10	15	20	25	30	35	40	45	50	55	60
planting alder	5	5	5	5	5	5	5	5	5	5	5	5	
planting willows	55						30						
Area alder	5	10	15	20	25	30	35	40	45	50	55	60	
Area willows	55	50	45	40	35	30	25	20	15	10	5	0	
harvesting alder													5
harvesting willows		55	50	45	40	35	30	25	20	15	10	5	

It is an afforestation method with potentially greater economic attractiveness than in BC I. In this process, the production of wood biomass in short-rotation forestry plays a decisive role, as this production target is integrated into the basic objective of new forest formation.

In the case of willow short-rotation plantations, the plant material consists of annual rods cut into 25 cm long cuttings.

Projected Expenditure and Revenues

Expenditures

The following calculation is based on an alder forest (BCI) or an alder/willow mix (BCII) established at the valuation date (t = 0), which is managed until the harvest at the average age of 60 years. The nominal costs have been discounted in two scenarios at a rate of 1% per annum and 2% per annum. While real interest rates averaged 3% per annum during the 20th century, they are currently much lower, so lower real interest scenarios have been used here.

Basis for calculating of the total costs:

Bogwood GmbH will incur costs in the following categories:

- administrative costs
- renting / purchasing costs
- afforestation
- forest maintenance
- timber harvesting with classic equipment + additional costs for special harvesters
- drying of willow (in BCII)

Land rent or purchasing costs:

Renting[18]: 363.70 € / ha / a arable land; 175.80 € / ha / a grassland

Purchase[19]: 17,100 € arable land; 6,700 € grassland

Administrative costs:

50 € / ha / a[20]: ***3,000 € / a***

For the calculation in BC I it is assumed, that the administrative costs are incurred for 1 ha in the first year, for 2 ha in the second year, etc. After 60 years the administrative costs for the whole area of 60 ha must be calculated.

For BC II administrative costs for the whole 60 ha incurred from the very beginning.

Rewetting costs:

For rewetting of peatlands rewetting costs of 40 – 110 € / t $CO_{2\text{-eq}}$ / ha can be expected[21]. Bogwood GmbH would be able to rewet the site in the Thurbruch at a cost of 50 € / t $CO_{2\text{-eq}}$ / ha, because the necessary pumping stations and weirs already exist. Assuming an emission of 20 t $CO_{2\text{-eq}}$ / ha /a, the rewetting of one hectare peatland costs 1,000 €. This price has also been calculated in the Alnus guide[22].

1,000 € / ha; 60,000 € for the whole area

Afforestation costs BC I:

3,000 seedlings/ha, 1 €/plant + 0.4 € working time/plant

3,000 € /ha for the seedlings, 1,200 € working time / ha

Tab. 2: Stand establishment costs for a alder afforestation [23]

Amount of plants	3,000 – 3,500 / ha
Unit price of the plant	0.75 – 1.50 €/Plant
Planting	0.20 – 0.50 €/Plant

Afforestation costs per year: 4.200 €

Young growth care BC I

[18] Bodenrichtwertkarte 2018 für Flächen der Land-und Forstwirtschaft Landkreis Vorpommern
[19] Bodenrichtwertkarte 2018 für Flächen der Land-und Forstwirtschaft Landkreis Vorpommern
[20] Schäfer, A. & Joosten, H. (Hrsg.) (2005): Erlenaufforstung auf wiedervernässten Niedermooren : ALNUS-Leitfaden. Institut für Dauerhaft Umweltgerechte Entwicklung der Naturräume der Erde (DUENE) e.V., Greifswald.), page 18
[21] https://www.bundesregierung.de/breg-de/aktuelles/moore-die-natuerlichen-filter-399710
[22] Schäfer, A. & Joosten, H. (Hrsg.) (2005): Erlenaufforstung auf wiedervernässten Niedermooren : ALNUS-Leitfaden. Institut für Dauerhaft Umweltgerechte Entwicklung der Naturräume der Erde (DUENE) e.V., Greifswald.), page 17
[23] Achim Schäfer 2020, Manuskript für UBA Projekt „Anreize für Paludikultur zur Umsetzung der Klimaschutzziele 2030 und 2050"

The routine silvicultural treatment of the alder stands carried out in three phases: young growth care, young stock care and stand care[24]. Details are explained in the Innovation programme[25].

The costs are 250 € per hectare for the first thinnings[26]. The thinning must be conducted 4 times until the wood is in such a high quality that it can be sold without loss. We assume a first thinning after 15 years, where most of the trees of the first planted 10 ha are 10 years old.

After 15 years: 10 ha

After 25 years: 20 ha

After 35 years: 30 ha

After 45 years: 40 ha

Thinning in later stages of tree age are at least cost neutral or generate some returns: The harvest costs can be compensated with the income from the sale of the discarded low-quality wood[27]. We therefore calculate with forest care costs in the first years. After 40-50 years costs and expenditures are in balance.

Afforestation costs and young growth care BC II:

Here the afforestation and young growth costs for alder trees include the same components as in BCI and are similar in magnitude. Additional costs will be incurred for establishing and maintaining the short-rotation willow plantation.

Planting and care of willows is indicated with 2,300 – 3,000 € / ha in 3 years[28]. Other literature calculates with a similar price, but only in the year of planting:[29,30,31]. We base on this literature and calculate with 2,500 € / ha.

Recultivation measures for the remaining willow plantation are necessary after 30 years, because of the reduced regrowth. Recultivation must thus be carried out for 30 ha. The costs for this are around 1 000 € / ha. Every 5 years, recultivation measures are required to convert 5 ha of willow to alder production. Here too, a price of 1 000 € / ha can be assumed because the roots of the willows have to be dug up in the same way.

Nominal costs:

T = 4, 9, 14, 19, 24, 34, 39, 44, 49 years: 45 ha -> 45,000 €
T = 30 years: 30 ha -> 30,000 €

Timber harvest BC I:

---

[24] Schäfer, A. & Joosten, H. (Hrsg.) (2005): Erlenaufforstung auf wiedervernässten Niedermooren: ALNUS-Leitfaden. Institut für Dauerhaft Umweltgerechte Entwicklung der Naturräume der Erde (DUENE) e.V., Greifswald.)

[25] BioBIGG (2020): Innovation Programme: Material use of *Alnus glutinosa* from Paludiculture as Construction Material in Mecklenburg Western Pommerania (MV)

[26] Schäfer, A. & Joosten, H. (Hrsg.) (2005): Erlenaufforstung auf wiedervernässten Niedermooren : ALNUS-Leitfaden. Institut für Dauerhaft Umweltgerechte Entwicklung der Naturräume der Erde (DUENE) e.V., Greifswald, page 16

[27] Schäfer, A. & Joosten, H. (Hrsg.) (2005): Erlenaufforstung auf wiedervernässten Niedermooren : ALNUS-Leitfaden. Institut für Dauerhaft Umweltgerechte Entwicklung der Naturräume der Erde (DUENE) e.V., Greifswald, page 17

[28] https://www.landwirtschaftskammer.de/landwirtschaft/ackerbau/nawaro/kurzumtriebsplantagen.htm

[29] Unseld, R. (2014): Anlage und Bewirtschaftung von Kurzumtriebsflächen in Baden-Württemberg: Eine praxisorientierte Handreichung

[30] https://www.energiepflanzen.com/weiden/

[31] Wagner, P. et al. (2012): DLG-Merkblatt 372: DLG-Standard zur Kalkulation einer Kurzumtriebsplantage

Within the context of previous case studies, the total harvest costs are between 23 and 35 €/ solid cubic meters[32]. This exceeds the costs of fully mechanized thinning in deciduous stands on non-wetted floors.

Bogwood GmbH can expect harvest costs of 30 € / m³

After 60 years of growth on average an amount of 348 m³ *Alnus* timber has grown on one hectare[33]. Minus bark loss and harvest loss of 10% each[34], 278.4 m³ is the timber yield after harvesting one hectare[35].

278.4 m³ x 30 € = 8,352 € / ha

Timber harvest BC II:

The harvest- and transportation costs are estimated at 809 €/ha[36] based on a previous study.

Drying costs:

Harvested Wood from short-rotation plantations has a high water content (45 - 65%), which varies seasonally depending on the tree species, weather and site conditions. Therefore, wood must be dried.

15 € /t TM [37]are described as costs. Assuming that TM (dry mass) is identical with atro (absolutely dry), for a biomass increase of $12t_{atro}$/ha/a (see below), 180 € / ha /a must be calculated. That means after every harvest 900 € / ha.

Revenues

<u>**Basis for calculating of the total revenues:**</u>

- Timber revenues
- Silvicultural subsidies

Timber harvest revenues BC I

The price range for alder timber with an average diameter > 40 cm is 100 – 150 € / m³ (solid cubic meters)[38].

With an assumed price of 100 € / m³:

278.4 m³ / ha -> 27,840 € for the harvest of the first ha in year 60, after that recurring nominal revenue of 27.840 € per year

Timber and biomass harvest revenues BC II

---

32 Röhe, P. Schröder, S. (2017): Paludikultur mit Anbau der Schwarzerle; Forstwirtschaft und Klimaschutz auf nassen Mooren; AFZ-Der Wald 23/2017
33 Lockow, K.-W. (1998) Ertragstafel für die Roterle (*Alnus glutinosa* [L.] Gaertn.) im nordostdeutschen Tiefland
34 https://de.wikipedia.org/wiki/Festmeter
35 See also 1st business case
36 Wagner, P. et al. (2012): DLG-Merkblatt 372: DLG-Standard zur Kalkulation einer Kurzumtriebsplantage: page 18
37 Landesamt für Umwelt, Landwirtschaft und Geologie Sachsen: Anbauempfehlungen; Schnellwachsende Baumarten im Kurzumtrieb
38 Utschig, H. Waldwachstumskundliche Charakterisierung der Schwarzerle (*Alnus glutinosa* (L.) GAERTNER) am Beispiel der Wuchsreihe Wasserburg 642

The yields and revenue from alder are as in BCI. The amount of expected biomass from willow per year is dependent on several factors (tree species, variety, location). There are different calculations in literature, ranging from 6 to 15 and more t_{atro}/ha/a[39,40,41]. A biomass increase of 12t_{atro}/ha/a is realistic. Converted to absolutely dry wood a wood chip price of 144.09 € / t_{atro} can be calculated[42]. This yields an income of 1,729.08 € / ha / a.

Subsidies BCI

Currently, part of the afforestation costs of Bogwood GmbH would be eligible for state subsidies for silvicultural measures.

The following subsidies are available (the basis of the data is the currently valid "Guidelines for the Promotion of Forestry Measures" for MV from 10.02.2005)[43]:

- Foundation of the stock (subsidies I)
  Planting material, plantation, land preparation and crop protection against wild animals
  Aid is granted up to 85 % of eligible expenditure for alder crops
  85%: 3,570 € / a
  214,200 € can be reimbursed for the whole area, planted with alder trees.
- Young growth and young stock care (subsidies II)
  Improvement of structure and stability in young stands up to 10 m mean height
  Funding is available for up to two maintenance measures at 220 € per ha
  60 ha x 2 measures x 220 € = 26,400 €
- First afforestation bonus (subsidies III)
  Annual premium of 300 € per ha (farmers) or 175 € per ha (other); up to a duration of 20 years.
  20 x 60 ha x 175 €
  Assuming Bogwood GmbH is not considered an agricultural enterprise, in the first year the subsidy is 175 € for one ha, in the 2nd year 350 € for two ha,…

Subsidies BCII

With the amendment of the Federal Forest Act, short-rotation coppice plantations are not considered to be forests according to § 2 section 2, as long as the respective harvesting takes place within 20 years. This means that no afforestation subsidies may be applied for willows in MV. There has been a cultivation subsidy for short-rotation plantations (subsidies IV) within the framework of the GAK (Joint task for the improvement of the agricultural structure and coastal protection) from 2015[44]. This subsidy ended 2018 so that also this source can no longer be tapped.

Financial viability

---

[39] Atro: absolut trocken (absolutely dry)
[40] Becker, R. (2014): Schnellwachsende Baumarten im Kurzumtrieb; Anbauempfehlungen
[41] Wagner, P. et al. (2012): DLG-Standard zur Kalkulation einer Kurzumtriebsplantage, page 6
[42] Wagner, P. et al. (2012): DLG-Standard zur Kalkulation einer Kurzumtriebsplantage
[43] Summary in Schäfer, A. & Joosten, H. (Hrsg.) (2005): Erlenaufforstung auf wiedervernässten Niedermooren : ALNUS-Leitfaden. Institut für Dauerhaft Umweltgerechte Entwicklung der Naturräume der Erde (DUENE) e.V., Greifswald.), page 19
[44] https://www.wald21.com/energiewald/recht-foerderung/

The first cycle exploitation of the 60 hectare site for timber in all scenarios extends over a period of 120 years.

BCI – Production of timber from Alder (*Alnus glutinosa*)
In order to produce timber on a 60 hectare rewetted site, the company, Bogwood GmbH, will have invested a sum of 1,586,620 Euro at nominal value. Of this sum, 450,600 Euro will have been refinanced through silvicultural subsidies at nominal value (see tab. 3). Whereas the expenditures incurred at the beginning, the timber revenues begin in year 60 (27,840 €).

Tab. 3: Expenditure and income for the BCI scenario with purchasing of the land

	Expenditure and income at …		
	Nominal Value	Real value (adjusted for Inflation at 2% p.a.)	Real value (adjusted for Inflation at 1% p.a.)
Expenditure	*1.586.620,00 €*	*863.765,51 €*	*1.092.848,04 €*
Land purchase	480.000,00 €	480.000,00 €	480.000,00 €
Administration	268.500,00 €	74.254,14 €	135.700,35 €
Rewetting	60.000,00 €	60.000,00 €	60.000,00 €
Afforestation	252.000,00 €	147.513,84 €	190.194,21 €
Young growth care	25.000,00 €	12.931,43 €	17.920,43 €
Timber harvesting	501.120,00 €	89.066,10 €	209.033,06 €
Income	*2.121.000,00 €*	*537.061,86 €*	*1.020.769,84 €*
Timber revenues	1.670.400,00 €	296.887,00 €	696.776,85 €
Subsidies I	214.200,00 €	125.386,76 €	161.665,08 €
Subsidies II	26.400,00 €	12.637,21 €	18.023,55 €
Subsidies III	210.000,00 €	102.150,88 €	144.304,36 €
Balance		**- 326.703,66 €**	**- 72.078,20 €**

To assess the financial viability of the endeavor, two real value scenarios have been calculated, where inflation is assumed at 2% and 1% per annum respectively. In both cases the break-even point is not reached even in year 120. The projected costs exceed the projected revenues from subsidies and timber sale.

A closer look at the cost structure reveals that BCI could be profitable if the company implementing the business model did not have to buy the land they are afforesting. This condition would be fulfilled, if for example Bogwood GmbH had been founded as a joint venture by the landowners in the Thurbruch. Tab. 4 shows that where land must not be purchased for afforestation, production of alder timber for furniture and other high value uses is financially viable under both real value assumptions.

Tab. 4: Expenditure and income for the BCI scenario without purchasing of the land

	Expenditure and income at …		
	Nominal Value	Real value (adjusted for Inflation at 2% p.a.)	Real value (adjusted for Inflation at 1% p.a.)
Expenditure	*1.106.620,00 €*	*383.765,51 €*	*612.848,04 €*
Land purchase	N/A	N/A	N/A

Administration	268.500,00 €	74.254,14 €	135.700,35 €
Rewetting	60.000,00 €	60.000,00 €	60.000,00 €
Afforestation	252.000,00 €	147.513,84 €	190.194,21 €
Young growth care	25.000,00 €	12.931,43 €	17.920,43 €
Timber Harvesting	501.120,00 €	89.066,10 €	209.033,06 €
Income	*2.121.000,00 €*	*537.061,86 €*	*1.020.769,84 €*
Timber revenues	1.670.400,00 €	296.887,00 €	696.776,85 €
Subsidies I	214.200,00 €	125.386,76 €	161.665,08 €
Subsidies II	26.400,00 €	12.637,21 €	18.023,55 €
Subsidies III	210.000,00 €	102.150,88 €	144.304,36 €
Balance		**153.296,34 €**	**407.921,80 €**

BCII – combined alder/willow model

In this business case, Bogwood GmbH will have invested a sum of 2,213,990 Euro at nominal value. Of this sum, 467,225 Euro will have been refinanced through silvicultural subsidies at nominal value (see Tab. 5).

Tab. 5: Expenditure and income for the BCII scenario with purchasing of the land

	Expenditure and income at …		
	Nominal Value	Real value (adjusted for Inflation at 2% p.a.)	Real value (adjusted for Inflation at 1% p.a.)
Expenditure	*2.213.990,00 €*	*1.342.846,56 €*	*1.638.649,71 €*
Land purchase	480.000,00 €	480.000,00 €	480.000,00 €
Administration	357.000,00 €	136.448,28 €	209.278,67 €
Rewetting	60.000,00 €	60.000,00 €	60.000,00 €
Afforestation alder	252.000,00 €	156.238,35 €	195.784,16 €
Afforestation willow	137.500,00 €	137.500,00 €	137.500,00 €
Recultivation willow	75.000,00 €	44.435,53 €	57.388,75 €
Young growth care	25.000,00 €	12.931,43 €	17.920,43 €
Timber harvesting alder	501.120,00 €	92.700,70 €	213.255,73 €
Harvesting willow	266.970,00 €	182.080,02 €	218.832,43 €
Drying costs (willow)	59.400,00 €	40.512,24 €	48.689,54 €
Income	*2.838.221,40 €*	*1.027.828,70 €*	*1.597.412,16 €*
Timber revenues (alder)	1.670.400,00 €	309.002,35 €	710.852,44 €
Biomass revenue (willow)	570.596,40 €	389.160,59 €	467.711,71 €
Subsidies I	214.200,00 €	132.802,59 €	166.416,54 €
Subsidies II	26.400,00 €	13.152,91 €	18.387,64 €
Subsidies III	226.625,00 €	112.011,75 €	156.628,66 €

Subsidies IV	130.000,00 €	71.698,50 €	77.415,16 €
Balance		**- 315.017,86 €**	**- 41.237,55 €**

The combined strategy of a staggered expansion of alder production with a degressive area of willow under short-rotation coppicing is not financially viable even with the inclusion of a now discontinued subsidy for short-rotation coppicing (subsidies IV) in any of the interest rate scenarios. This counter-intuitive finding is due to the low price for woodchips (144,09 Euro/ tonne). Discounting for real value at 1% p.a., a nominal wood chip price of at least 157 Euro/ tonne is required to edge the scenario into profit. Assuming a two percent inflation rate, a wood chip price of at least 261 Euro/ tonne is need to be break even.

The calculations for this business case also reveal that the key to financial viability is not having to purchase (or rent) the land on which the afforestation occurs. This remains the case when no subsidy is received for short-rotation coppicing (see tab. 6).

Tab. 6: Expenditure and income for the BCII scenario without purchasing of the land

	Expenditure and income at …		
	Nominal Value	Real value (adjusted for Inflation at 2% p.a.)	Real value (adjusted for Inflation at 1% p.a.)
Expenditure	*1.733.990,00 €*	*862.846,56 €*	*1.158.649,71 €*
Land purchase	N/A	N/A	N/A
Administration	357.000,00 €	136.448,28 €	209.278,67 €
Rewetting	60.000,00 €	60.000,00 €	60.000,00 €
Afforestation alder	252.000,00 €	156.238,35 €	195.784,16 €
Afforestation willow	137.500,00 €	137.500,00 €	137.500,00 €
Recultivation willow	75.000,00 €	44.435,53 €	57.388,75 €
Young growth care	25.000,00 €	12.931,43 €	17.920,43 €
Timber harvesting alder	501.120,00 €	92.700,70 €	213.255,73 €
Harvesting willow	266.970,00 €	182.080,02 €	218.832,43 €
Drying costs (willow)	59.400,00 €	40.512,24 €	48.689,54 €
Income	*2.708.221,40 €*	*956.130,20 €*	*1.519.997,00 €*
Timber revenues (alder)	1.670.400,00 €	309.002,35 €	710.852,44 €
Biomass revenue (willow)	570.596,40 €	389.160,59 €	467.711,71 €
Subsidies I	214.200,00 €	132.802,59 €	166.416,54 €
Subsidies II	26.400,00 €	13.152,91 €	18.387,64 €
Subsidies III	226.625,00 €	112.011,75 €	156.628,66 €
Subsidies IV	N/A	N/A	N/A
Balance		**93.283,64 €**	**361.347,29 €**

Tab. 6 shows that when there is no expenditure for land purchase it is financially viable under both real value assumptions, although BCI has a better financial output (compare tab. 4).

Assessment of the business case

Few investors will engage in a business model where the break-even is uncertain and so far in the future. However, there are actors for whom such an investment can be attractive:

- Existing forestry businesses, which are used to taking a long view on investments and which have a sufficient stream of revenue from other stands of timber.
- Landowners who already own drained peatland sites that can be rewetted and are suitable for afforestation. If the land had already been owned by Bogwood GmbH (e.g. if the various landowners had come together to setup Bogwood GmbH as a joint company), both business models would be profitable under both discounting scenarios.
- Wealthy Investors hedging against future inflation.

For most other investors, who do not own the land to be rewetted and afforested, the production of timber from *Alnus glutinosa* alone or an alder/willow mix will not constitute an attractive business proposition. Therefore, it is necessary to consider additional income streams that could significantly shorten the time to break-even.

Financing the lag-phase until the first harvest/break-even

From a financial perspective, the feasibility of alder production for high-value purposes can be increased significantly, if the mitigation of negative externalities are included as a revenue. CO_2-offsetting could potentially support this approach.

If drained peatlands are managed in the classical way, this means a constant and enormous emission output. In addition, farmers receive public funding through agricultural subsidies. A replacement of this unfavourable situation with false incentives for agriculture is urgently needed. A change of use towards rewetting on the one hand and the cultivation of moisture-tolerant trees on the other hand will bind an enormous amount of CO_2 in the soil as well as in the trees and reduce emissions therefore in two ways.

Even though no law is passed currently, many initiatives are pointing in that developmental direction of a voluntary CO_2-offsetting. It is already known and established e.g. for air travel and should also prove its worth in the agricultural sector, where projects to reduce emissions are being promoted. The idea is monetize ecosystem services in the form of certificates and shares that can be purchased to finance the necessary changes in agricultural use. Beneath private persons, an exclusive partner with a high CO_2 emission rate would be preferable as partners in the scheme.

In general, large CO_2-emitters like mineral oil companies are interested in mitigating the climate effects of their products. One (disputed) solution is to compensate their emissions caused by consumption of their petroleum-based products by means of a CO_2-reducing measure. The mineral oil company Shell for example is already spending 100 Mio € for afforestation as a compensation for the CO_2 release[45,46]. Most of the money is spent in afforestation projects in Peru and Indonesia. Afforestation in the Thurbruch via a cooperation with Bogwood GmbH would allow large CO_2-emitters to compensate the CO_2 emissions in Germany, i.e. in the country where the emissions took place.

---

[45] https://mobilitymag.de/shell-co2-ausgleich-klimacent/
[46] https://www.shell.de/geschaefts-und-privatkunden/shell-card/mobilitaet-von-morgen/co2-kompensation.html#iframe=L2Zvcm1zL2RlX2RlX3RvcGljc19mb3Jt

The premise of the advanced scenarios is that Bogwood GmbH will sell CO_2 offsetting instruments to producers of huge amounts of CO_2 that are interested in making compensatory payments initially to improve their public image, and/or once CO_2 offsetting becomes a legal requirement are obliged to do so. It would be possible to market offsetting instruments to a wide audience, however given the effort in marketing and administration, it would be advantageous for Bogwood GmbH to seek an exclusive partnership with one large company, such as a mineral oil company.
For land purchase, rewetting, afforestation and care of the forest an initial investment of at 0.5-0.75 million Euro is required in the first 1-2 years, during which the bulk of the costs occur. The reforestation project in Thurbruch would enable Bogwood GmbH to provide the partner company with compensation for its CO_2 emissions.

The precondition is that Bogwood GmbH must be certified that they can verifiably bind CO_2 at the specified amount and that they are allowed to sell this compensation in the form of certificates. The certification must be legally possible and certification authorities must exist. If the basis for this can be established, the added value from CO_2 can remain in the region.

In recent years, two instruments have been established in the State of Mecklenburg-Vorpommern that have successfully monetized ecosystem services. These are **MoorFutures®**[47] and **Waldaktie/Forest Shares**[48]. Whilst these instruments cannot be directly applied to the business case scenarios outlined in this manual because Bogwood GmbH is a commercial for-profit company, they are instructive for estimating potential revenue from offsetting schemes.

MoorFutures® - Credits from peatland rewetting

MoorFutures are carbon certificates for the voluntary carbon market. The MoorFutures standard was launched in 2010 to support peatland restoration in Northeast Germany. They are result-orientated payments for peatland ecosystem services. The price is determined by the costs of the specific rewetting project and thus differs with currently 35/54/67 € per mitigated ton CO_2-eq[49].

One MoorFutures certificate stands for one ton of carbon dioxide equivalents that is not released into the atmosphere by rewetting the peatlands. The proceeds are used to implement projects to rewet peatlands and at the same time contribute to the long-term regeneration of the peatland habitat. MoorFutures are therefore a sustainable investment in climate and nature conservation.

MoorFutures are not shares in the narrower sense and no dividends are granted.

In a current project in MV, the certificates are being sold for 35 € per unit (Polder Kieve[50]; similar area as the examined area in the Thurbruch). For each purchased MoorFutures, one ton of carbon dioxide equivalents will be recorded in the decommissioning register in favour of the investor. The revenues flow into a peat fund and are used specifically for the respective projects.
By converting the vegetation type "grassland" into peatland, about 20 t $CO_{2\text{-eq}}$ / ha / a are saved (depending on the current humidity of the area)[51]. In concrete terms, this means that rewetting would produce CO_2 savings of 17.5 t CO_2-eq /ha / a for the investigated area in the Thurbruch, which

[47] http://www.klimaschutzaktionen-mv.de/Land-und-Forst/Moore/MoorFutures/
[48] https://www.auf-nach-mv.de/waldaktie-wird-umgebaut
[49] Wichmann, s. (2018): Economic Incentives for Climate Smart Agriculture on Peatlands in the EU
[50] https://www.moorfutures.de/projekte/polder-kieve-mecklenburg-vorpommern/
[51] Cowenberg, J. et al. (2011): Assessing greenhouse gas emissions from peatland using vegetation as a proxy; Hydrobiologia 674, 67-89

is predominantly extensively used grassland[52]. After 60 years the theoretical savings are 63,000 t CO_2-eq. (As the detailed calculation requires detailed knowledge of the soil before and after rewetting), we will use Polder Kieve as reference scenario and as the basis for our calculation of the costs of the shares[53]).

Tab. 7: Comparison of shares in Polder Kieve and Thurbruch

	Polder Kieve	**Thurbruch**
area	54,5 ha	60 ha
project duration	50 years	60 years
project costs	500.000 €	600.000 €
CO_2-reduction	14,325 t	29,789.17 t
Price per share	35 €	38 €
total revenue	501,375€	1,131,988.62 €
total revenue / a		18,866.48 €

As the Polder Kieve was the first project of its kind, a generous risk reserve seemed appropriate[54]. Instead of the actual estimate of 38,655 t CO_2-eq over the project period in Polder Kieve, a reduction of only 14,325 t CO_2-eq was assumed. Thus, 24,330 certificates (1 t CO_2-eq each) were set aside to cover any risks or misjudgements. Now, a 30% reserve is taken as standard in rewetting projects.

Applying the MoorFutures® calculation basis to an afforestation regime as in BCI and II, the following revenue could potentially be generated from the Thurbruch site in the 60 years to harvest.

Tab. 8: MoorFutures®

	Income at …		
	Nominal rate	Discounting rate for current prices (p.a.)	Discounting rate for current prices (p.a.)
		2%	1%
	€/N ha	€/ha	€/ N ha
Income from MoorFutures® (60 years)	1.131.988,80 €	662.635,08 €	854.356,03 €

If Bogwood GmbH was able to generate income from the sale of a MoorFutures®-type certificate for CO_2 compensation, BCI as well as BCII would be a financially viable proposition in both the 1% and 2% inflation scenarios (see tab. 9 and 10)

Tab: 9: Expenditure and income for the BCI scenario with purchasing of the land and revenues from MoorFutures®

	Expenditure and income at …

[52] Konzept zum Schutz und zur Nutzung der Moore: Fortschreibung des Konzeptes zur Bestandssicherung und zur Entwicklung der Moore, page 72, tab. 13
[53] Couwenberg, J., Michaelis, D. (2025): Polder Kieve: MoorFutures-Projekt Mecklenburg-Vorpommern, 1. Monitoringbericht 2015
[54] Ministerium für Landwirtschaft und Umwelt Mecklenburg-Vorpommern: Projektdokument MoorFutures Polder Kieve (Mecklenburg-Vorpommern), page 19

	Nominal Value	Real value (adjusted for Inflation at 2% p.a.)	Real value (adjusted for Inflation at 1% p.a.)
Expenditure	*1.586.620,00 €*	*863.765,51 €*	*1.092.848,04 €*
Land purchase	480.000,00 €	480.000,00 €	480.000,00 €
Administration	268.500,00 €	74.254,14 €	135.700,35 €
Rewetting	60.000,00 €	60.000,00 €	60.000,00 €
Afforestation	252.000,00 €	147.513,84 €	190.194,21 €
Young growth care	25.000,00 €	12.931,43 €	17.920,43 €
Timber harvesting	501.120,00 €	89.066,10 €	209.033,06 €
Income	*3.252.988,80 €*	*1.199.696,94 €*	*1.875.125,87 €*
Timber revenues	1.670.400,00 €	296.887,00 €	696.776,85 €
Subsidies I	214.200,00 €	125.386,76 €	161.665,08 €
Subsidies II	26.400,00 €	12.637,21 €	18.023,55 €
Subsidies III	210.000,00 €	102.150,88 €	144.304,36 €
Revenue from MoorFutures®	1.131.988,80 €	662.635,08 €	854.356,03 €
Balance		**335.931,42 €**	**782.277,83 €**

Tab. 10: Expenditure and income for the BCII scenario with purchasing of the land and revenues from MoorFutures®

	Expenditure and income at …		
	Nominal Value	Real value (adjusted for Inflation at 2% p.a.)	Real value (adjusted for Inflation at 1% p.a.)
Expenditure	*2.213.990,00 €*	*1.342.846,56 €*	*1.638.649,71 €*
Land purchase	480.000,00 €	480.000,00 €	480.000,00 €
Administration	357.000,00 €	136.448,28 €	209.278,67 €
Rewetting	60.000,00 €	60.000,00 €	60.000,00 €
Afforestation Alder	252.000,00 €	156.238,35 €	195.784,16 €
Afforestation Willow	137.500,00 €	137.500,00 €	137.500,00 €
Recultivation Willow	75.000,00 €	44.435,53 €	57.388,75 €
Young growth care	25.000,00 €	12.931,43 €	17.920,43 €
Timber Harvesting Alder	501.120,00 €	92.700,70 €	213.255,73 €
Harvesting Willow	266.970,00 €	182.080,02 €	218.832,43 €
Drying Costs (Willow)	59.400,00 €	40.512,24 €	48.689,54 €
Income	*3.840.210,20 €*	*1.618.765,28 €*	*2.374.353,03 €*
Timber revenues (Alder)	1.670.400,00 €	309.002,35 €	710.852,44 €
Biomass revenue (Willow)	570.596,40 €	389.160,59 €	467.711,71 €
Subsidies I	214.200,00 €	132.802,59 €	166.416,54 €
Subsidies II	26.400,00 €	13.152,91 €	18.387,64 €
Subsidies III	226.625,00 €	112.011,75 €	156.628,66 €
Subsidies IV	N/A	N/A	N/A

Revenue from MoorFutures®	1.131.988,80 €	662.635,08 €	854.356,03 €
Balance		**275.918,72 €**	**735.703,32 €**

A prerequisite for MoorFutures® funding is that no further funding can be perceived (otherwise it would be double funding). Since rewetting and the associated reduction of CO_2 emissions are not eligible for grants in MV, the MoorFutures® can be issued for land there.

Waldaktie/Forest Share[55]

With the purchase of 2 forest shares at a value of 10 € each, trees can be cultivated on an area of 10 square meters. This is a symbolic compensation for the carbon dioxide emissions caused by a family of four during their annual holiday.

1 forest share = 5m² = 10€
60 ha = 600,000 m²
60 ha: 120,000 forest shares
1 ha: 2,000 forest shares

For an area the size of the Thurbruch, 120,000 forest shares could be sold.

