Innovation programmes for bio-based value chains in the South Baltic Region

June 2021

Innovation programmes for agro-industrial value-chains and biomass-based production in the South Baltic Region

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Executive summary

A structured transition to a circular and sustainable bioeconomy in the South Baltic Area (SBA) presupposes a clear understanding of needed innovations related to the development of new and existing bio-based value-chains. Key questions arise from this statement: What needs to be optimised to further the implementation of bioeconomy concepts? In which way can these optimisations take place, and how are they related to the final vision of a sustainable and circular bioeconomy?

To answer such questions, the BioBIGG project has developed 14 innovation programmes/roadmaps for potential products and/or improved production processes related to selected biological feedstocks in the SBA. The programmes are divided into four sectors: agriculture, forestry, agro-industry and households. A problem-driven innovation approach has been adopted to structure and analyse the selected bioeconomy concepts. The idea was to broaden the analytical focus from narrow suggestions on incremental technological innovations, towards a more systemic and process-oriented understanding of needed technological innovations. The report is part of the BioBIGG project and based on 16 pre-feasibility studies. It is suggested that these studies are read first via the homepage: https://biobigg.ruc.dk

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Agricultural sector

DIGITAL STRAW BALE MANAGEMENT IN DENMARK

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I. Authors note

This report (report 2) 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 of 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, focusing on needed optimization(s) for developing the technological concept to the desired TRL.

Report 3 presents a potential business case for the commercial value of the technological concept once implemented in the supply chain. This entails value propositions on customer satisfaction and cost minimizations.

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 development of low-cost passive RFID-systems can be traced all the way back to the 1940s. Based on the radar, the fundamental principle of RFID was demonstrated as a method of distinguishing between enemy and allied aircrafts under WW2. The system was called IFF (Identify Friend or Foe) and consisted of a (suitcase sized) RFID tag emitting an identifiable radio signal from an allied aircraft to a radar station within a certain range. This was one of the first military and operational identifications of a physical object by radio-waves.

In the 1960s the first commercial application of RFID-systems was invented to prevent off-the-shelf products from being shoplifted (i.e., Electronic Article Surveillance, EAS). The principle is still widely used today for electronic devices, clothes and food products. In the 1970s, 1980s and 1990s the commercial application expanded into animal tagging, toll systems, road tariffs, access control, cashless paying, ski passes and other related applications (Uckelmann 2012). However, high unit prices hindered the application of RFID-systems for low-end products related to supply chain management and inventory logistics (Sarma 2012).

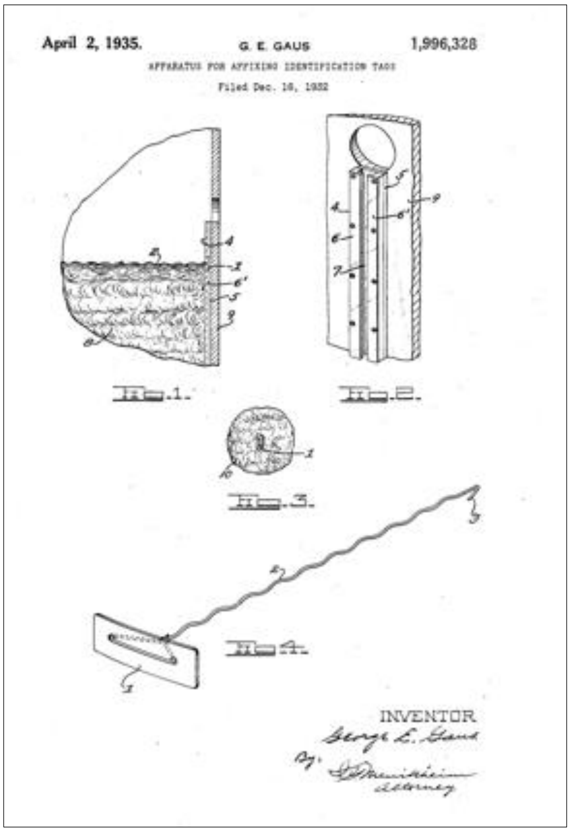
In 1999 a research group at MIT (Massachusetts Institute of Technology) thereby established an organization called the Auto-ID centre, in order to expand the market potential for RFID-systems. The purpose was to develop low-cost passive RFID-units (approx. 0.084 €/unit) for identifying crates, boxes etc. in an open system; i.e., use once, then discard. The design principle was minimalistic; drive down unit price by removing any non-essential components in the tags. This is also referred to as a 'bottom-of-the-pyramid' innovation by Falkenberg et. al. (2019): i.e., technologies developed to curb various features of an existing product, in order to generate a significant cost reduction. The approach was a huge commercial success, and is widely acknowledged as the breakthrough of low-cost RFID units around 2004 (Sarma 2012, p. 46).

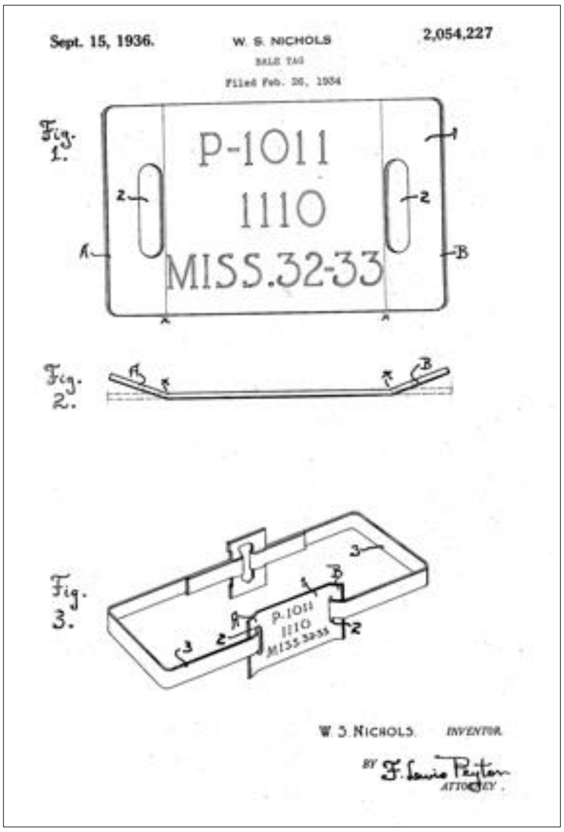
Spill-over to bales

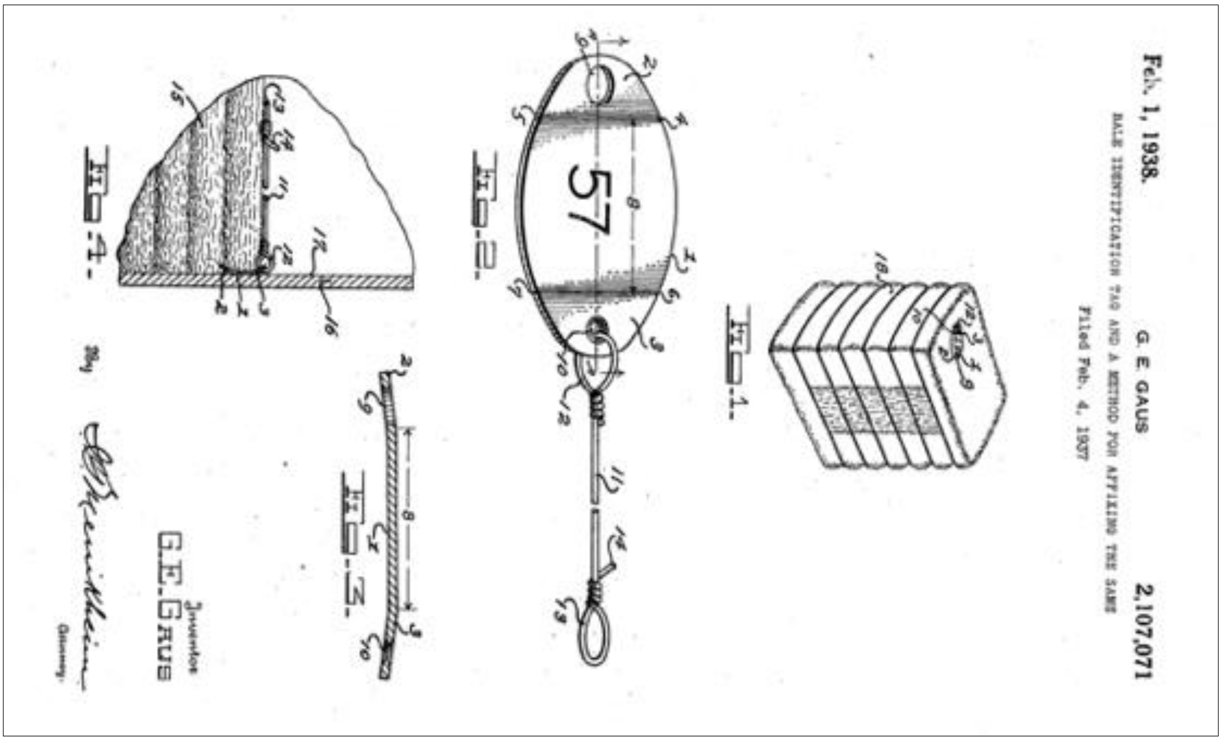
Passive RFID-units for bale identification were commercialized around 2010 in North America. The market pull was primarily established within the hay to feed sector. By digitalizing the identification of bales with type, moisture content, preservatives added and baling time, hay-suppliers had the opportunity to sort, prioritize, valuate and sell identifiable bales in accordance to nutritional feed value. Non-digital bale identification can be traced all the way back to the 1930s (see also annex 2). In 1935[1], 1936[2] and 1938[3] three patents were respectively established for cotton bale tags (specifying information about the bale and the producer). The inventions had the purpose of developing fixated metal tags on bales, as an incentive to reduce the risk of fraud. A market tendency widely related to poor tagging and cotton bale fires in North America (see figure 1 for patent drawings).