Tab. 11: Forest Shares

	Nominal rate	Discounting rate for current prices (p.a.)	Discounting rate for current prices (p.a.)
		2%	1%
	€/N ha	€/ha	€/ N ha
Revenue from forest shares	1.200.000,00 €	702.446,86 €	905.686,72 €

The forest shares instrument may not be used if funding for afforestation is available from other sources. However, if the application states that the subsidies are too low, it would at least be conceivable that forest shares could be used to cover the difference (forest shares minus the subsidies). Assuming no eligibility for silvicultural subsidies and the issuing of forest share type certificates, the potential expenditure and revenue in BCI is shown below:

Tab. 12: Expenditure and income for the BCI scenario with purchasing of the land and revenues from Forest Shares

	Expenditure and income at …		
	Nominal Value	Real value (adjusted for Inflation at 2% p.a.)	Real value (adjusted for Inflation at 1% p.a.)
Expenditure	*1.586.620,00 €*	*863.765,51 €*	*1.092.848,04 €*
Land purchase	480.000,00 €	480.000,00 €	480.000,00 €

[55] https://www.auf-nach-mv.de/waldaktie-wird-umgebaut

Administration	268.500,00 €	74.254,14 €	135.700,35 €
Rewetting	60.000,00 €	60.000,00 €	60.000,00 €
Afforestation	252.000,00 €	147.513,84 €	190.194,21 €
Young growth care	25.000,00 €	12.931,43 €	17.920,43 €
Timber harvesting	501.120,00 €	89.066,10 €	209.033,06 €
Income	*2.870.400,00 €*	*999.333,85 €*	*1.602.463,57 €*
Timber revenues	1.670.400,00 €	296.887,00 €	696.776,85 €
Subsidies I	N/A	N/A	N/A
Subsidies II	N/A	N/A	N/A
Subsidies III	N/A	N/A	N/A
Revenue from Forest shares	1.200.000,00 €	702.446,86 €	905.686,72 €
Balance		**135.568,34 €**	**509.615,52 €**

Tab. 13: Expenditure and income for the BCII scenario with purchasing of the land and revenues from Forest Shares

	Expenditure and income at ...		
	Nominal Value	Real value (adjusted for Inflation at 2% p.a.)	Real value (adjusted for Inflation at 1% p.a.)
Expenditure	*2.213.990,00 €*	*1.342.846,56 €*	*1.638.649,71 €*
Land purchase	480.000,00 €	480.000,00 €	480.000,00 €
Administration	357.000,00 €	136.448,28 €	209.278,67 €
Rewetting	60.000,00 €	60.000,00 €	60.000,00 €
Afforestation Alder	252.000,00 €	156.238,35 €	195.784,16 €
Afforestation Willow	137.500,00 €	137.500,00 €	137.500,00 €
Recultivation Willow	75.000,00 €	44.435,53 €	57.388,75 €
Young growth care	25.000,00 €	12.931,43 €	17.920,43 €
Timber Harvesting Alder	501.120,00 €	92.700,70 €	213.255,73 €
Harvesting Willow	266.970,00 €	182.080,02 €	218.832,43 €
Drying Costs (Willow)	59.400,00 €	40.512,24 €	48.689,54 €
Income	*3.908.221,40 €*	*1.658.577,06 €*	*2.425.683,71 €*
Timber revenues (Alder)	1.670.400,00 €	309.002,35 €	710.852,44 €
Biomass revenue (Willow)	570.596,40 €	389.160,59 €	467.711,71 €

Subsidies I	214.200,00 €	132.802,59 €	166.416,54 €
Subsidies II	26.400,00 €	13.152,91 €	18.387,64 €
Subsidies III	226.625,00 €	112.011,75 €	156.628,66 €
Subsidies IV	N/A	N/A	N/A
Revenue from Forest Shares	1.200.000,00 €	702.446,86 €	905.686,72 €
Balance		**315.730,50 €**	**787.034,00 €**

As the tables 12 and 13 show, with a forest share type scheme, no subsides are necessary to achieve a net profit. The net income is higher in the short-rotation scenario of BCII.

A combination of MoorFutures® and forest shares is conceivable: While MoorFutures® support rewetting, forest shares provide funds for afforestation and maintenance.

Sale of CO_2-Offsetting – nEHS

The national emissions trading system (nEHS) will start in 2021 with a fixed price system in Germany with a CO_2 pricing for transport and heating[56], i.e. the price per ton of CO_2 is fixed and politically determined. Under this system, certificates are sold to companies that place heating and fuel on the market. The costs of the certificates are then paid by the fuel trade: if companies sell heating oil, liquid gas, natural gas, coal, petrol or diesel, they need a certificate as a pollution right for every ton of CO_2 that the substances will cause in consumption.

The federal and state governments agreed in the Mediation Committee to set the CO_2 price at an initial 25 euros from January 2021. Thereafter, the price will gradually increase up to 55 euros in 2025. For the year 2026, a price corridor of at least 55 and at most 65 euros will apply.

The distribution of CO_2 right to pollute certificates will regulated by the government. Given a scenario whereby CO_2 -emitters can reduce the amount of CO_2 for which they have to purchase right to pollute certificates by documenting CO_2 compensation activities. For this purpose, there must be a system for certifying verifiable and long-term CO_2 offsetting activities. One or more accreditation agencies must exist to which companies seeking to provide CO_2 offsetting service can apply for the right to issue compensation certificates to their customers, and the criteria to be fulfilled must be clear. After successful certification, the corresponding quantity of certificates is issued (depending on the amount of savings), which can then be resold to third parties.

Scenario: Sale of CO_2-Certificates to Shell as an offsetting measure to reduce mandatory compensation requirements

The fixed price system in Germany is nearly decided, only the introduction date and the exact costs of the certificates are still under discussion.

[56] https://www.bundesregierung.de/breg-de/themen/klimaschutz/co2-bepreisung-1673008

It must be possible that companies invest in CO_2-reducing measures in which the CO_2 savings are offset against the governmental CO_2 certificates.
For this scenario, we assume a conservative nEHS price corridor with 25 € in year 1-4 and 55 € in the following years. In order to provide an attractive service to Shell, Bogwood GmbH will offer CO_2 compensation at a lower price than right to pollute certificates. Due to the lower price and the additional image benefits of paying for actual carbon saving, the product will be attractive to CO_2 emitters, like Shell.
For calculation purposes, it will be assumed that Bogwood GmbH will be able to sell CO_2 compensation certificates at a price 10% below the nEHS corridor values. Year 1-4: 22,50 Euro and Year 5-60: 49,50 Euro.
Through rewetting and reforestation with alders, emissions of about 17.5 t CO_2 per hectare and year can be avoided[57].
Given an emission reduction of 17.5 t CO_{2}-eq / ha / a and the afforestation regime under BCI, emission reductions over time will be as follows:

Year 1: 17.5 t (17.5 t x 1 ha)
Year 2: 35 t (17.5 t x 2 ha)
Year 3: 52.5 t (17.5 t x 2 ha)
Year 4: 70 t (17.5 t x 4 ha)
Year 5: 87.5 t (17.5 t x 5 ha)
Year 6: 105 t (17.5 t x 6 ha) …
.
.
.

After 60 years, when 60 hectares of forest are planted, a total of 1050 t CO_{2}-eq / a can be compensated by the Bogwood GmbH site.

Tab. 14: Revenue from CO_2 offsetting certificates over 60 years BCI

	Nominal rate	Discounting rate for current prices (p.a.)	Discounting rate for current prices (p.a.)
		2%	1%
	€/N ha	€/ha	€/ N ha
Revenue from CO_2 Offset Certificates	1.580.512,50 €	743.431,43 €	1.074.277,73 €

Adding the revenue from CO_2 offsetting certificates to the BCI Scenario ensures a constant and increasing revenue stream during the time to first harvest. The potential revenue from CO_2 offsetting certificates is greater than from timber and is allows for Bogwood GmbH to generate profits from rewetting and afforestation with alder trees (see tab: 15 below).

Tab. 15: Expenditure and income for the BCI scenario with purchasing of the land and revenues

	Expenditure and income at …

[57] Konzept zum Schutz und zur Nutzung der Moore: Fortschreibung des Konzeptes zur Bestandssicherung und zur Entwicklung der Moore, page 72, tab. 13

	Nominal Value	Real value (adjusted for Inflation at 2% p.a.)	Real value (adjusted for Inflation at 1% p.a.)
Expenditure	*1.586.620,00 €*	*863.765,51 €*	*1.092.848,04 €*
Land purchase	480.000,00 €	480.000,00 €	480.000,00 €
Administration	268.500,00 €	74.254,14 €	135.700,35 €
Rewetting	60.000,00 €	60.000,00 €	60.000,00 €
Afforestation	252.000,00 €	147.513,84 €	190.194,21 €
Young growth care	25.000,00 €	12.931,43 €	17.920,43 €
Timber harvesting	501.120,00 €	89.066,10 €	209.033,06 €
Income	*3.701.512,50 €*	*1.280.493,28 €*	*2.095.047,57 €*
Timber revenues	1.670.400,00 €	296.887,00 €	696.776,85 €
Subsidies I	214.200,00 €	125.386,76 €	161.665,08 €
Subsidies II	26.400,00 €	12.637,21 €	18.023,55 €
Subsidies III	210.000,00 €	102.150,88 €	144.304,36 €
CO_2 offset certificates	1.580.512,50 €	743.431,43 €	1.074.277,73 €
Balance		**416.727,77 €**	**1.002.199,53 €**

For the BCII scenario the situation looks even better: Because the whole area is planted from the very beginning, the CO_2-Certificates can be sold from the 1st year onwards for the whole area. It must be noted that the emission reduction of willow will not be as much as for alder. The values lie between 17.5 t CO_2 per hectare and year (afforestation after rewetting) and 8.5 t CO_2 per hectare and year (rewetting with utilization, e.g. reed[58]). Because no information on short-rotation plantations can be found in the literature, we calculate with 10 t CO_2 per hectare and year emission reduction with willows.

Tab 16: Revenue from CO_2 offsetting certificates over 60 years BCII

			Discounting rate for current prices (p.a.)	Discounting rate for current prices (p.a.)
			2%	1%
		€/N ha	€/ha	€/ N ha
Revenue from CO_2 Offset Certificates Alder		1.658.081,25 €	1.388.475,02 €	1.133.141,38 €
Revenue from CO_2 Offset Certificates Willow		757.350,00 €	522.606,91 €	624.628,41 €
Cumulated		2.415.431,25 €	1.911.081,93 €	1.757.769,79 €

Tab. 17: Expenditure and income for the BCII scenario with purchasing of the land and revenues

	Expenditure and income at …

[58] Konzept zum Schutz und zur Nutzung der Moore: Fortschreibung des Konzeptes zur Bestandssicherung und zur Entwicklung der Moore, page 72, tab. 13

	Nominal Value	Real value (adjusted for Inflation at 2% p.a.)	Real value (adjusted for Inflation at 1% p.a.)
Expenditure	*2.213.990,00 €*	*1.342.846,56 €*	*1.638.649,71 €*
Land purchase	480.000,00 €	480.000,00 €	480.000,00 €
Administration	357.000,00 €	136.448,28 €	209.278,67 €
Rewetting	60.000,00 €	60.000,00 €	60.000,00 €
Afforestation Alder	252.000,00 €	156.238,35 €	195.784,16 €
Afforestation Willow	137.500,00 €	137.500,00 €	137.500,00 €
Recultivation Willow	75.000,00 €	44.435,53 €	57.388,75 €
Young growth care	25.000,00 €	12.931,43 €	17.920,43 €
Timber Harvesting Alder	501.120,00 €	92.700,70 €	213.255,73 €
Harvesting Willow	266.970,00 €	182.080,02 €	218.832,43 €
Drying Costs (Willow)	59.400,00 €	40.512,24 €	48.689,54 €
Income	*5.123.652,65 €*	*2.867.212,13 €*	*3.277.766,79 €*
Timber revenues (Alder)	1.670.400,00 €	309.002,35 €	710.852,44 €
Biomass revenue (Willow)	570.596,40 €	389.160,59 €	467.711,71 €
Subsidies I	214.200,00 €	132.802,59 €	166.416,54 €
Subsidies II	26.400,00 €	13.152,91 €	18.387,64 €
Subsidies III	226.625,00 €	112.011,75 €	156.628,66 €
Subsidies IV	N/A	N/A	N/A
CO_2 offset certificates	2.415.431,25 €	1.911.081,93 €	1.757.769,79 €
Balance		**1.524.365,57 €**	**1.639.117,08 €**

Summary

The combination of most of the scenarios of BCI and BCII with or without subsidies show that a lot of possibilities generate an attractive income in a long term. Most profitable are the CO_2 certificates in BCII. Interestingly, the net income is high even if the land must be purchased. In this case it should be noted that a lot of money must be invested in the first year and the income is postponed to a later period.

Tab 18: Overview

	Subsidies	purchase of land	Real value (adjusted for Inflation at 2% p.a.)	Real value (adjusted for Inflation at 1% p.a.)
BCI	I, II, III	+	- 326.703,66 €	- 72.078,20 €
	I, II, III	-	153.296,34 €	407.921,80 €
	I, II, III, Moorfutures®	+	335.931,42 €	782.277,83 €
	I, II, III, Forest Share	+	135.568,34 €	509.615,52 €
	I, II, III, CO_2 offset certificates	+	416.727,77 €	1.002.199,53 €
BCII	I, II, III, IV	+	- 315.017,86 €	- 41.237,55 €
	I, II, III	+	- 386.716,36 €	- 118.652,71 €
	I, II, III	-	93.283,64 €	361.347,29 €
	I, II, III, Moorfutures®	+	275.918,72 €	735.703,32 €

	I, II, III, Moorfutures®	-	755.918,72 €	1.215.703,32 €
	I, II, III, Forest Share	+	315.730,50 €	787.034,00 €
	I, II, III, Forest Share	-	795.730,50 €	1.267.034,00 €
	I, II, III, CO_2 offset certificates	+	1.524.365,57 €	1.639.117,08 €
	I, II, III, CO_2 offset certificates	-	2.004.365,57 €	2.119.117,08 €

Outlook

We could show that rewetting and afforestation with alder (BCI) is an interesting business case, if subsidies can be claimed and even more so if CO_2 offsetting certificates could be sold by landowners to third parties. To achieve the climate protection goals it becomes more and more important to establish compensation payments for emissions. The ability to compensate or ideally even to overcompensate CO_2 emissions (combination of rewetting and afforestation) is dependent on finding sufficient carbon dioxide sink projects. Current tendencies to locate projects that compensate European CO_2 emissions in the Global South are unsustainable and unethical in terms of global justice. Therefore there is a concrete need for offsetting projects in Europe. Commercial for-profit activities in this sphere should be an important element that complement activities like moor futures in the non-profit sector, as they can provide an incentive for landowners to engage in peatland rewetting and afforestation and offer a source of income in rural areas around the Baltic Sea. To this end it is essential that policy makers establish regulations that permit farmers and SMEs in particular to offer for-profit CO_2 emission offsetting services to large corporate CO_2 emitters (and to the general public). In addition, to ensure verifiable CO_2 offsetting, policy makers should support the creation of standards and accreditation bodies for actors providing CO_2 emission offsetting services.

For the business case "Alders on rewetted peatlands in MV ", i.e. rewetting and afforestation with optimal CO_2 savings, a separate eco-paper could be developed. The Ministry of Agriculture and Environment of Mecklenburg-Vorpommern is open to this approach, so that this can be further consolidated.

The business case manual shows, that a double-cut afforestation with a combination of *Alnus* and *Salix* (BC II) is more profitable than with *Alnu*s alone. But only with governmental subsidies an interesting business case can be created. However, it should be mentioned that the reduction in CO_2 emissions is much higher if dry peatlands are rewetted and then additionally planted immediately (like in BCII). Also the amount of generated biomass is higher. But also other possibilities to make this business model attractive, should be pursued. If for example willow wood chips are used in a biomass heating plant, additional subsidies are available for the energy production. It would be worthwhile to calculate the double-cut afforestation with the use of willow for energy in a future report.

POSSIBILITIES FOR AN INTEGRATED WOOD PELLET PRODUCTION

COLOURBOX9818068

Author:	*Valerie Sartorius, Jennifer Nitzschke, Lena Huck,* Agency of Renewable Resources (FNR)
Editor:	*Martin Behrens,* Agency of Renewable Resources (FNR)

Project Title:	Bioeconomy in the South Baltic Area: Biomass-based Innovation and Green Growth
Project Acronym	BioBIGG
Work Package	Work package 5: Implementation of innovative agro-industrial value-chains and biomass-based production in SME's
Deliverable:	Deliverable 5.3: Cross-border implementation models and business case manuals for SMEs

Published by:	BioBIGG

Business case: Integration of a wood pellet production into an operating sawmill

The integration of a wood pellet production into an operating sawmill is possible for small as well as medium sized companies whereby the overall restriction is a sawmills' cutting quantity. Because a pellet production is only feasible if the production capacity exceeds at least 15.000 t/a. This number can vary as it depends on a consistent feedstock availability, short transport routes, reliable customers and the possible use of existing energy sources such as waste heat of a combined heat and power plant. For small companies it is advisable to involve a consultancy company, which will help in the early years with advice and deed. The energy costs count to the main expenses of the company as energy and heat are required for the pelleting and drying process. Germany's large wood supply and high sawmill density as well as free competition and transparent pricing form a good basis for regional pellet production.

<table>
<tr><td colspan="2">Country</td><td colspan="2">Germany</td></tr>
<tr><td colspan="2">Name of company or project</td><td colspan="2">Integrated Wood Pellet Production</td></tr>
<tr><td colspan="2">Web site</td><td colspan="2"></td></tr>
<tr><td colspan="2">Description of the company or projects</td><td colspan="2">Implementation of a pellet production into an operating sawmill at regional level.</td></tr>
<tr><td colspan="2" rowspan="3">Type of production (choose one or more, mark box(es))</td><td>Energy production</td><td>x</td></tr>
<tr><td>Circular bioeconomy development</td><td>x</td></tr>
<tr><td>Production of non-energy high value added products</td><td></td></tr>
<tr><td colspan="2" rowspan="5">Source of biomass (choose one or more, mark box(es))</td><td>Agriculture and food industry</td><td></td></tr>
<tr><td>Municipal waste and sewage</td><td></td></tr>
<tr><td>Fishery and algae</td><td></td></tr>
<tr><td>Wood</td><td>x</td></tr>
<tr><td>Several sources</td><td></td></tr>
<tr><td colspan="2">Description of products from biomass</td><td colspan="2">Production of wood pellets for the heat and/or energy production</td></tr>
<tr><td rowspan="3">How does the business case fulfil sustainability criteria (please explain the following benefits)?</td><td>Economic benefits</td><td colspan="2">The production, the sale and the consumption stay within the region</td></tr>
<tr><td>Social benefits</td><td colspan="2">Creates jobs in the region,</td></tr>
<tr><td>Environmental benefits</td><td colspan="2">Reduces the transport ways and therefore reduces CO_2 emissions. Promotes the sustainable bioeconomy in the region.</td></tr>
<tr><td colspan="2" rowspan="3">Technology readiness level (choose the appropriate box and mark it with x)</td><td>5. Technology validated in relevant environment</td><td></td></tr>
<tr><td>6. Technology demonstrated in relevant environment</td><td></td></tr>
<tr><td>7. System prototype in operational environment</td><td></td></tr>
</table>

		8. System complete and qualified	
		9. System operational	x
Transferability to small and medium sized companies in the BSR countries		The project is transferable to small and medium sized companies but depends on the sawmill's cutting quantity	
Existing enabling policies and economic factors (describe the policy measures like subsidies, tax breaks, price policy, regulations that are crucial for making this business case economically viable).		When producing pellets care must be taken, that the product fulfils the air quality regulation, which means that some wood residues and tree species cannot be used for the pellet production. The profitability of the company also depends on the pellet standards, if these become mandatory, it can be difficult for many, especially small business topics to meet all the requirements without additional costs and a lot of extra effort. On the other hand, it secures a sustainable production.	
Hashtags (select from drop down menu up to six most relevant hashtags (key words) related to this case in a ranked order starting from the most important)		#Circular Bioeconomy	
		#GHG emission Reduction	
		#Environmental friendly	
		#Woody/Forestry Biomass	
		#Heat	
		#Regionality	
	Business model block	Description	Notes
Infrastructure	Key partnerships	The network the organization uses to operate its business model	Cooperation with consultant company, distributors and sawmills in the region
	Key activities	The main activities required for making the business work	Create firm customer base, good marketing, and secure feedstock availability throughout the year.
	Key resources	Most important tangible and intangible assets required for the business model	Available feedstock (sawdust, wood chips), technology
Value proposition	Value proposition	Value offered to customers in mix of products and services	Environmentally friendly and energy efficient wood pellets from the region
Customer interface	Customer relationships	Type of relationships the organization has with customers	A trustworthy and open relationship
	Customer segments	Specific groups of customers the organization aims to reach and serve	Single households, business apartments, buildings with a central pellet heating/ pellet furnace
	Distribution channels	How organization reaches its customers	Through distributors, marketing
Roughly cost of the implementation and operation			
Financial viability	Cost structure	Most significant costs for operating the business model	Heating costs for the drying and pelleting process
	Revenue stream	What kind of cash flows different customers create for the organization	

Comments	The success of an integrated pellet production into an operating sawmill depends on the cutting quantity of the sawmill. Furthermore, the cooperation with a distributor is advisable as well as the involvement of a consultant company.
Who entered data and when	Valerie Sartorius, 23.11.2020

Agro-industrial sector

KERATIN HYDROLYSATE PRODUCTION FROM POULTRY FEATHERS

COLOURBOX33938251

19.04.2020

Business Case

Keratin hydrolysate production from poultry feathers

Gdańsk University of Technology

Aleksandra Gołąbek

Dariusz Mikielewicz

1 Executive Summary

The global economy is constantly changing towards a more sustainable and based on the idea of a circular economy and cascading approach. This approach influences, among others, the development of technologies using organic waste and residues from plant and animal production as a raw material in subsequent processes, thereby increasing its added value and extending the value chain. One of such waste is slaughter feathers, which today, despite their valuable properties, are largely not processed in a way that would allow their potential to be used. Bearing in mind the pursuit of a sustainable economy and the situation related to poultry feathers, a solution has been proposed that is based on their use in the production of keratin hydrolysate. Keratin hydrolysate is a water-soluble solution that is increasingly used in many industries, for example as a component of cosmetics, drugs, food, and feed, and even as a component of biodegradable packaging materials. In addition, the use of post-slaughtering feathers to produce a valuable ingredient is beneficial for environmental reasons and could be financially profitable.

To be able to implement the proposed solution, it is necessary to analyze its cost-effectiveness and associated risk, which was the subject of this study. Due to the lack of installation for the production of keratin hydrolysate, operating in real conditions, and the availability of the process description in laboratory conditions, it was assumed that the production of the product takes place on a small scale, corresponding to the laboratory scale, the product is sold in an online store, and the consumers are mainly people interested in body care and the production of own cosmetics.

The analysis allowed to state, that it is possible to produce keratin hydrolysate from poultry feathers, which can be financially profitable, despite the small scale of production. Risk assessment is also beneficial for the adopted solution, and the biggest concern is the risk that the proposed method will not work on an industrial scale. The following study may form the basis for more accurate calculations once the process parameters are known that allow obtaining the keratin hydrolysate from poultry feathers in real conditions.

2 Finance

One of the most important stages of developing a Business Case is determining the anticipated costs and possible profits associated with the production of a product. This makes it possible to assess the profitability of the adopted solution and helps to decide on further development or resignation from the adopted idea. The production of keratin hydrolysate from poultry feathers is a solution tested only on a laboratory scale, and at the moment there are no known parameters of the process that would allow it to be produced on an industrial scale. Therefore, the two-stage alkaline-enzymatic hydrolysis process (Fig. 1) was used to assess the cost-effectiveness of the above solution, which was carried out under laboratory conditions, and was described in detail by Czech scientists [1].

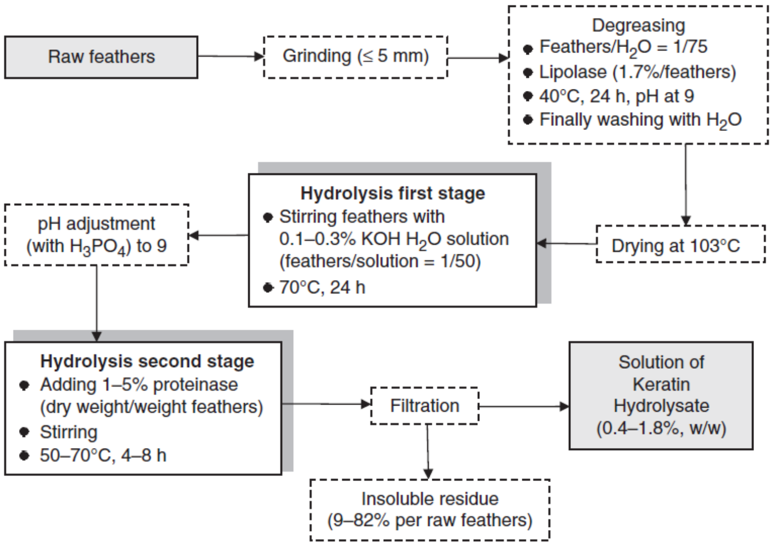


Fig. 1. Diagram of processing poultry feathers into keratin hydrolysate during two-stage alkaline-enzymatic hydrolysis [1].

Scientists emphasize in their work, that it is possible to apply a given process on an industrial scale because it is characterized by high efficiency and takes place at relatively low-temperature levels and at atmospheric pressure, which also translates into smaller financial outlays associated with the selection of appropriate equipment.

2.1 A financial appraisal

As was mentioned before, the selected project, which is subject to a cost-effectiveness analysis, is the production of keratin hydrolysate from poultry feathers. This solution, although it is not currently used on a scale other than the laboratory, has many advantages, which in the coming years will additionally gain value due to the intensive development of global bioeconomy. Although keratin hydrolysate is available on the market, it is most often made of sheep's wool. This raw material also belongs to the organic but is successfully used in other industries, for example in the production of clothes, footwear, quilts, etc. At present, poultry feathers are not so widely used and are largely incinerated or stored in landfills. Also, feathers are classified as slaughter waste, therefore their use as a raw material in further processes is very beneficial due to the desire of the whole world to develop a sustainable economy, which is based on extending the raw materials processing chain and the use of post-processing waste for the production of high-quality and niche products. The production of keratin hydrolysate from poultry feathers will not only allow the use of waste, which is currently not widely used but also will allow to obtain a high-quality product from them, which is popular mainly in the cosmetics industry.

During analyzing the cost-effectiveness of the solution, it is worth checking the price range of similar products that are available on the market. In this case, the market analysis includes keratin hydrolysates made from sheep's wool, which are available on the Polish market. These products, together with their volume variants and prices, are summarized in the table below.

Tab.1. Keratin hydrolysates available on the Polish market.

Keratin hydrolysate	Price [PLN]	Source
15 mL	6.99	[2]
30 mL	10.5	[3]
100 mL	20.95	[4]
15 g	4.9	[5]
115 g	23.9	[5]
1 kg	121.9	[5]

From the table above it can be concluded that the greater the packaging capacity, the more attractive the purchase price of the product. On the other hand, the purchase price of a larger package is closer to the real cost of production than the price of a smaller package. The provided pieces of information also help to find out whether the new solution will be able to compete with existing products in terms of price.

The next stage of assessing the cost-effectiveness of the solution is the assessment of financial expenditure incurred for the purchase of appropriate equipment and products needed for the production of keratin hydrolysate from poultry feathers. Due to the lack of an existing installation on an industrial scale for the production of keratin hydrolysate from poultry feathers, the cost estimation was based on a laboratory scale and it was assumed that the emerging company will deal with small-lot production. Table 2 summarizes the chemical apparatus that was used (or similar) in the two-stage alkaline-enzymatic hydrolysis process carried out by Czech scientists [1], together with their prices and nominal power, while Table 3, based on the same literature source, presents the cost of purchasing appropriate substrates needed to carry out the process and assess its quality. Prices in Polish currency have been adopted, converting foreign currencies according to the exchange rate as at 01/02/2020 (1€ = 4.2571 PLN, 1 $ = 3.8 PLN). The green color indicates the apparatus that is used to test the quality of the obtained product. It can be assumed that the samples will be sent to a certified laboratory that will monitor their quality and omit the cost of purchasing this equipment in the cost summary.

Tab. 2. Chemical apparatus needed for the production of keratin hydrolysate from poultry feathers.

Equipment type	Name of device	Nominal power [kW]	Price [PLN]	Source
Heater plate	Ceran CT 3010	1.2 / 1.8	911.96	[6]
Magnetic stirrer with temperature control	IKA RCT with ETS-D4 control Model	0.6	1 519.96	[7]
Drier	Binder™ B28	0.25	4 035.73	[8]
Incubator	Binder™ BFD 53	0.4	17 905.36	[9]

Electronic balance	KERN 440-47N	Battery powered	1 283.0	[10]
Electronic balance	Kern PLS 420-3F	Battery powered	2 669.22	[11]
Rotary vacuum evaporator	Heidolph Laborota 4000	1.5	12 350.0	[12]
pH meter	Piccolo HI 98111	Battery powered	1 058.38	[13]
Mineralization apparatus	DK 6 Kjeldahl Digestion Unit	1.1	14 900.94	[14]
Distillation apparatus	Parnas-Wagner distillation apparatus	-	2 225.44	[15]
Extraction apparatus	Soxhlet extraction apparatus	-	1 757.2	[16]
Filter papers (100)	Filpap KA-1	-	16.82	[17]
Total cost of the apparatus (excluding apparatus for testing product quality)			**29 400.43 PLN**	

Tab. 3. Substrates needed for the production of keratin hydrolysate from poultry feathers.

Substrate type	**Amount**	**Price [PLN]**	**Unit price**	**Source**
Savinase® 16.0L	250 mL	1 370.0	5.48 PLN/mL	[18]
Distilled water	20 L	65.99	0.003 PLN/mL	[19]
Grease-X BIOZYME	2.7 kg	138.74	0.051 PLN/g	[20]
NaOH	5 kg	39.9	0.008 PLN/g	[21]
KOH	1 kg	15.5	0.016 PLN/g	[22]
10% H_3PO_4	5 L	76.0	0.015 PLN/mL	[23]
Water	-	-	0.00421 PLN/l	[24]

Initially, 100 g of white poultry feathers were prepared, while in the two-stage alkaline-enzymatic hydrolysis process 2 g was used, from which the solution of keratin hydrolysate was made. Table 4 summarizes the amounts of substrates needed to prepare 100 g feathers, and carry out the process for 2 g together with the cost of using individual ingredients and the cost of using the ingredients during the process for 100 g feathers. It is assumed that the feathers are waste, and therefore they are free (at this stage the costs of transporting the raw material are omitted).

Tab. 4. The costs associated with the use of substrates for the production of keratin hydrolysate from 2 and 100 g of poultry feathers.

Substrate type	Amount	Price [PLN]
Preparation of 100 g of poultry feathers		
Feathers	100 g	-
Water	7.5 l	0.032
Grease-X BIOZYME	1.7 g	0.087
1% NaOH solution	75 g	1.166
The total cost of feather preparation		*1.285*
Preparation of concentrated enzyme solution		
Savinase® 16.0L	2 mL	10.96
Distilled water	50 mL	0.165
The total cost of preparation		*11.125*
Process cost for 2 g of feathers		
Feathers	2g	-
Water	100 mL	0.00042
KOH	0.3 g	0.005
10% H_3PO_4	0.25 mL	0.004
Enzyme solution	5 mL	1.07
Distilled water	30 mL	0.1
The total cost of preparation		*1.18*
Process cost for 100 g of feathers		
Feathers	100 g	-
Water	5 000 mL	0.021
KOH	15 g	0.25
10% H_3PO_4	12.5	0.2
Enzyme solution	250 mL	53.5
Distilled water	1 500 mL	5.0
The total cost of preparation		*58.97*

As a result of the two-stage alkaline-enzymatic hydrolysis process using 2 g poultry feathers, approximately 100 mL of keratin hydrolysate solution was obtained (assuming that some amount evaporated during boiling to inactivate the enzyme). Assuming that the density of keratin hydrolysate obtained from poultry feathers is equal to the density of sheep wool keratin hydrolysate of 1 g/mL [5], it can be assumed that during the process 100 g of keratin hydrolysate solution was obtained. The estimated cost of substrates for producing this amount of product is about PLN 1.2.

Assuming that the conversion of 100 g feathers to keratin hydrolysate requires an increase of 50 times in the amount of each substrate consumed, the cost of these substrates can also be multiplied 50 times. As a result, it can be assumed that about 5 000 mL (equivalent to 5 000 g) of keratin hydrolysate solution is obtained, and the cost of ingredients used to make it is about PLN 60.3.

Using the description of the process in the literature [1], the amount of electricity consumed by individual devices during its duration can be estimated, and thus the cost associated with it. Table 5 summarizes the operating time of devices during the process, the amount of electricity consumed and its approximate cost. It was assumed that 100 g feathers are processed once, the devices operate at nominal power, and the price of 1 kWh of electricity is 0.59 PLN/kWh [25].

Tab. 5. The cost of electricity consumed during the process.

Device type	Working time	Electricity consumption [kWh]	Cost [PLN]
Heater plate	33 min	0.99	0.58
Magnetic stirrer	8.28 h	4.96	2.93
Incubator	48 h	19.2	11.33
Drier	4 h	1	0.59
Total	**60.83**	**26.15**	**15.43**

As can be deduced from the table above, the production time of the keratin hydrolysate from poultry feathers takes a relatively long time and adding other works such as cutting and weighing the material and its transport between individual devices, it can be assumed that the production time of 5 000 mL of keratin hydrolysate is about 62 hours. In addition, the mixing process at one stage should be carried out every hour, and at 8 hours at another stage, incubation processes last 24 hours, therefore, it would be necessary to ensure continuity of processes and introduce 3-shift work time so that the process can run without the downtime and be constantly monitored. The work also can be organized in a way that allows stopping work over the weekend. This requires the employment of at least 3 people with chemical education (1 person for each shift) and at least 1 person worked as a technical worker. The median earnings as a chemist in Poland is 4 510 PLN/month [26]. The total cost of the employer, in this case, is 5 433.66 PLN/month. Therefore, the monthly costs incurred for the remuneration of employees with chemical education are approximately 16 301 PLN. It can be assumed that the minimum salary for a technical worker is equal to the minimum salary in Poland, i.e. about 3 132.48 PLN/month [27]. The total costs incurred for the payment of salaries are **19 433.48 PLN/month**.