[1] USPTO Patent 1996328
[2] USPTO Patent 2054227
[3] USPTO Patent 2107071

Figure 1: Patents for bale-tagging in 1935, 1936 and 1938







1. Innovation pathway for concept

By reviewing USPTO-patents for bale identification (i.e., United States Patent and Trademark Office) it is possible to distinguish between two main pathways for passive RFID-systems between 2010 – 2021 (see also annex 1):

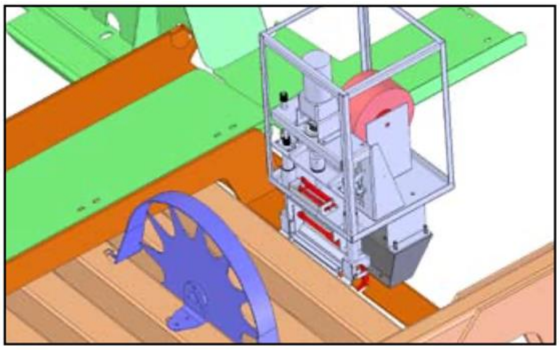
The Hayboss G2 Bale Identification system: UHF RFID-tag encased by an adhesive label and attached to a bale twine, via an autonomous activation of a component, lifting the twine and another component attaching the adhesive tag around the lifted twine (called a tagger).

Bale properties are stored on the tag and accessible by manually scanning the tag with a reader. Bale information can also be transferred to an internal bale management system by manual means. The technology is based on a patent invention by Harvest Tec[4]. Smaller variations to the system were adapted and patented by AGCO[5] leading to the commercialization of the Hayboss G2 Bale Identification System (TRL9). A similar system has also earlier been commercialized by New Holland[6] (i.e., CropID system).

The Bale Link System (BLS): UHF RFID-filament woven into one of the strands of the twines used for binding the bale in the pressing chamber. The filament is thereby attached to a bale, as an integrated part of the binding procedure. It is assumed that the applicable procedure is a double knotter system; i.e., a bale is secured in an upper and lower twine via two supply rolls. The first roll binds the bale in a knotter system. The second roll (with a RFID filament) is joined into the system by binding the two twines together.

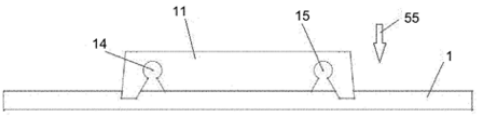
Bale properties are stored on an external cloud-based server, and linked to the Bale-ID on the filament. When scanning the bale, the server transmits information about the bale to the user via an internal bale management app. The filament, app and integration into a double knotter system were invented by Hesston for Massey Ferguson (a hay equipment brand) and patented by AGCO[7]. The Bale Link System is currently being field tested for final approval in 2022 (TRL 6-7).

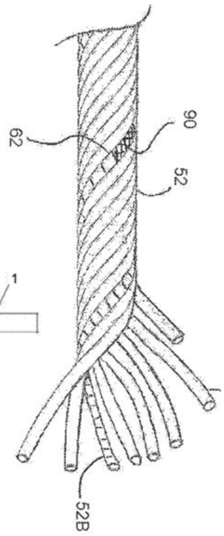
Figure 2: Visualizations of physical bale identification pathways



[4] Patent 7,621,111
[5] Patent 10,127,491and 10,949,732
[6] Patent 9,943,036
[7] Patent 10,492,371

Pathway 1 (above): (left) Visualization of the principle for a RFID-tagger mounted at the top backend of the pressing chamber in a baler. (right) image of adhesive CropID RFID-tag attached to a twine.





Pathway 1: (left) Visualization of an adhesive Hayboss G2 RFID tag attached to a twine and an antenna above - transmitting data to the tag. **Pathway 2:** (right) visualization of the RFID-filament woven into one of the strands of a twine. **Alternative Pathway:** (middle) visualizations of non-adhesive RFID-tags (i.e., patent drawing by Octinion and Vulcan RFID bale-tag) not applicable for the technological concept.

Key differences between the two pathways are thereby related to data storage and attachment procedures. From this perspective, the BLS is assumed to be the most promising pathway for the development of the technological concept. This is based on three factors:

(1) There is potentially an increased risk for the adhesive tags to be torn off by shear force, when bales are managed under pathway 1 (i.e., personal comment by supplier). The adhesive bonding is also expected to slowly degrade over time due to weather conditions and semi-open storage facilities in DK and the SBR. The ruggedness of the RFID-tag is expected to be less applicable for the operational environment.

(2) The woven attachment procedure is expected to be an implementable and cost-effective pathway, as it supports the development of a direct application technology for RFIDs in balers, utilizing a double knotter binding system. An external tagger is needed for pathway 1.

(3) The cloud-based approach to bale identification is more adaptable and flexible, as data is stored externally in the processing layer (cloud). Or in other words, the identification and use of data is not limited by the RFID-unit or bale-location. This infrastructure is expected to support R&D and large-scale commercialization possibilities in contractual supply markets.

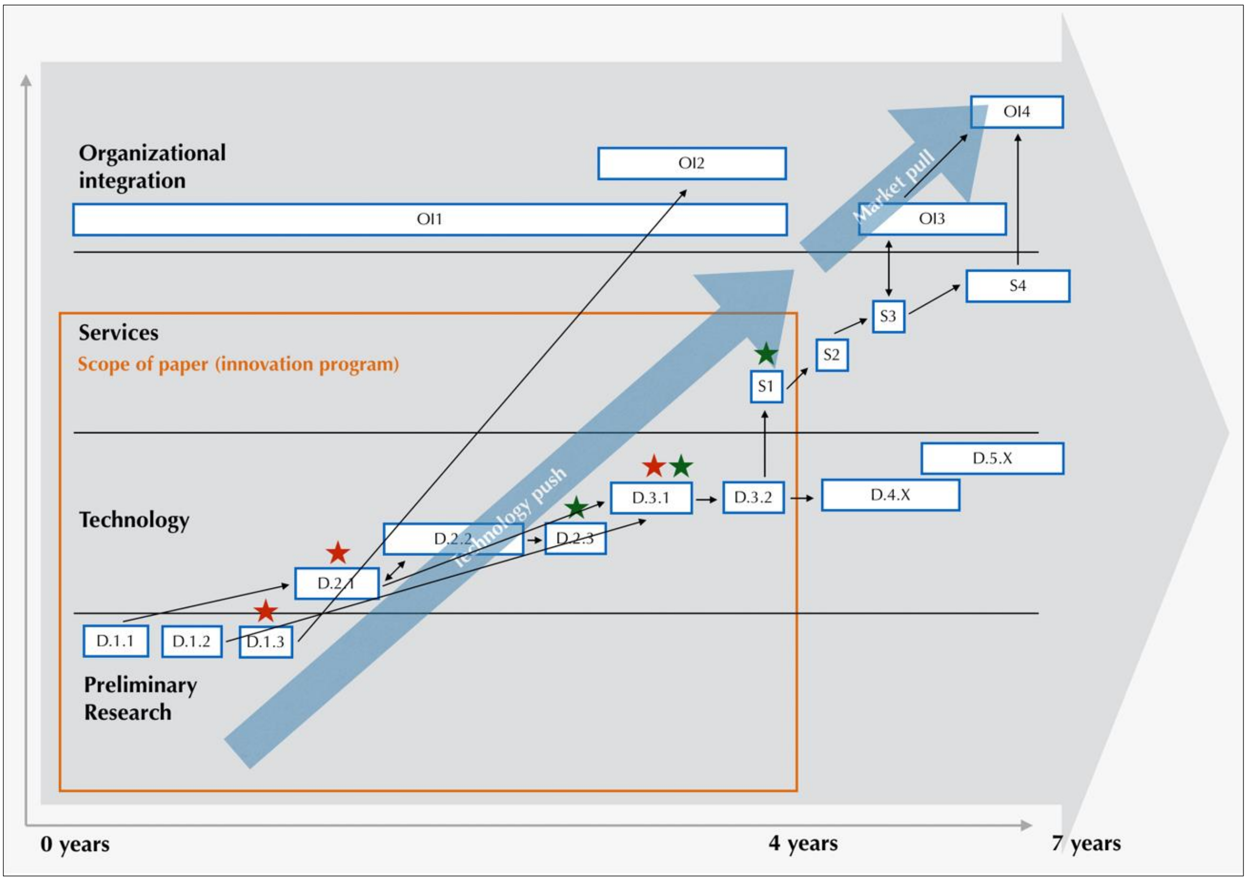
2. Innovation program for concept

The innovation program (IP) is divided into two sub-projects. A seed-money project for preliminary research on the operational environment, and a R&D-project for validation of the concept in a simulated operational environment (TRL3/4 – 5). The technological push of the IP, is expected to generate a market pull towards an organizational integration of the concept to the relevant organizational environment (TRL5-6).

2.1. Roadmap overview

In fig. 3 a roadmap for developing and implementing the technological concept is presented. The main purpose of the roadmap is to give an outline of the long-term planning approach, expected bottlenecks (red stars), milestones (green stars) and interlinkages between subprocesses (black arrows). The roadmap has been adapted from the generic model by EIRMA (1997) divided into 4 vertical thematical layers. Scope of the innovation program is delimited by the orange box.

Figure 3: Roadmap for technology concept and scope of IP



Innovation Program:	
Preliminary Research (seed-money project)	
D.1.1.	Mapping of sensory data (state of play) and future trends related to sensory devices in DK.
D.1.2.	Mapping of bale binding procedures (state of play) and design possibilities for RFID systems in DK.

D.1.3.	Letter-of-intent for supplier panel.
Experimental validation: Proof-of-concept (R&D project)	
D.2.1.	Defining hardware components for system concept.
D.2.2.	Initial laboratory test of system concept (TRL3).
D.2.3.	Simulated test of system concept in laboratory setting (TRL4).
Validated in a simulated operational environment (R&D project)	
D.3.1.	Operational installation of system concept documented.
D.3.2.	Simulated test of system concept in operational setting (TRL5).
[Beyond the scope of the Innovation Program]:	
Demonstrated in an operational environment (TRL6-8) (beyond scope of IP)	
D.4.X	Demonstrated in an operational environment (TRL6-8).
Integrated into straw supply chains as a bale management system (TRL9) (beyond scope of IP)	
D.5.X	Integrated into support structure for supply chain.
D.5.X	Integrated into consortium supply chain.

Services provided by technology	
S1	LMIS: Sorting procedure and inventory overview validated in operational environment
S2	LMIS: Sorting procedure and inventory overview demonstrated in operational environment
S3	LMIS: Sorting procedure and inventory overview provided by support structure to operational environment
S4	LMIS: Sorting procedure and inventory overview provided by internal unit in consortium to operational environment
Organizational integration of technology	
OI1	University
OI2	Test-group (straw suppliers)
OI3	Commercial support structure (Spin-off company from university)
OI4	Consortium of suppliers

2.2. Preliminary research on operational environment

The first part of the IP should be structured as a seed-money project (Duration: 1 year, estimated budget: 50.000 – 60.000 €). The purpose of the project will be to conduct a screening process of the operational environment (see D. 1.1/1.2 below). In this way, the potential implementation of the concept can be evaluated before a substantial R&D investment is made, while reducing uncertainty inherent in such early stages of an R&D project.

2.2.1. Deliverable 1.1 - Sensory data mapping

The first deliverable will define state of play for the collection and utilization of sensory data by straw suppliers in DK. Hereunder, moisture and bale weight sensors will constitute the primary focus areas, as they represent key enabling technologies for the concept (see pre-feasibility study for elaboration). The state of play will contain a technical overview of the devices, operational overview of sensory data flows and a market overview of commercial use within the relevant environment.

The first deliverable will also define the expected future demand for sensory devices. This is important to know at an early stage of R&D, as a low commercial adoption of sensory devices in balers and/or tractors, can generates a bottleneck for the scalability of the concept in the operational environment around 2026-27 (see roadmap). Key activities are presented in table 1 below.

2.2.2. Deliverable 1.2 - Bale binding procedures

The second deliverable will define state of play and future trends for bale binding procedures within the operational environment. According to Rasspe (no date) around 70 % of square bales in EU are secured with a double knotter system, thereby indicating a large market potential for the integration of RFID-filaments. Nevertheless, a survey on binding procedure needs to be conducted in DK. If the results from the survey indicate a low application of double knotter systems, it is necessary to re-evaluate the design of the technological concept to include RFID-taggers (see picture above). This is expected to support the scalability of the concept for suppliers with a single- and double knotter system. Key activities are elaborated in table 1. This would of course also entail adaption of the ruggedness of RFID-tags to the operational environment.

2.2.3. Deliverable 1.3 - (non-binding) Letter of intent

If the technological concept is evaluated as implementable, a letter of intent will be established with a panel of 2-3 straw suppliers. The panel is created to support the future validation of the concept in an operational environment (TRL5). This reduces the risk of creating a proof-of-concept (TRL3/4) which cannot be tested further, due to lack of early stakeholder involvement.

Activities will include a workshop for the definition of test runs and collaboration forms, such as practical clarifications on how and when to conduct the validation process (i.e., utilization of machinery, test-bales, test period, potential costs for tests and so forth). Key activities are elaborated in table 1.

Table 1: framework for deliverables and activities in seed-money project

Preliminary research on operational environment		
Deliverable 1.1. (Sensory data mapping)		
List of activities:		**Duration:**
Activity 1.1.	**State of play:** Literature review on technical product-sheets for moisture sensors, bale weight sensors, installation procedures, measurement procedures, CAN-bus systems and data-formats.	1 months
Activity 1.2.	**State of play:** Operational overview of sensory data utilization and market overview of commercial use within the operational environment. Overview based on telephone interviews with large-scale straw suppliers.	2 months
Activity 1.3.	**Forecasting analysis:** Qualitative projection on expected demand for sensory devices in balers and/or loaders, based on telephone interviews with sensory device suppliers and related market experts.	3 months
Output:	1 report on sensory devices: State-of-play and future demand	
Potential bottlenecks:	Scalability issues of concept due to lack of sensory device installations	
Relevant stakeholders:	Danish Straw Association, DSE Test Solutions.	
Deliverable 1.2. (Bale binding procedures)		
List of activities:		**Duration:**
Activity 1.4.	**State of play:** Literature review on technical product-sheets for binding- and knotting systems for large square bales. Followed by interview with system-manufacturers.	1 months

Activity 1.5.	**State of play:** Survey and interviews with large scale straw suppliers on the utilization of binding- and knotting systems in the operational environment.	4 months
Output:	1 report on bale-binding systems used in the operational environment	
Potential bottleneck:	Low utilization of double knotting systems in operational environment	
Relevant stakeholders:	Danish Straw Association, Hesston, Rasspe	
Deliverable 1.3. (Letter of intent)		
List of activities:		**Duration:**
Activity 1.6.	**Letter-of-intent:** Workshop with 2-3 large straw suppliers on future operational test collaboration.	1 months
Output:	1 (non-binding) Letter-of-intent on future collaboration for operational test (see D.3.2.)	
Potential bottleneck:	No interest by target group in future operational tests	
Relevant stakeholders:	Danish Straw Association, Halmselskabet Danmark	

2.3. Experimental validation: proof-of-concept

The second part of the IP, constitutes the first half of the actual R&D project (Duration: 2 years, estimated budget: 300.000 €). This project will entail the development of a validated proof-of-concept from TRL2 to TRL4 divided into three sequential deliverables.

2.3.1. Deliverable 2.1 - Defining components for the system

The BLS-pathway is expected to be fully commercialized in 2023 (TRL9). It is thereby assumed, that AGCOs RFID-filament is available as a test-component before the R&I project is initiated. The external outdoor antennas (omnidirectional), cables, TCU, tractor battery and sensory devices will be procured from other sources (RFID- and tractor-manufacturers). In order to test a wide range of products, several test-kits for antennas, cables and TCUs will be purchased. The components will be pre-selected in relation to expected operational- and market requirements for the application (i.e., readability, humidity, ruggedness, costs etc.).

The compatibility between components and AGCOs RFID-filament is highly important. Proprietary technologies are sometimes designed to be incompatible with competitive products, even though they represent standardized technologies. The potential solution(s) for such a bottleneck will be to either (1) develop a temporary RFID-unit emulating the filament or (2) establish a collaboration with ACGO in the design of the concept. A third hybrid-solution could also be to develop a cloud-based system with a RFID-tag. Each mitigating effort is expected to create different minor, but manageable, challenges within the first duration of the R&D project.

2.3.2. Deliverable 2.2 – Laboratory test

When the abovementioned preparatory activities are completed, the initial test will commence. The first run will be under ‘laboratory’ settings with a single large square bale. The success-criteria will be to design the system, read the bale, conduct sorting procedures and create a digital overview. No uncontrolled externalities or simulated operational conditions will be integrated into this part of the project.

The RFID-filament will be attached to the top twine. The external antenna will read the filament and send the ID to the TCU. The TCU will also be connected to the battery and the sensory devices, measuring moisture and weight of the bale. The TCU will combine sensory and non-sensory bale data to the ID. Test-results will be cross-validated with literature- and manufacturing data.

Based on the data-collection in the TCU, a simple beta-version of the API and LMIS will be developed. Multiple data-points will be processed into pre-defined quality categories and communicated to a user-interface to test performance until stable (see pre-feasibility study for elaboration on the LMIS).

Developing a beta-version of the LMIS is a major milestone towards TRL4. There are two reasons for this. First, it constitutes the main incremental innovation of the concept; namely an automated categorization of bale-properties and supply chain services (i.e., sorting procedures and inventory overview). Secondly, it constitutes a Key Performance Indicator (KPI) for the components, as it quantifies the digital detection of a bale throughout the system. The development will be coordinated by an overall system planner and an expert panel on programming and RFID-systems, both in general, and in relation to bale- or bulk identification processes.

2.3.3. Deliverable 2.3 – Simulated test in laboratory setting

In this test-phase, the operational conditions will be emulated in a rudimentary way. This entails an external antenna and bale being manually positioned/pushed at different angels, speeds, ranges and under different weather conditions. Test-runs will be conducted for multiple bales of different quality. The primary purpose is to define outer limits of bale/RFID readability (i.e., maximum speed, maximum range etc.) via the KPI (i.e., non-detected and detected bales). The results (i.e., system boundaries) will thereafter be compared to standard baling- and management operations. If > 99 % of bales are readable within standard operation procedures, the concept will be validated under TRL4.