An additional cost that should be incurred during introducing a product to the market is the purchase or production of packaging in which it will be sold. Since the described production of keratin hydrolysate from poultry feathers takes place on a relatively small scale, the purchase of equipment for self-production of packaging may prove to be unnecessary expenditure and in this case, it will be more profitable to purchase such packaging from an external supplier. Table 6 summarizes the purchase prices of packaging with capacities corresponding to the volumes of keratin hydrolysate packaging available on the market (according to Tab. 1) [28]. Assuming that within about 62 hours, the laboratory can produce 5 000 mL of keratin hydrolysate, it is possible to produce almost 10 000 mL of product in a working week (5 days of 24 hours). On a monthly scale (4 working weeks), this amount can be around 40 000 mL. On this basis, the average monthly cost of purchasing packaging with different capacities can be estimated.

Tab. 6. The costs of purchasing packaging.

Container volume	Price [PLN/container]	Number of containers needed [containers/month]	Total cost [PLN/month]
15 mL	0.34	2 666	906.44
30 mL	0.5	1 333	666.5
100 mL	0.46	400	184
1 000 mL	0.85	40	34

Another cost is the labeling of the containers so that it contains all the required information about the product and the company that produces it. Using the price calculator [29], the approximate monthly cost was be calculated, depending on the size of the container, which translates into the size of the label. The costs of purchasing labels are shown in Table 7. It was assumed that the labels would be self-adhesive and delivered on a roll. The material from which they can be made is a PE foil, which is adapted to flexible containers and is used in the production of labels for cosmetics packaging.

Tab. 7. The cost of purchasing labels.

Container volume	Number of labels needed [labels/month]	Total cost [PLN/month]
15 mL	2 666	1 325.09
30 mL	1 333	984.11
100 mL	400	1 237.81
1 000 mL	40	957.87

The last stage that should be considered during assessing the cost of production and sales of poultry feather keratin hydrolysate is the cost incurred for setting up an online store, thanks to which it will be possible to sell products. The cost of setting up such a store by an external company is about 6 200 PLN with regulations [30] and it is a one-off cost. The annual costs of maintaining a store are around 300 PLN [30]. However, if a company does not want to invest in an online store, it can either order the design of a website with the option of editing (so-called CMS), which will be the company's showcase – the cost, in this case, is about 4 000 PLN and 300 PLN per year for maintaining the site or setting up free accounts on various social networks on which it will promote the product and contain information on its sale. Such accounts can also be run in parallel with the online store to make more attractive a company's offer.

Table 8 shows the estimated annual costs associated with the production and sale of poultry feather keratin hydrolysate, including one-off costs, monthly expenses, and possible profits, assuming that the price of keratin hydrolysate from poultry feathers will be 1 PLN higher than the price of keratin hydrolysate from sheep wool (Tab. 1). A monthly production of 40 000 mL (480 000 mL/year) is assumed. However, taking into account that the devices used during the process (among others, incubator and drier) can contain a greater amount of material than is presented in the description of the process, it was assumed that it is possible to produce at the same time and with the same amount of electricity consumption the double amount of keratin hydrolysate, so a monthly production of 80 000 mL (960 000 mL/year) was assumed. The costs incurred for this process and the possible profits are also summarized in Table 8. The table below does not include additional costs, such as renting the premises, laboratory tests of samples and small laboratory equipment, designing packaging labels, etc.

Tab. 8. Summary of costs associated with the production and sale of keratin hydrolysate from poultry feathers.

One-off costs [PLN]					
Purchasing of the process apparatus		29 400.43			
Setting up an online store		6 200.0			
Total cost		35 600.43			
Costs of production and sale of keratin hydrolysate from poultry feathers [PLN]					
Cost type		**480 000 mL/year**		**960 000 mL/year**	
		PLN/month	**PLN/year**	**PLN/month**	**PLN/year**
Substrates for the process		482.4	5 788.8	964.8	11 577.6
Energy consumptions		123.44	1 481.28	123.44	1 481.28
Salaries		19 433.48	233 201.8	19 433.48	233 201.8
Online store maintenance		-	300.0	-	300.0
Purchasing of containers	**15 mL**	906.44	10 877.28	1 812.88	21 754.56
	30 mL	666.5	7 998.0	1333.0	15 996.0
	100 mL	184.0	2 208.0	368.0	4 416.0
	1 000 mL	34.0	408.0	68.0	816.0
Purchasing of labels	**15 mL**	1 325.09	15 901.08	2 650.18	31 802.16
	30 mL	984.11	11 809.32	1 968.22	23 618.64
	100 mL	1 237.81	14 853.72	2 475.62	29 707.44
	1 000 mL	957.87	11 494.44	1 915.74	22 988.88
Costs of production and sale	**15 mL**	22 270.85	267 550.2	24 984.78	300 117.4
	30 mL	21 689.93	260 579.2	23 822.94	286 175.3
	100 mL	21 461.13	257 833.6	23 365.34	280 684.1
	1 000 mL	21 031.19	252 674.3	22 505.46	270 365.5
Possible sales profits	**15 mL**	21 333.33	256 000.0	42 666.67	512 000.0
	30 mL	15 333.3	184 000.0	30 666.67	368 000.0
	100 mL	8 780.0	105 360.0	16 760.0	201 120.0
	1 000 mL	4 916.0	58 992.0	9 832.0	117 984.0

Difference between profits and production and sale costs	**15 mL**	-937.52	-11 250.2	**17 681.89**	**211 882.6**
	30 mL	-6 356.6	-76 279.16	**6 843.73**	**81 824.72**
	100 mL	-12 681.13	-152 173.56	-6 605.34	-79 564.08
	1 000 mL	-16 115.19	-193 382.28	-12 673.46	-152 381.5

The data presented in the table indicate that in most cases the production of keratin hydrolysate from poultry feathers is associated with financial losses. However, this is due to the fact, that production is small concerning the costs that have to be incurred, which mainly consist of employee salaries costs. Therefore, additional calculations should be made for larger production, while taking into account that the process time and electricity consumption may be extended. The solution can also be various types of grants that would finance payments to employees in the initial period of development of the company – then in each case, the production of keratin hydrolysate would have financial benefits. Another solution is to increase the price of products sold, but it may be associated with the choice of competitive solutions by consumers because it has already been assumed that keratin poultry hydrolysate is 1 PLN more expensive than sheep's keratin hydrolysate and another increase could significantly discourage potential buyers.

Despite the high cost associated with employee wages, selling double the amount of keratin hydrolysate in 15 mL and 30 mL containers allows for financial benefits. For the more favorable case, the ROI (return on investment) coefficient was determined, which was calculated as follows:

$$ROI_{\%} = \frac{gross\ profit - expenses}{investments} = 52{,}5\%$$

In this case, the payback period is:

$$PP = \frac{1}{ROI_{\%}} \cdot 100 \approx 2\ years$$

The presented calculations can only be considered as approximate because the possibilities of producing keratin hydrolysate from poultry feathers on a larger scale are not known, so the actual production costs may differ from the presented ones. Despite this, the calculated payback period and possible profits seem to be promising and should constitute the basis for further development of the proposed solution.

2.2 A sensitivity analysis

Keratin hydrolysate is a product that is still gaining popularity due to its valuable properties. The growing interest in the product is also due to the easier access to a variety of cosmetics, thanks to the increasing number of drugstores or online stores dealing in the sale of cosmetics. Women most often use keratin hydrolysate and products that contain it in their composition, because it has a positive effect, among others on skin, hair, and nails. Increasing awareness about caring for beauty using natural cosmetics has contributed to the wider use of this product. An increasing number of people decided to prepare cosmetics themselves, combining the suitable ingredients, and this is associated with increased interest in buying each product separately. This influenced the appearance of offers for the purchase of pure keratin hydrolysate, which can be combined with other ingredients to obtain a cosmetic with the desired properties.

As was mentioned before, keratin hydrolysates available on the Polish market are made of sheep's wool by controlled hydrolysis. Considering that there are offers from various companies involved in the production of this product, which can be purchased in different capacities, it can be considered that this process is cost-effective and well tested. This may be the biggest competition for keratin hydrolysate produced from poultry feathers because the method of its production has not been tested in real conditions and is based only on the results obtained in the laboratory. However, the calculations carried out suggest that this process may also be profitable. Assuming that interest in the keratin hydrolysate will be constantly growing, and large quantities of raw material (poultry feathers) are available, which are the basis for its production, the proposed solution has a chance to appear on the market and generate profits. Also, the attractiveness of such a product should be influenced by the fact that it arises from raw material currently treated as waste, therefore its use contributes to the development of the bioeconomy and care for the natural environment.

3 Project Definition

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% from Poland [31]. These data relate to a large number of companies involved in breeding and slaughtering of poultry in Poland. The northern region of Poland, which consists of three regions: West Pomeranian, Pomeranian, and Warmia and Mazury Voivodehip is at the domestic forefront in poultry production. These regions belong also to the SBA (South Baltic Area) region. A large amount of meat produced is also associated with a large number of slaughter waste, including blood, feathers, and guts. There is, therefore, a real potential to use this waste in such a way as to minimize as much as possible the amount that will go directly to disposal, and thus extend the chain of use of a given raw material and increase its value. In Poland, in 2017 the poultry production amounted to 3 307 521 tonnes [32]. Enterprises located in the northern region of Poland were responsible for producing about 17% of this amount, more precisely: West Pomeranian 155 908 tonnes, Pomeranian 129 977 tonnes, and Warmia and Mazury 285 189 tonnes. According to literature sources, feathers account for about 7% of the chicken weight, and the average (a performance of around 5 000 heads per hour) slaughtering enterprise generates about 7 tonnes of feathers per day [33]. It can, therefore, be estimated that the mass of feathers produced for individual voivodeships in 2017 was about:

- West Pomeranian 10 913 tonnes (about 30 tonnes per day),
- Pomeranian 9 098 tonnes (about 25 tonnes per day),
- Warmia and Mazury 19 963 tonnes (about 55 tonnes per day).

Although there are various ways of using the poultry feathers, the best, from the point of view of the bioeconomy and cascading approach, are methods for obtaining valuable products, for example, ingredients of cosmetics, drugs, food products or biodegradable materials. One such method may be the production of keratin hydrolysate.

3.1 Business Objective

The production of keratin hydrolysate from poultry feathers has many benefits. The first and most important, from a long-term point of view, is a real impact on reducing the amount of slaughter waste, which translates into environmental protection and respect for the principle of sustainable development. Often the main goal of new solutions is to get the highest possible income without respecting the natural environment. In the production of keratin hydrolysate from poultry feathers, it is possible to obtain financial benefits resulting from the production of a product that is valuable due to its properties and desired on the market, but, equally important, such production contributes to the extension of the value chain, which is in accordance with circular economy and sustainable development. Such solutions are appreciated by the members of the European Union who, working together, try to influence the inhibition of adverse climate change. It is also important that currently feathers are largely utilized by incineration, which affects the generation of harmful compounds into the atmosphere. The use of feathers in the proposed way allows to avoid this, once again contributing to environmental protection. Important aspects also include the increase in the attractiveness of the region, which will be open to bio-investments, thanks to which it will reduce the production of unused waste, and thus develop a branch of the cosmetics industry that has significant potential for further development.

3.2 Benefits and Limitations

The following table summarizes the benefits associated with the production of keratin hydrolysate from poultry feathers, which have a significant impact on the attractiveness of the proposed idea, as well as restrictions and barriers that may negatively affect its development. They are mainly associated with economic, social, and environmental factors.

Tab. 9. Summary of benefits and limitations associated with the production of keratin hydrolysate from poultry feathers

Benefits	Limitations
• Keratin hydrolysate is a component with valuable properties that have a positive effect on the skin, hair, and nails, including accelerating their regeneration. • A large amount of raw material that can ensure the continuity of the process throughout the year. • The presented technology is based on the use of valuable waste from the poultry industry, which is currently mainly incinerated. • There is no keratin hydrolysate made from poultry feathers on the market, so it will be a completely new product. • The use of feathers as raw material in another process is beneficial from an	• A lack of legal regulations that would force the use of bio-waste as raw materials in subsequent processes, which causes little interest in the development of technology for the production of keratin hydrolysate from poultry feathers. • A lack of available and tested technology working in real conditions, which translates into difficulties in assessing the amount of investment outlays and forecast profits. • Too low public awareness of the need to use bio-waste in further processes under sustainable development principles.

environmental point of view and in line with the European Union's policy to fight again climate change. • The European Union, as well as regional authorities, can support financially bio-waste solutions such as feathers, which can increase the attractiveness of a given solution and encourage investment in its development. • A region where a keratin hydrolysate production line would be created could gain image-wise as a region that cares for the environment and supports investment in the development of high-quality products. • The growing interest in cosmetics and natural ingredients can contribute to the ever-increasing demand for keratin hydrolysate, making its production economically profitable.	

3.3 Option Identification and Selection

The table below compares the proposed solution, which is the production of keratin hydrolysate from poultry feathers to the currently used methods in the field of post-slaughter feathers, together with the benefits and difficulties associated with the proposed solution.

Tab. 10. Comparison of solutions regarding the use of slaughter feathers

Innovative solution/product	Conventional solution/product	Benefits of Innovative solution/product	Difficulties associated with innovative solution/product
Production of keratin hydrolysate from poultry feathers	Incineration of poultry feathers	The use of waste to produce a valuable component.	No tested technology working under real conditions.
		No emission of harmful compounds into the atmosphere during the production of keratin hydrolysate.	The duration of the keratin hydrolysate production process is longer than the duration of the feather incineration.
		Production of keratin hydrolysate is in accordance with the sustainable development principles	No legal requirements imposing the need to use bio-waste in subsequent processes.
Production of	Storing feathers	Reduction of unused bio-	Higher costs

keratin hydrolysate from poultry feathers	at landfills	waste.	associated with the production and sale of the product and the need to store raw material.
		The production process is not burdensome and does not emit any odors and does not adversely affect soils and surface waters.	

3.4 Scope, Impact and Interdependencies

Poultry feathers are still a problem due to their management, and the constantly increasing production of poultry does not indicate that this problem will disappear in the coming years. Therefore, further research on the use of feathers for the production of keratin hydrolysate is important to use material that is now mainly treated as a waste. At the moment most of the stock is neutralized by incineration, hence available amounts of feathers are a good reason to promote the production of keratin hydrolysate from them. Also, keratin is a product that can be widely used in numerous industries therefore, the development of the selected concept is time-worthy and justified. The potential profits from appropriate management of the feathers may include not only development of a new technology, but also environmental and social benefits.

The most important factor affecting the development of technology for the production of keratin hydrolysate from poultry feathers are legal issues, which currently do not put pressure on entrepreneurs regarding sustainable management of bio-waste. The introduction of appropriate legal regulations and their enforcement, as well as supporting entrepreneurs, who want to invest in bio-solutions, should be the basis for the development of new technologies based on the use of bio-waste. Such activities should translate into increased interest in the production of niche, valuable products from raw materials that are currently not used.

Another important factor that determines the success of the adopted concept is the price of keratin hydrolysate from poultry feathers, and the costs associated with its production. The production and sales costs, as well as the quantity of the product manufactured, and the final price should be determined in such a way that it is possible to obtain revenues enabling covering all costs and building the company's capital. On the other hand, a product cannot be too expensive, because it will not gain the interest of consumers who, having the choice of the same product, will be guided by a lower price.

The factor favoring the development of the proposed technology is the constantly developing cosmetics industry, increasingly based on ingredients of natural origin, which also includes keratin hydrolysate. Due to its properties, it can be added to creams, shampoos, conditioners, and various lotions, improving their performance. Self-made cosmetics are also becoming more and more popular, therefore having a product that is willingly used as their ingredient in the offer may be profitable due to the constantly growing market.

3.5 ***Market Assessment***

Table 11 presents a summary of how the production of keratin hydrolysate made from poultry feathers could be associated with political, legal, economic, social, technological, and environmental factors.

Tab. 11. The relationship of the proposed solution for the production of keratin hydrolysate from poultry feathers with individual factors.

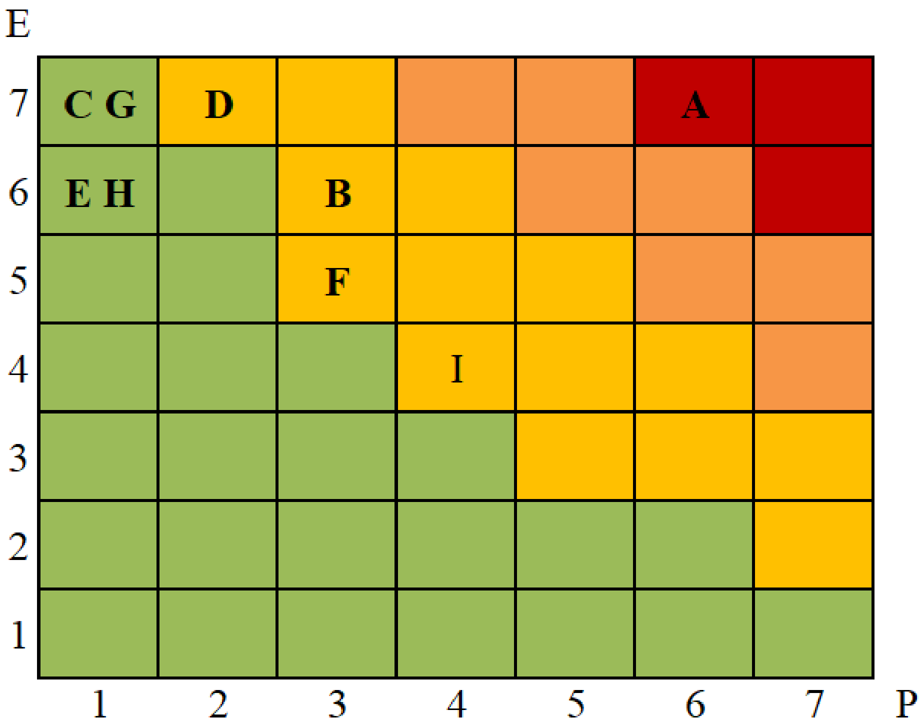
Political	• Support of local and state government institutions in the further development of the project, including various types of financing in the form of awards for progress in technology implementation and increasing production. • Promoting bio-solutions by regional and state government institutions and encouraging other entities to develop in this direction.
Economical	• The emergence of a competitive solution on the market. • Additional income resulting from the sale of a valuable product that is produced from raw material treated as waste. • New jobs for qualified employees. • The creation of new jobs for qualified employees would affect their stay in the country, which would contribute to the development of the Polish economy.
Sociological	• Launching a product can contribute to increasing public awareness of the amount and type of bio-waste generated, the necessity to process it, and different opportunities for their use in everyday life. • Consumer inclination towards natural cosmetics can contribute to high interest in the product.
Technological	• Striving to reduce production costs can contribute to the development of technologies that allow faster and cheaper production of the product. • Development of a technology that would allow the production of keratin hydrolysate on an industrial scale.
Legal	• Introduction of legal regulations regarding the obligation to use bio-waste in other processes and enforcement of their compliance, which would have a positive impact on project development. • Simplification of legal regulations and administrative issues in the field of bio-waste processing would have a positive impact on project development time and encourage other enterprises to invest in bio-innovation.
Environmental	• The use of feathers for the production of keratin hydrolysate reduces the amount of unused waste and promotes a sustainable economy. • Extending the value chain of raw materials and increasing their added value. • Important environmental aspect - the amount of feathers disposed at landfills and incinerated is decreasing.

3.6 Risk Assessment

To determine the potential risk associated with the production of keratin hydrolysate from poultry feathers, a so-called Risk Map was made. It considers the risks associated with the adopted solution and allows determine what impact they will have on its development. The risk assessment took into account factors, that are decisive mainly at the initial stage of introducing the solution to the market, including the lack of proven technology in real conditions or the risk of lack of qualified employees.

RISK LEVEL „R"		PROBABILITY „P"		EFFECT „E"	
Name	**Scale**	**Name**	**Scale**	**Name**	**Scale**
Negligible	1-12	Very low	1	Insignificant	1
Noticeable	13-25	Small	2	Short	2
Monitoring necessary	26-38	Possible	3	Little	3
Immediate response	39-49	Big	4	Perceptible	4
		Threatening	5	Average	5
		Very dangerous	6	Significant	6
		Certain	7	Disastrous	7

RISK	P	E	R = P x E
A – the technology developed in the laboratory will not be effective in real conditions	6	7	42
B – the cost of producing and selling keratin hydrolysate will exceed profits	3	6	18
C – consumers will not be interested in a product made from slaughter feathers	1	7	7
D – decrease in the amount of available raw material in the future, resulting from limiting the consumption of poultry meat	2	7	14
E – problem with acquiring customers due to the availability on the market of keratin hydrolysate from sheep wool	1	6	6
F – a lack of investors' interest, wanting to develop the proposed technology	3	5	15
G – a lack of employees with appropriate education and experience	1	7	7
H – introduction of legal regulations that will be unfavorable to the proposed technology	1	6	6
I – a lack of financial support from governmental bodies at regional and state level	4	4	16


E
7
6
5
4
3
2
1
C G
D
A
E H
B
F
I
1
2
3
4
5
6
7
P

4 References

1. Mokrejš P., Svoboda P., Hrncirik J., Janacova D., Vasek V. Processing poultry feathers into keratin hydrolysate through alkaline-enzymatic hydrolysis. Waste Management & Research, 29(3), 260–267.
2. Website: https://www.ekobieca.pl/product-pol-7158-ZSK-Hydrolizat-Keratyny-naturalny-kosmetyk-do-wlosow-15-ml.html (access on 17.04.2020).
3. Website: https://esent.pl/pl/p/Keratyna-hydrolizowana-30-ml/25?gclid=EAIaIQobChMI0fW62aDv6AIVB-h3Ch3etwAWEAQYASABEgKRufD_BwE (access on 17.04.2020).
4. Website: https://sklep.zrobswojkosmetyk.pl/pl/p/Keratyna-hydrolizowana-na-matowe-wlosy-i-paznokcie-100ml-Esent/3022?gclid=EAIaIQobChMI0fW62aDv6AIVB-h3Ch3etwAWEAQYAiABEgItrPD_BwE (access on 17.04.2020).
5. Website: https://www.zrobsobiekrem.pl/pl/p/Hydrolizat-keratyny/200?utm_source=shoper&utm_medium=shoper-cpc&utm_campaign=shoper-kampanie-google&shop_campaign=3431557113&gclid=EAIaIQobChMI0fW62aDv6AIVB-h3Ch3etwAWEAQYBCABEgJKkPD_BwE (access on 17.04.2020).
6. Website: https://www.rommelsbacher.de/en/products-from-a-to-z/ceranr-doppelkochtafel-ct-3010.html (access on 17.04.2020).
7. Website: http://www.cheshirenterprise.com/ika-rct-basic-hot-plat-magnetic-stirrer-with-ets-d4-control-model/ (access on 17.04.2020).
8. Website: https://www.fishersci.co.uk/shop/products/b028-230v-standard-series-b-incubators-mechanical-adjustment/15652076#?keyword=Binder+eb+28 (access on 17.04.2020).
9. Website: https://www.fishersci.co.uk/shop/products/kb-series-cooling-incubator-compressor-technology-1/p-8319009#?keyword=Binder+KB53+incubator (access on 17.04.2020).
10. Website: https://www.moga.pl/waga-laboratoryjna-kern-440?m=2292 (access on 17.04.2020).
11. Website: https://www.scalesandbalances.co.uk/acatalog/Kern-PLS-4-1.html (access on 17.04.2020).
12. Website: http://www.hylandscientific.com/product.aspx?itemid=1402&prodid=6420&pagetitle=Heidolph-Laborota-4000 (access on 17.04.2020).
13. Website: https://www.bionovo.pl/p/ph-metr-piccolo-hi-98111-hanna-instruments/ (access on 17.04.2020).
14. Website: https://us.vwr.com/store/product/15095636/kjeldahl-digestion-units-dk-series-velp-scientifica (access on 17.04.2020).
15. Website: https://www.witeg.de/en/products/laboratory-glassware/miscellaneous/macro-apparatus-for-determination-of-nitrogen (access on 17.04.2020).
16. Website: https://www.wilmad-labglass.com/ProductList.aspx?t=329 (access on 17.04.2020).
17. Website: https://www.fisherww.sk/index.php/view/productdetails/virtuemart_product_id/2840/virtuemart_category_id/62 (access on 17.04.2020).

18. Website: https://www.sigmaaldrich.com/catalog/product/sigma/p3111?lang=pl&region=PL (access on 17.04.2020).
19. Website: https://www.zenox.pl/product/Woda-destylowana/2101420-GEB26?gclid=EAIaIQobChMI_cPtzN7s6AIVzed3Ch2tmQd6EAQYBCABEgK5TfD_BwE (access on 17.04.2020).
20. Website: https://www.ebay.com/itm/Grease-X-BIOZYME-like-Bio-Clean-Drain-Septic-Bacteria-2-lb-/174145943588 (access on 17.04.2020).
21. Website: https://www.zdrowapaczucha.pl/p463,soda-kaustyczna-wodorotlenek-sodu-5-kg.html?gclid=EAIaIQobChMI3Zzh89Ds6AIVheR3Ch1m0QzzEAQYAyABEgKlzvD_BwE (access on 17.04.2020).
22. Website: https://techlandlab.pl/sklep/wodorotlenek-potasu/ (access on 17.04.2020).
23. Website: https://pol-aura.pl/kwas-ortofosforowy-roztwor-10-czda-7664-38-2-p-765.html (access on 17.04.2020).
24. Website: https://www.sng.com.pl/Portals/2/dok/Taryfy/GD.RET.070.195.D.2018.KR.pdf (access on 17.04.2020).
25. Website: https://globenergia.pl/ile-kosztuje-1-kwh-energii-elektrycznej-z-czego-sklada-sie-rachunek/ (access on 17.04.2020).
26. Website: https://wynagrodzenia.pl/moja-placa/ile-zarabia-chemik (access on 17.04.2020).
27. Website: https://poradnikprzedsiebiorcy.pl/-minimalne-wynagrodzenie-2015 (access on 17.04.2020).
28. Website: https://www.butelki-plastikowe.pl/ (access on 17.04.2020).
29. Website: https://www.labelprint24.com/pl/products/etykiety-na-roli-1.php (access on 17.04.2020).
30. Website: https://sukcesstrony.pl/ile-kosztuje-strona-internetowa-cennik (access on 17.04.2020).
31. Website: https://www.money.pl/gielda/eurostat-produkcja-miesa-drobiowego-w-ue-wzrosla-do-15-2-mln-ton-w-2018-roku-6363117912901251a.html (access on 17.04.2020).
32. Website: https://bdl.stat.gov.pl/BDL/start (access on 17.04.2020).
33. Staroń P., Banach M., Kowalski Z.: Keratin – origins, properties, application. CHEMIK 2011, 65, 10, p. 1019–1026 (in Polish).

PRODUCTION OF A BODY LOTION WITH KERATIN HYDROLYSATE FROM POULTRY FEATHERS

COLOURBOX33938251

15.09.2020

Business Case

Production of a body lotion with keratin hydrolysate from poultry feathers

Gdańsk University of Technology
Aleksandra Gołąbek
Dariusz Mikielewicz

1 Executive Summary

Striving for sustainable development by European Union countries requires the use of practices that will allow reducing the amount of waste produced that is not used in subsequent processes and ensure the biodiversity of resources on our planet. This translates into the development of the circular economy idea, which is strongly related to the cascading approach and the use of each raw material most efficiently. Such efforts are beginning to take place concerning poultry – in 2018, the Member States of the European Union produced 15.2 million tons of poultry meat [1], which translates into a very large amount of slaughter waste. One such waste is feathers, which have become the subject of research by scientists who want to make valuable products from them. An example of a product that can be produced from poultry feathers is keratin hydrolysate, known for its moisturizing effects, used primarily in the cosmetics industry – it is an ingredient of hair and skin cosmetics. The production of a body lotion with keratin hydrolysate in its composition can therefore contribute to reducing the number of feathers, which are currently not widely used and are mainly incinerate.

The production of a body lotion containing keratin hydrolysate from poultry feathers is beneficial from an environmental point of view, but it should also be determined whether it can be profitable and whether there will be a demand for such a product. When assessing profitability, it is assumed that the keratin hydrolysate is produced under the assumptions included in the previous business case [2], and the remaining ingredients are purchased at market prices from external suppliers. Therefore, it is still assumed that there is small-scale production, and body lotions are sold via an online store. The final product may become a product for people who care for their skin and choose cosmetics based on ingredients of natural origin.

The conducted analysis allowed to establish that the production of the body lotion containing poultry feather keratin hydrolysate may be profitable despite the small scale of production and assuming that the production of the keratin hydrolysate from poultry feathers and the production of the body lotion takes place at the same plant. Also, the benefits and limitations of the proposed solution are presented, how it will be related to various factors, and a risk analysis related to the project implementation was performed. The presented study may be the basis for a more detailed assessment of the profitability of the solution and its potential implementation in real conditions.

2 Finance

The most important point in assessing the profitability of a given solution is to estimate the costs to be incurred in connection with the commencement of the presented project and the possible profits. The number of profits will allow determining whether the further development of the project is a good idea, or whether it will be a better solution to change the concept or completely abandon it. The production of keratin hydrolysate from poultry feathers is a process that was carried out only on a laboratory scale, and the same case is with the production of a body lotion containing this ingredient – there are studies conducted by Czech scientists who produced keratin hydrolysate and then used it as an ingredient in the cream and examined its properties [3]. Scientists have proven that adding keratin hydrolysate to the cream resulted in, inter alia, reduction of transepidermal water loss (TEWL), and improvement of skin hydration [3]. The process of producing a cream with the addition of keratin hydrolysate, which was presented by scientists, is relatively easy and consists of mixing a commercially available cream base and keratin hydrolysate. Then the mixture should be homogenized for 10 minutes, and the cream should be kept for 2 hours at room temperature before use [3]. The prepared mixture may be stored for up to 5 months, provided that it is stored at an appropriate temperature of about 5°C [3].

2.1 A financial appraisal

The subject of the cost-effectiveness analysis is the production of a body lotion containing keratin hydrolysate, obtained from poultry feathers. The presented solution is not currently used on an industrial scale, however, the development of bioeconomy, mainly consisting in extending processing chains and striving to introduce a circular economy, and taking into account the increasing demand for poultry meat, it can be concluded that the idea is attractive considering the above-mentioned factors.

The use of keratin hydrolysate obtained from poultry feathers for the production of a body lotion allows for the management of waste such as slaughter feathers, which is very beneficial due to problems with their disposal – feathers burning contributes to the emission of harmful compounds to the atmosphere, storage in landfills is associated with the generation of odors and the risk of water contamination and soil near the landfill, while processing feathers into a feather meal (animal feed) eliminates these problems, but the product is poor in nutrients [4].

Keratin hydrolysate is an ingredient often used in hair cosmetics (masks, balms, conditioners, and shampoos), but due to the idea of using it in skincare cosmetics, only such solutions have been reviewed. Currently, it can buy skincare products on the market that contain keratin obtained from sheep's wool. One of the foreign companies that deals with the production of cosmetics with keratin hydrolysate is the company SUB & TARCTIC from New Zealand, whose mission is based on the sustainable use of available raw materials in an unconventional way while supporting sheep breeders [5]. Their offer includes, among others, hand and nail cream (Fig. 1). According to the manufacturer, the proper use of the cream increases skin hydration by about 23% [6]. The price of such a cream (50 mL) is NZD 35.95, so about PLN 89.

Fig. 1. Hand and nail conditioner with keratin hydrolysate from sheep wool [6].

On the Polish market, for example, there is available an body lotion with keratin from the "Bioer" brand (Fig. 2) [7]. The price for a 200 mL pack is PLN 61.

Fig. 2. Body lotion by "Bioer" containing keratin hydrolysate [7].

The presented products differ in purpose and composition, as well as capacity, which makes it difficult to assess the price impact of the use of keratin hydrolysate in them. However, it can be seen that the price of such cosmetics is several dozen PLN.

The next stage of economic assessment of the adopted solution is to estimate the costs associated with the production of the cosmetic and the purchase of appropriate ingredients and the assumption that the body lotion will be sold in an online store. In the beginning, it is worth considering the purchase price of the ingredients needed to produce it. It is assumed that the keratin hydrolysate is an ingredient produced in the same enterprise as the body lotion, therefore only its production cost (cost of the process) is considered, at the prices quoted in the previous study [2]. Additionally, the cost of purchasing a lotion base should be added. Taking into account the results of the research contained in the previously cited publication of

Czech scientists, it was decided that the produced body lotion will consist only of the base and keratin hydrolysate, the content of which will be 4% in accordance with the base weight of the ointment [3]. This value was chosen because it is a compromise between the improvement in skin hydration (14% for men and 15% for women after 48 hours of testing) and the reduction of TEWL (36% in men and 38% in women after 48 hours of testing) [3].