Table 2: framework for deliverables and activities in first part of R&D-project

<table>
<tr><th colspan="3">Experimental validation: Proof-of-concept</th></tr>
<tr><td colspan="3">Deliverable 2.1. (Defining components for system)</td></tr>
<tr><td colspan="2">List of activities:</td><td>Duration:</td></tr>
<tr><td>Activity 2.1.</td><td>Selecting RFID components: UHF, RO Passive RFID-filaments (BLS-unit or alternative), Outdoor external omnidirectional antennas, cables, mounting units. Several RFID test-kits will be procured for evaluation in D.2.2.</td><td>3 months</td></tr>
<tr><td>Activity 2.2.</td><td>Selecting sensory devices: Most applicable commercial devices for weight and moisture will be used, based on results from D.1.1. (A.1.2)</td><td>1 months</td></tr>
<tr><td>Activity 2.3.</td><td>Selecting Telematic Control Unit (TCU): Based on D.1.1. (A.1.1 and A.1.2.) and D. 2.1. (A.1.1. and A.1.2) a compatible TCU will be selected. The TCU will also function as the reader for the filament.</td><td>3 months</td></tr>
<tr><td rowspan="2">Output:</td><td colspan="2">System concept(s) developed for testing.</td></tr>
<tr><td colspan="2">1 technical report on selected systems.</td></tr>
<tr><td>Potential bottlenecks:</td><td colspan="2">No access to RFID-filament as a stand-alone component (proprietary component by AGCO)</td></tr>
<tr><td>Relevant stakeholders:</td><td colspan="2">Prosign RFID Solutions, ATLAS-RFID, Hesston, Harvest Tec</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td colspan="3">Deliverable 2.2. (laboratory test)</td></tr>
<tr><td colspan="2">List of activities:</td><td>Duration:</td></tr>
<tr><td>Activity 2.4.</td><td>Test preparation: Defining laboratory set-up and testing procedure. Procuring bales representative for operational environment (used in D.2.2. and D.2.3).</td><td>3 months</td></tr>
<tr><td>Activity 2.5.</td><td>Initial laboratory test: Bale identification to TCU will be tested until stable performance (TRL3). Iterative process to A.1.4.</td><td>4 months</td></tr>
</table>

Activity 2.6.	**API and LMIS development:** based on TCU data-points, automated soft- and middleware program is developed and tested until stable performance. KPI also established for testing in D.2.3. and D.3.2.	5 months
Output:	Proof-of-concept (major milestone).	
	1 report on test preparation.	
	1 report on test results.	
Potential bottleneck:	No real bottlenecks expected. Only commercially proven technologies used for testing.	
Relevant stakeholders:	Natural Resources Institute Finland (Production Systems), Häme University of Applied Sciences (HAMK Tech Research Unit and Bioeconomy Research Unit). I.e., similar experimental testing has been conducted by mentioned stakeholders on round bales.	
Deliverable 2.3. (simulated test)		
List of activities:		**Duration:**
Activity 2.7.	**Test preparation:** Defining test conditions for rudimentary simulation of operational environment. Literature review of production process of bales and loaders for simulation criteria. Literature review of similar RFID-tests.	2 months
Activity 2.8.	**Simulated test:** Identification of RFID-filament by external omnidirectional antenna at different range, speed and angel under different weather conditions. Test-results compared to simulation criteria (see A.1.7.). More than 98 % readability under simulated operational conditions for validation (TRL3-4).	3 months
Output:	Validated proof-of-concept (minor milestone).	
	1 report on test preparation.	
	1 report on test results.	
Potential bottleneck:	Poor readability of RFID-filament by external antenna due to angel and/or moisture content in bale; i.e., high moisture content can potentially diminish the radio-waves to/from the filament and external antenna, and as a consequence reduce read-distance and angel to external antenna from filament (Penttilä et. al. 2019).	
Relevant stakeholders:	None (besides project group)	

2.4. Validation in a simulated operational environment

The third part of the IP, constitutes the second part of the R&D project (Duration: 1 year, estimated budget: 150.000 €). This project entails the validation of the system in an simulated operational setting. The main success factor will be to develop a stable performance throughout the simulated supply chain; i.e., bale identification, intermediary bale management and inventory overview. The operational test will be planned and executed in collaboration with the supplier panel in an iterative process.

2.4.1. Deliverable 3.1 - Installation procedure for the validated concept

In order to reduce the risk of technical uncertainties in the operational test, an installation procedure for the system will be defined beforehand. This includes all installation processes for components integrated into the baler, tractor and loader. Final adjustments to the procedure will be completed after the operational test, in order to supports the commercial implementation of the system.

The final form of the documentation depends on the complexity of the installation. If the installation is simple, it should be developed directly to suppliers. If the installation is more complex, it should be developed to mechanics. This also feeds into a fundamental discussion on how the commercial installation of the system should be rolled-out; i.e., in a de-centralized manner (installed by each supplier) or a centralized manner (installed by a unit of mechanics). Such a discussion is however beyond the scope of this report.

2.4.2. Deliverable 3.2 - Operational test for the validated concept

The operational test is fully automated and should reflect the technology concept described in the pre-feasibility study. The test duration will be one week. Two balers will be used in the baling operation of approximately 20 – 30 tons of straw (i.e., 40 – 60 test bales). Each baler will have the system installed and conduct the operation, as they would in a typical commercial setting.

After a successful bale identification process, the second stage will be initiated (i.e., service communication). This entails two loaders picking-up test bales and triggering the colour-sorting procedures (i.e., on-field, intermediate storage and delivery). The inventory overview of the LMIS will also be verified parallel to this process. In order to detect, manage and/or record any unforeseen technical issues, a programmer and equipment mechanic will oversee both operations.

A major milestone for the R&D-project will be accomplished when > 99 % of the bales are managed in the following sequential way: (1) a correct attachment of RFID-filament on bale, (2) a correct read by the external antenna, (3) a correct transmission of data-points to the LMIS and (4) a correct sorting procedure transmitted back. The inventory overview created in the LMIS will not be defined as a milestone here, as it is proven beforehand in D.2.2. and D.2.3. Applicability in an operational environment will also be assessed and evaluated in collaboration with the supplier panel.

Table 3: framework for deliverables and activities in second part of R&D-project

Validation in a simulated operational environment		
Deliverable 3.1. (installation procedure)		
List of activities:		**Duration:**
Activity 1.9.	**Installation procedure of RFID-system:** Defining installation of RFID-system (validated in D.2.2. and D.2.3) into balers and tractors used in D.3.2.	4 months
Activity 1.10	**Documentation of installation procedure:** Documentation of installation procedure for centralized or de-centralized communication.	3 months
Output:	1 report on installation procedure of RFID-system.	
	1 video on installation procedure of RFID-system.	
Potential bottlenecks:	Difficulties in conducting a direct installation of RFID-binding material into balers supply roll.	
Relevant stakeholders:	Hesston, Harvest Tec	
Deliverable 3.2. (operational test)		
List of activities:		**Duration:**
Activity 1.4.	**Test preparation:** Defining operational set-up and testing procedure. Installing RFID-system into balers and tractors. Procuring straw for simulated baling operation.	3 months
Activity 1.5.	**Operational test for validated concept:** Final test-preparation and execution of operational test: i.e., identification and bale management in a simulated supply chain. Validated under TRL5 if > 99 % of produced bales are identified and managed successfully.	2 months
Output:	Operational validation of technological concept (major milestone).	
	1 report on test preparation.	
	1 report on test results.	
	1 report on applicability in a operational environment	
Potential bottleneck:	Poor readability of RFID-filament/bale by external antenna due to interference from other technical components installed in baler and/or loader	
Relevant stakeholders:	Straw supply panel defined in D.1.3.	

1. Conclusion

The technological concept is essentially a digital spin-off from the Bale Link System developed by Hesston for the North American hay sector. The key difference is the services provided by the conceptual LMIS; i.e., automated bale sorting procedures and automated inventory overview of categorized bales on field, intermediate storages and upon delivery.

The innovation program (IP) is divided into two sub-projects. (1) A seed-money project for preliminary research on the operational environment (i.e., sensory data mapping and bale binding procedures) and the establishment of a straw supplier panel to validate the basic concept. (2) A R&D-project for the validation of the basic concept in a simulated operational environment (TRL3/4 – 5). Duration of the IP is expected to be 4 years with an estimated budget of 0,4 – 0,5 mio. € (public funding).

The main success factor for the IP will be to develop a stable performance of the technological concept throughout a simulated supply chain; i.e., bale identification, intermediary bale management and inventory overview. The operational test will be planned and executed in collaboration with the supplier panel in an iterative process. The R&D-project can be viewed as an incremental innovation focusing on cloud-based bale identification and automated supply chain management. Bottlenecks in the program are primarily expected to be related to the accessibility and compatibility of the components constituting the system, the physical bale identification and the operational settings. Main potential bottlenecks are as follows:

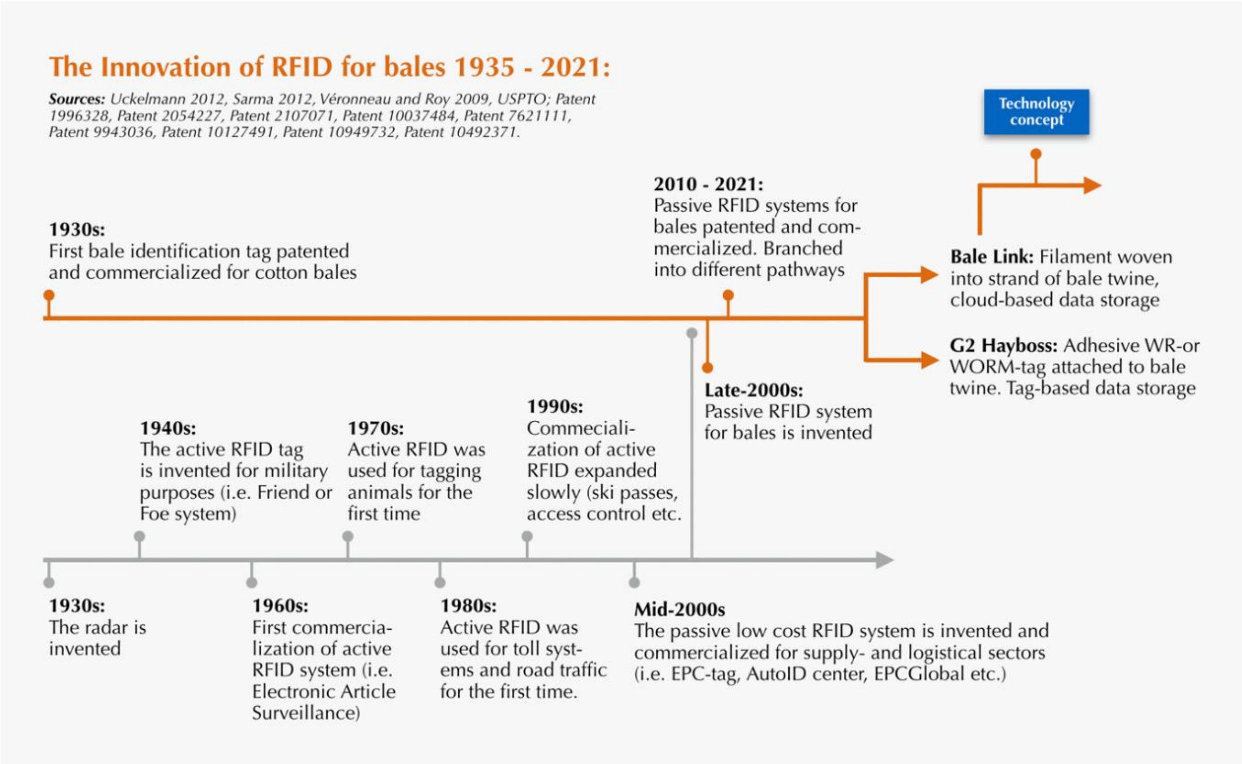
- **(D.2.1)** No access to RFID-filament as a stand-alone component for the system concept as it is a proprietary component by AGCO.
- **(D.2.3)** Poor readability of RFID-filament/bale by external antenna due to high bale moisture content and/or read-angle of filament bale position to antenna.
- **(D.3.1)** Difficulties in establishing a simple and direct installation procedure for RFID-filament/binding material into baler.
- **(D.3.2.)** Poor readability of RFID-filament/bale by external antenna, due to interference from other technical components in baler or loader.

The potential bottlenecks will be investigated further in D.1.2. and D.2.1. and, if relevant, expected to be mitigated through an iterative trial-and-error process in D.2.3. and D.3.2.

ANNEX 1

Patent nr.	Brief description of invention.	Filed	Approved
Note:	*Minor changes have been made to the descriptions below. The full descriptions can be found on USPTO. The assignee of the invention is marked with bold in the beginning of the description.*		
7,621,111	**Jeffrey Roberts (Harvest tec):** Continuation of patent no. 7415924 B2. The method and system that has been invented allows for individual bales to be marked with identification tags as they are baled. At the time of marking, information pertaining to that bale is recorded and associated with the identification tag, including but not limited to bale moisture, bale weight, hay preservative applied, field position, and hay quality. The placement of the tag and coordination of information gathered from various inputs is accomplished by specific sequencing of signals inputted to a microprocessor and recorded to memory, based on the position of the system's components on a hay baler. Two embodiements has been proposed; (1) a method and system that has been invented mounts on a hay baler 1-1 and employs a device that tags bales 1-2 with an identification tag such as a radio frequency identification device (rfid) as the bale is formed. One such tagging device is a star wheel 1-3 rotating on the outside surface of the formed bale. This wheel can be both a timing device used for sequencing the marking of bales and recording information about, and part of an inserting device for placing identification tags used to identify each bale. When this method of tagging the bale is used the rfid tag 1-6 is made of an edible material so that it does not have to be removed before the bale is fed to livestock. (2) Alternatively, the tag dispenser can work in conjunction with a twine-tagging device 1-12 to affix the tag around or under the bale twine, located adjacent to the timing star wheel 1-3. In this embodiment, the device 1-12 affixes an rfid tag around or under the twine of the bale when the dispenser 1-7 receives the signal from the microprocessor.	2006, 2008	2009
9,943,036	**New Holland (based on patent 7415924 B2):** In a first aspect, the present invention relates to a tagger assembly of an agricultural baler. Embodiments of the present invention can be used for applying a label, for example an adhesive label, such as e.g. a radiofrequency identification (*RFID*) tag with adhesive back coating, around a moving lineal object, for example wire, cord, ribbon, rope, banding or twine, used for packing a bale of agricultural crop material, such as hay, straw, silage, cotton or other biomass.	2012	2018
10,037,484	**New Holland:** Three embodiments/innovations describing how a stake including an *RFID* tag may be inserted into a *bale for identification* purposes and, in at least one embodiment, to store the harvesting data of the agricultural product in the bale locally on the *RFID* tag.	2015	2018
10,127,491	**AGCO Corporation:** The baler is provided with binding material comprising identification tags at spaced intervals along the binding material. The formed bale is bound with the binding material using a knotter system on the baler to obtain a completed bale. The identification tag in the completed bale is identified with the read module and the sensed parameters are associated with the identification tag on the completed bale to obtain an identified bale.	2018	2018
10,276,015	**DEERE & COMPANY:** A RFID-based system for monitoring, communicating and storing properties of organic material in the absence of air in a bale wrapped with film (or without film). **Note:** The innovation is understood as only referring to round bales due to the visualization of the innovation, but it is not clear. For further information go to USPTO.	2016	2019
10,303,997	**AGCO Corporation:** The *bale identification* assembly has a bale drop sensor with a paddle. As a completed bale passes through the discharge chute, the completed bale interacts with the paddle causing the bale drop sensor to activate. Activation of the bale drop sensor activates the antenna for a specified active cycle, and during its active cycle, the read module assigns any identification tag that is sensed to the completed bale that is leaving the discharge chute. A controller receives information from at least one crop sensor and/or bale sensor and associates the information about the completed *bale with the identification* tag on the completed bale.	2018	2019
10,492,371	**AGCO Corporation:** A *bale identification* assembly for use with an agricultural baler having a first supply roll mounted on the baler providing a binding material used by the knotter system to bind the formed bale, wherein the binding material on the first supply roll is free of identification tags. The *bale identification* assembly includes a second supply roll mounted on the baler providing an identifying filament. The knotter system joins the identifying filament from the second supply roll with the binding material from the first supply roll while tying a knot to bind the formed bale.	2018	2019
10,657,433	**AGCO Corporation:** Continuation of patent no. 10,303,997	2019	2020
10,949,732	**AGCO Corporation:** The *bale identification* assembly includes a controller configured to receive signals from the bale length sensor and the position sensor and to generate a signal to alter the length of the bale by causing an additional flake to be added to the bale by the plunger or the bale to be finished with fewer flakes to prevent the knotter system from tying a knot in the binding material such that the identification tag is positioned in a portion of the binding material used to form the knot.	2018	2021

ANNEX 2



The Innovation of RFID for bales 1935 - 2021:
Sources: Uckelmann 2012, Sarma 2012, Véronneau and Roy 2009, USPTO; Patent 1996328, Patent 2054227, Patent 2107071, Patent 10037484, Patent 7621111, Patent 9943036, Patent 10127491, Patent 10949732, Patent 10492371.
Technology concept
1930s: First bale identification tag patented and commercialized for cotton bales
2010 - 2021: Passive RFID systems for bales patented and commercialized. Branched into different pathways
Bale Link: Filament woven into strand of bale twine, cloud-based data storage
G2 Hayboss: Adhesive WR-or WORM-tag attached to bale twine. Tag-based data storage
Late-2000s: Passive RFID system for bales is invented
1940s: The active RFID tag is invented for military purposes (i.e. Friend or Foe system)
1970s: Active RFID was used for tagging animals for the first time
1990s: Commecialization of active RFID expanded slowly (ski passes, access control etc.
1930s: The radar is invented
1960s: First commercialization of active RFID system (i.e. Electronic Article Surveillance)
1980s: Active RFID was used for toll systems and road traffic for the first time.
Mid-2000s The passive low cost RFID system is invented and commercialized for supply- and logistical sectors (i.e. EPC-tag, AutoID center, EPCGlobal etc.)

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- Uckelmann, D. (2012). *Quantifying the Value of RFID and the EPCglobal Architecture Framework in Logistics.* Springer-Verlag Berlin Heidelberg
- Sarma, S. (2012): *How Inexpensive RFID Is Revolutionizing the Supply Chain.* Innovations / Volume 7, Number 3.
- Penttilä, K. (1) Suokannas, A. (2) and Pölönen, I. (3) (2019). *Verification of RFID System Usability in Silage Bale Life Cycle Management.* 1. Energy Efficiency Research Group, HAMK Tech Research Unit, Häme University of Applied Sciences, Lotilantie 16, 37630 Valkeakoski, Finland. 2. Production Systems, Natural Resources Institute Finland, Maarintie 6, 02150 Espoo, Finland. 3. Bioeconomy Research Unit, Häme University of Applied Sciences, PL 230, 13101 Hämeenlinna, Finland

ENERGETIC USE OF PALUDI BIOMASS IN MECKLENBURG-VORPOMMERN

Innovation Programme: Energetic Use of Paludi Biomass in Mecklenburg-Vorpommern (MV)

Introduction

Wet peatlands are among the most important carbon reservoirs on earth. When drained, however, peatlands emit enormous amounts of greenhouse gases, especially carbon dioxide[1]. In Mecklenburg-Vorpommern, emissions from drained peatlands account for about 30% of total greenhouse gas emissions[2]. Efforts are therefore being made to restore as many of these areas as possible to their original condition. Various moisture-loving plants can grow in this wet biotope, whose biomass can be harvested and used economically (principle of paludiculture).

Due to their low feed value and reduced resistance to treading, peatlands are used mainly as grazing areas in exceptional cases, e.g. for water buffalos[3]. While dominant populations of reeds and cattail can be used as building and insulation materials, heterogeneous populations are suitable for energy production. Appropriate plants that produce large quantities of biomass per year are reed (*Phragmites australis*), reed-grass (*Phalaris arundinacea*), cattail (*Typha spec.)* and sedges (*Carex spec*.). Direct combustion, similar to straw and miscanthus, seems to be more promising than its alternatives, such as fermentation in a biogas plant or fuel production concerning practical technology, energy yield, and profitability[4].

The thermal utilization of biomass from rewetted peatland sites can contribute to the provision of essential services in rural areas and offer a wide range of opportunities for regional development. The innovative use of Paludi biomass in a biomass heating plant makes it possible to keep land in permanent use and establish regional value chains based on biomass. The energy supply can thus be mostly independent of developments on the world market and at long-term stable prices. This not only opens up perspectives for rural areas but can also make an important contribution to achieving climate protection goals[5].

The main concept, then, is to replace classical fossil-based heating systems with thermal power plants that use biomass from paludiculture (see Fig. 1).

[1] Deutsche Welle (2017): Peatlands: Neglected piece of the climate puzzle (https://www.dw.com/en/peatlands-neglected-piece-of-the-climate-puzzle/a-41890864)
[2] Hirschelmann, S. et al., (2019): Moore in Mecklenburg-Vorpommern im Kontext nationaler und internationaler Klimaschutzziele -Zustand und Entwicklungspotenzial; Faktensammlung Greifswald Moorzentrum, page 16
[3] Müller, J. & Sweers, W. (2014): Sumpfpflanzen als Futter? In: Paludikultur – Bewirtschaftung nasser Moore: Klimaschutz, Biodiversität, regionale Wertschöpfung. Wendelin Wichtmann, Christian Schröder, Hans Joosten (Hrsg.). Schweizerbart Verlag.
[4] Wichmann, S. et al. (2014?): Heizen mit Schilf – Bereitstellung von Biomasse aus Niedermooren
[5] Schröder, C., Nordt, A., Bork, L. (2016): Klimagerechte regionale Energieversorgung durch Paludikultur in Vorpommern-Rügen; BMEL Modellvorhaben Land(auf)Schwung

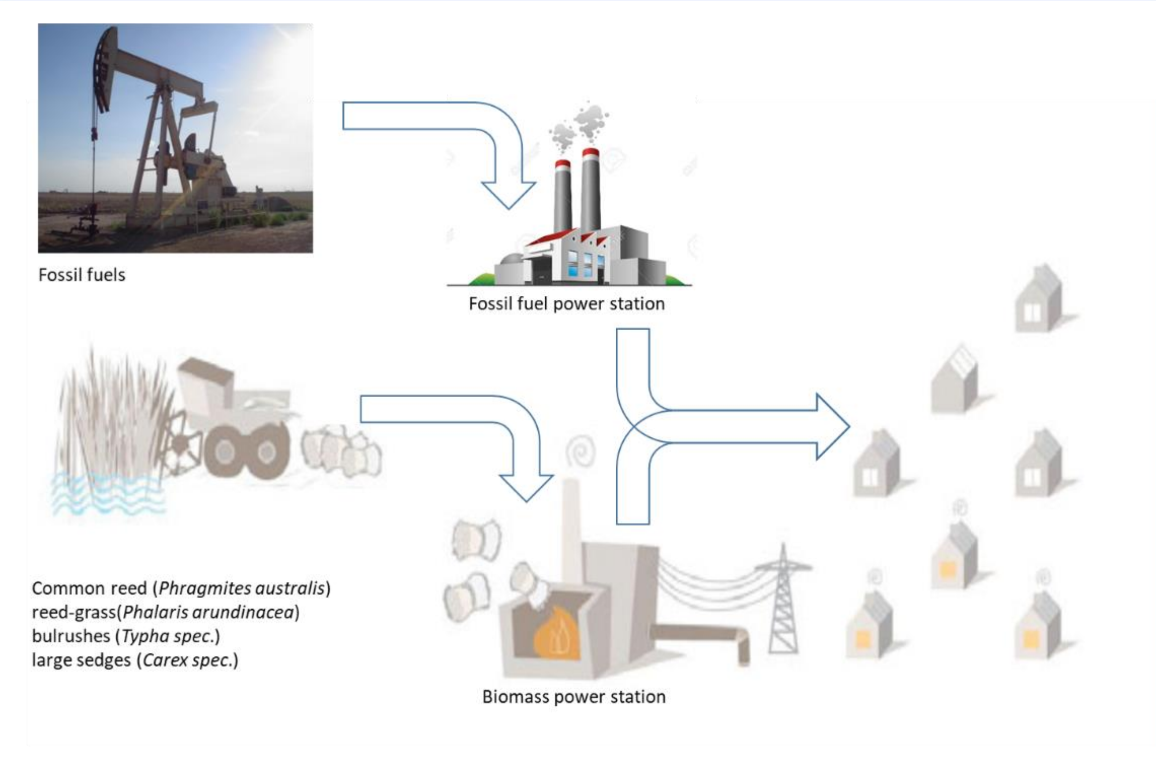

Fig 1: Value chain of energy production from fossil fuels and based from Paludi biomass[6]

Regional Innovation Efforts Today

Even today, a large portion of the energy supply is still provided by fossil fuels. In addition to the classic energy supply, MV already has some thermal power plants that utilize renewable raw materials in the form of straw[7]:

- Straw heating plant Gülzow/ M-V (1,000 kW), operator: Landgesellschaft MV
- Straw heating plant Gut Demmin/ M-V (600 kW), operator: agricultural business
- Straw heating plant Schwasdorf/ M-V (600 kW), operator: agricultural business

So far, the combustion of hay from wet meadows for municipal heat supply has only been successfully established in the Malchin heating plant Agrotherm in the neighboring district of Mecklenburgische Seenplatte[8]. In this plant, the technology of a straw heating plant was adapted for Paludi biomass. The capacity of the boiler was specifically chosen so that fuel needs could be met by local biomass suppliers without need to purchase in additional hay. The plant can be run additionally on wood chips via a side entrance if it is necessary to supplement the hay if once too little hay is available (e.g. the areas cannot be mowed because of too high water level).

The Agrotherm plant is already at TRL 9[9]. So, there is only a limited need for technological innovation. The implementation of the new concept was realized with financial funding (project money from the German Federal Environmental Foundation) and knowledge support (University of Greifswald). The plant went online in 2014 with Paludi biomass and is now running successfully for more than 6 years. If the development goes according to plan, the investment costs will be charged after 15 years. The

[6] Modified after Wichtman, W. et al. (2014): Think rural! Think paludicultural! F. Dünkel et al. (Hrsg.), Think Rural!, DOI 10.1007/978-3-658-03931-8_19,© Springer Fachmedien Wiesbaden
[7] Busse, S. et al. (2019) VoCo – Vorpommern Connect Meilensteinbericht 1, page 14
[8] BioBIGG (2019): Development of a common framework for a sustainable and circular bioeconomy
[9] Technology Readiness Level 9

economic viability of the plant is given, because the biomass can be purchased at a low price due to cooperation with the producer, Moorhof GmbH and transport cost are low due to close proximity (12 km). Additionally, the price for the heat produced could be negotiated with Energicos GmbH that is at a similar level to the price of natural gas[10].

Until now no other company has adopted the concept. Urgent innovation is therefore needed to make the concept more attractive to investors.

Innovation Roadmap

Current Situation

MV is the most sparsely populated federal state in Germany, with about 70 inhabitants per square kilometer. The state in the northeast was the first to be able to cover its electricity consumption entirely from renewable sources (gross electricity consumption), with renewables accounting for 37% of total primary energy consumption[11]. It is essential to increase this proportion in the coming years to reach the Paris agreement[12].

Municipal heating networks in the eastern federal states have usually undergone reconstruction or renewal of the heat supply systems from 1990 to 2000. The next renewal is expected in the next 5 to 10 years. This offers a "historical window" in municipal heating networks to take significant steps towards more climate neutrality of the heat supply to households on a broad scale through conversion and expansion[13].

Vision

A major step towards emission-free energy supply in the region of Vorpommern would be to replace all fossil energy sources with renewable raw materials on a large scale and, besides, to use new biomass that is produced by climate-friendly peatland use, based on the model of the energy plant in Malchin[14]. This can be achieved by adapting that concept to a location in Vorpommern. The long-term goal is to solely use renewable energies, including biomass from wetlands.