According to a previous business case, the production of keratin hydrolysate from poultry feathers is assumed at the level of 960 000 mL per year [2]. Taking into account that the weight of keratin hydrolysate in the proposed solution is to constitute 4% of the weight of the body lotion, assuming that the total weight of one product is 200 g, the weight of keratin hydrolysate will be 8 g, and the weight of the base is 192 g. Therefore, the annual production of keratin hydrolysate at the level of 960 000 mL will allow for the production of 120 000 packages of body lotion annually (the density of keratin hydrolysate is assumed to be 1 g/mL [8]). There are many types of balm or cream bases available on the Polish market, with varied compositions. To calculate the profitability of the presented solution, a cream base consisting mainly of natural ingredients, enriched with vitamins E and B5 was selected. It contains karite butter and sweet almond oil, which have beneficial properties when it comes to skincare. The use of such a base will allow obtaining a cosmetic that does not differ from the products available on the market. The proposed base can be purchased in packages of various sizes, but due to its use for greater production than for one's own needs, it was decided to purchase the base in 10-kilogram packages. The cost of one package is PLN 720 [9]. Considering that 192 g of the base are needed for one package of the produced body lotion, one package (10 kg) is enough to produce 52 full packages of the body lotion. Assuming the annual production of the lotion at the level of 120 000 units, the annual demand for the base is 2 304 packages of 10 kg. Additionally, to ensure the durability of the cosmetic, a preservative should be added to it. According to the information provided, the recommended concentration of the preparation is 0.2 – 1% [10]. Therefore, a maximum of 2 grams of the preservative should be added to a package containing a 200-gram lotion. The proposed preservative can be purchased in kilogram packages, and the cost of one package is PLN 229 [10]. The table below shows the cost of producing body lotion. It was assumed that the production takes place in the same plant as the production of keratin hydrolysate, and the price of the hydrolysate results from the costs of purchasing the substrates needed to carry out the process, the cost of electricity consumed, and payments to employees during the year. These costs have been estimated in an earlier study [2].

Tab. 1. Costs related to the purchase of ingredients for the production of a body lotion.

Substrate type	**Amount**		**Price [PLN]**
Preparation of 120 000 body lotions			
Keratin hydrolysate (from poultry feathers)	960 000	g	249 324
Cream base	23 040 000	g	1 658 880
Cosmetic preservative	240 000	g	54 960
The annual cost of body lotions preparation			***1 713 840***
The total cost of one body lotion preparation			***14***

To be able to produce a body lotion, the purchased ingredients should be homogenized for about 10 minutes and mixed [3]. Thanks to the use of a preservative, there is no need to store the lotion at a low temperature – it can be stored at room temperature. The table below lists the devices necessary to produce a body lotion, along with their prices and nominal power. The purchase of a dispenser for pouring the lotion into the packaging was also taken into account, with the indication that the purchase of a compressor is required for its operation. According to the previous study [2], the weekly production of keratin hydrolysate can be about 20 000 mL (20 000 g), so it can be assumed that about 4 000 g can be obtained per day (ignoring that the process takes about 62 hours – it is assumed that the production of the lotion begins only when it is possible to ensure the continuous supply of keratin hydrolysate), which makes it possible to produce 500 pieces of body lotion a day. Also, 96 000 g of base and 1 000 g of preservatives are needed for this. Overall, 101 000 g of products are used for daily production, so a 150-liter homogenizing mixer was selected.

Tab. 2. Chemical apparatus needed for the production of body lotion.

Equipment type	Name of device	Nominal power [kW]	Price [PLN]	Source
Homogenizer mixer	SPX-VH-100	4 (emulsify); 1.5 (stirrer)	56 400	[11]
Body lotion feeder	LPF-1000 S/S	0.02	8 800	[12]
Compressor	MacAllister 1,5 HP	1.1	258	[13]
Total cost of the apparatus			**65 458**	

The next step is the assessment of the electricity used for the operation of the above-mentioned devices. According to the literature [3], the homogenization process should be carried out for 10 min, but due to the mass of ingredients, it can be assumed that this time will be extended to 20 min. Then the product should be mixed – it can be assumed, that a mixing time is equal to 10 minutes. Then the process of pouring the body lotion into the packaging takes place – taking into account that the process of preparing the ingredients, the homogenization and mixing process may take about one hour, the remaining 7 hours of work (assuming that the employee works 8 hours a day) can be used to pour the product into bottles, their closure, and labeling. Based on the calculations, it was determined that 71 packages should be filled within one hour, i.e. a minimum of 1.2 packages per minute. It is assumed that along with closing the package and preparing the next one, the worker will be able to fill 2 packages per minute, i.e. 120 packages per hour. Therefore, the filling process will take approximately 4.5 hours. The remaining time can be used for the labeling of products, cleaning, etc. The table below summarizes the estimated operating time of the devices along with electricity consumption and its cost. It was assumed that the price of 1 kWh of electricity is PLN 0.59 [14] and the devices are working at nominal power.

Tab. 3. The cost of electricity consumed during the process.

Device type	Daily working time		Daily electricity consumption [kWh]	Cost [PLN]
Homogenizer mixer (emulsify)	0.33	h	1.33	0.79

Homogenizer mixer (stirrer)	0.17	h	0.25	0.15
Body lotion feeder	4.5	h	0.09	0.05
Compressor	4.5	h	4.95	2.92
Total	**-**	**-**	**7**	**4**

Analyzing the data contained in the table above, it can be concluded that the monthly (22 working days) cost of electricity consumption is PLN 88, i.e. PLN 1056 per year. The calculation does not take into account the additional fees charged by the electricity supplier.

Another component of the costs associated with the production of a body lotion is the cost of purchasing the packaging in which it will be sold. It is assumed that the product will be sold in 200 mL packages, and instead of the usual cap, there will be a pump that facilitates the application of the cosmetic. A brown bottle was chosen, which protects the cosmetic against the effects of sunlight. The price of such a package is PLN 3.22 [15]. Therefore, the annual cost of purchasing the packaging will amount to PLN 386 400.

To complete the cosmetic packaging, a label with all relevant information should be placed on it. For this purpose, the annual cost of purchasing labels was estimated. It was decided to choose self-adhesive labels made of PE foil, which are delivered in roll form. According to the valuation on the website of the label manufacturer [16], the cost of purchasing 120 000 labels will be approximately PLN 15 300.

Also, the produced body lotion with keratin hydrolysate from poultry feathers can be sold via an online store - this option allows reaching consumers and avoids additional costs associated with renting business premises for the sale of the product. The cost of setting up an online store with regulations is a one-off cost of about PLN 6 200 and PLN 300 per year as part of the cost of its maintenance [17]. An option that does not require investment outlays is to set up accounts on various social networks where it is possible to promote a given product.

Another one-off cost that must be incurred is the cost of introducing a cosmetic product to the European market. This process is regulated by the Regulation of the European Parliament and of the Council 1223/2009 /EC of November 30, 2009, on cosmetic products, effective from July 11, 2013. In Poland, these provisions are contained in the Act of October 4, 2018, on cosmetic products (Journal of Laws 2018, item 2227). One of the requirements of the person responsible for placing the cosmetic on the market is to ensure that the product is safe and that the safety assessment of the product has been carried out, ending with the issue of the Cosmetic Product Safety Report [18]. Additionally, the product should be submitted to the European Internet database (Cosmetic Products Notification Portal "CPNP"). The safety assessment can be performed in specialized laboratories, and it includes, among others, the assessment of the compliance of the cosmetic composition with applicable law, the preparation of a complete physicochemical and toxicological profile of the ingredients included in the finished product, along with a risk assessment supported by toxicological analysis of the ingredients [19]. It is also advisable to perform dermatological and hypoallergenic tests and evaluation of application and use. The microbiological purity should also be determined and a maintenance test should be performed, as well as an aging test and a test regarding cosmetic compatibility with the packaging [19]. The table below lists the individual components related to the marketing of a cosmetic product along with its costs.

Tab. 4. Costs of the marketing of cosmetic product [19].

Type of an activity	Cost [PLN]
Preparing a safety report	400
Cosmetic product notification in the CPNP system	100
Documentation verification	100
Defining the scope of cosmetic product research	50
Verification and development of the list of cosmetic product ingredients according to INCI	100
Basic physical and chemical indications	150
Basic dermatological test (group of 20 probants)	350
Hypoallergic test	500
Application and performance assessment basic variant (group of 15 probes)	600
Determination of microbiological purity according to ISO 11930:2012	100
Preservation system test according to PN EN ISO 11930:2012	800
Aging test and compatibility of the mass of the product with the packaging	650
Total cost	**3 900**

The last component that should be taken into account when analyzing the profitability of an investment is an assessment of the costs incurred as part of the payment of salaries. Since the presented production of body lotion consists of placing the ingredients in a homogenizing and mixing apparatus, and then pouring the product into packaging, such work may be performed by an unskilled technical worker. The cost borne by the employer of employing such an employee is approximately PLN 3 200/month [20]. Additionally, the whole process can be supervised by a qualified employee with a chemical education, employed part-time. The cost of employing such an employee is approximately PLN 3 500/month [21]. Therefore, the monthly cost of employing employees is approximately PLN 6 700.

Table 5 summarizes the annual costs associated with the production of a body lotion containing poultry feather keratin hydrolysate, assuming that the hydrolysate production is 960 000 mL/year and takes place at the same plant as the body lotion production. Possible profits from the sale of the product were also estimated, assuming that its price would be PLN 30. Also, one-off costs that have to be incurred for the purchase of the necessary equipment as well as the marketing and sale of the product on the market were included. The calculation does not include costs such as the cost of renting rooms and a possible warehouse for storing products, costs related to administrative services (for example, hiring an accountant), costs of graphic label designs, etc.

Tab. 5. Summary of costs associated with the production and sale of body lotion with keratin hydrolysate from poultry feathers.

One-off costs [PLN]	
Purchasing of the process apparatus	65 458
Setting up an online store	6 200

The marketing of body lotion	3 900
Total cost	**75 558**
Costs of production and sale of body lotion with keratin hydrolysate [PLN]	
Cost type	**Annual cost [PLN]**
Substrates for the process	1 713 840
Energy consumption	1 056
Salaries	80 400
Online store maintenance	300
Purchasing of containers	386 400
Purchasing of labels	15 300
Costs of production and sale	**2 197 296**
Possible sales profits	**3 600 000**
Difference between profits and production and sale costs	**1 402 704**

Analyzing the above data, it can be concluded that the production of a body lotion containing keratin hydrolysate from poultry feathers may be a profitable solution, despite the relatively low selling price (PLN 30) concerning the presented cosmetics. This is because only a small amount of keratin hydrolysate is used in the production of the lotion, yet it has a positive effect on the properties of the cosmetic. The proposed price allows reaching consumers, which additionally reduces the risk that the product will not interest them.

To estimate the profitability of an investment, it is worth calculating the ROI (return on investment) using the following formula:

$$ROI_{\%} = \frac{gross\ profit - expenses}{investments} = 56\%$$

When calculating the index, the investment costs related to the purchase of equipment for the production of keratin hydrolysate from poultry feathers (PLN 29 400 [2]) were also taken into account. It is assumed that the body lotion will be produced in the same plant, so without such equipment it would be impossible to produce keratin hydrolysate, and thus the lotion with its addition, because there are no companies producing keratin hydrolysate from poultry feathers on the market. Other costs related to the production of keratin hydrolysate were included in the costs of obtaining the substrates for the production of the lotion. Additionally, the payback period was also calculated:

$$PP = \frac{1}{ROI_{\%}} \cdot 100 \approx 1.8\ years$$

The presented calculations, although they are only approximate, indicate the attractiveness of the solution - the payback time is less than two years, which is the appropriate time when it comes to introducing new solutions to the market. The presented calculations can be the basis for further project development and its implementation.

2.2 A sensitivity analysis

In 2017, Poland was the sixth largest cosmetics market in Europe [22]. The cosmetics market in Poland in 2019 generated revenues of over EUR 4 billion [23]. There is a growing trend in skincare-related revenues (the cumulative annual CAGR growth in 2016-2019 was 4.7%) [23]. 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 [23]. The main importers of Polish cosmetics are Germany (15% of exported products), Russia (11.7%) and the United Kingdom (9.4%) [23].

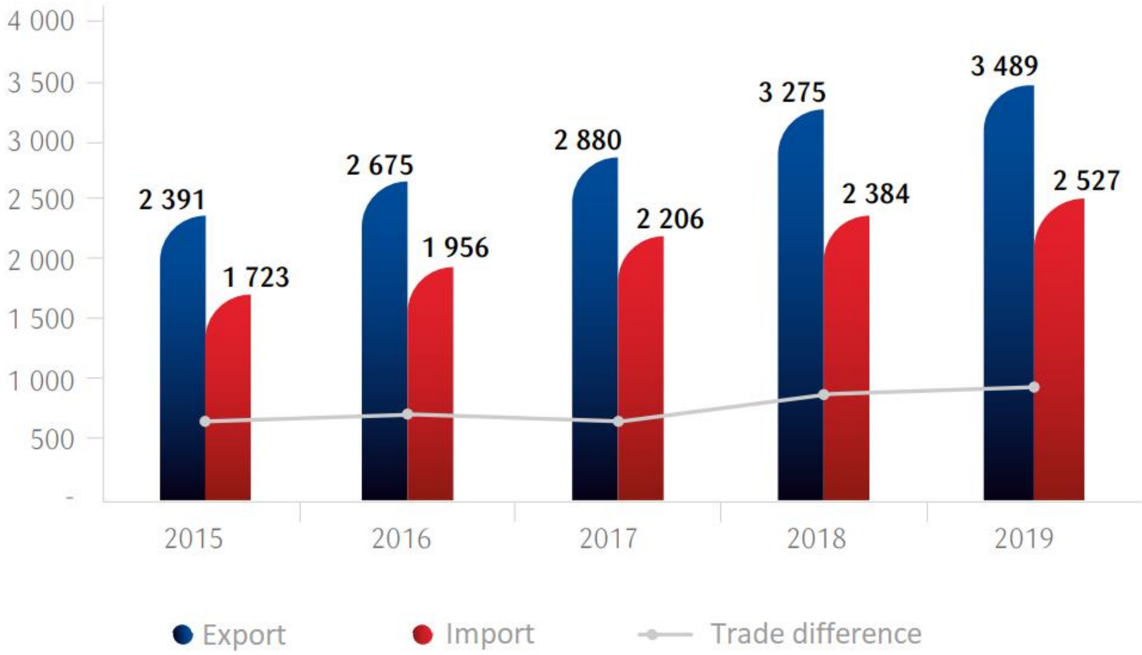


Fig. 3. Cosmetics industry in Poland – trade (million EUR) [23].

Poles spent an average of EUR 24.8 on skin care cosmetics (including body lotions) in 2019 (the European average was EUR 33.7), and the projected expenditure on this type of cosmetics in 2023 is to reach an average of EUR 30 (European average EUR 36.8) [23]. In addition, the share of online stores in the sales structure of cosmetics in Poland and Europe is increasing year by year – in 2019 in Poland 9.1% of sales were made by online stores and it is estimated that in 2023 this level will increase to 12.4% [23].

The above data shows that the cosmetics industry in Poland is constantly developing, and the products are appreciated by consumers, including foreign ones. This is good news when considering the idea of making a body lotion as there is a good chance that there will be a demand for such a product. Additionally, the majority of Polish cosmetics industry companies are small and micro-enterprises [22], which also shows that even small companies have a chance to survive on the market and compete with larger companies.

3 Project Definition

The subject of the presented project is the production of a body lotion containing keratin hydrolysate obtained from feathers from poultry slaughter. Poland is in the forefront of poultry producers in Europe - production for 2019 amounted to 3 596 297 tons [24]. Polish regions belonging to the southern Baltic area (Pomeranian, West Pomeranian, Warmia and Mazury) in 2019 had a production of 580 067 tons of poultry [24]. Due to the fact that feathers account for an average of 7% of the weight of poultry [25], it can be estimated that approximately 40 604 tons of feathers were generated in this region. This amount is so large that it can be successfully used as a raw material in other processes. From the point of view of the cascade approach and the circular economy, it would be advantageous to use feathers for the production of cosmetics or drugs - thanks to this, a high-quality product is created, the sale of which can generate profits, so the benefit is twofold - post-production waste that is currently used in an ineffective way or is simply incinerated is reused, and in addition, economic benefits are achieved.

One of the considered ideas for using poultry feathers is to produce keratin hydrolysate and then use it as an ingredient in a body lotion. Due to the development of the cosmetics industry in Europe, as well as the efforts of the European Union countries to introduce a circular economy and use raw materials to the maximum extent, such solution seems to fit these goals very well and should be considered more broadly.

3.1 Business Objective

The production of a body lotion with keratin hydrolysate from poultry feathers is an idea that can be crucial in the era of the move towards a circular economy, which is one of the most important issues currently being discussed when it comes to environmental protection and the preservation of biodiversity. The presented solution is innovative, because currently there are no products on the market that contain keratin hydrolysate produced from poultry feathers – keratin hydrolysate produced from sheep's wool is often used. Therefore, the most important business goal is to reach consumers and to convince them (for example through various marketing campaigns) that the offered product is of high quality and its production contributes to the development of a sustainable economy. If the market is willing to accept a new product, it should be ensured that the production is profitable and that the expenses are not greater than the revenues. Therefore, it is necessary to control the costs of running a business, strive for the lowest possible production costs, thus maintaining good quality of the cosmetic and adjusting prices to the trends prevailing on the market. The proposed price for the packaging of the product described (PLN 30 – approx. EUR 6.5) is at the prices of mid-range cosmetics and taking into account the fact that the cosmetic is based on ingredients of natural origin, and the use of keratin hydrolysate from poultry feathers has a positive effect on the condition of the skin, the price is not excessive and the product should find its supporters. In addition, when the idea turns out to be a profitable solution, expanding the installation should be considered, as well as starting the production of other cosmetics containing keratin hydrolysate from poultry feathers (shampoos, hair conditioners, etc.). Competitive solutions should also be monitored and changes made so that the proposed solution does not lose its attractiveness – sometimes it is enough to change packaging and graphic design to gain interest from consumers again.

3.2 Benefits and Limitations

The production of a body lotion with hydrolysed poultry feather keratin can be a solution with many benefits, but the development of the idea requires taking into account various constraints that may arise from various factors, which in turn may adversely affect the implementation of the proposed project. The table below lists the more important considerations regarding the potential benefits and limitations.

Tab. 6. Summary of benefits and limitations associated with the production of body lotion with keratin hydrolysate from poultry feathers.

Benefits	Limitations/Problems
• The production of a body lotion with keratin hydrolysate produced from poultry feathers will be new to the market. • The beneficial effect of adding keratin hydrolysate from poultry feathers to the cream has been proven - thanks to it, skin hydration increased and transepidermal water loss decreased. • The production of the proposed body lotion is based mainly on ready-made ingredients and a small number of devices and is relatively simple. • The use of keratin hydrolysate from poultry feathers in the body lotion has a positive effect on reducing the amount of post-slaughter waste, the management of which may be problematic at present. • Feathers' waste management is a solution that complies with the idea of a circular economy, which is particularly supported by the European Union. • The development of the cosmetics market in Poland and Europe may positively affect the adoption of a new solution and increase interest in products, the production of which uses valuable raw materials, which are now treated as waste. • Enterprises that start such production may be positively perceived in terms of caring for the natural environment and extending the processing chains of a given raw material.	• Post-slaughter feathers are now treated as waste, so there are legal barriers to changing the waste status and there may be administrative problems that may block idea of using feathers as a raw material in other processes. • Administrative barriers may adversely affect the interest in the presented solution - it may translate into a lack of potential investors and reluctance to take investment risk. • The production of a body lotion containing keratin hydrolysate obtained from poultry feathers is strongly dependent on the production of the keratin hydrolysate itself - its production is tested only in laboratory conditions and currently there are no companies on the market that deal with such production on an industrial scale, and this is associated with the current lack of a key ingredient on the market. • There is a risk that consumers will not be interested in a product that is based on poultry feathers due to the fact that it contains ingredients of animal origin, however, for example, hydrolyzed sheep wool keratin is a popular product. Therefore, it is important to make the public aware that poultry feathers, like sheep's wool, are some kind of waste and will be generated anyway, and their use can only bring benefits.

3.3 Option Identification and Selection

The next step is to evaluate the project in comparison with existing solutions and to list the benefits and difficulties associated with the use of such an innovative solution. The table below assesses the production of a body lotion containing keratin hydrolysate from poultry feathers, most of which are now burned for energy purposes or turned into feathers meal.

Tab. 7. Comparison of solutions regarding the use of poultry feathers

Innovative solution/product	Conventional solution/product	Benefits of Innovative solution/product	Difficulties associated with innovative solution/product
Production of body lotion with keratin hydrolysate from poultry feathers	Incineration of poultry feathers	The use of waste to produce a valuable product.	Administrative problems related to the change in the waste status, which will result in a lack of raw material for the production of keratin hydrolysate.
			Risk that consumers will be more likely to choose vegan products with ingredients that are not of animal origin.
		Selling a body lotion can have economic benefits.	Possible difficulties in acquiring customers and entering the market – a good marketing campaign is necessary.
Production of body lotion with keratin hydrolysate from poultry feathers	Producing of feathers meal	Body lotion is a more valuable product from the point of view of the cascading approach pyramid.	The production of keratin hydrolysate from poultry feathers is tested only in laboratory conditions, while the production of feathers meal takes place on an industrial scale.
		A body lotion can reach a wider audience and can be more profitable to sell.	The offered product will be new to the market, so it is not known how much consumer interest will be - feathers meal is a well-known product on the market and there is a demand for such a product.

3.4 Scope, Impact and Interdependencies

The poultry industry, apart from meat production, also generates waste which, due to their organic nature, may be a problem when it comes to their disposal. An example of such waste is post-slaughter feathers, which are processed into feathers meal, but just as often simply burned. Considering that feathers consist of approximately 91% of keratin [26], the use of which has a very good effect on the properties of the skin, hair and nails, they should be used in a way that allows their advantages to be used - for example, to produce keratin hydrolysate and then adding it as an ingredient in a body lotion.

It was decided to produce a body lotion with keratin hydrolysate, because the literature provides information that its addition has a beneficial effect on the condition of human skin. Additionally, the balsam production process itself is not complicated and when using a ready-made cream base, the process comes down to homogenization of the mixture and its mixing. Thanks to this, there is a chance that there will be investors who would like to take a risk and invest in the presented solution.

The intensive development of the cosmetics market in Poland and Europe may also have a positive impact on the presented solution – there is a chance that such a balm would find its supporters who would choose it not only because of its valuable properties, but also because it follows the idea of sustainable development. The use of waste as raw materials in other processes is constantly promoted by the European Union and is the basis of the circular economy.

For a company that would undertake such production, proceeding in accordance with the circular economy and the cascade approach may positively affect its image, and also facilitate the application for various types of funding, as well as provide the basis for applying for various grants and financial awards.

3.5 Market Assessment

The production of a body lotion, which includes the hydrolysate of keratin from poultry feathers, is at this stage an innovative solution, and its implementation may depend on many factors. The most important of them are listed in the table below and assess how they might be related to the proposed project.

Tab. 8. The relationship of the proposed solution for the production of body lotion with keratin hydrolysate from poultry feathers with individual factors.

Political	• Government units (at the regional or national level) can support bio-innovative solutions and promote them in various ways – presenting the company as innovative, caring for the natural environment, using financial rewards for the further development of the company, support through grant financing.
Economical	• The use of waste to produce a valuable product allows achieving financial benefits. • The development of bio-innovative solutions in Poland may affect the creation of new units dealing not only with the production of the described product, but also, for example, process equipment. This would increase jobs for skilled workers who are currently often looking for work abroad. • Keratin hydrolysate added to the body lotion, despite its small share in the weight of the cosmetic, has a positive effect on its properties, thanks to which a given amount of hydrolysate can be used to produce

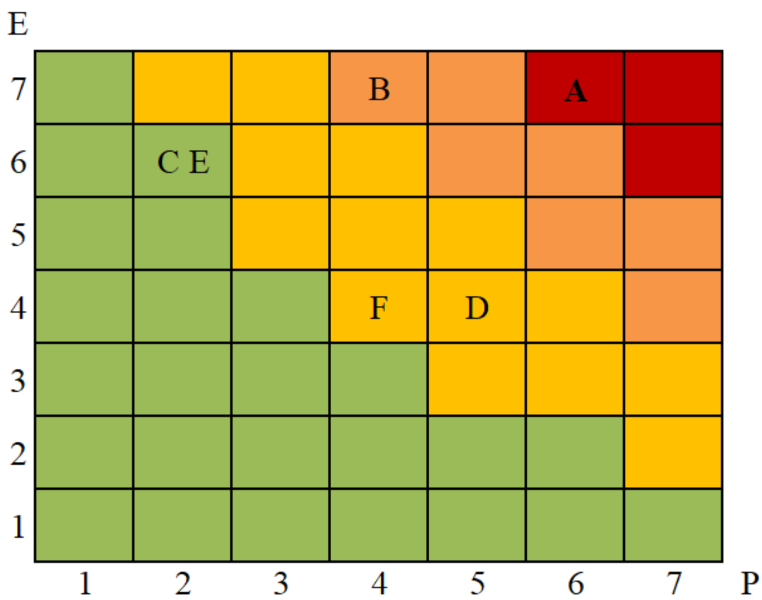
	a large number of packages, which translates into higher profits.
Sociological	• Bio-innovative enterprises in the region can positively influence the perception of the region and attract new investors and employees. • The use of natural cosmetics, which include products made from post-process waste, should increase the public awareness of the amount of waste generated and the fact that, despite the term "waste", such products are often still very valuable and should be used in other processes for extending the processing chain for a given raw material.
Technological	• There are still no companies on the market that produce keratin hydrolysate from poultry feathers, therefore a pilot plant should be carried out on an industrial scale - it requires further research and continuous improvement of the production process. • Reduction of production costs in the plant, for example by using renewable energy sources for the production of electricity.
Legal	• Polish law is not clear on waste management and changing the status of waste, which would make it possible to use them in other processes. Administrative procedures related to waste management should be simplified and new regulations should be created. • The European Union, by introducing various strategies and regulations, aims to develop a sustainable economy, so the proposed solution will be consistent with the idea of a circular economy.
Enviromental	• The use of feathers in the production of body lotion reduces the amount of waste that is sent to landfills or for incineration. • The use of waste in further processes has a positive effect on the extension of the raw material processing chain and is consistent with the idea of a sustainable economy.
	•

3.6 Risk Assessment

To determine the potential risk associated with the production of body lotion with keratin hydrolysate from poultry feathers, a so-called Risk Map was made (see next page). It considers the risks associated with the adopted solution and allows determine what impact they will have on its development.

RISK LEVEL „R”		PROBABILITY „P”		EFFECT „E”	
Name	**Scale**	**Name**	**Scale**	**Name**	**Scale**
Negligible	1-12	Very low	1	Insignificant	1
Noticeable	13-25	Small	2	Short	2
Monitoring necessary	26-38	Possible	3	Little	3
Immediate response	39-49	Big	4	Perceptible	4
		Threatening	5	Average	5
		Very dangerous	6	Significant	6
		Certain	7	Disastrous	7

RISK	P	E	R = P x E
A – problems with the installation for the production of keratin hydrolysate from poultry feathers	6	7	42
B – enterprises will be interested only in the production of lotion, without the production line for keratin hydrolysate from poultry feather	4	7	28
C – the product will not appear on the market due to a poor marketing strategy	2	6	12
D – consumers will be leaning towards vegan cosmetics	5	4	20
E – complicated administrative procedures will discourage investors from taking investment risk	2	6	12
F – a lack of financial support from governmental bodies at regional and state leve	4	4	16



References

1. Website: https://tvn24.pl/biznes/ze-swiata/produkcja-miesa-drobiowego-w-unii-europejskiej-polska-liderem-ra921491-4505821 (acces on 20.07.2020).
2. Production of keratin hydrolysate from poultry feathers – Business Case. BioBIGG Project.
3. Mokrejš, P., Huťťa, M., Pavlačková, J., Egner, P. Preparation of Keratin Hydrolysate from Chicken Feathers and Its Application in Cosmetics. J. Vis. Exp. (129), e56254, doi:10.3791/56254 (2017).
4. Tesfaye T., Sithole B., Ramjugernath D. Valorisation of chicken feathers: recycling and recovery routes. Proceedings Sardinia 2017 / Sixteenth International Waste Management and Landfill Symposium/ 2 - 6 October 2017; S. Margherita di Pula, Cagliari, Italy / © 2017 by CISA Publisher, Italy.
5. Website: https://subandtarctic.com/products/handcream (access on 01.09.2020).
6. Website: https://www.cosmeticsdesign-asia.com/Article/2019/10/24/Sustainable-keratin-Kiwi-entrepreneur-brings-new-value-to-crossbred-wool-through-skin-care (access on 01.09.2020).
7. Website: https://bioer.pl/cialo/1240-intensywny-balsam-do-ciala-z-keratyna-mocznikiem-i-maslem-kakaowym-200ml-marki-bioer.html?search_query=keratyna&results=10&cate= (access on 01.09.2020).
8. Website: https://www.zrobsobiekrem.pl (access on 02.09.2020).
9. Website: https://e-naturalne.pl/pl/p/Baza-kremowa-A/119 (access on 02.09.2020).
10. Website: https://www.zrobsobiekrem.pl/pl/p/DHA-BA-konserwant-akceptowany-przez-Eco-cert/207 (access on 03.09.2020).
11. Website: https://www.alibaba.com/product-detail/SPX-Cream-Cosmetic-Laboratory-Homogenizer-Industrial_60181174465.html (access on 03.09.2020).
12. Website: http://aaatech.pl/dozownik-do-plynow-gestych-lpf1000-ss-p-186.html (access on 03.09.2020).
13. Website: https://www.castorama.pl/kompresor-bezolejowy-mini-macallister-1-5-hp-1100-w-id-1051699.html (access on 03.09.2020).
14. Website: https://globenergia.pl/ile-kosztuje-1-kwh-energii-elektrycznej-z-czego-sklada-sie-rachunek/ (access on 04.09.2020).
15. Website: https://www.naturalne-piekno.pl/butelki/1700-butelka-pet-200-ml-brazowa.html#/351-nakretki_i_pompki-pompka_czarna (access on 04.09.2020).
16. Website: https://www.labelprint24.com/pl/products/etykiety-na-roli-1.php (access on 04.09.2020).
17. Website: https://sukcesstrony.pl/ile-kosztuje-strona-internetowa-cennik (access on 04.09.2020).
18. Website: https://www.kosmetyczni.pl/uploads/dokumenty/Wprowadzanie_do_obrotu_2019.pdf (access on 05.09.2020).

19. Website: https://cosmeceuticum.pl/wp-content/uploads/2018/01/OFERTA-2018.pdf (access on 05.09.2020).
20. Website: https://poradnikprzedsiebiorcy.pl/-minimalne-wynagrodzenie-2015 (access on 05.09.2020).
21. Website: https://wynagrodzenia.pl/moja-placa/ile-zarabia-chemik (access on 05.09.2020).
22. Report on the condition of the cosmetics industry in Poland 2017, Warsaw, 2017.
23. Website: https://wspieramyeksport.pl/api/public/files/1948/Kosmetyczna_lipiec_2020.pdf (access on 06.09.2020).
24. Website: https://bdl.stat.gov.pl (access on 06.09.2020).
25. Staroń P., Banach M., Kowalski Z.: Keratin – origins, properties, application. CHEMIK 2011, 65, 10, p. 1019–1026 (in Polish).
26. Thyagarajan D., Barathi M., Sakthivadivu R., Scope of Poultry Waste Utilization. IOSR-JAVS, Volume 6, Issue 5, 2013, PP 29-35.

BIOPLASTIC FROM POTATO STARCH (POLISH REGION)

COLOURBOX26675650

17.04.2020

Business Case

Bioplastic from potato starch

Gdańsk University of Technology

Roksana Bochniak

Dariusz Mikielewicz

1 Executive Summary

Potato cultivation is one of the key pillars of the Polish economy. In 2018, Poland was third main producer of potatoes in European Union, producing 14,3% of all potatoes and having highest cultivated area (17,8%)[1]. Polish agricultural holdings which grew potatoes constitute about 25% in total EU stakeholders in this sector. During processing potatoes at local factories, many types of wastes are obtained, the vast majority of which can be reused to produce an innovative product that is sold at a profit.

Actions taken by the European Union, aimed at implementing the cascading approach and circular bioeconomy in most industry sectors, force entrepreneurs to take on new challenges that would allow using unused waste. In the case of the potato processing industry, there are many attractive business opportunities for profitable waste utilization. Starch, which until now has been mostly processed into alcohol or feed, is especially valuable waste. This business case proposes a new, more profitable approach – the production of cutlery from bioplastics from potato starch. This type of product not only allows profitable use of waste, but is also desirable in the growing market for organic products. Also, the demand for this type of products will increase as a result of the ban on the use of disposable cutlery made of petroleum-based plastics from 2021. This opens a huge market only for bioplastic producers.

A model was established in which a bioplastic cutlery production line is introduced at the existing potato processing factory. This type of solution allows not only to eliminate material transport, but also is an additional attribute in the promotion and marketing of the company - reuse of waste for the production of bioplastics, which are environmentally friendly and allow to displace harmful petroleum-based plastics from the market, proves the company's ecological commitment. Manufactured bioplastics in the form of cutlery / plates can be sold wholesale.

2 Finance

2.1 A financial appraisal

Currently, bioplastics are reported to be a more expensive product than traditional petroleum-based plastics. It is estimated that price of HDPE (high-density polyethylene), which is a material of which most of plastic bags are made of, amounts in about 1.3 €/kg - which is over 3 times lower than a starch-based polymer prices (up to 5 €/kg)[2]. However, these prices may refer to the model in which starch is produced for the needs of production of bioplastics, which generates the cost of planting potatoes cultivated strictly for the production of starch, its processing and transport, or to the model in which the bioplastic producer purchases this starch from other companies. In the presented model, starch produced during processing of potatoes for food purposes is used - thus, the raw material is available at no additional cost, for free. This is an important aspect that allows to minimize the cost of raw materials. Despite the fact that the final product will cost more than traditional plastics, it should be emphasized that currently bioplastics from starch have the lowest life cycle energy requirement per kilogram (25.4 MJ/kg compared to HDPE, which needs 80 MJ/kg) and the lowest CO2 emission factor (1.14 $kgCO_2eq/kg$ compared to HDPE, which generates 4.84 $kgCO_2eq/kg$)[3]. These two factors may

[1] *Source:https://ec.europa.eu/eurostat/statistics-explained/index.php/The_EU_potato_sector_-_statistics_on_production,_prices_and_trade#Potato_production_in_the_EU_is_highly_concentrated*. Eurostat, 2018.

[2] *http://www.wrap.org.uk/content/plastic*

[3] *Gironi F.,Piemonte V. (2011): Bioplastics and Petroleum-based Plastics: Strengths and Weaknesses, Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 33:21, 1949-1959.*

in the future, after tightening the penalties for increased CO2 emissions, play a great role in the cost of process production, and ultimately, despite the higher expenditure on raw materials, it may turn out that the rising costs associated with high CO_2 emissions will increase the price of petroleum plastics.

Starch can be used for production of bio-plastics by modifying its properties and increasing its plasticity. It was proposed to use the technology presented by Keshav[4]. According to it, a following steps have to be made to obtain starch-based bioplastic: hydration of starch with water; hydrolysis with a weak acid, occuring in the temperature between 90-180°C; evaporation of water from the starch solution; addition of plasticizer and other additives to improve properties of the final product. The manufactured material can be formed like traditional plastics, i.e. in extruders. Assuming that there is 2 000 tonnes of starch available annually, and that bio-plastic line is working 350 days in a year (with two weeks of technical stoppage), the line must be able to process approx. 5,71 tonnes of starch per day. With that amount of starch, approx. 36,52 tonnes of starch polymer per day can be produced. After drying and pelletising, this quantity is reduced to **19,24 t/d**. The next steps require extrusion, conditioning, moulding and confenctioning. A production line with such capacity would produce 6 734 tonnes of bio-plastic annually (Figure 1).

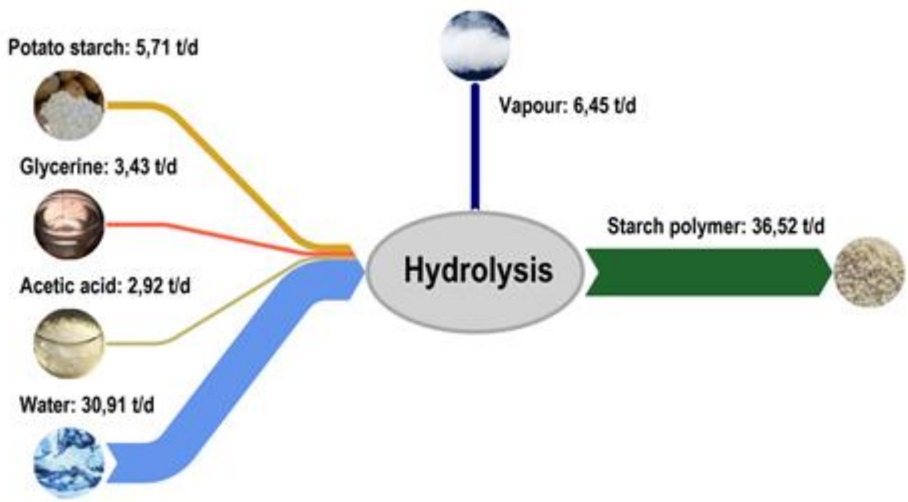


Fig 1. Material flow in starch-based bio-plastics production[4]

The tables below summarize the estimated calculations of the costs of the described above production model. Land costs were omitted, as the line is built on the premises of an existing factory, and some staff cost is not foreseen (waste management, administration, maintenance) because most of these duties can be performed by persons already employed in the company. The financial analysis presented below is estimated - due to the initial stage of technology (TRL4/5), there are no data of Polish prices of i.e. machinery, so the same costs as in the studies on the implementation of bioplastics production in other countries were assumed[5]. Table 1 summarizes the approximate costs of the input materials. Due to the lack of official market data, prices available on sales portals were used.

[4] *Keshav S. (2016). Production of bioplastics using potato starch. Doctoral dissertation, University of Mauritius.*

[5] *Michael D.: Biodegradable plastics: The potential for Australian potato as an input for biodegradable polymers. A report for Horticulture Australia by Wondu Business and Technology Services, 2004.*

Table 1. Financial outlays on raw materials and amount of produced bioplastics

Raw materials:	Amount, t/a	Amount, t/d	Cost, PLN/t	Cost, PLN/a
Starch	2 000,0	5,71	0	0
Glycerine	1 200,5	3,43	1 700	2 040 850
Acetic acid	1 022,0	2,92	3 700	3 781 400
Water	10 818,5	30,91	10	108 185
				5 930 435,00

Products:	Amount, t/a	Amount, t/d
Starch polymer (after drying)	6 734	19,24
Vapour	2 258	6,45

Table 3 lists the one-off costs, production costs (based on literature data)[6] and the costs of remuneration to be borne by the employer.

Table 3. Initial one-off investment outlays and annual costs associated with the production of bioplastics

One-off costs	PLN
Machinery	500 000
Laboratory tests	500 000
Training and recruitment	100 000
	1 100 000,00

Production costs:	PLN/t	PLN/a
Extrusion	2 470	16 632 980
Condition and packing	3 770	25 387 180
Moulding	4 550	30 639 700
Confectioning	4 550	30 639 700
Staff costs	-	1 483 200
		104 782 760,00

Staff costs:	Person/shift	Shifts	Months	Cost/M, PLN	Cost/a, PLN
Operators	2	3	12	5 000	360 000
Mechanical	1	3	12	6 700	241 200
Electical	1	2	12	6 700	160 800
Lab. Assistant	2	1	12	7 500	180 000
Shift leader	1	3	12	6 700	241 200
R&D	2	1	12	7 500	180 000
Marketing&promotions	2	1	12	5 000	120 000
					1 483 200,00

[6] *Michael D.: Biodegradable plastics: The potential for Australian potato as an input for biodegradable polymers. A report for Horticulture Australia by Wondu Business and Technology Services, 2004.*

In table 4, some of the most important parameters related to the investment were collected, such as: initial financial outlays, which are a sum of one-off costs, raw material costs, production and staff costs; basic assumptions regarding the annual production scale, weight of the finished product, quantity of manufactured products; annual costs associated with production; the cost of producing a single cutlery and a kilogram of the finished product. The assumed price of one piece of cutlery is competitive on the disposable products market and is in line with the average price of such type of product. The ROI parameter – Return of Investment was calculated as:

$$ROI = \frac{gross\ profit - expenses}{investment} \cdot 100\%$$

While the PBP – Payback period was calculated as:

$$PBP = \frac{1}{ROI} \cdot 100$$

In the presented analysis, the investment requires large financial outlays, however, it has a fast payback period of about 2 years. It should be mentioned that the costs of raw materials and production can be minimized through activities such as the implementation of low-temperature energy sources management technologies for electricity production, or close cooperation with raw material producers to negotiate favorable prices. The following analysis is estimated and the presented values may change due to the significant number of assumed variables. Some aspects and costs have been omitted due to the lack of this type of data. However, it is a good basis for a broader financial analysis and shows the attractiveness and possibility of implementing the proposed project.

Table 4. Most important parameters related to the project

Initial financial outlays, PLN
113 296 395,00
Working days annualy
350
Weight of cutlery, kg per piece
0,002
Amount of produced cutlery
3 367 000 000
Total annual cost of production, PLN
112 196 395,00
Producing cost of 1 kg of bioplastic, PLN
16,66
Producing cost of 1 piece of cutlery, PLN
0,03
Price of 1 piece of cutlery, PLN
0,05
Annual sales profit
168 350 000,00

ROI, %	
	48,59
Payback period	
	2,06

2.2 A sensitivity analysis

According to the European Bioplastics in cooperation with Nova-Institute, global bioplastics production capacity is set to increase from around 2.11 million tonnes in 2019 to approximately 2.43 million tonnes in 2024[7]. Therefore, it is a dynamically developing and future-proof market - the expected increase in production goes hand in hand with the product demand.

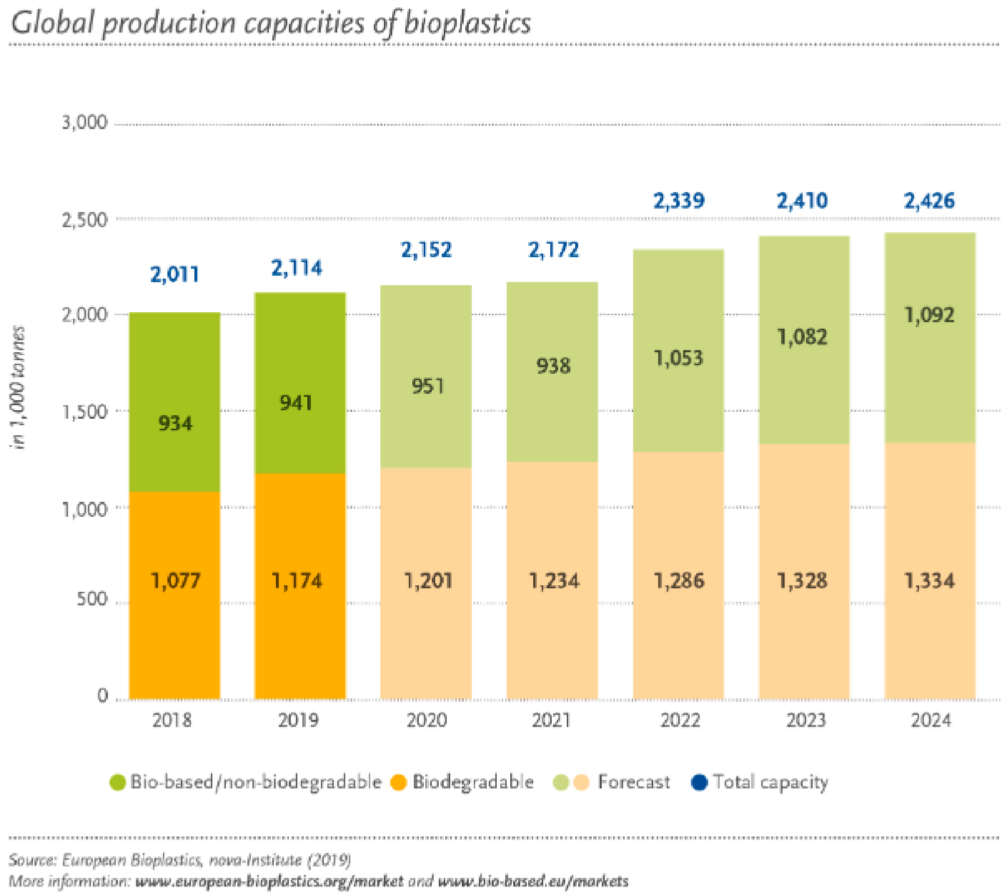


Fig 2. Global production capacities of bioplastics[7]

There is a huge potential of bioplastics industry on the market, mainly due to the increasingly restrictive provisions of both Polish and European law. Some restrictions introduced by the Polish state authorities and the European Union act only in favor of bioplastics, due to their lack of environmental harm and the closing of processing chains in accordance with the circular economy. The latest EU directive, banning the use of single-use plastic products such as cutlery,

[7] *European Bioplastics, Nova-Institute (2018). http://www.european-bioplastics.org/market*

plastic cotton swabs, straws, coffee stirrers from 2021[8], introduces a monopoly for bioplastics manufacturers.

In 2009, EU adopted regulation that set mandatory emission reduction targets for automotive sector. If the average CO_2 emissions of a manufacturer's fleet exceed its target in a given year, an excess emissions premium for each car registered must be paid[9]. According to the global automotive information site JATO, in 2021, these penalties will cost companies almost 34 billion €[10]. Similar regulations may soon hit the petroleum plastics market, which have a high life cycle energy requirement per kilogram (from 77 to even 120 MJ/kg) and CO_2 emission rates higher than bioplastics (from 3 to almost 8 $kgCO_2eq/kg$)[11]. Due to the low values of CO_2 emission rates (1 - 3,8 $kgCO_2eq/kg$), bioplastics remain free from fines and financial expenses related to environmental damage.

3 Project Definition

Potatoes are one of the most popular and important crops grown not only in Poland, but also worldwide.

Since 2015 a relatively constant value of the growing area in Poland has been observed, amounting to approx. 300 000-341 000 ha[12]. The SBA region in Poland, due to its location, is beneficial for growing many plants, including potatoes. In the Pomeranian Region, the share of potatoes in the sowings structure in recent years is above 3%, i.e. around 19 000 ha and is higher than the national average. In Warmia-Mazury Region in 2017 there were about 7 500 h of potato cultivation area. In West Pomeranian Region, in 2017 about 10 600 ha was used for potato cultivation. Figure 3 presents map of yields of potatoes in 2017 in Poland. Therefore, a steady supply of raw material for the production of bioplastics from potato waste is ensured.

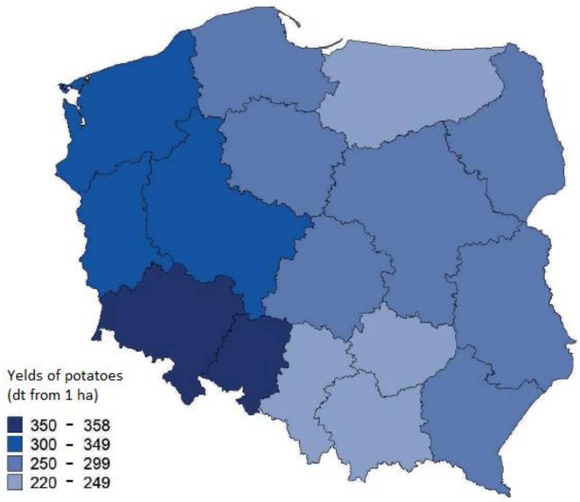


Fig 3. Yields of potatoes (dt from 1 ha) in 2017 in Poland[13]

---

[8] *Proposal for a Directive of the European Parliament and of the Council on the reduction of the impact of certain plastic products on the environment - Final compromise text (2019).*

[9] *Source: https://ec.europa.eu/clima/policies/transport/vehicles/cars_en*

[10] *Source: https://www.jato.com/2021-co2-targets-would-generate-e34-billion-euros-in-penalty-payments-within-europe/*

[11] *Gironi F.,Piemonte V. (2011): Bioplastics and Petroleum-based Plastics: Strengths and Weaknesses, Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 33:21, 1949-1959.*

[12] *Crop production in 2017. Statistics Poland, Warsaw 2018.*

[13] *Production of agricultural and horticultural crops in 2017. Statistics Poland, Warsaw 2018.*

From the point of view of bioplastics production, the most desirable waste component from potato processing is starch. The production plant located in the SBA region in Poland, potatoes for food purposes, was considered in this business case. This factory produces 2 000 tons of waste starch per year. Due to the fact that this is a large production plant with adequate infrastructure and space, the introduction of an additional line for the production of cutlery made of bioplastic is being considered. To minimize costs of raw material and transport, in the initial variant only starch from own factory was considered, however, the possibility of further increasing of production by buying starch from other sources, for example from corn, cannot be excluded.

Single-use cutlery and plates, sold wholesale, are the initial products considered in the analysis. This is due to the previously mentioned EU directive, which bans these kind of products made from traditional plastics - this opens a huge market demand for this type of products made of ecologically friendly materials. However, modification of the presented production line for the production of other types of items should not be excluded - especially the medical sector, which consumes huge amounts of disposable plastic elements, should be taken into account. In the future, this sector may face restrictions similar to those targeted at the disposable cutlery market.

In addition to starch, products such as glycerin, acetic acid and water are used in the production of bioplastic. Glycerin is produced in Poland, which is also an important economic aspect and allows the use of local sources. It is worth mentioning that glycerin is often a by-product in fat and feed processingS plants, and it is a waste in the production of biodiesel. So there are many sources of waste glycerin that can be used to further reduce costs. In the case of acetic acid, it is also produced by many plants located in Poland, which eliminates the costly import of raw materials from other countries.

3.1 Business Objective

The business goal is to create a new production line in existing plant, which due to the lack of financial outlays on the main component of bioplasic (starch) will be simple to implement and maintain. At the same time, thanks to new opportunities for bioplastic manufacturers in Poland, caused by recent EU directives, the goal is to exploit the emerging market gap. In Poland, there are few companies producing fully biodegradable bio-plastics. The most known is the Biotrem company, which produces disposable dishes and cutlery from bran. Another enterprise is Maropak, which is producing packaging from sugarcane and from corn starch (PLA). However, none of these companies is operating within the SBA region as both are located in Masovian Region. In Pomeranian Region, there are companies declaring production of recycled packaging (Plast-Box SA located in Słupsk), however, there is no information about a factory that would specialize in the production of completely biodegradable bioplastics, in particular from waste. The new product manufactured in accordance with the cascading approach and circular bioeconomy philosophy fits perfectly in the new EU guidelines. Due to the strict policy directed against traditional plastics, CO_2 emissions and environmental pollution, it is important to quickly enter the industry of ecological materials and sustainable development, because in the long term each industry sector will have to implement environmentally friendly solutions. Developing own brand and product with this first production line, largely independent of suppliers due to the use of own waste, will allow to build an own market position at an early stage of plastic production sector changes. Later, it will allow subsequent development and expansion, after the introduction of the abovementioned restrictions of banning petroleum based plastic cutlery.

An important aspect is the human factor - the existing employees are familiar with working in a mass production plant, which will minimize the costs of operators training, while the additional workforce can be obtained from over 7 100 unemployed people with higher education and 10 178 people with vocational education only in the Pomeranian Region. Early development of own production staff will result in later profit, when the requirement to manufacture products only from bioplastics will be mandatory for more sectors, not just for the production of single-use cutlery and plates, and will allow entry to other markets (e.g. medical, toys sector).

3.2 Benefits and Limitations

Benefits	**Limitations**
• Technology constantly developed in research centers - perspective of improvement and optimization to reduce production costs • Demand for this type of products due to new restrictions introduced by the EU and the growing awareness of the society that wants to use environmentally friendly technologies • Due to the specific group of consumers who is able to pay more for a plant-based and environmentally friendly product, the profitability of the project is possible even at a price higher than traditional plastic (good marketing strategy) • Early entry into the bioplastic market, which is still developing in Poland, can ensure stable markets and even a monopoly in some sectors • Increasing the attractiveness of the company in the opinion of consumers • Possible financial reductions/co-financing from the state or EU due to production in accordance with the circular bioeconomy • Selling at high price a product from the waste that was originally unused • Being a desirable job place because of being a company developing interesting technologies and fighting unemployment in the region	• High financial risk at the initial stage of production • Building a sector in the region almost from scratch - large amounts of work and staff training • Adjusting the final price of the product to the financial outlays, so that it still remains competitive with traditional plastics • Higher spending on research and development • Administrative difficulties related to the launch of an innovative product from waste on the market (no legal regulations) • Increased expenditure on marketing strategy and promotion to convince consumers of the benefits of a new product and encourage them to purchase despite its higher price

3.3 Option Identification and Selection

Innovative solution/product	**Conventional solution/product**	**Benefits of Innovative solution/product**	**Difficulties associated with innovative solution/product**

Cutlery from bioplastics	Petroleum-based cutlery	Biodegradability	Higher price
		Reduction of environmental pollution, especially water pollution	Slightly worse properties of the product
		No fees for exceeding emission standards / environmental pollution	Higher costs at the initial stage of production
Cutlery from bioplastics	Animal feed/alcohol	A larger target group of consumers than in the case of selling alcohol	The production of alcohol from waste is a technology known and proven in Poland, free from financial risk
		Higher market value of the product than animal feed	Use as animal feed does not generate investment costs (waste is simply sold at a very low price)
		A product located high in the cascading approach pyramid	The need to invest in equipment and staff training

3.4 Scope, Impact and Interdependencies

The latest EU directives on disposable cutlery are promising and create exclusive markets for bioplastic manufacturers. In addition, the policy related to reducing CO_2 emissions works in favor of the presented solution due to its low emissivity and low energy consumption. There is also an emphasis on implementing a circular economy in European countries. Since the production model presented in the above business case is in line with all recent EU requirements and recommendations, various types of financial support can be expected, including not only co-financing, but particularly favorable credit terms from banks.

The above model assumes the initial use of own produced waste, however, to increase production and develop the brand, buying waste from other companies should be considered. Post-production waste from biomass processing is often sold at very low prices to nearby farmers for feed or fertilizer, part is burned for energy purposes in an inefficient way (very low calorific value, construction problems with biomass-fired boilers). For many entrepreneurs, biomass waste is a problem they want to get rid of. In this case, it is possible to increase the input material (starch) at a small additional cost. Other companies getting rid of waste often have to pay for its collection, transport and disposal, so they will be interested in cooperation and selling wastes at a low price or even giving it for free. Then one should take into account transport costs, but using local sources will not be high costs. Then the only expense would be the costs of transport, but using local sources they will not be too high. The situation is similar with other raw materials needed for production. Since 2016, biodiesel production in Poland has been growing, which also means an increase in the amount of raw glycerin, which is waste from the production of this fuel. The resulting waste will have to be properly managed, so new local sources of glycerin can be expected and its price will be reduced. Also, glycerin is a waste in many other sectors (fat processing and feed industry). Acetic acid is also a by-product of fermentation process, i.e. in technical alcohols production or biogas plants. Acquiring partners from all this sectors can significantly reduce the cost of this raw material. In order to establish cooperation with regional suppliers of this type of raw materials, and find sources of waste that can be used in own production, it is advisable to join any thematic clusters associating biomass processing plants in the SBA region. The regional policy favors such undertakings and organizes associations of local entrepreneurs and clusters, so it simplifies this issue.

In the material flow of the presented production of bioplastics, vapour is produced in an amount of almost 7 t/d. At this stage of the design analysis, the parameters of this vapour are unknown, however, it is a potential additional energy source that can offset some energy costs. It can be used in ORC technology (Organic Rankine Cycle), allowing the use of low-temperature waste heat sources, or in the micro-CHP systems (combined power and heat generation). It can be additionally used in other potato processing production processes in the company's main production profile, reducing costs. It is advisable to keep tracking the latest technologies market and cooperating with research centers to implement new techniques for managing low-temperature waste energy sources.

3.5 Market Assessment

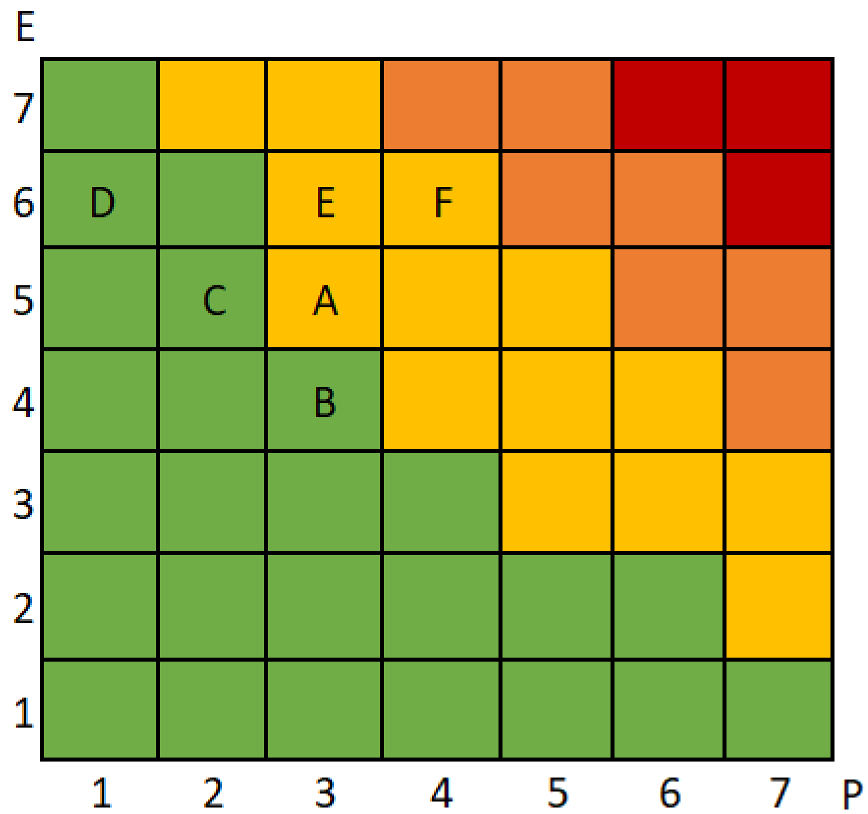
Political	**Economical**	**Sociological**	**Technological**	**Legal**	**Environmental**
- the new EU regulations will force changes in Polish law - improving the company's image as a leader in waste reuse technology - the formation of clusters of entrepreneurs	- the possibility of early building a position on the disposable products market - more favorable credit terms for company (due to the environmentally friendly production)	- changing public awareness - a good campaign can change the perception of plastics from products that must be "as cheap as possible" into a product that you can pay for more if it is environmentally friendly	- development and industrialization of the region - company development, including inventing technologies which could be potentially patented - a chance to develop and sell ,,know-how”	- being one of the first producers in the region may result in the possibility of cooperation with legislators on regulations related to the products from waste, which can increase company influence in the region	- reduction of environmental pollution, in particular in aquatic ones - reduced CO_2 emissions - reduction of consumption of energy from non-renewable sources

3.6 Risk Assessment

RISK LEVEL „R”		PROBABILITY „P”		EFFECT „E”	
Name	**Scale**	**Name**	**Scale**	**Name**	**Scale**
Negligible	1-12	Very low	1	Insignificant	1
Noticeable	13-25	Small	2	Short	2
Monitoring necessary	26-38	Possible	3	Little	3
Immediate response	39-49	Big	4	Perceptible	4
		Threatening	5	Average	5
		Very dangerous	6	Significant	6
		Certain	7	Disastrous	7

RISK	P	E	R = P X E
A – The manufactured product will not have the desired properties	3	5	15
B – The use of raw materials of natural origin is associated with dependence on crops, weather conditions, etc.	3	4	12
C – Lack of cooperation with other starch producers	2	5	10
D – Lack of public interest in organic products	1	6	6

E – The price will be too high for consumers	3	6	18
F – Potential problems with the adaptation of process equipment for the production of bioplastics	4	6	24



BIO-BASED PLASTIC FROM POTATO STARCH (GERMAN REGION)

COLOURBOX26675650

Author: *Valerie Sartorius, Jennifer Nitzschke, Lena Huck,* Agency of Renewable Resources (FNR)

Editor: *Martin Behrens,* Agency of Renewable Resources (FNR)

Project Title: Bioeconomy in the South Baltic Area: Biomass-based Innovation and Green Growth

Project Acronym BioBIGG

Work Package Work package 5: Implementation of innovative agro-industrial value-chains and biomass-based production in SME’s

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

Published by: BioBIGG

Business case: Bio-based plastics form potato starch

Bio-based plastics from potato starch is a feasible business model if there is a large supply of potatoes and available technology. Using potato residues adds an additional value to the model. However, the different starch quality has to be taken into account. More research should be conducted in order to reduce production costs, as well as expanding the product range.

Country	Germany	
Name of company or project	Biobased-Plastics from Potato Starch	
Web site	Example: BioTec https://www.biotec.de/	
Description of the company or projects	Using potato starch as a renewable resource to produce biodegradable bio-based plastic (including the use of potato by-products)	
Type of production (choose one or more, mark box(es))	Energy production	
	Circular bioeconomy development	X
	Production of non-energy high value added products	x
Source of biomass (choose one or more, mark box(es))	Agriculture and food industry	X
	Municipal waste and sewage	
	Fishery and algae	
	Wood	
	Several sources	
Description of products from biomass	Potatos are produced for the agriculture and food industry. Starch from the potatos is processed. Biomass includes the whole potato and potato residues (by-product from other industries)	
How does the business case fulfil sustainability criteria (please explain the following benefits)? – Economic benefits	Potato starch can be used to produce bio-based plastics, which are in demand	
Social benefits	Urban areas are strenghtened, Job opportunities	
Environmental benefits	Renewable resource, by-product from other industrial processes can be used	
Technology readiness level (choose the appropriate box and mark it with x)	5. Technology validated in relevant environment	
	6. Technology demonstrated in relevant environment	
	7. System prototype in operational environment	
	8. System complete and qualified	
	9. System operational	X
Transferability to small and medium sized companies in the BSR countries	Yes, as long as country has a potato production and the available technology to process the potato starch into bio-based plastics	
Existing enabling policies and economic factors (describe the policy measures like subsidies, tax breaks, price policy, regulations that are	European Green Deal: focus on renewable resources. As fossil fuels are finite, new ways have to be found to produce plastics.	

crucial for making this business case economically viable).			
Hashtags (select from drop down menu up to six most relevant hashtags (key words) related to this case in a ranked order starting from the most important)	#Fossil fuel substitution #Food residues #Environmental friendly #Circular Bioeconomy #Regionality #Sustainable Jobs		
	Business model block	Description	Notes
Infrastructure	Key partnerships	The network the organization uses to operate its business model	Partnership with biomass producer and different research institutions in order to perfect the process (reducing production costs)
	Key activities	The main activities required for making the business work	Research and technology
	Key resources	Most important tangible and intangible assets required for the business model	Technology and available biomass (potatos)
Value proposition	Value proposition	Value offered to customers in mix of products and services	Environmentally friendly, various different types of products allowing customers to choose from a large selection of bio-based plastic types, biodegradability
Customer interface	Customer relationships	Type of relationships the organization has with customers	?
	Customer segments	Specific groups of customers the organization aims to reach and serve	Packaging industry, bio-based plastics mostly used for food packaging
	Distribution channels	How organization reaches its customers	Direct distribution (?)
Roughly cost of the implementation and operation			
Financial viability	Cost structure	Most significant costs for operating the business model	Machines/Technology: Thermoplastic starch is produced by restructuring 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).Biomass (potatos), Marketing (gaining new customers)
	Revenue stream	What kind of cash flows different customers create for the organization	?

Comments	The model relies on the accessibility of technology. Whilst residues can be used, producers tend to use a mix of potatoes and potato residues, as the quality of the starch differs. Costs for potatos are relatively low; however the process of breaking down starch is rather cost-intensive. More research should be conducted and efforts should be made to produce biobased plastics from potato residues, as there is an added value and this is in line with the concept of the circular bioeconomy. Moreover, product range should be increased in order to provide more environmentally friendly options to the consumer. Biodegradability of the bio-based products being essential.
Who entered data and when	Lena Huck, 23.11.2020

BREWERS' SPENT GRAIN FOR LOW-ALCOHOL NOURISHING BEVERAGES

COLOURBOX13707495

04.05.2020

Business Case

Low-alcohol nourishing beverage with a high amount of fiber and plant-based protein

Gdańsk University of Technology
Paweł Dąbrowski
Dariusz Mikielewicz

1 Executive Summary

The brewing industry in Poland belongs to one of the fastest-growing branches of the economy. The reason for this is a gradual increase in beer consumption, which is becoming the most popular beverage in the country, which results from the change in consumer preferences, who are choosing increasingly weaker alcohols [1].

The beer from malt production in Poland was rising significantly in the last years. Almost 40 years ago the beer production was about 11 million hectoliters per year. Nowadays the annual production is 4 times larger. Also, the production of beer per capita is growing year by year [2]. Now it is over 100 liters per capita. In 2015 Poland was fourth in Europe (behind the Czech Republic, Germany, and Austria) in terms of beer consumption per capita. Moreover, in terms of total beer production, the amount of 40.4 million hectoliters of beer placed Poland in third place in Europe, behind Germany and Great Britain [1].

The idea for this project was created due to the continuous increase of interest in bioeconomy in the European Union, as well as in Poland. For many years, the European Union has been emphasizing solutions based on bio-waste, bio-products. The aim of extending the product processing chain in industrial areas such as sugar production, wood processing, food production and the utilization of straw can be considered as the main and primary goal. The concept of Circular Economy (or Circularity) and Cascading Approach is becoming more and more popular. To implement bioeconomy assumptions, it is necessary to find as many possibilities as possible to utilize waste in a different way than before. Each waste should be looked at from a new perspective, considering if it can be used in another process, increasing its value. Burning or producing biogas from bio-waste should be a last resort.