Roadmap Elements / Action fields

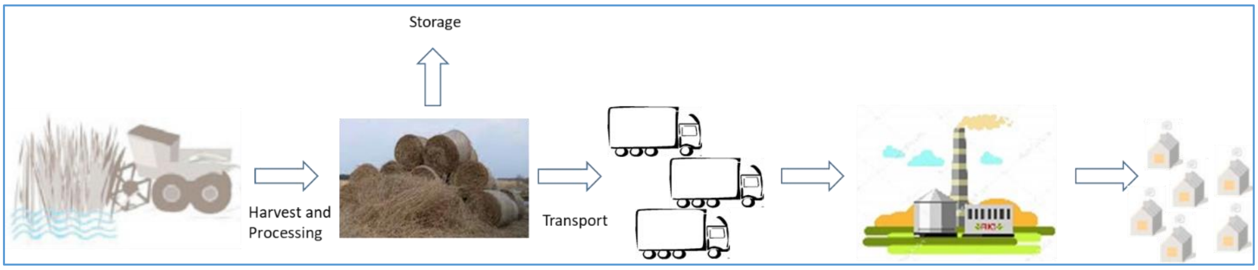

Fig.2: Value chain of energy production from Paludi biomass

[10] BioBIGG (2018: Development of a common framework for a sustainable bioeconomy, page 70-74
[11] https://www.foederal-erneuerbar.de/landesinfo/bundesland/MV/kategorie/top%2010/auswahl/289-anteil_erneuerbarer_
[12] The Paris Agreement is the first-ever universal, legally binding global climate change agreement, adopted at the Paris climate conference (COP21) in December 2015.
[13] Busse, S. et al. (2019) VoCo – Vorpommern Connect Meilensteinbericht 1, page 44
[14] BioBIGG (2019): Development of a common framework for a sustainable and circular bioeconomy

The principle of the value chain is to cultivate humidity tolerant plants (profitable growth on peatlands), harvest the biomass, and transport it to an energy power plant, which can convert the biomass into energy and distribute it to households as the end consumer (see Fig. 2). The concept has already been realized in the Agrotherm company in Malchin[15], and the technology readiness level is the highest one (TRL 9). The economic energetic use of Paludi biomass is proven, but no further companies are imitating the concept. The main reasons are the lack of suitable wet areas (most of the peatlands are drained), the lack of local heating spots, and the non-competitive price of fossil-based energy. Currently, central heating with fossil fuels is cheaper, and the biobased alternative with regional energy supply in small biomass heating power stations is not at all a financial alternative. Establishing the concept of Agrotherm to another region to economically use paludiculture biomass for energetic use needs innovative ideas, such as

- Rewetting of peatlands (suitable areas)
- Biomass heating power plants converted to use Paludi biomass
- Establishment of a regional energy supply system (e.g. also energy-neutral villages)
- Introduction of a remuneration system for ecosystem services
- sensitization of the public

Implementing the new concept of energy supply with biomass from peatlands needs a stepwise evaluation along a roadmap: The preconditions must be checked to see whether the concept is in principle feasible or if some features make it difficult or impossible to realize the plan. Depending on the humidity of the area and the current use, one of the first activities is the preparation of the soil to transfer the area into a peatland and cultivate moisture loving plants as basic material for the heat generation.

The most critical step is the calculation of the price for the end consumer, which should be in the same order of magnitude as the current price. This price is mainly dependent on remuneration systems for ecosystem services, the agreements with the involved actors, investigations on rewetting and planting as well as in the technology adaption. In this respect, the steps of planning (preconditions) and implementation (activities) should always be interactive and reflective.

[15] See also BioBIGG (2020): Business case model: Regional energy supply through thermal utilisation of paludiculture biomass in the district of Vorpommern-Rügen

Tab.1: Roadmap

		short term (up to 2021)	mid term (up to 2022)	long term (up to 2025)
preconditions	location			
	acceptance			
	heating networks			
	legal framework			
activities	agreements with the involved acteurs			
	changing the area use (rewetting, planting)			
	calculation of heat and biomass demand			
	network adaption			
	technology adaption			

For conversion of municipal heat production from fossil to renewable energy in the form of Paludi biomass, the following roadmap elements must be observed (Tab.1):

Location

A suitable area is either a peatland or a drained peatland, which in the first step, needs to be rewetted, in order for paludiculture to be cultivated. The soil must be able to produce enough biomass for energy to the heating network. This can be done either regularly or at specific periods of the year. In the latter case, the possibility of interim biomass storage (either in the field or at the heat suppliers) must be given.

The cultivation of Paludi biomass also has to be close to the heat supplier and the heating network to minimize transportation costs.

Acceptance of the affected people

The realization of a Paludi biomass heating plant is dependent on the willingness of the actors (landowners, farmers, heat suppliers, inhabitants in the surrounding) to change their running system and their behavior, as well as of the persuasive power of the bioeconomy stakeholders.

In contrast to fossil fuels, the investment and operating costs of a biomass heating plant are higher[16]. To persuade actors to shift towards Paludi bioenergy, valid and convincing solutions must be found to maintain economic profitability.

Beneficial arguments for the transformation to Paludi biomass are securities. These include not only long-term supply contracts but also financial guarantees for farmers and heat suppliers. Not to forget the inhabitants living in the surrounding area, who have to adapt to changing environmental conditions, increased traffic due to the transportation of the biomass, and possibly changing working conditions for the employees.

Connection to heating networks

To initialize paludiculture heating plants, heating networks are needed to distribute heat to the households. In the best case, there is already an existing local network with a power plant of appropriate size so that costs for their establishment are then eliminated.

The connection of biomass heating plants to existing heating networks is beneficial as already established end user guarantee a regular consumption of the thermal energy. Additionally, the costs connected with establishing a new network, are removed.

Favorable time slots arise when the heat supply systems require renovation. If this is the case, the company owner must invest in new technology anyway. He needs a special boiler and adapt it according to the Paludi-biomass-concept (see below: "technology adaption"). A conversion of the technology to a new system is then much cheaper, because only the additional costs of the special boiler need to be invested on top.

Many large-scale plants in heating networks as well as private heating plants were modernized in the years after 1990 in Eastern Germany. So the next renovation can be expected in the next 5 to 15 years[17]. It would be a good opportunity if many companies would then take the chance to convert their technology to the described sustainable biomass utilization concept.

Legal framework

All laws concerning nature protection, water rights and the cultivation of biomass must be examined for the investigated area.

Some laws make it difficult or at least require a bureaucratic effort to harvest the biomass. For example, peat sites are often legally protected habitats and there are permit reservations by nature conservation authorities. A further example is the cultivation of reed: Reed is under nature conservation in Germany. Its mowing can lead to damage or change of the characteristic condition of the biotope and needs the evaluation and permission of the nature conservation authority in each individual case.

Beneath legal obstacles there are other framework conditions that facilitate the financial challenge of the new concept.

Farmers and heat suppliers can usually be seen as entrepreneurs who might be convinced to change their system if they are be offered an adequate income (at least comparable to the previous one) and planning security. Because the costs of a biomass heating plant are higher than its fossil alternative, optional possibilities to generate this income must be identified. One instrument is funding opportunities in the form of ecosystem services that contribute to sustainability and emission reduction.

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[16] Schröder, C., Nordt, A., Bork, L. (2016): Entwicklung einer klimagerechten regionalen Energieversorgung durch Paludikultur am Beispiel des Landkreises Vorpommern-Rügen; BMEL Modellvorhaben Land(auf)schwung
[17] Busse, S. et al. (2019) VoCo – Vorpommern Connect Meilensteinbericht 1, page 10

To provide incentives for the implementation of the new form of land use and renewable energy source, the legal framework must be adapted.

So far, there are only a few possibilities for financial support of the innovative bioenergy supply:

- Rewetting of drained peatland (if it is necessary)
- 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[18].
- relevant version of the Renewable Energy Sources Act (EEG)
- relevant version of the cogeneration act (Kraft-Wärme-Kopplungsgesetz KWKG)

In Germany, the remuneration possibilities for biomass under the EEG are steadily declining and, especially for new plants, only partially profitable. Moreover, biomass plants are subject to a restrictive expansion path according to § 4 No. 4 EEG. In principle, electricity from paludiculture biomass is also entitled to additional payments under the KWKG, although these cannot be cumulated with EEG support[19].

Therefore, further incentives are necessary to increase enticement and later on also the competitiveness of the company[20]:

- Remuneration of the climate protection performance of the thermal utilization of biomass from wet peatlands

  The climate protection benefits of thermal utilization of paludiculture biomass result on the one hand from the reduction of emissions by raising the water levels on the production areas and on the other hand from the substitution of fossil fuels. A remuneration of these climate protection achievements does not take place so far. Incentives for emission reduction by rewetting and adaptation of land use should be set in the future by a climate protection area bonus. The climate protection performance of the thermal utilization of biomass should be rewarded by means of a subsidy related to the production facilities.

- Introduction of funding opportunities for heat generation plants: an increase in the energy and climate fund through a fund feed from taxes

- A regional certificate trading system for renewable heat can be suitable. Such a system is already in place within the European legal framework and can develop its potential, especially in regions with no district heating supply.

- Heat certificates[21]
  With the establishment of Paludi heat certificates, consumers can compensate for their local heat consumption, which they cannot cover themselves through renewable energy sources. The certificate could be sold directly by the heating plant operators to interested parties. A second possibility is to sell it indirectly via the heat suppliers utilizing a surcharge per kilowatt-hour used.

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[18] BioBIGG (2020) Business case – Rewetting and Afforestation of a Drained Peatland
[19] GMC + IKEM (2017): Impulspapier: Verwertung von Paludikultur-Biomasse; Rechtliche Handlungsempfehlungen für die energetische und stoffliche Verwertung von Paludikultur-Biomasse
[20] GMC + IKEM (2017): Impulspapier: Verwertung von Paludikultur-Biomasse; Rechtliche Handlungsempfehlungen für die energetische und stoffliche Verwertung von Paludikultur-Biomasse
[21] Hohlbein, M. (2020): ENERGIEBIOMASSE von nassem Moor-Grünland zur thermischen Verwertung

Planning Implementation

Agreements with the involved actors

After an early involvement of the actors (contacts, discussions, events, personal cooperation), agreements and contracts must be negotiated.

Changing the area use

As soon as all conditions for implementing the new system are given, the suitable area must be rewetted (if it is a drained one) and cultivated with suitable wet resistant plants.