2 Finance

Creating a good finance analysis where one determine the anticipated costs and possible profits associated with the production of a product is one of the most important stages of developing a Business Case. A good finance plan can reduce the risk of the project, saves a lot of money and show whether the project is feasible or not. This makes it possible to assess the profitability of the adopted solution and helps to decide on further development or resignation from the adopted idea. The production of a new beverage from Brewers' Spent Grain is an idea based on literature reports and main bio-trend in European Union. The development of a new product on the market always involves some risk and uncertainty regarding the acceptance of a given product by consumers, and hence the sales volume. However, in-depth market analysis along with the definition and specification of all costs can reduce this risk and ensure project success. First of all, there is a need to define the production line and main processes that are involved (Fig. 1). The next step is to define the costs associated with every process to prepare the total annual costs analysis.

Any prices showed in current analysis in Polish currency have been adopted, converting foreign currencies according to the exchange rate as at 01/02/2020 (1€ = 4.2571 PLN, 1 $ = 3.8 PLN).

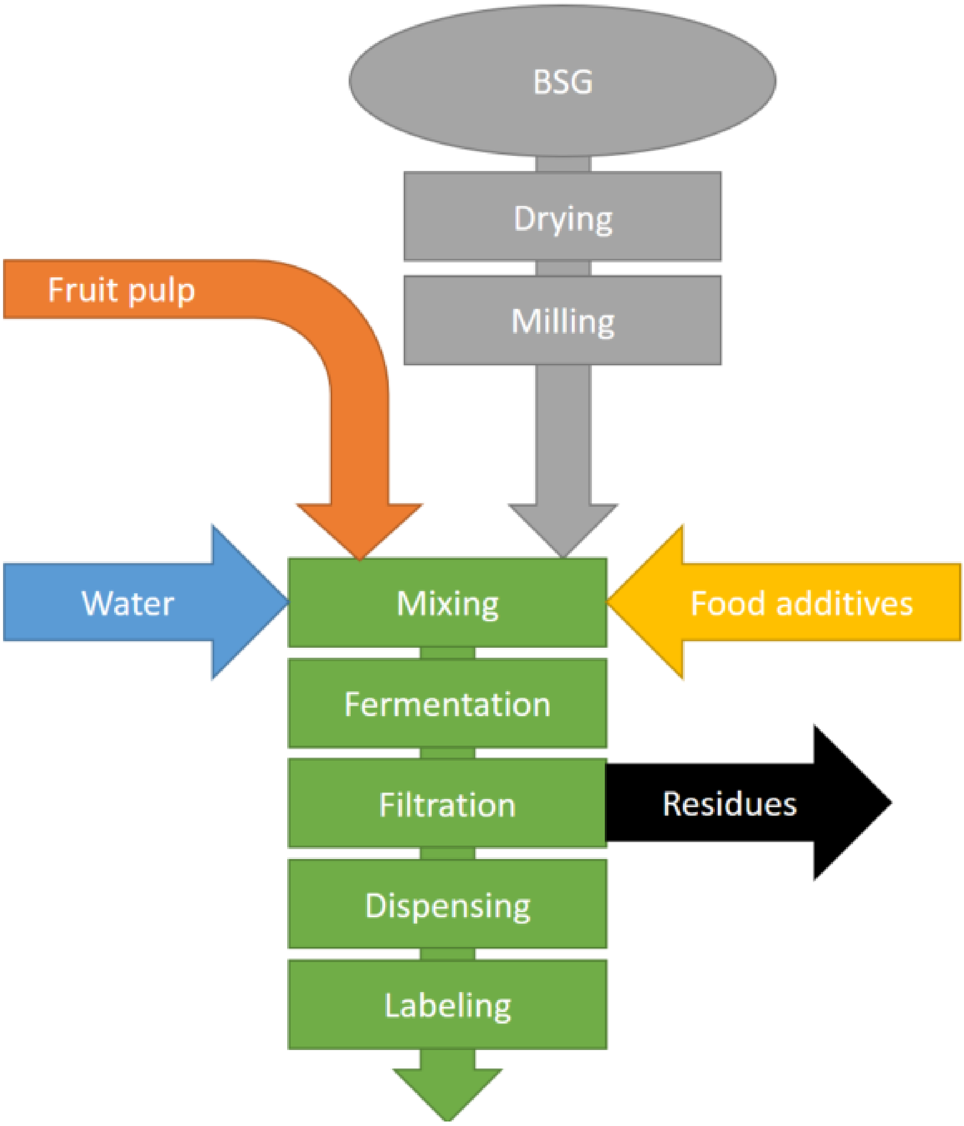


Fig. 1 *Diagram of the beverage from Brewers' Spent Grain production*

2.1 A financial appraisal

During analyzing the cost-effectiveness of the proposed project, it is worth to check the market of the similar products. In this case, there are no the exact product for comparisons because no one use BSG to produce beverages. However, to prepare the market analysis, the bio beverages rich in nutrients, fibers or proteins which are available on the Polish market was taken into account. As can be seen in Table 1, the average price of bio beverages is 5.17 PLN for 330 ml packaging. This is the final price that the consumer is paying. It includes the margin of a retail store, wholesalers, distribution costs, as well as promotion costs. The manufacturer's selling price may be 80% lower. Hence, it was assumed that the average producer price of bio beverages rich in nutrients, fibers or proteins is PLN 2.87 per 330 ml. The provided information help to find out whether the new product will be competitive with existing products in terms of price. Nevertheless, it is worth to keep in mind that simple economy profits are not all. Using the BSG in beverage production fits perfectly into cascading approach and circularity so the global benefits, excluding the economical one are way bigger. The added value associated with the use of waste for more important purposes than feed and the health and nutritional properties of the new beverage is also a large uneconomical profit.

Table 1 Bio beverages rich in nutrients, fibers or proteins

Beverage type	**Volume [ml]**	**Price per 330 ml [PLN]**
Soy milk – vanilla [3]	330	4.79
Rice drink – coconut [4]	1 000	3.23
Oat drink [5]	1 000	3.26
Bio energetic drink [6]	330	6.59
Kvass [7]	330	6.79
Protein drink [8]	330	6.38

Developing an accurate recipe for low-alcohol beverage rich in nutrients and plant-based fibers will be an important task that experienced brewers together with the R&D department will have to take on. However, already at the stage of planning the costs of the entire project, it is necessary to specify a certain outline of the product and a list of ingredients that it will contain. From the literature review, it is suggested to add 10% BSG dry matter to produce the beverage [9]–[11]. It is generally seen that BSG incorporation leads to an increase in fiber and protein levels and a decrease in starch levels in these products, being correlated with the level of BSG added as ingredient. The amount of BSG cannot be too high due to a texture, taste and smell that BSG is changing in product.

It was decided that the new beverage should consist mainly (excluding water) of fruit and BSG. According to new trends, the product should be as natural as possible. The greatest effort should be made to avoid artificial ingredients and to prepare the beverage in accordance with the latest bioeconomy standards. However, it is not possible for the beverage to contain no food additives at all. The composition of a new beverage is as follows: 70% of water, 18% of fruit pulp, 10% of Brewers' Spent Grain and only 2% of food additives such as acidifiers (citric acid), thickeners (pectin, xanthan), salts, preservatives (benzoates) or anti-oxidants (ascorbic acid). The amounts of raw materials and their costs used in a new BSG beverage are shown in Table 2. The annual amounts of raw materials during the BSG beverage production is assumed as 40 000 tons. To prepare such amount of product, there is a need of 4 000 tons per year of Brewers' Spent Grain which correspond with the annual amount of residues from breweries in Pomerania Region.

Prices of fruit pulp, depending on the type of fruit, fluctuate within 22 PLN/kg (pear) to 36 PLN/kg (lychee). These are retail prices. For wholesale quantities, better conditions could be negotiated. A price of 25 000 PLN/t for fruit pulp was used for calculations. The price of wet BSG is in the range PLN 150-180 per ton. The least attractive case, i.e. 180 PLN/t, was used for the calculations. The cost of water is estimated as 10 PLN/t. The food additives prices are very diverse, it depends primarily of the type and quality of additive. The prices of various food additives that could be used in the new beverage are as follows citric acid 2 400 PLN/t, pectin 3 000 PLN/t, ascorbic acid 16 000 PLN/t, benzoates 10 000 PLN/t. The total cost per ton will depend on the amount of individual food additives used during the production process. However, at the beginning state of production planning the mean cost of food additives is assumed as 10 000 PLN/t.

Table 2 Amounts and costs of raw materials used in a new BSG beverage

Raw materials	Amount, t/a	Amount, t/d	Cost, PLN/t	Cost, PLN/a
BSG	4 000.0	11.43	180	720 000
Fruit pulp	7 200.0	20.57	25 000	180 000 000
Food additives	800.0	2.29	10 000	8 000 000
Water	28 000.0	80.00	10	280 000
Sum	**40 000.00**	**114.29**		**189 000 000**

The annual and daily amounts of new BSG beverage and residues produced are shown in Table 3. The amount of 39 000 tons per year of product is taken into account during the next steps of financial analysis. There are a number of ways to sell the beverage, i.e. PET bottles, glass bottles, aluminum cans, juice boxes or even plastic drink bags. Moreover, every container comes in various capacities. Choosing the right packaging is no less important than choosing the layout or even the taste of the product. It is even more significant when it comes to a bio product, which in addition to the taste and nutritional value is to bring a change in society's view of new problems related to bioeconomy. Packaging is the main hotspot for most environmental impacts contributing between 49% (2 l PET bottles) and 79% (aluminum cans) of the total GWP [12]. That is the reason to choose a 0.33 l PET bottle as a beverage container into further considerations.

Table 3 Annual and daily amounts of new BSG beverage and residues produced

Products	Amount, t/a	Amount, t/d
BSG drink	39 000	114.29
Residues	1 000	6.45

In addition to the appropriate recipe and composition of the proposed beverage, an important aspect affecting the price of the product is the selection of appropriate processes during its creation. As can be concluded from Fig. 1, to produce the low-alcohol BSG beverage there is a need of drying the BSG and then milling it. After that all the ingredients should be mixed and then need some time to fermentation. When beverage is fermented there are just dispensing and labeling processes. The cost of BSG drying is 0.65 EUR/kg (2.77 PLN/kg) [13] which is 2 770 PLN/t. The energy demand for BSG milling varies greatly. First of all, it depends on whether the product is wet, semi-dry or dry. BSG was adopted as semi-dry (after the drying process), and energy demand 0.1 MJ/kg [14]. For an average electricity price of PLN 0.55 per 1 kWh (3.6 MJ), the cost of milling is PLN 15.28/t. Mixing is not a very energy-consuming process, hence its cost was assumed at 20 PLN/t. The fermentation process was assumed as free of costs. The energy consumption of packaging and distribution of the drink in 330 ml PET bottles is 1.09 MJ/l [14]. Considering the above assumptions of the price of electricity, the cost of bottling (without bottles) is 166.55 PLN/t. After adding the cost of bottle (0.1 PLN per piece), labeling and associated processes the entire cost of dispensing and labeling was assumed as 500 PLN/t. All the costs of individual processes are summarized in Table 4.

Table 4 Annual and daily costs of individual processes during new BSG beverage production

Production costs	PLN/t	PLN/a
BSG drying	2 770	11 080 000
BSG milling	15.28	61 120
Mixing	20	800 000
Dispensing and labeling	500.00	19 500 000
Staff costs	-	1 663 200
		33 104 320

Table 5 shows one-off costs of new BSG beverage production line. These costs account for a large proportion of all costs. however, it should be remembered that food industry equipment must meet high requirements and standards due to the fact that they are in contact with food. The laboratory tests in the R&D department are also significant. This tests will be aimed at developing the right recipe that will appeal to consumers.

Table 5 One-off costs of new BSG beverage production line

One-off costs	PLN
Machinery	50 000 000
Laboratory tests	2 000 000
Training and recruitment	500 000
	52 500 000

It is planned that the described enterprise will employ 24 people. Personnel needs are summarized in Table 6. The total annual costs of staff will be about 1 663 200 PLN.

Table 6 Staff requirements and costs of new BSG beverage production line

Staff costs	Person/shift	Shifts	Months	Cost/M, PLN	Cost/a, PLN
Operators	4	3	12	5 000	720 000
Mechanical	1	3	12	6 700	241 200
Electrical	1	2	12	6 700	160 800
Lab. Assistant	1	1	12	7 500	90 000
Shift leader	1	3	12	6 700	241 200
R&D	1	1	12	7 500	90 000
Marketing&promotions	2	1	12	5 000	120 000
					1 663 200

In $ROI = \frac{gross\ profit - expenses}{investment} \cdot 100\%$

While the PBP – Payback period was calculated as:

$$PBP = \frac{1}{ROI} \cdot 100$$

In the presented analysis, the investment requires large financial outlays, however, it has a reasonable payback period of about 5 years. It should be mentioned that the costs of raw materials can be minimized trough close cooperation with breweries to negotiate favorable prices. The following analysis is estimated and the presented values may change due to the significant number of assumed variables such as beverage composition, food additives prices or particular production processes costs. Some aspects and costs have been omitted due to the lack of this type of data. However, it is a good basis for a broader financial analysis and shows the attractiveness and possibility of implementing the proposed project.

Table 7, some of the most important parameters related to the investment were collected, such as: initial financial outlays, which are a sum of one-off costs, raw material costs, production and staff costs; basic assumptions regarding the annual production scale, volume of the finished product, quantity of manufactured products; annual costs associated with production; the cost of producing a single 330 ml PET bottle and a 1 liter of the finished beverage. The assumed price of one 330 ml PET bottle of BSG beverage is competitive on the bio-beverages market and is in line with the average price of such type of product. The ROI parameter – Return of Investment was calculated as:

$$ROI = \frac{gross\ profit - expenses}{investment} \cdot 100\%$$

While the PBP – Payback period was calculated as:

$$PBP = \frac{1}{ROI} \cdot 100$$

In the presented analysis, the investment requires large financial outlays, however, it has a reasonable payback period of about 5 years. It should be mentioned that the costs of raw materials can be minimized trough close cooperation with breweries to negotiate favorable prices. The following analysis is estimated and the presented values may change due to the significant number of assumed variables such as beverage composition, food additives prices or particular production processes costs. Some aspects and costs have been omitted due to the lack of this type of data. However, it is a good basis for a broader financial analysis and shows the attractiveness and possibility of implementing the proposed project.

Table 7 The most important parameters related to the project

Initial financial outlays, PLN
276 267 520
Working days annually
350
Volume of BSG drink, liters per unit
0.33
Amount of produced BSG drink
118 181 818
Total annual cost of production, PLN
223 767 520
Producing cost of 1 liter of BSG drink, PLN
5.74
Producing cost of 1 unit of BSG drink, PLN
1.89
Price of 1 unit of BSG drink, PLN

	2.83
Annual sales profit	
	334 454 545
ROI, %	
	21.06
Payback period	
	4.75

2.2 A sensitivity analysis

The value of revenues of the public finance sector generated by the brewing industry in 2014 amounted to PLN 9.9 billion. The largest share in them was excised tax, which amounted to PLN 3.56 billion. In 2014, in the entire supply chain, the brewing industry generated 205 000 jobs. Three main brewing companies, which account for over 82% of the beer sales in Poland, are the most responsible for such high production, supply and consumption of beer in Poland. These are Kompania Piwowarska, Grupa Żywiec and Carlsberg Polska [1]. Moreover, the production and consumption of beer per capita is growing year by year [2]. Now, the production is over 100 liters per capita (Fig. 2) and is still growing.

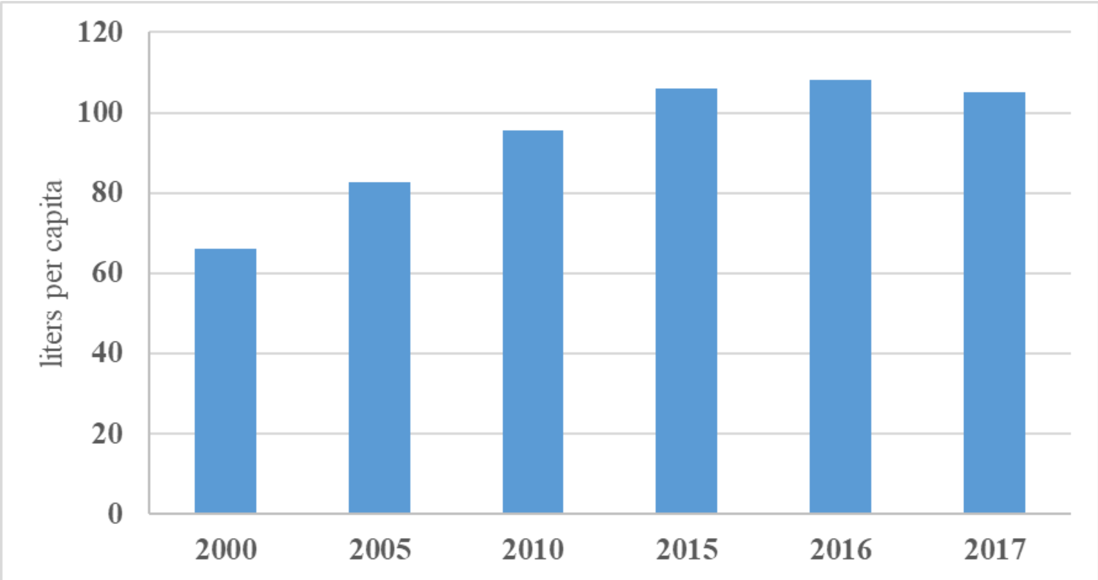


Fig. 2 *Production of beer from malt per capita in Poland*

The beverage market in Poland is very diverse, each category has its own rules. They have one thing in common - the importance of the health trend is growing in each segment [15], [16]. The domestic beverages market in the period of October 2017 - September 2018 was worth PLN 15.3 billion and was responsible for 14.7% of the value of sales in food category [15]. The entire market of beverages has the highest sales in the summer season. According to the Nielsen report [15] - the exception is the category of juices, nectars, drinks, for which the sales peaks occur during the holiday periods. Carbonated drinks also have high sales during Christmas [16]. Large group of consumers expect from beverages only to taste good, but they prefer other products than 2-3 years ago. Increasingly, buyers are choosing non-concentrated juices - the sales growth rate for this type of juice has reached nearly 20% for the 2018 [16]. There are also more demanding consumers for whom quenching their thirst or taste are not the only important attributes of beverages. Waters containing vitamins and sometimes herbs are getting more and more attention. Their sales have doubled in the years 2017-2018. From year to year, Polish consumers are increasingly open to experimenting, according to the Nielsen Shopper Trends report [15], already 25% of buyers willingly reach for new products and try new brands. Moreover, fresh and organic juices recorded a 13% increase in sales value over the period considered.

The bottles in which the drinks are sold are not insignificant. In the period from January to September 2018, the highest value shares were generated by liter packs. Apart from them, the best-selling drinks were in the following volumes: 225 ml, 330 ml, 1500 ml and 500 ml. Within the water, juice and beverage market in Poland, a trend can be observed of searching for high-quality products, i.e. containing good and healthy ingredients. Customers read labels, buy consciously and look for drinks no longer just to satisfy their thirsts. About 54% of Polish customers surveyed said that they read labels carefully, and 61% are looking for products with a short and natural list of ingredients [17]. They are looking for added value - a product that will positively affect the body and health. That is why one-day juices, drinks with chia seeds, and large amounts of mineral water are increasingly being bought [16].

Consumer and market are still evolving. Therefore, there is a need to adapt to changes. The client is experimenting a lot and looking for drinks with healthy additives. The beverage market is changing and developing dynamically. Health-related trends are not without significance for the development of individual beverage categories. The importance of small packaging (up to 750 ml) is growing, there is a niche to be filled. More and more products are profiled for the needs of a specific group of recipients - for athletes, children, vegans, lactose-intolerant customers. There is an opportunity for creating a new low-alcohol beverage rich in nutrients and plant-based fiber. Customers also appreciate the locality of products, based on natural materials and those that fit into the idea of bioeconomy and circularity. Polish consumers are looking for regional products and beverage producers, which meet their expectations.

3 Project Definition

From a nutritional point of view, the high protein and fiber content of BSG makes it very interesting and healthy product for human. This waste from breweries also represents a valuable raw material and source of compounds that alone also have potential for use as functional, bioactive ingredients in human nutrition. Thus, ingestion of BSG or derived products can provide several benefits to human health [9].

This was the way of thinking used when developing this project. The main product is a low-alcohol beverage made out of Brewers' Spent Grain (BSG) rich in nutrients and plant-based fibers. The bio-waste ready to be utilized is Brewers' Spent Grain, which is the main residue from brewery processes. It represents around 85% of total by-products generated during beer production. This lignocellulosic material is made during the mashing process and contains about 28% of lignin, 12–25% of cellulose, 19.2–41.9% of hemi-cellulose, and 14–31% protein on a dry weight basis [18], [19]. The composition of the BSG is very promising and allows its very wide use, e.g. as a food ingredient in animal or human nutrition, for energy purposes, in charcoal production, as a building material, in a paper manufacture, as an adsorbent, in a biotechnological processes, as an additive in brewing or substrate for cultivation of microorganisms or enzyme production [19]. Right now, BSG is mainly used to feed cattle but the possibilities for this product are much bigger.

The map of Poland, divided into voivodeships with the number of breweries in each of them is shown in Fig. 3 [1], [20]. The light blue color shows regions that are the part of the South Baltic Area (SBA). Analyzing the distribution of breweries in Poland in October 2016, it should be noted that it is uneven. It shows that in the SBA region the most breweries are situated in Pomeranian Region. On the other hand, there are 18 small breweries that produce up to 20 000 hectoliters per year and only 1 large brewery which annual production is greater than 200 000 hectoliters. In comparison to the West Pomeranian Region and Warmia and Mazury region, the annual generation of Brewer's Spent Grain in those 2 regions can be much bigger than in Pomeranian Region. However, large breweries that are the part of the big, international companies are much different from the local, small breweries and their view on the problem of a waste (or by-product) utilization is also different.

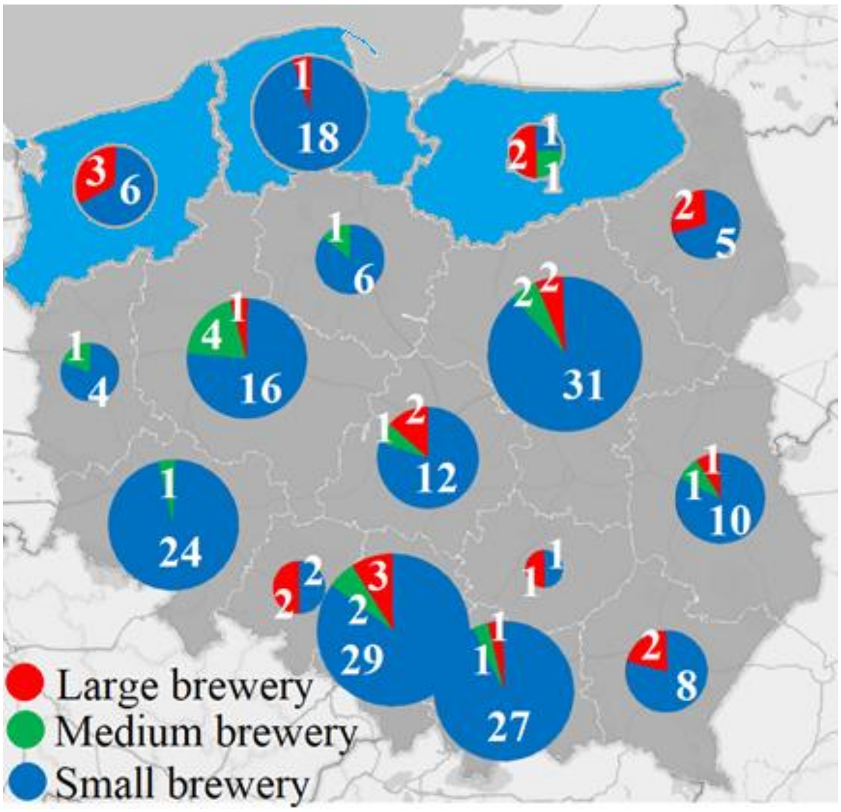


Fig. 3 *Breweries in Poland according to regions and breweries' size. Regionss colored in blue are part of the South Baltic Area (SBA)*

Brewers' Spent Grain is generated in large amounts. Every 100 liters of beer produced in the brewery generates about 20 kg of BSG [18]. Assuming the annual beer production in Poland at the level of 40 million hectoliters [2], 800 000 tonnes of BSG is available for further processing every year.

In order to ensure food safety in the feed/food supply chain as well as to be able to utilize food waste products as either feed or food ingredients, the European Union has implemented specific regulations that impact the by-products from any food production process [21]. Due to the fact that the BSG is at the moment merely intended for farming purposes, it must undergo periodic laboratory tests, which will confirm that it does not endanger the animals [22]. That requires time and financial resources. Moreover, it has to be dried which requires energy and dedicated machines. Hence, at this moment, BSG is not a very profitable by-product.

However, this is a material that fits perfectly into the rhetoric of the European Union about the development of sustainable and circular bioeconomy, which consists of a cascading approach, use of waste, leftovers and residues and circularity.

3.1 *Business Objective*

The business objective is to create a new company near the existing breweries to utilize their bio-waste (Brewers' Spent Grain) and to produce an innovative low-alcohol beverage rich in nutrients and plant-based fibers. It is crucial that the new product will be able to compete with existing beverages. Moreover, it should partially replace other sources of protein, in particular of animal origin, reducing meat production and thus reducing CO_2 emissions and water consumption. The new company should be located in close proximity to breweries, so that the cost of BSG transport (whose volume is high due to the high moisture content) is as low as possible.

All of the above fits perfectly into European Union strategy based on implementing policy promoting bioeconomy and bio-based solutions that will allow to reduce the climate changes. The new product can also contribute to mission of extending the product processing chain and increasing the value of BSG. The food purposes (BSG as a beverage) are of higher level than the feed purposes (BSG as a cattle feed).

The new business idea is clearly connected and focused on a circular economy, which is of big interest now in European Union. The breweries are located very often in suburban or rural areas which are non-industrialized areas with high unemployment rate. The new investments there would create a new opportunities for regional market and reduce the unemployment rate.

3.2 *Benefits and Limitations*

Benefits	**Limitations**
• The possibility of producing a short series of seasonal and experimental beverages, • High-quality products; product-oriented production, the use of good, local products that customers know and appreciate, • A growing number of customers and people interested in bio-products, increasing consumer awareness in the bioeconomy, • Development of fashion for craft products, • Increase in consumer awareness, searching for new custom products, • A negative image of mass group products in comparison with local products made according to a new bio-standards, • Possible subsidies from state institutions for new installations that utilize bio-residues, • Acting in line with EU policy - a pro-ecological image of the company, • Additional revenues - sale of bio-waste as a bio-product at a higher price, • New work places, development of the company • Regional development,	• High production costs and thus the high final product cost compared to a competitive non-bio-based solutions, • High investment risk, • A lack of experience in working with bio-wastes, • A lack of tested recipes for new beverages, • Difficulties with obtaining the right taste, smell and color of products containing BSG, • Difficulties with maintaining the repeatable quality of products constituting a company's permanent offer, • More restrictive regulations on products made from residues, • The need to change legislation regarding the possibility of introducing bio-waste into production cycle (as a product/food), • The need to open a new R&D cell in the company to raise the TRL.

• Greater competitiveness connected with broader, • Promoting pro-ecological solutions at national and regional level.	

3.3 Option Identification and Selection

Innovative solution/product	**Conventional solution/product**	**Benefits of Innovative solution/product**	**Difficulties associated with innovative solution/product**
Low-alcohol nourishing beverage with a high amount of fiber and protein production from Brewers' Spent Grain	Brewers' Spent Grain as a feed for cattle	Product of higher value (food>feed)	The need to develop new technology
		Higher price of beverage compared to cattle feed	The need to build dedicated facility
		New work places for regional market	Legislation regarding the possibility of introducing bio-waste into production cycle
		New plant-based fiber and protein source	
		Reduction of animal protein intake and subsequent reduction of CO_2 emissions	

3.4 Scope, Impact and Interdependencies

The European Union focuses more and more on bioeconomy in recent years. The legislation is made in such a way that using bio-materials in production is favored. There is also an emphasis on implementing a circular economy in European countries by extending the production chains and adding more bio-based products in them. The business model presented above is in line with all recent EU recommendations and trends so various types of financial support can be expected, including co-financing, particularly favorable credit terms from banks and funds from EU programs as well as funds from government and local entities.

The very important factor affecting the development of technology for the production of new low-alcohol beverage with high fiber and protein content from Brewers' Spent Grain (BSG) are regional legal issues, which currently do not put pressure on entrepreneurs regarding sustainable management of bio-waste. For many entrepreneurs, biomass waste is a problem they want to get rid of. Post-production waste from brewery is often sold at low prices to nearby farmers for cattle feed without any second-thoughts about whether this material has more value. Better cooperation between entrepreneurs, regional stakeholders and government entities is essential for the development of new technologies based on the use of bio-waste. The legal regulations, which would support entrepreneurs, who want to invest in bio-solutions, should be the basis for the innovative bio-solutions. Improved cooperation and new funds invested in bioeconomy should provoke increased interest in the production of valuable products from raw materials that are currently considered as a waste.

Another important factor that determines the success of the adopted concept is the price of beverage from Brewers' Spent Grain, costs associated with its production and consumer interest in the new product, and thus the volume of production and sales. All those aspects should be balanced to make a profit. The beverage market is huge and very competitive these days. According to Eurostat [23], the beverages manufacturing sector of the EU-27 generated an estimated EUR 34.0 billion of value added in 2006. Moreover, Poland was the most specialized Member State for the manufacture of beverages, as these activities contributed about four times the EU average to value added within the whole of the non-financial business economy in 2005. It shows that, on the one hand, successfully introducing a new beverage to the market is a challenge, and on the other, the potential profits associated with it can be significant.

The factor favoring the development of the proposed technology is the growing number of customers and people interested in bio-products and increasing consumer awareness in the bioeconomy. High-quality products, product-oriented production and the use of good, local products that customers know and appreciate can be a key to success of proposed beverage. The constant development of fashion for craft products would increase the interest in BSG beverage and results in making bigger profit in constantly growing market.

The above model assumes creating a new company that will be placed in Pomeranian Region near breweries and collecting waste (BSG) from these breweries to create new product. To maximize incomes and reduce the transport costs, the efforts on logistics should be done. It should be taken into account to establish tight cooperation with regional breweries and create or join thematic bio-clusters associating breweries in the SBA region. The regional policy favors such undertakings and organizes associations of local entrepreneurs and clusters, so it simplifies the issue of transport. Moreover, such entity would be helpful in negotiating prices, ensuring continuity of supply and production, improving production logistics.

3.5 Market Assessment

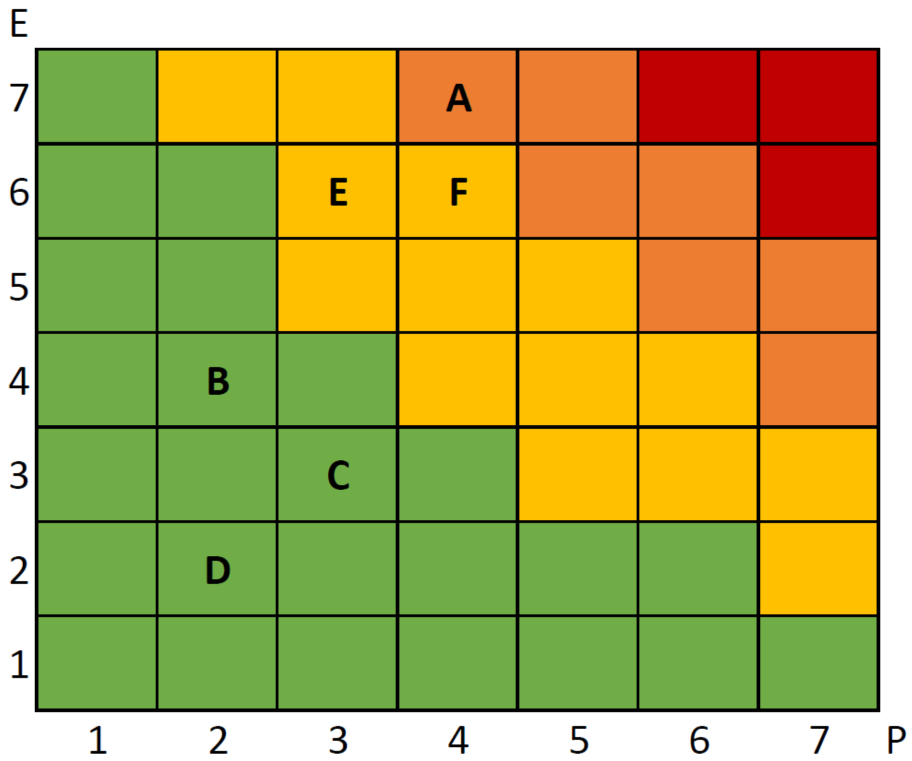
Political	• The formation of bio-clusters composed of regional government institutions and breweries to unite stakeholders • Promoting bio-solutions by government institutions and encouraging to develop waste management solutions.
Economical	• Getting financial support in the form of awards from government and low interest loans from banks due to the environmentally friendly production. • High income resulting from the sale of a valuable product produced from cheap bio-based waste. • New jobs for employees in region.
Sociological	• Increasing public awareness of the amount and type of bio-waste generated and showing the ways for utilizing. • Consumer inclination towards local products made according to a new bio-standards and development of fashion for craft products can contribute to high interest in the product. • Creating a new healthy product that would replace the animal-based proteins and increase the fiber consumption.

Technological	• Development of a technology that would allow to utilize high amounts of BSG. • Development and industrialization of the region.
Legal	• Introduction of legal regulations regarding the obligation to use bio-waste in higher-value processes (e.g. food>feed), which would have a positive impact on business development. • Simplification of legal regulations and administrative issues in the field of bio-waste processing as a food would have a positive impact on business development.
Environmental	• The use of BSG for the production of new beverage reduces the amount of unused waste (or waste sold very cheap as a feed) and promotes a sustainable economy. • Extending the value chain of raw materials and increasing their added value.

3.6 Risk Assessment

RISK LEVEL „R”		**PROBABILITY „P”**		**EFFECT „E”**	
Name	**Scale**	**Name**	**Scale**	**Name**	**Scale**
Negligible	1-12	Very low	1	Insignificant	1
Noticeable	13-25	Small	2	Short	2
Monitoring necessary	26-38	Possible	3	Little	3
Immediate response	39-49	Big	4	Perceptible	4
		Threatening	5	Average	5
		Very dangerous	6	Significant	6
		Certain	7	Disastrous	7

RISK	**P**	**E**	**R = P X E**
A – Failure to obtain a permission for the production of a beverage for people from BSG (as a waste)	4	7	28
B – Restrictions on the supply of BSG from breweries	2	4	8
C – Increase in prices on the BSG market	3	3	9
D – Difficulties in maintaining the same taste of the product due to the variable properties of BSG	2	2	4
E – No interest in the product	3	6	18
F – Long duration of developing new recipes of beverages	4	6	24


E
7
6
5
4
3
2
1
A
E
F
B
C
D
1
2
3
4
5
6
7
P

4 Bibliography

[1] B. Wojtyra and Ł. Grudzień, “Rozwój przemysłu piwowarskiego w Polsce w okresie tzw . piwnej rewolucji w latach 2011 – 2016,” *Pr. Geogr. Przem. Pol. Tow. Geogr.*, vol. 31, no. March, pp. 52–67, 2017.

[2] Warsaw, “Statistical Yearbook of Industry - Poland,” *Main Stat. Off.*, 2018.

[3] “Soy Milk - Vanilla.” [Online]. Available: https://biogo.pl/pl/p/Mleczko-sojowe-waniliowe-330-ml-Rumix/34986. [Accessed: 30-Apr-2020].

[4] “Rice drink Coconut.” [Online]. Available: https://biogo.pl/pl/p/Napoj-ryzowo-o-smaku-kokosowym-bezglutenowy-BIO-1-l-Lima/34397. [Accessed: 30-Apr-2020].

[5] “Oat drink.” [Online]. Available: https://biogo.pl/pl/p/NAPOJ-OWSIANY-BEZGLUTENOWY-BIO-1-L-NATUMI/22975. [Accessed: 30-Apr-2020].

[6] “Energetic drink BIO.” [Online]. Available: https://biogo.pl/pl/p/NAPOJ-ENERGETYZUJACY-O-SMAKU-TRAWY-CYTRYNOWEJ-BIO-330-ml-LITTLE-MIRACLES/20117. [Accessed: 30-Apr-2020].

[7] “Kvass.” [Online]. Available: https://biogo.pl/pl/p/KWAS-CHLEBOWY-Z-SOKIEM-ZURAWINOWYM-BIO-330-ml-EKO-NATURA/21648. [Accessed: 30-Apr-2020].

[8] “Protein drink.” [Online]. Available: https://www.bodyandfit.com/pl-pl/Produkty/Białka/Przekąski-białkowe/Napoje-białkowe/Smart-Protein-Drinks/p/56547?gclid=Cj0KCQjw7qn1BRDqARIsAKMbHDYz8lmGzp3gujkbpzgaL-PSoW-EcZ-ya5TC22gAi6X-T4K_jXj7h5UaAsX5EALw_wcB. [Accessed: 30-Apr-2020].

[9] K. M. Lynch, E. J. Steffen, and E. K. Arendt, “Brewers’ spent grain: a review with an emphasis on food and health,” *J. Inst. Brew.*, vol. 122, no. 4, pp. 553–568, 2016.

[10] A. L. McCarthy *et al.*, “The hydroxycinnamic acid content of barley and brewers’ spent grain (BSG) and the potential to incorporate phenolic extracts of BSG as antioxidants into fruit beverages,” *Food Chem.*, vol. 141, no. 3, pp. 2567–2574, 2013.

[11] S. Plessas, M. Trantallidi, A. Bekatorou, M. Kanellaki, P. Nigam, and A. A. Koutinas, “Immobilization of kefir and Lactobacillus casei on brewery spent grains for use in sourdough wheat bread making,” *Food Chem.*, vol. 105, no. 1, pp. 187–194, 2007.

[12] D. Amienyo, H. Gujba, H. Stichnothe, and A. Azapagic, “Life cycle environmental impacts of carbonated soft drinks,” *Int. J. Life Cycle Assess.*, vol. 18, no. 1, pp. 77–92, 2013.

[13] K. Waldron, *Handbook of waste management and co-product recovery in food processing*. Woodhead Publishing Limited, 2009.

[14] A. Ladha-Sabur, S. Bakalis, P. J. Fryer, and E. Lopez-Quiroga, “Mapping energy consumption in food manufacturing,” *Trends Food Sci. Technol.*, vol. 86, no. December 2018, pp. 270–280, 2019.

[15] Nielsen, “Rynek napojów bezalkoholowych w Polsce,” 2019.

[16] “https://hurtidetal.pl/article/art_id,25651-60/rynek-napojow-bezalkoholowych-w-polsce/.” .

[17] P. Grauer, “Rynek napojów bezalkoholowych w Polsce,” no. nr 55, pp. 4–5, 2018.

[18] T. Pinheiro, E. Coelho, A. Romaní, and L. Domingues, “Intensifying ethanol production from brewer’s spent grain waste: Use of whole slurry at high solid loadings,” *N. Biotechnol.*, vol. 53, no. April 2018, pp. 1–8, 2019.

[19] S. I. Mussatto, G. Dragone, and I. C. Roberto, “Brewers’ spent grain: Generation, characteristics and potential applications,” *J. Cereal Sci.*, vol. 43, no. 1, pp. 1–14, 2006.

[20] “Piwna Mapa Polski.” [Online]. Available: https://www.mapotic.com/piwna-mapa-polski/places?attr7896=b8s1,vj7c,c64q&fbclid=IwAR3KjkgBRDrQQmPyI4t07wfQAjxcaa1vpqDMezxUtXQmgQWRjG6v-8NiHB4&lat=53.59902495724183&lng=19.9127197265625&zoom=7&fcat=6398,639

9,6400,6401,6402. [Accessed: 22-Jul-2019].

[21] K. Kerby and F. Vriesekoop, “An Overview of the Utilisation of Brewery By-Products as Generated by British Craft Breweries,” *Beverages*, vol. 3, no. 4, p. 24, 2017.

[22] Food Standards Agency, “Feed Hygiene Regulation,” *Feed Hygiene Regulation (183/2005): How to Apply for Approval or Registration, and Related Information.*, 2013. [Online]. Available: https://www.food.gov.uk/sites/default/files/media/document/EU Feed Hygiene Regulation %28183-2005%29 -- Approval and registration activities.pdf. [Accessed: 22-Jul-2019].

[23] Eurostat, *European Business, Facts and Figures*. 2009.

PROCESSING AND PREPARATION OF ORGANIC APPLE WASTE TO PRODUCE HIGH-QUALITY PROTEINS

COLOURBOX43433944

ERNST MORITZ ARNDT
UNIVERSITÄT GREIFSWALD

Max Mittenzwei
max.mittenzwei@uni-greifswald.de

25 February 2022

Lehrstuhl für Wirtschafts- und Sozialgeographie
Friedrich-Ludwig-Jahnstr. 17a
17489 Greifswald

Business Case: Processing and preparation of organic apple waste to produce high-quality proteins

1 Introduction

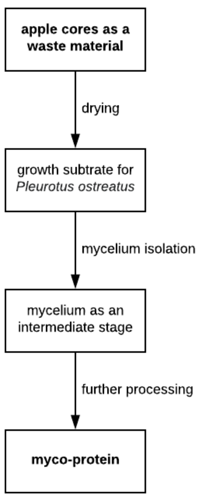
The horticulture industry's growth produces a massive amount of fruit waste (25%-40% of the total processed fruit). These residues, especially cell wall polysaccharides and other functionally essential bioactive molecules such as proteins, vitamins, minerals, and natural antioxidants, are generally good sources of carbohydrates. Apple pomace is residual solid biomass with a high moisture content obtained as a by-product during apple fruit processing to prepare juice, cider, or wine[1]. As outlined in the pre-feasibility study, apple pomace as a residue from various manufacturing processes is a well-researched by-product. It consists of a mixture of peel, core, seed, calyx, stem, and soft tissue. Therefore, it is a poor animal feed choice because of high sugar content but shallow protein content[2]. However, it was made clear that it works exceptionally well as a growth substrate for basidiomycetes, thus as a resource for mycoprotein's production, a believed growth market still in its infancy[3]. Feedstock for mycoprotein production has been historically relatively costly[4]; hence using a by-product in the sense of circular economy is seen as a great opportunity. Implementing the cascading approach on a bio-based by-product, as frequently recommended by the European Union Bioeconomy Strategy, can help widen the bioeconomic portfolio and act as a exemplary for further

[1] Shashi Bhushan et al., "Processing of apple pomace for bioactive molecules," *Critical reviews in biotechnology* 28, no. 4 (2008).
[2] Francielo Vendruscolo et al., "Apple pomace: a versatile substrate for biotechnological applications," *Critical reviews in biotechnology* 28, no. 1 (2008).
[3] Zafer Bashi et al., "Alternative proteins: The race for market share is on: Consumer interest in non-meat-based protein options is increasing globally. Food industry players that want to capture the opportunity must understand the evolving market dynamics and where to place their bets.," 2019.
[4] Ibid.

developments. This Business Case focuses on the production of mycoprotein on a growth substrate derived from apple pomace (apple cores, mainly), outlines a project to overcome particular challenges, and concludes in a SWOT analysis for a subsequent business start-up. In 2019 there were a total of 1879.6 ha of fruit cultivation area in Mecklenburg Western Pomerania. Of this area, 1686.4 ha were used to grow apple trees, which clearly dominated the fruit cultivation; the areas of other tree fruit species (pears, cherries, plums) just add up to 135.7 ha. The usage of the total apple harvest in Germany is broken down as follows (as of 2019): 71% is used as regular table fruit, while 27% is utilized as commercial or industrial fruit, while 1% of the apples are not harvested or marketed[5]. Mecklenburg Western Pomerania, however, occupies a unique position. In the project region, 85-90% of the apple harvest is used for commercial or industrial processing, mainly for juice or baby food, and the number of apples that are sold as table fruit is meager[6]. In one of the companies, apple residues (apple core housings) are a by-product of the production chain. On this basis, the following business case will be carried out.

2 Background information

Fig. 1 *– Conceptual outline*



Mycoprotein is still a relatively under-exploited resource globally, but it provides great promise for high-quality, non-seasonal protein production, a critical necessity for potential food safety and human nutrition[7]. The most significant obstacle to production is the dependency on a single carbon source, which also needs special processing until it is appropriate for use. Also, the literature presented in the pre-feasibiltiy study made a clear point in regards to the expected growth market and equally strong demand-side. However, at the moment the cultivation of mushrooms using apple residues as a substrate is still in the experimental stage and needs to be commercialized in the future in order to expand its application[8]. Nonetheless, Ahlborn et al. recently concluded:

---

5 BMEL 2020

6 "Apfelernte in Mecklenburg-Vorpommern könnte besser als im Vorjahr ausfallen." proplanta press release, July 10, 2020, https://www.proplanta.de/agrar-nachrichten/pflanze/apfelernte-in-mecklenburg-vorpommern-koennte-besser-als-im-vorjahr-ausfallen_article1594335806.html, accessed November 2020.

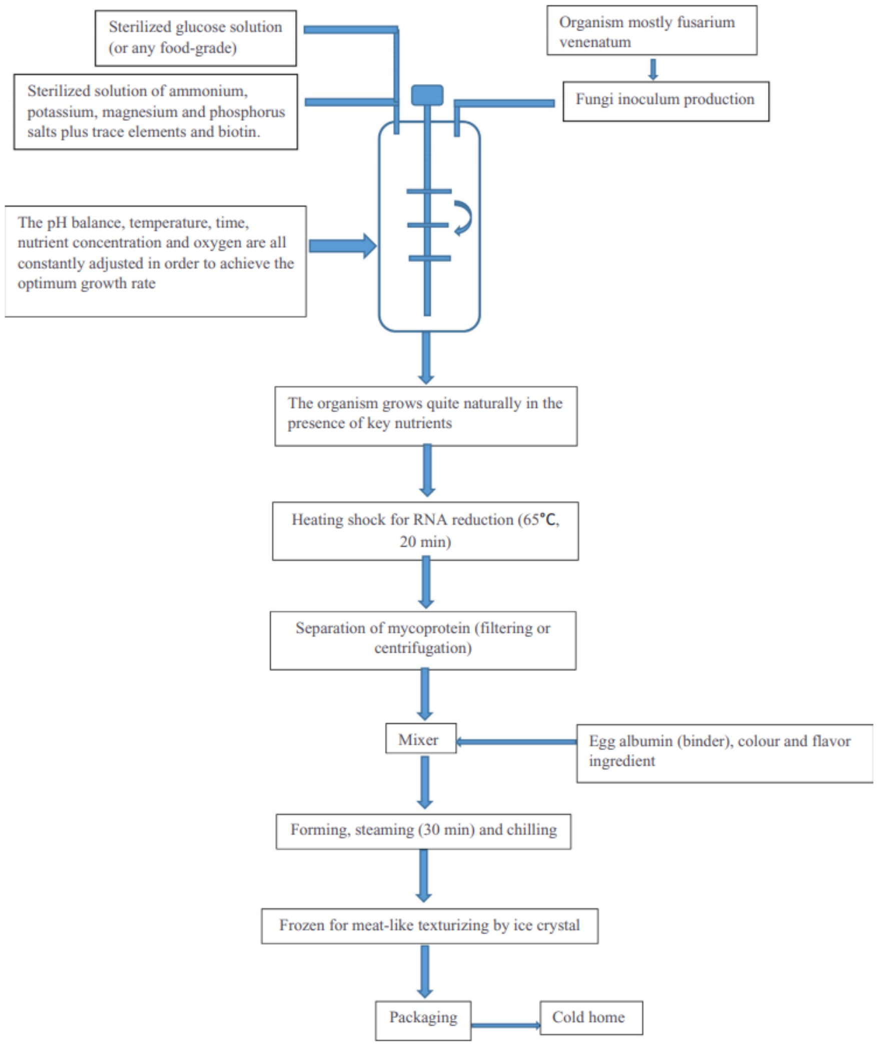
7 Tim J. A. Finnigan et al., "Mycoprotein: The Future of Nutritious Nonmeat Protein, a Symposium Review," *Current developments in nutrition* 3, no. 6 (2019).

8 Fengzhi Lyu et al., "Apple Pomace as a Functional and Healthy Ingredient in Food Products: A Review," *Processes* 8, no. 3 (2020).

"Vegetative mycelia of mushrooms, produced by submerged cultivation on industrial side streams such as apple pomace showed beneficial nutritional properties. The substrate, apple pomace, can be valorized by fermentation with basidiomycetes and the resultant biomass appears to be suitable for use as an alternative protein source. The mycelia contain all essential amino acids and polyunsaturated fatty acids, especially linoleic acid (45%). Vitamin D2 may easily be produced from the ergosterol present in the mycelium by exposure to UV-B light. In addition, ergosterol could be used as an indicator for fungal growth in cultures containing debris from by-products of the agro industry."[9]

Therefore, it becomes obvious that the assumption is based on recent scientific findings. The initial framework derived from the earlier work is shown in Fig. 1. As explained, apple cores build the basis for the substrate, on which *Pleurotus ostreatus* can grow in submerged

***Fig. 2** – Process of submerged cultivation of mushrooms (SCM)*



[9] Alexander Stephan et al., "Edible mushroom mycelia of Pleurotus sapidus as novel protein sources in a vegan boiled sausage analog system: functionality and sensory tests in comparison to commercial proteins and meat sausages," *European Food Research and Technology* 244, no. 5 (2018).

cultivation. Fig. 2 pictures the process of growing basidiomycetes as a SCM in more detail and with the various needed inputs.

The "sterilized glucose solution", in our case, would be made from apple waste – apple cores. Besides, there are multiple steps to go from the by-product "apple core" to a sterilized substrate source, which implications are discussed in the following.

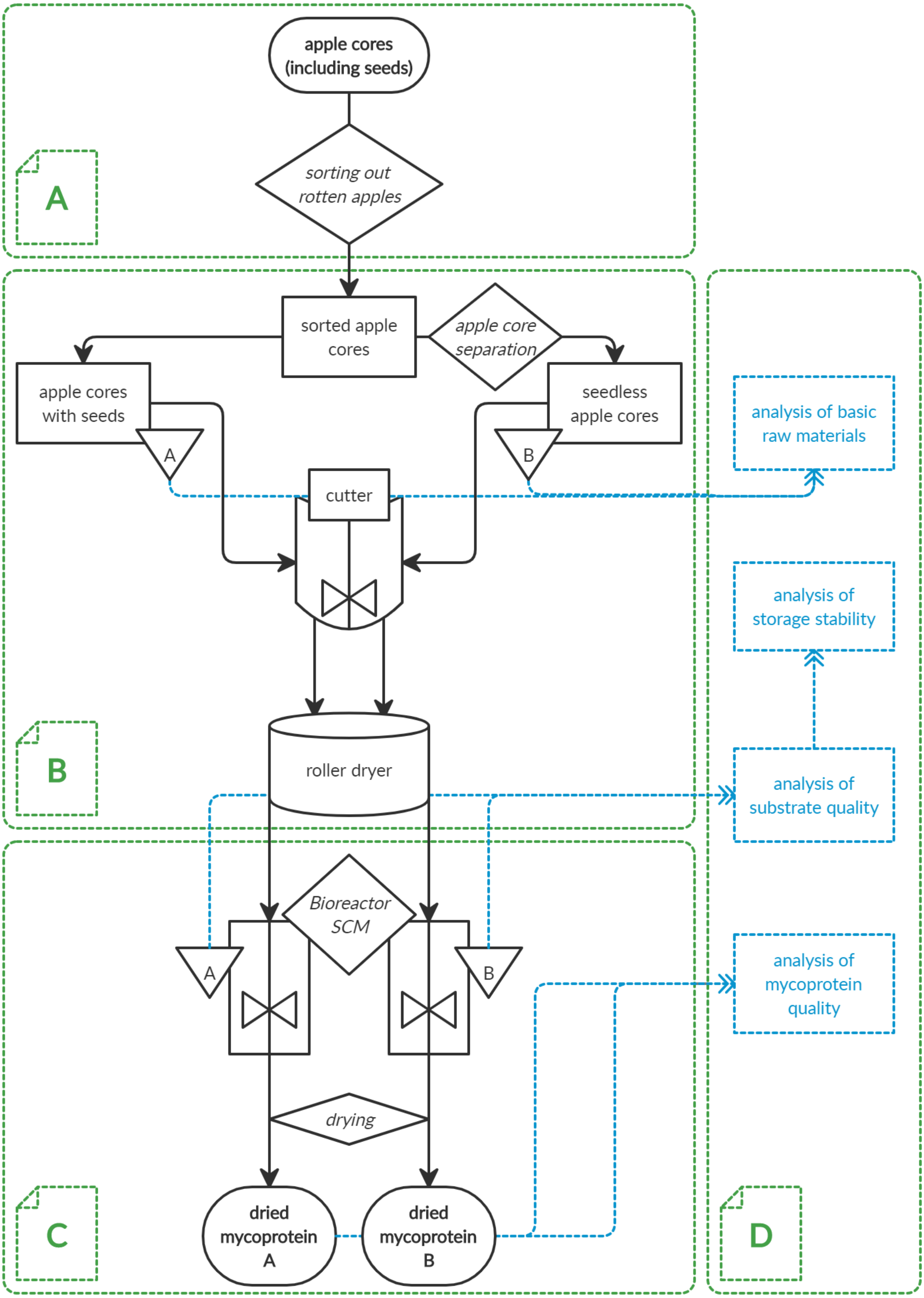
3 Project definition

One of the most critical stages of creating a business case is establishing a financial analysis in which the projected costs and potential profits associated with the manufacture of a product are calculated. A successful funding plan will reduce the project's risk, save much money, and illustrate whether the project is feasible. This allows the approach's profitability to be measured and helps determine whether to further improve or resign from the idea adopted. In the beginning, the costs of the steps need to be estimated. However, this can be incredibly challenging when the TRL level is low, as is the case here, as it is seen as TRL 3. Further, the process itself is also highly innovative; thus never been done in this way before. Even though apple pomace is validated as a functioning basis for SCM of basidiomycetes, apple cores as waste material from dry apple production were not explicitly tested. Although there are intense supporting arguments for apple cores to inhabit approximately the same features as apple pomace and thus behave chemically in the same way, it cannot be verified to a hundred percent since it was not tested under laboratory conditions. Thus, necessary research steps and especially laboratory testing, are still to be done.

By interviewing participants of the APPLE project[10], which is financed by the BMBF (Federal Ministry of Education and Research) within the Plant³ Alliance, these steps became even more apparent. APPLE aims to solve the challenges mentioned above, thus analyzing the resource apple cores in a laboratory setting, developing the needed process engineering, and optimizing it. Fig. 3 illustrates the production chain structure, based on the theoretical assumptions, literature, and interview material, and visualizes the work division within the project.

[10] financed by the BMBF (Federal Ministry of Education and Research) within the Plant³ Alliance

Fig. 3 - Flowchart of the production chain (own graphic on the basis of APPLE project flowchart)



Currently, 670 t of apple cores are generated seasonally as a by-product of a local producer of dried apple products. The cores are currently disposed of as a biologic by-product for a fee and need to be transported to a specialized waste management facility. Per year, this generates costs of about 50000 €, which can be potentially mitigated or even transformed into income by using the apple cores as a resource. Due to the microbial instability caused by fermentation or pest infestation, local utilization is necessary. A radius of not more than 50 km for the site is assumed. As a first step, rotten apple cores (Fig. 4) must be sorted out in order to guarantee a unitary raw material without contaminants. In the project, two growth substrates will be tested: one in which the apple cores were separated and one in which they are still part of the core. The separation process is not yet developed and is part of the project's outline. The prepared apple cores are then slized down by a cutter, which operation guidelines are to be determined, before getting dried in a roller dryer, for which the same applies. The process inside the bioreactors is described in Fig. 2 and the previously conducted pre-feasibility study and should be referred to at this point. However, the project also needs to design the separation of the submerged culture from the nutrient medium and the subsequent extraction and drying of mycoprotein. The work is subdivided into four categories – A, B, C, and D – and a clear division of tasks is aspired. Initially, the local producer needs to prepare the apple cores to ensure optimal further processing and sort the apple cores. B then prepares the growth substrate and defines the substrate composition for optimal basidiomycete growth and optimizes bioavailability of the substrate, while C carries out the SCM, also developing and establishing an enzyme technology for efficient hydrolysis of apple core casings. During the project, the most crucial role has D. The ongoing analysis of the testing results supplied from the other participants over the project's duration allows for an ongoing improvement to an effective and efficient process at the end. APPLE predicted a calculatory benefit of an estimated 350000 € per year, with a raw material price of 0.45 € per kg. Therefore, their calculation suggests recouping after four years if the development project is a success. If the project is successful and the source material turns out to be genuinely utilizable, a company would then be founded.

Fig. 4 *- Apple core sample*

4 Business overview

The resulting company's objective is to combine the categories A, B, C, and D as depicted in Fig. 3. Due to the growing market for alternative protein solutions, its market entrance is believed to fit right into a time of massive demand and fill the open market gap. There are also no competitors in Mecklenburg Western Pomerania and Germany. Thus, it is also believed that the company will benefit from this unique characteristic, not least due to the product being produced under the EU guidelines regarding the circular economy. The biotechnological refinement of a rapidly perishable by-product, which up to now has been disposed of at great expense, can create a new valuable resource for human nutrition. The depth of added value is continuously increased by optimizing the individual processing steps during the project. The final developed prototypes result, on the one hand, in cost savings through the utilization of the by-product and its use as a cost-effective growth substrate and, on the other hand, in added value through the production of an innovative protein source in great demand. If the concept is technologically and economically feasible, it can also be transferred to other raw material sources and enable new utilization branches[11]. Thus, the long-term goal is to create a platform strategy for other by-products on a biomass-basis. There are, however, some bottlenecks. First of all, the SCM production chain is believed to be quite energy-consuming – a trait that still needs to be solved and for which the project needs to function as a benchmark[12]. Then, the efficiency of the submerged cultivation, as well as its scalability, are to be determined. While the project will try its best to gather essential critical data on the expected production efficiency, compare them with the actual production cost, and do a continuing analysis over the project's duration, the outcome can not be known, although the continuous optimization of the growth substrate builds a key pillar in the project's outline. As one of the essential parameters of the fixed costs, the growth substrate can be seen as the primary focus. Other risks can be seen in the processing of the apple cores into an efficiently usable growth medium and the mycelium's processing into a protein source for human consumption. The respective drying's technical possibilities must be evaluated during the project and compared with the product's requirements. The prototype of the mushroom mycelium powder to be developed must be examined in detail in its nutritional-physiological characteristics under aspects of consumer safety in order to assign a suitable intended purpose.

On the side of the business itself, the typical risks associated with founding are seen. While a positive outcome of the project can appease the financial risk, and there are strong arguments for a viable demand, the professional expertise of the required human capital could

[11] APPLE project application
[12] Pedro F. Souza Filho et al., "Mycoprotein: environmental impact and health aspects," *World journal of microbiology & biotechnology* 35, no. 10 (2019).

be a potential hurdle. Founding a company in a new sector requires large amounts of work and trained staff, something which Mecklenburg Western Pomerania lacks. Introducing a new product on the market needs increased marketing and promotion expenditures, especially when the project itself is not brought to a broad audience yet. Legal regulations in the food sector could be a problem, same as administrative difficulties inside the company. Lastly, while only given a small chance, competitors may enter the market in the years of the project phase, meaning the product will have a more challenging entry than anticipated. Recently, Swedish start-up Mycorena has developed a fungi-based ingredient for vegan products, raised 429000€ and opened a facility – the first non-Quorn mycoprotein facility in Europe[13]. While not directly competing, the possibility is there and should be acknowledged. Regarding the facility's location, costly problems might arise as well and are best to be tackled during the project's end phase. The following table presents the final SWOT-analysis of the project as well as the business creation.

***Table 1** – SWOT analysis*

Strengths	**Weaknesses**
¬ high expected demand ¬ high expected buying power of consumers ¬ small financial risk due to a preceding project ¬ research is done in the project ¬ valorization of a waste material ¬ follows EU guidelines and especially bioeconomy goals	¬ mid-term foundation, long time horizon ¬ TRL 3 meaning still a long way to go ¬ energy-solution not yet sufficient ¬ unknown attributes of the raw material ¬ product unknown to a broader audience
Opportunities	**Threats**
¬ funding can be expected due to the bioeconomic nature ¬ filling a market niche nationally and internationally ¬ providing jobs in an otherwise structurally weak region ¬ the building of cluster structures ¬ changing public awareness ¬ help to pave the way for the following companies ¬ attractive reduction of CO2 emissions ¬ help to bolster the bioeconomic image of the region	¬ competitors might enter the market earlier ¬ project outcome might be disastrous ¬ the project might fail due to internal reasons ¬ changing mindset of the consumers ¬ the product fails to stake a claim on the market ¬ higher energy consumption might lead to a bad image

[13] https://www.foodnavigator.com/Article/2020/02/13/Mycorena-Swedish-start-up-brings-Promyc-one-step-closer-to-market

5 Conclusion

In total, the market outlook is very positive. For successful implementation, the financial and actorial demands are solved in a joint project before a business founding occurs. With successful implementation and prototype development, the short-term goal after completing the project is to establish the intended holistic exploitation of the organic apple core. A high-quality, alternative protein source can be produced in an established process. In the medium term, this process should be transferable to other plant-based regional raw material sources from waste, so that in the long term, this R&D project will have a regional impact and enable a resource-saving, bio-economic restructuring in the region. Thus, concrete economic and social success can be achieved in the region concerned with a bio-economic approach. The added value from the currently unusable organic apple core casings will possibly create the basis for the development of new marketable product groups based on the production of organic apple-based mycoprotein. Of particular social relevance is the avoidance of CO2-laden disposal, while the findings from the scientific and economic examination of the technological feasibility can also be transferred to other organic residues.

Bibliography

"Apfelernte in Mecklenburg-Vorpommern könnte besser als im Vorjahr ausfallen." proplanta press release, July 10, 2020. https://www.proplanta.de/agrar-nachrichten/pflanze/apfelernte-in-mecklenburg-vorpommern-koennte-besser-als-im-vorjahr-ausfallen_article1594335806.html, accessed November 2020.

Bashi, Zafer, McCullough, Ryan, Ong, Liane, and Ramirez, Miguel. "Alternative proteins: The race for market share is on: Consumer interest in non-meat-based protein options is increasing globally. Food industry players that want to capture the opportunity must understand the evolving market dynamics and where to place their bets." 2019.

Bhushan, Shashi, Kalia, Kalpana, Sharma, Madhu, Singh, Bikram, and Ahuja, P. S. "Processing of apple pomace for bioactive molecules." *Critical reviews in biotechnology* 28, no. 4 (2008): 285–296.

Finnigan, Tim J. A., Wall, Benjamin T., Wilde, Peter J., Stephens, Francis B., Taylor, Steve L., and Freedman, Marjorie R. "Mycoprotein: The Future of Nutritious Nonmeat Protein, a Symposium Review." *Current developments in nutrition* 3, no. 6 (2019): nzz021.

Lyu, Fengzhi, Luiz, Selma F., Azeredo, Denise Rosane Perdomo, Cruz, Adriano G., Ajlouni, Said, and Ranadheera, Chaminda Senaka. "Apple Pomace as a Functional and Healthy Ingredient in Food Products: A Review." *Processes* 8, no. 3 (2020): 319.

Souza Filho, Pedro F., Andersson, Dan, Ferreira, Jorge A., and Taherzadeh, Mohammad J. "Mycoprotein: environmental impact and health aspects." *World journal of microbiology & biotechnology* 35, no. 10 (2019): 147.

Stephan, Alexander, Ahlborn, Jenny, Zajul, Martina, and Zorn, Holger. "Edible mushroom mycelia of Pleurotus sapidus as novel protein sources in a vegan boiled sausage analog system: functionality and sensory tests in comparison to commercial proteins and meat sausages." *European Food Research and Technology* 244, no. 5 (2018): 913–924.

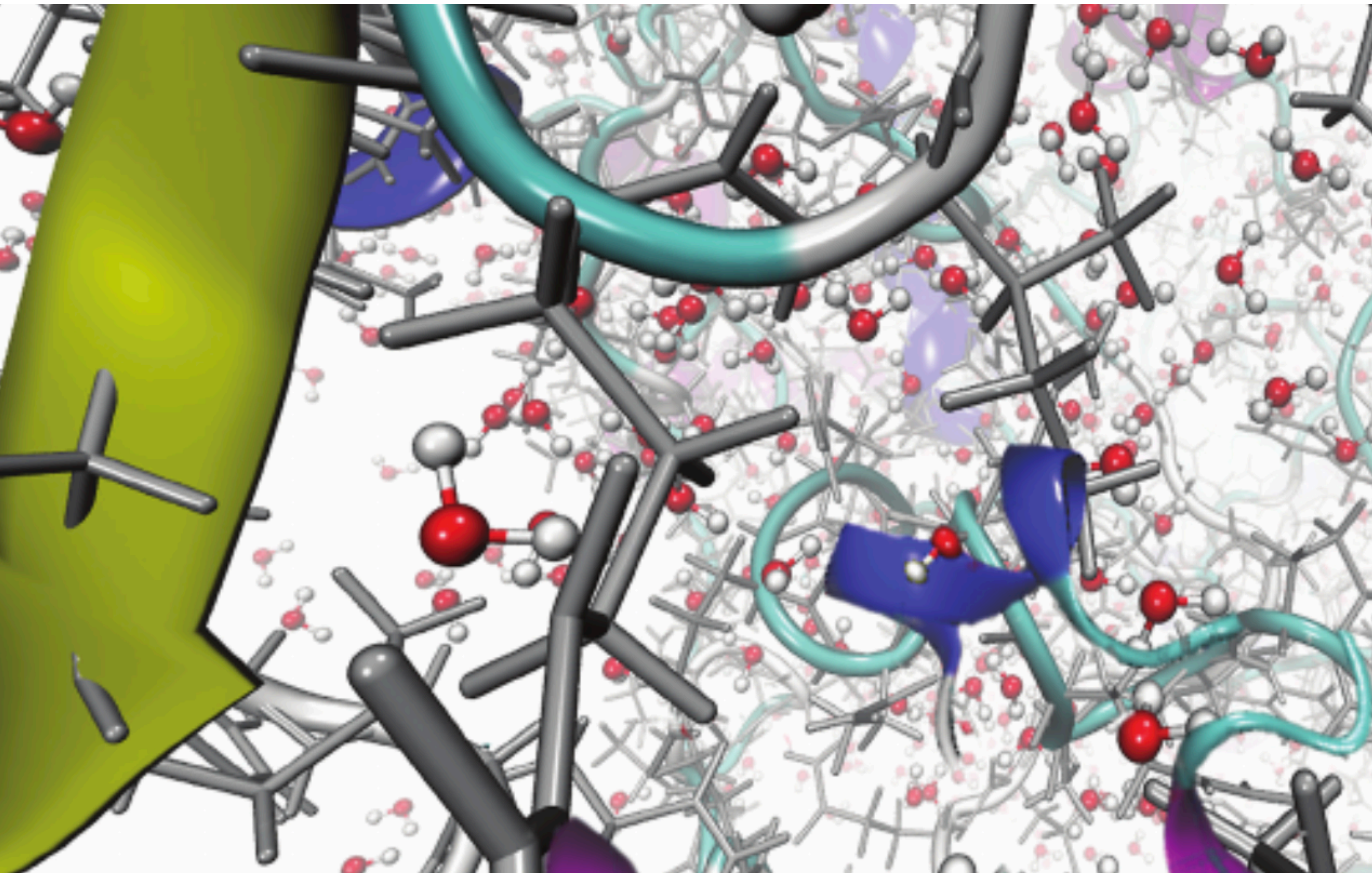
Vendruscolo, Francielo, Albuquerque, Patrícia M., Streit, Fernanda, Esposito, Elisa, and Ninow, Jorge L. "Apple pomace: a versatile substrate for biotechnological applications." *Critical reviews in biotechnology* 28, no. 1 (2008): 1–12.

LEAF PROTEIN CONCENTRATE PRODUCTION FROM INTERMEDIATE CROPS

LEAF PROTEIN CONCENTRATE PRODUCTION FROM BROCCOLI AND KALE LEAVES

COLOURBOX1065531

PROTEIN-BASED SUPERABSORBENT POLYMERS



REPORT

BUSINESS MODEL MANUAL – INCL FIVE EXAMPLES

Authors	*Carl Jonson, Carl Jonson AB, Helena Tillborg, Tillborg Wolf Consulting AB*
Editors	*Thomas Prade, Faraz Muneer, William Newson, Sven-Erik Svensson, Antonio Capezza, Eva Johansson,* Swedish University of Agricultural Sciences (SLU), Sweden

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.
Copyrights	All rights reserved to authors and partners in BioBIGG. © 2020 BioBIGG
Published by	BioBIGG

1. About business modelling

1.1 About the report

The purpose of this report is to give an introduction to business modelling, with a theoretical background and general examples in section 1, followed by five specific example of business models in section 2-6. The three SLU cases within the BioBIGG project serve as examples, but the general theory can be applied to any research result with innovation potential:

1) PROTEIN CONCENTRATES FROM KALE AND BROCCOLI RESIDUES
2) PLANT-BASED PROTEIN CONCENTRATES FROM INTERMEDIATE CROPS
3) BIOBASED SUPERABSORBENTS

1.2 Basic theory

Business modelling is about identifying potential ways to earn money and, for the future company, to make profit. In the business modelling process, value creating products and services are identified for corresponding potential customers and target markets as early as possible. In research, or when in the invention phase, the best way to identify potential value is to involve external partners and together create and identify possible business models.

There are a number of different tools to be used in the business model process. One of the most common is the Business Model Canvas developed by Alexander Osterwalder[1] (see Fig. 1).

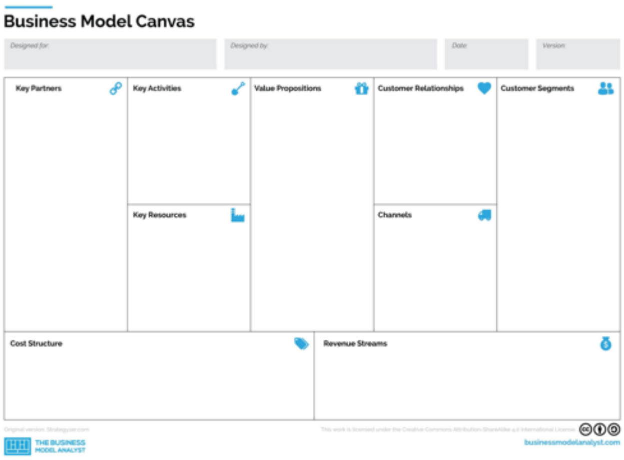


Figure 1. The spread sheet for Business Model Canvas

Even in very early stages of the innovation process, when the research results are still under evaluation and/or in the verification phase, it is recommended to involve external actors and be creative in the identification process of new business models. To be creative about different types of business models, and identity as many as possible, makes it easier to find the best solution for the specific case. The picture below (Fig. 2) shows a typical value chain for a sector, and the different phases where value is created, hence the basis for

[1] http://alexosterwalder.com

corresponding business models. Business models can be found based on a single section or a combination of several.

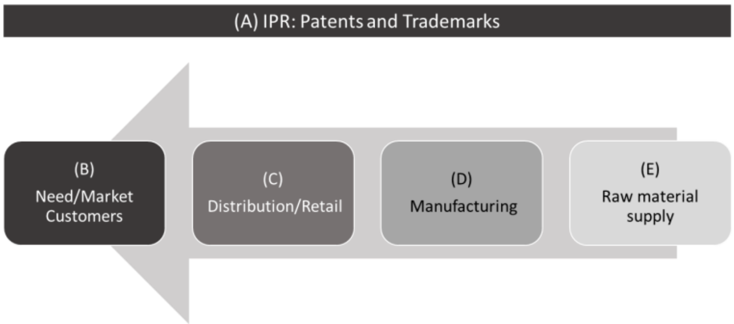


Figure 2. A typical value chain. Value is created in the different phases, opening up for different business models.

1.3 Examples of different business models

Let´s use Tesla Inc, the company behind the electrical vehicle, as an example. Their business model is to own almost the entire value chain from (A) to (E). Section (A) is the trademark and possible patents. Tesla sell their cars through their own webshop, Tesla.com (B), but also through external retailers/distribution channels (C). The cars are manufactured in Tesla factories (D) and some raw material supplies and core components, such as batteries, (E) are owned and produced by Tesla Inc or subsidiaries partly owned by the company.

Other companies, e.g. Gore-Tex and the Swedish company Välinge Innovation, have focused on only one phase of the value chain; product development and Intellectual Property Rights (IPR, A). Both companies sell licences for the patents to different producers around the world, and their business model is thus to earn money by receiving licence fees. Gore-Tex is well known for its durably waterproof, windproof and breathable fabric. Välinge Innovation has developed a glueless click floor and has over 250 licences worldwide.

If a researcher or an company develops a new crop, the researcher/the academia or the company will have a possibility to Plant breeder’s rights (PBR). The PBR Act states that anyone who creates a novel crop variety can obtain exclusive rights to it. This opens two possible business models: Either to licence the PBR to external actors (A), i.e. a similar business model as Gore-Tex and Väling Innovation in the above example –or to build and operate the plant and link the business model to raw material supply (E). Monsanto Company and their Beneforte broccoli variety can be used as an example. Monsanto, through their subsidary Seminis, sells Beneforte seeds to different farmers. The business model for Seminis is in section (A) and (E). Section (A) relates to the PBR rights and section (E) to generate revenue by growing and selling the seeds. Farmers who grow and sell the Beneforte broccoli apply a business model related to section (D).

The Swedish company Spotify Technology S.A has as business model to generate revenues by selling (B, C) premium streaming subscriptions to users and advertising placements to third parties. Spotify is not producing any music or manufacturing music instruments (D, E), but focusses only on distribution.

1.4 Business modelling in the manufacturing processes:

When evaluating the business potential in the manufacturing phase of the value chain, it is important to understand the impact on sales margin depending on the refinement level of a raw material. It is a general observation that the number of process steps in manufacturing (the refinement level) relates to the sales margin and production volume (see Fig. 3 below).

The Low refinement section (I) involves only a few process steps. Wheat grass, for example, is harvested, dried, packed and sold as health food supplements. A sidestream (i.e. byproducts regarded more or less as waste) can turn into a medium valued product just by adding a few more refinement steps. An example is the whey industry. Section (I) defines as few competitors on the market, relatively low demand and medium sales margin. Due to the low refinement, there is a risk that if a product turns into a success, it is easy for others to copy. This will lead to decreasing margins and probably the product will eventually become a bulk product. However, the business potential in section (I) is worth-while evaluating to find "low hanging fruits".

The "Bulk" section (II) is characterize by mass production, low sales margins and a mature market with few possibilities to compete as a new actor.

The last section (III) "High value products" consists of knowledge intense products, complex refinery processes and new process technology. The business is about low production volumes but high sales margins. In this section you´ll find extraction of specific ingredients/nutrients in isolated form like proteins and phytochemicals.

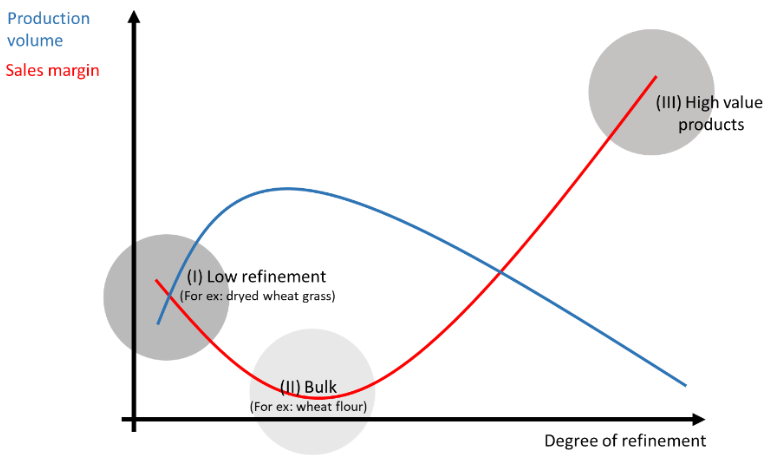


Figure 3. Refinement vs Sales Margin /Production Volume

When evaluating the business potential for manufacturing (E) it is recommended to start looking for business opportunities in section (I) and section (III) at first. To enter the "Bulk" section (II) is usually more demanding due to the mature market, low margin and well established collaboration between existing actors.

2. Business model #1: License IPR to external actors

2.1 General remarks

If potential IPR can be generated in a case, e.g. process or product related IPR, this brings an opportunity to licens the IPR to external actors. Important steps are to carry out a novelty patent search, identify potential competing innovations and identify companies who act in this market segment today.

When establishing a licencing business model, the licences have to be identified, licence agreements made and the licence fee determined. The size of the licence fee depend on the costs for maintaining the patent, possibillities to exit the agreement for both parties and a annual fee to make sure the licensee will prioritize the launch of the new products or services. Usually the annual fee is the minimum royalty paid to the owner of the IPR. It is also quite common that a down payment is made at the signing of the agreement. Royalties can either be paid as a percentage of the net sales value or as a set amount per unit sold. A percentage is preferable, to reduce inflation influence. If not, inflation should be compensated through a suitable index. Sometimes a percentage is not useful or advisable. If the invention is included as a component in a machine, it is not possible to expect to receive a royalty of, for example, 5% on the value of the entire machine. In such cases, a certain amount per machine sold must be accepted.

The licensing agreement usually limits the rights to certain geographical areas and applications. There are exclusive and non-exclusive (also called simple licence) right agreements. An exclusive right means that no one else subsequently has access to the invention, but such licences are usually limited with regard to geography or application area.

To be successful in licensing a business model, the future company needs to be attentive on future market needs and continuously invest in research and development.

2.2 Case-specific example

The production of protein concentrates from kale and broccoli residues uses quite mature technologies, and it is thus more challenging to find areas to protect with IPR. However, production processes for superabsorbents involve some novel knowledge about e.g. process design and integration with residual streams. In the superabsorbant case, work is ongoing for submitting a scientific article for the process to produce biobased SAP from potato juice[2].

2.3 To consider for the licensing IPR business model:

When going for the IPR business model, a business lawyer is needed, as well as a patent office. It is preferable to consult professionals who are familiar with the potential licensees businesses. As mentioned, it is recommended to involve potential external actors as earliy as possible in the research and verification processes. Possible external actors (licensees) should

[2] Capezza, A. J., M. Faraz, T. Prade, W. R. Newson, O. Das, M. Lundman, R. T. Olsson, M. S. Hedenqvist and E. Johansson "Revalorization of a protein side-stream: an integrated industrial approach towards non-toxic biodegradable superabsorbents." submitted to Materials Chemistry A.

be searched among those who could benefit by either increased market share, revenue or strengthen their position by licensing the IPR. By using an evaluation agreement i.e. material transfer agreement or similar, the project will faster receive response from the market.

3. Business Model #2: Trademarks and productification

3.1 General remarks

For a given case, there could be a potential of creating a trademark, a brand. A future company could then only focus on licensing the trademark to different food and/or material producers. In this case the business model is the marketed and established trademark, not producing the product itself. Instead collaboration with manufacturers (D) and distributors (C) will support the market launch.

An example is the trademark/brand Potex, formed by Lyckeby Starch. Potex is a fibre made from potatoes. It has certain properties useful for food production, enriched dietary products and provides an alternative for those suffering from gluten allergy. Fibrex, based on sugar beet fibres, is another example.

Midsona Sverige AB develops and markets strong brands within the health and lifestyle markets. This and similar companies could be suitable partners for collaboration and business evaluation.

Another way of creating brands is to establish a certification process for proven health effects, product sustainability and other product properties. Such a certified brand could then be licensed to different food manufacturers who fulfil the specifications, to strengthen their own brand and increase sales and revenues. An example is the food label brand “KRAV”, an eco-label for food, products, retailers and restaurants. The KRAV organisation sets up criteria for the label and is responsible for the approval/certification process. The KRAV business model is described as follows on their website[3]: *To be KRAV-certified and to use the KRAV label, there is a fee for the certification process and for the KRAV licence. The fee for the certification process is paid to the certification body, and the license fee is paid to KRAV*.

3.2 Case-specific example

It is well known that the future sustainable food plate will contain more plant-based and less animal-based food. It could be worth looking into the possibility to create and develop trademarks and products based on the knowledge within the SLU research group and the BioBIGG project.

One option is to build on the increased knowledge regarding properties of extracted juices, fibres and proteins from kale and broccoli residues obtained in the project. With reference to the existing fibre products mentioned above, Sven-Erik Svensson, SLU, suggested spontaneously the names Kalex and Brocex for the fibre fraction from kale and broccoli, respectively. The business potential of these products and trademarks should be investigated.

The health effects of fractions derived from the protein extraction process could be further studied. There are possibly products to be extracted from the broccoli or kale residues to be considered as “superfood”, either used directly (from milled plants or plants extracts) or

---

[3] www.krav.se

added as ingredients in other consumer health food. To initiate an “SLU certified health product” label is a possibility to enable supply of more plant-based food.

3.3 To consider if going for trademarks and productification:

First step is to collect the research result generated within the area of extraction of plant proteins and nutraceuticals from kale and broccoli residues. Identify proven positive health effects and properties for the identified ingredients. Specific and proven health effects or properties could be a business opportunity to establish a brand or label.

The next step is to compare the characteristics (competitive analysis) with similar known brands (for example Potex, Fibrex and/or KRAV) and estimate the potential market size.

If there is a potential, create a “Business opportunity” presentation for potential partners including a proposal for collaboration in the verification phase.

4. Business model #3: Production of raw material/ingredients

4.1 General remarks

A possible business model is to produce and sell protein concentrates from plants, such as kale and broccoli residues or from intermediate crops. The customers in this case are the manufacturers of material, food, feed or health products.

Thus, an ingredient extraction company could be established and become a supplier of different compounds. Ingredion Incorporated, who is a leading ingredient solutions company, can serve as example. In this case the keys for success are efficient and stable extraction processes, well verified characteristics of the extracted ingredients and close collaboration with well-established distributors or producers of end products.

Due to the low protein value, all side-streams from protein extraction from kale and broccoli and intermediate crops biomass should be evaluated, and potential stakeholders for all possible revenue streams identified. There might be potential to sell juice, fibres and other nutrients and phytochemicals to obtain a reasonable level of business potential for the investment in an extraction facility. In some cases, it could be needed to add additional refinement steps to increase the future revenue stream. For example, a fibre fraction can be refined to animal feed or for use as plant substrates instead of used as biogas substrate. The three phases in Fig. 3 in section 1.4 above (low refinement (I), bulk (II) and high value products (III)) need to be considered to find a suitable combination of refinement, production economy and the range of potential products.

4.2 Case specific example

An example from the third SLU case is to produce biobased, sustainable superabsorbent (SuSAP) raw material for the hygiene and health-care industry. This is an alternative business model to the one described in example #1. The customer in this case is a manufacturer of biobased superabsorbent, e.g. in the South Baltic area.

There are two alternatives: Either the project's team or another raw material supplier of potato juice can integrate the production process of SuSAP into existing production or a new company can be started that produces the SuSAP raw material. For both alternatives it is preferable to have process related IPR. The latter is higher value-adding and thus produces a higher margin, but also requires more investments for a production plant.

4.3 To consider for production of raw materials/ingredients

For the kale and broccoli as well as the intermediate crop case: Due to a great diversity of side-streams and potential products and markets the number of partners involved in the verification processes needs to be high. It is recommended to have in mind building a total circular bio-based production facility when evaluating the business potential. It is necessary to refine both external partner´s side-streams and internal side-streams within the extraction processes to achieve profitability in the investment. Preferably the financial risk should be shared between several actors within the circular bio-based economy.

For the case of producing raw materials for SuSAPs from potato juice: Process related IPR is recommended. It is recommended to involve the hygiene and medical-care industry as early as possible for product development and evaluation of a raw material for SuSAP production. For a future company, it is important to receive Letter of Intent for future sales of raw material for SuSAP before establishing a production plant. The financial risk is probably lower for this case, if the SuSAP meets market requirements, compared to establishing a circular biobased extraction plant based on kale & broccoli or intermediate crops.

5. Business model #4: Research-based consultants

5.1 General remarks

The increasing knowledge obtained during the BioBIGG research project could also generate a service-related business model. In this business model, the research group together with key external partners start a consulting firm, with the mission to support food manufacturers to develop new manufacturing processes and sustainable product solutions based on plant proteins materials. This type of business model is called “Research-based consulting” (Fig. 4).

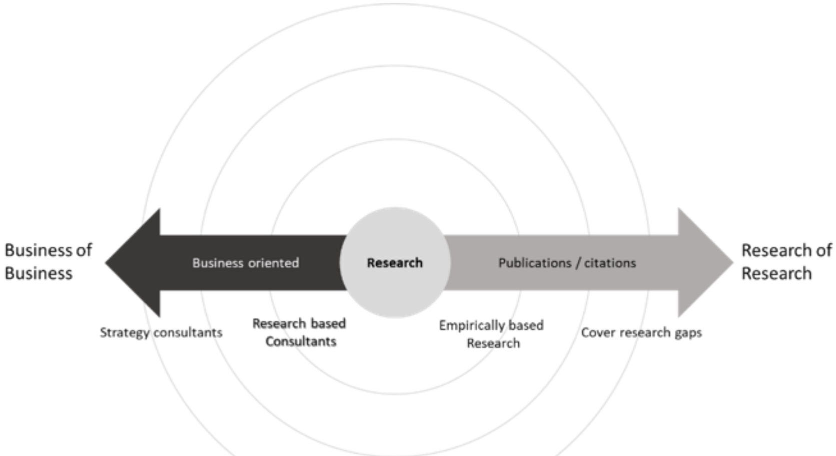


Figure 4: The field of tension between the unique and the universal in the knowledge development process.
Source: Vinnova Rapport VR 2017:04

The research-based consultancy is driven by the needs of the client, not the consultants´ own wish to gather data. This type of consulting is also called clinical research or contract research. The contract researcher helps the client by collecting and analysing data from the client work[4]. The asset in this kind of company is the knowledge and experience built within the company, which can, when generalised, be shared to other clients.

Research-based consultant firm earnings include usually both consultant fees for the work performed and publications and books related to the research area. Examples of contract research-based consultant firms are McKinsey & Co, Boston Consulting Group, Deutsche Bank Research and Oxford Analytica.

5.2 Case-specific example

SLU has the expertise in many relevant areas for sustainable food and feed supply, such as system analysis, protein extraction and concentration processes as well as harvesting technology.

The demand for applied knowledge within industry and society in these areas is high. The possibility to respond to this demand by an applied research organisation is worth investigating. It would help the transformation into sustainable society, and encourage new business opportunities in the region. Within SLU, there are some experience of commercial

[4] Reference in Vinnova Report 2017-04: Schein, E. H., 1991, page 3

contract research to build on, but there has no dedicated effort to build such an organisation yet.

5.3 To consider for research-based consultants

To start the research-based consultancy firm, it is recommended to establish an organisation for innovation and especially a visionary board and a strategy board to strive towards business-based research. The key to success is both to meet the client´s need but also to establish a methodology for data collection and for own publication. The consulting company´s success and growth is often based on market communication, publishing popular science reports and trend analysis in the fields of expertise. A research-based consulting firm can act as both a career stepping-stone and a link to the market for researchers.

6. Business model #5: Manufacture and distribution of an own brand

6.1 General remarks

In this business model the products are developed, manufactured and distributed under an own brand/trademark. The competition is with existing products and usually a dealer network has to be built. Launching an own product and brand on the market is significantly more costly than just being a subcontractor to an already established brand.

If this business model is chosen, it is probably the result of an evolving will to start a company and thereby taking a larger share of the value chain. The business model requires a separate company and is not run within the SLU research organisation.

6.2 Case-specific example

Establishing a new food brand and producing your own food similar to "Anamma foods" or "Food for progress" requires large investments in both time and capital. An easier way could be to build a new brand and launch new products in the cultivation sector instead. For example, there would be an opportunity to produce fertilizers, growing media (potting materials) and perhaps plant nutrients (in concentrated juice form) for agriculture and home growers. This business opportunity takes advantage of the side streams from plant protein extraction such as brown juice and fibre fractions as occurring in the first two SLU cases. By collaborating with plant protein extraction companies and making use of their side streams the business model could be very close to a total circular biobased model.

6.3 To consider when to manufacture and distribute an own brand

This challenging business model requires all competences to be located within the company, and these competences need to be attracted and involved early in the verification and developing process. A success factor is to develop both brand and product together with distribution/retailer partners. The retailer´s market knowledge will accelerate the generation of product solutions that are both more profitable and responding to customer preferences.

Examples of successful companies are Anamma Foods (today owned by Orkla Foods), Food for Progress AB (Oumph brand) and Oatly AB (oat drinks). All mentioned companies are examples of clear positioning in the market and early involvement of product development, business competence and investor skills. It is recommended to listen to people who have done the entrepreneurial journey already. The mentioned companies usually have people within their network who have previously made the journey and are willing to assist.

Household sector

PYROLYSIS WITH THATCHING MATERIAL COMMON REED (PHRAGMITES AUSTRALIS) IN MECKLENBURG-WESTERN POMERANIA OR MECKLENBURG-VORPOMMERN

COLOURBOX31721058

Author:	*Valerie Sartorius, Jennifer Nitzschke, Lena Huck,* Agency of Renewable Resources (FNR)
Editor:	*Martin Behrens,* Agency of Renewable Resources (FNR)
Project Title:	Bioeconomy in the South Baltic Area: Biomass-based Innovation and Green Growth
Project Acronym	BioBIGG
Work Package	Work package 5: Implementation of innovative agro-industrial value-chains and biomass-based production in SME's
Deliverable:	Deliverable 5.3: Cross-border implementation models and business case manuals for SMEs
Copyrights:	All rights reserved to the partners in BioBIGG. Copyright © 2020 BioBIGG.
Published by:	BioBIGG

Business case: Bio-char from pyolysis of old thatching reed

The business case about bio-char from pyrolysis of old thatching reed is based on the pre-feasibility desk-study about ‘Pyrolysis of old thatching reed in Mecklenburg Western-Pomerania (MWP)’ and the subsequent innovation programme. For the realisation of the project, the next step would be to make tests with the material. Preceding the implementation of this the business case, a positive outcome of the test-phase with old thatching reed at the pyrolysis plant GreenCarbon GmbH and the decision of the plant managers to include the material into their production of Terra Preta or soil conditioner would be needed. At the moment, there are no further plans for conducting these tests.

There is one pyrolysis plant in MWP that uses wood and in smaller quantities also other types of biomass. They produce bio-char and refine it into various end products like Terra Preta, soil conditioner or feed supplement for animals. The integration of old thatching reed as pyrolysis material would contribute to more flexibility for the pyrolysis plant regarding availability of raw material. The bio-char from old thatching reed would probably serve well for their Terra Preta and soil conditioner. Further tests have to be made for the actual implementation.

Country	Germany, Mecklenburg Western-Pomerania (MWP)	
Name of company or project	Project: Pyrolysis of old thatching reed in MWP, Pyrolysis plant with expressed interest in the project: GreenCarbon GmbH	
Web site	http://www.greencarbon-gmbh.de/	
Description of the company or projects	The project: Old thatching reed will be turned into bio-char through pyrolysis. The bio-char will be used for producing Terra preta or soil conditioner.	
Type of production (choose one or more, mark box(es))	Energy production	
	Circular bioeconomy development	x
	Production of non-energy high value added products	
Source of biomass (choose one or more, mark box(es))	Agriculture and food industry	
	Municipal waste and sewage	
	Fishery and algae	
	Wood	
	Several sources	x
Description of products from biomass	Bio-char for production of Terra Preta or soil conditioner	
How does the business case fulfil sustainability criteria (please explain the following benefits)?	Economic benefits	The old thatching reed serves as additional material for the pyrolysis plant, therefore contributes to flexibility. The company that produces and sells the bio-char products can pay the thatcher's for the old thatching reed. Normally the thatcher's have to pay money to the incineration or composting plants for the disposal of the material.
	Social benefits	Supports regional economy and regional thatching culture.
	Environmental benefits	The bio-char stores CO^2 in the soil

Technology readiness level (choose the appropriate box and mark it with x)		5. Technology validated in relevant environment	x
		6. Technology demonstrated in relevant environment	
		7. System prototype in operational environment	
		8. System complete and qualified	
		9. System operational	
Transferability to small and medium sized companies in the BSR countries		Yes. Best if pyrolysis plant is already at hand. Can be done everywhere with rather dry biomass available near the location.	
Existing enabling policies and economic factors (describe the policy measures like subsidies, tax breaks, price policy, regulations that are crucial for making this business case economically viable).		Already existing at the company: Inscription in the Input List for Organic Agriculture ("Betriebsmittelliste Ökologischer Landbau"), ISO 9001:2015 - Managementsystem	
Hashtags (select from drop down menu up to six most relevant hashtags (key words) related to this case in a ranked order starting from the most important)		#Biochar	
		#Circular Bioeconomy	
		#Sequestration of CO2	
		#Regionality	
		#Environmental friendly	
	Business model block	Description	Notes
Infrastructure	Key partnerships	The network the organization uses to operate its business model	Biomass supply chain, Reed thatching companies
	Key activities	The main activities required for making the business work	Establishing contact with reed thatching companies, integration of reed bio-char in existing product list
	Key resources	Most important tangible and intangible assets required for the business model	Maintenance of usual plant operation and biomass availability
Value proposition	Value proposition	Value offered to customers in mix of products and services	Environmental friendly and regional organic soil conditioner
Customer interface	Customer relationships	Type of relationships the organization has with customers	Mostly online or via telephone marketing oriented
	Customer segments	Specific groups of customers the organization aims to reach and serve	Farmers with interest in ecological organic soil conditioning
	Distribution channels	How organization reaches its customers	Distributors, website, personal presence
Roughly cost of the implementation and operation			
Financial viability	Cost structure	Most significant costs for operating the business model	Staff cost, fix costs of the plant

	Revenue stream	What kind of cash flows different customers create for the organization	Payment of biomass, Sale of bio-char products
Comments		The business case is based on the assumption of a positive outcome of the test-phase with old thatching reed at the pyrolysis plant GreenCarbon GmbH and the decision of the plant managers to include the material into their production of Terra Preta or soil conditioner. At the moment there are no further plans for conducting these tests.	
Who entered data and when		Jennifer Nitzschke, 24.11.2020	

SUSTAINABLE BIO-BASED ALTERNATIVES AS A SUBSTITUTE FOR PLASTIC PACKAGING, DISHES AND CUTLERY IN THE CATERING SECTOR ON THE BEACHES OF ROSTOCK

COLOURBOX47342830

Author: *Valerie Sartorius, Jennifer Nitzschke, Lena Huck,* Agency of Renewable Resources (FNR)

Editor: *Martin Behrens,* Agency of Renewable Resources (FNR)

Project Title: Bioeconomy in the South Baltic Area: Biomass-based Innovation and Green Growth

Project Acronym BioBIGG

Work Package Work package 5: Implementation of innovative agro-industrial value-chains and biomass-based production in SME's

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

Published by: BioBIGG

Business case: Sustainable bio-based alternatives as substitutes for plastic packaging, dishes and cutlery in the catering sector on beaches

The following business case is based on the prefeasibility study and the innovation program on “Sustainable bio-based alternatives as substitutes for plastic packaging, dishes and cutlery in the catering sector on the beaches of Rostock”. It is a feasible project, which can be carried out on all beaches, regarding their size. The project depends on waste disposal companies’ willingness to conduct practical research. This, the practical research as well as the project promotion constitute the main costs of the project.

Country	Germany	
Name of company or project	Sustainable bio-based alternatives as substitutes for plastic packaging, dishes and cutlery in the catering sector on the beaches of Rostock	
Web site		
Description of the company or projects	Plastic packaging, dishes and cutlery are substituted with biodegradable materials which can be used for the production of biogas when feeding them into the biomass	
Type of production (choose one or more, mark box(es))	Energy production	
	Circular bioeconomy development	x
	Production of non-energy high value added products	
Source of biomass (choose one or more, mark box(es))	Agriculture and food industry	
	Municipal waste and sewage	Biodegradable municipal waste
	Fishery and algae	
	Wood	
	Several sources	
Description of products from biomass	The biodegradabel materials are made of paper, cardboard, wood, palm and banana leaves and bamboo.	
How does the business case fulfil sustainability criteria (please explain the following benefits)?	Economic benefits	Supports market for sustainable and biodegradable materials, creates jobs in the region
	Social benefits	It is a community undertaking, because everybody can contribute to keep the beach plastic free and use it is a community enterprise, because everybody can contribute to keep the beach plastic free and use biodegradable materials. It promotes teamwork and mutual esteem.
	Environmental benefits	Decrease of environmental pollution, improves cascading process.
Technology readiness level (choose the appropriate box and mark it with x)	5. Technology validated in relevant environment	
	6. Technology demonstrated in relevant environment	
	7. System prototype in operational environment	
	8. System complete and qualified	x

		9. System operational	
Transferability to small and medium sized companies in the BSR countries		Is transferable to small and medium sized beach areas.	
Existing enabling policies and economic factors (describe the policy measures like subsidies, tax breaks, price policy, regulations that are crucial for making this business case economically viable).		The success of the project depends on a uniform labelling of biodegradable products so they can easily be recognized by the customers and sorting machines. Bans on the use of various environmentally harmful materials are beneficial. Regulations within the state on waste collection and recycling are crucial too.	
Hashtags (select from drop down menu up to six most relevant hashtags (key words) related to this case in a ranked order starting from the most important)		#Plastic substitution	
		#Environmental friendly	
		#Clean water	
		#Regionality	
		#Social acceptance	
		#Purification/Cleaning	
	Business model block	Description	Notes
Infrastructure	Key partnerships	The network the organization uses to operate its business model	Cooperation with waste disposal companies to improve the composting process. Kiosk and restaurant owners who declared to only use biodegradable dishes and packaging
	Key activities	The main activities required for making the business work	Technology and research
	Key resources	Most important tangible and intangible assets required for the business model	Technology and waste disposal companies
Value proposition	Value proposition	Value offered to customers in mix of products and services	Sustainable and environmentally friendly way to enjoy food near the beach with the side effect of using the biodegradable materials for the biogas production
Customer interface	Customer relationships	Type of relationships the organization has with customers	Voluntary cooperation, to be role model and motivator
	Customer segments	Specific groups of customers the organization aims to reach and serve	Kiosk, stall and restaurant owner near the beach, beach visitors, producers of biodegradable packaging and dishes
	Distribution channels	How organization reaches its customers	Marketing, social media, sign at the beach
Roughly cost of the implementation and operation			

Financial viability	Cost structure	Most significant costs for operating the business model	Project promotion; Technology: the success of feeding the biodegradable material into the biogas production depends on the effectiveness of the composting process and the labelling of the biodegradable products
	Revenue stream	What kind of cash flows different customers create for the organization	
Comments		The success of the project depends on a uniform labelling of biodegradable products, the development to biodegradable products, on the waste companies' willingness to cooperate, on the involvement of the public and kiosk, stall and restaurant owners near the beach.	
Who entered data and when		Valerie Sartorius, 23.11.2020	