Calculation of the heat and biomass supply and demand

Analysis of the
- theoretical biomass potential
- short-time available biomass potential[22]
- heat demand
- size of the plant

For the investigated region, the biomass potential must be evaluated to calculate, whether the available biomass can satisfy the demand to produce enough energy from the biomass all over the year (depending on the demand of local (regenerative) energy). The theoretical biomass potential refers to the amount of biomass that can be produced using all peatland areas. Those areas, which currently are not rewetted, need some time for rewetting and cultivation and therefore are not available in a short time. Other areas will be used for alternative purposes and are therefore not available for the energetic use of the plants growing on them (e.g. grazing land). Further limitations of the potential result from restrictions under the Nature Conservation Act. After deducting all areas that are not suitable for the energetic use of biomass, the potential that is available for heat supply in the region results.[23]

The short-time available biomass must be matched with the biomass which is required to supply the region with heat (heat demand). This demand is mainly known for investigated regions which already have a heating network.[24]

Municipal plants with a capacity of 800 to 1500 kW are ideal for thermal utilization of the growths of wet peatland sites. With this size, heat production costs can be achieved that are competitive with the heat production costs of gas heating plants. For this size, 500-2,000 t biomass are needed as fuel per year, depending on capacity utilization.[25] The calculations should be based on this specifications. If bigger areas should form a network, more than one heating plant should be planned and the available biomass potential should be adapted. In this case it should be evaluated, whether the individual companies should act regionally or whether they should be combined in sub-networks.

Adaption of the regional heating network

This step is dependent on the structure of the already existing network. Often, only a few adaptions are necessary (inclusion of more or fewer households as heat recipients). It is possible that, based on experience with the established network, there will be small changes over time, but these can be implemented without much effort.

Technology adaptation

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[23] See also BioBIGG (2020): Business case – Rewetting and Afforestation of a Drained Peatland
[24] See also BioBIGG (2020): Implementation Model - Renewable energy with paludiculture
[25] Schröder, C.; Nordt, A.; Bork, L. (2016) Entwicklung einer klimagerechten regionalen Energieversorgung durch Paludikultur am Beispiel des Landkreises Vorpommern-Rügen; BMEL Modellvorhaben Land(auf)Schwung

The technology of the heating plant Agrotherm has already been described[26]. This pilot plant acts as the basis for the wide-scale adaption of the firing technology. Basis are biomass heating plants with boilers that are able to burn hay-like materials. These boilers can already be purchased as there are serial models on the market[27]. Agrotherm adapted this technology for the use of Paludi biomass.

When the first Paludi biomass can be harvested (depending on the cultivated species) and brought to the heating plant, the new technique must be adapted and implemented in the company.

Stakeholders:

The following actors are needed to implement the concept of energetic use of Paludi biomass:

Research institutions

Universities, local institutions (Stiftung Umwelt und Natur, DUENE[28])

Employees in projects:

The Greifswalder peatland research groups are famous for their research, application-oriented projects, and prominent scientists, which influence the regional and trans-regional (Brussels) environmental development. They are up-to-date with new laws and incentives concerning paludiculture and regularly calculate emissions in drained and rewetted peatlands.

SMEs

Agrotherm

The company already has a running system and experience with Paludi biomass.

Experts for heating technology solutions should be involved in the planning of the technical reconstruction of the plant. Preferably they come from Agrotherm and have experience with the technology.

Local heating plants

As mentioned above, local heating networks are needed to distribute heat to households. They must be contacted and convinced to change their system. In contrast to fossil fuels, the investment and operating costs of a biomass heating plant are higher.

Farmers

Farmers are the actors who provide the biomass, which means they cultivate the plants, monitor its growth, harvest it, and transport it to the heating plant. They have to convert parts of their business system to paludiculture. They will only do so if they are convinced of the concept and see fruitful opportunities for a stable and, even better, growing income in the long term.

Decision makers

Ministry of Agriculture and Environment MV[29]

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[26] BioBIGG (2019): Development of a common framework for a sustainable and circular bioeconomy

[27] Meier, D. (2014): Wärme vom Niedermoor - Einzigartiges Heizwerk in Malchin nutzt Naßflächen-Mahd als Brennstoff; Energie aus Pflanzen 4, p. 34-37

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

[29] https://www.regierung-mv.de/Landesregierung/lm/

The Ministry in MV manages bog shares in MV. Together with the Greifswald research institutions, they look for relevant areas for rewetting, generate projects, and sell these shares.

Federal Ministry of Agriculture and Environment

The Federal Ministry influences amending the laws. They are essential for changing incentives into a more sustainable direction.

Underline of the Innovation Programme

Financing

In order to evaluate the economic viability of a company that will produce energy from Paludi biomass, the incurred costs have to be determined. This is the basis to calculate the future heating price.

Calculation of the price

- investment costs / refinancing
- personnel costs
- raw material (harvesting costs are determined by the investment costs in the technology, its capacity utilization, and the realizable clout[30])
- transport costs
- storage costs
- heat production costs
- arising quantities of ashes, as well as their removal
- Funding programmes
- Remuneration of ecosystem services

Results / Summary

To replace fossil energy with energy from Paludi biomass on a larger scale, the following innovations are necessary which have to be re-evaluated for every new Paludi biomass heat and power plant:

- Adaption of the heating network (regional energy supply)
- Provision of biomass, which always guarantees sufficient energy supply in quantity and quality
- Biomass transport logistics
- cost-effective technical conversion of already existing biomass combined heat and power plants analogous to Agrotherm

It is already shown that the concept of using Paludi biomass for energetic use is feasible and can be realized. The following preconditions needs to be given in order for a successful economic implementation to take place:

- Interest in heat production from paludiculture (actors must be involved and convinced)
- Close and proficient cooperation between agriculture, municipalities, and heating plant operators
- Old investment portfolio shows a "window of opportunity"
- Examination of the existing heat demand now and in the future
- existing heating network

[30] Dahms, T. et al., (2017) Paludi-Pellets-Broschüre: Halmgutartige Festbrennstoffe aus nassen Mooren. Universität Greifswald, Greifswald.

- Sufficient biomass is available or
- Sufficient potential areas within a radius of 10-20 km can be used for cultivation of Paludi biomass

In contrast to fossil fuels, the investment and operating costs of a biomass heating plant are higher. The competitiveness of stalk-based biomass heating plants is, therefore, difficult to achieve with low gas prices. Alternatively, existing and future subsidies need to be used to the fullest extent.

Forestry and biomass-related sectors

MATERIAL USE OF ALNUS GLUTINOSA FROM PALUDICULTURE AS CONSTRUCTION MATERIAL IN MECKLENBURG VORPOMMERN

COLOURBOX44507557

Innovation Programme: Material use of *Alnus glutinosa* from Paludiculture as Construction Material in Mecklenburg Vorpommern (MV)

Introduction

In Mecklenburg-Vorpommern (MV), the alder (*Alnus glutinosa*) grows on an area of around 40,000 hectares, which accounts for 7% of the forest area[1]. Its wide distribution is due to the many wet habitats (1/4 of the total forest area) to which the alders are well adapted.

The majority of the alder forests are in private ownership. The owners are interested in reforestation and economically use of the wood. However, wet forest locations pose a particular challenge to forestry operations with regard to profitable management[2].

The reasons for this are obvious: soils sensitive to traffic cause comparatively higher costs for timber harvesting, but also for the establishment and maintenance of the stand. In addition, the range of possible tree species is significantly limited due to the location, deciduous and softwood species dominate, the stands are often poorly maintained and industrial wood assortments predominate, resulting in comparatively low average timber revenues. Finally, these areas are often particularly valuable and therefore sensitive sites from a nature conservation point of view. Often there are legally protected habitats or species with different protection statuses and often there are approval requirements by nature conservation authorities, which in many cases results in a great deal of bureaucratic coordination work when implementing management measures.

In order to manage these forest sites, which from a forestry point of view are "problematic", it is useful to separate strategic and operational considerations[3] to evaluate the economic use of wood from these sites.

Technology readiness level

- Technology validated in relevant environment
- **Technology demonstrated in relevant environment**
- System prototype in operational environment
- System complete and qualified
- System operational

The cultivation of alders is sufficiently proven. The next step will be to show that the maintenance of the *Alnus* forest on this wet area can be upgraded from TRL 5 (Alnus trees can grow on rewetted peatlands and timber can be harvested with special technology) to TRL 6 (use of the special technology as well as the implementation of all steps of the value chain in the area in Brudersdorf).

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[1] RÖHE, P.; SCHRÖDER, J. (2010): Grundlagen und Empfehlungen für eine nachhaltige Bewirtschaftung der Roterle in Mecklenburg-Vorpommern. Waldbesitzerverband für Mecklenburg-Vorpommern e.V.,
[2] AFZ Der Wald: KWF-Thementage vom 1./2. Oktober 2013 (2013): Umweltgerechte Bewirtschaftung nasser Waldstandorte; Allgemeine Forstzeitschrift für Waldwirtschaft und Umweltvorsorge, page 20
[3] AFZ Der Wald: KWF-Thementage vom 1./2. Oktober 2013 (2013): Umweltgerechte Bewirtschaftung nasser Waldstandorte; Allgemeine Forstzeitschrift für Waldwirtschaft und Umweltvorsorge, page 20-22

Innovation Roadmap

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-Vorpommern (MV)". Some of the data used in the study are results of the ALNUS project "Renaturierung von Niedermooren durch Schwarzerlenbestockung" ("Renaturation of fen by black alder stocking").

Alder forests on rewetted peatlands are regarded as valuable habitats for species and biotope conservation. The positive effects of alder forests for the protection of nature and climate is comprehensively documented[4]. If the relevant laws are observed, there is no reason not to market the wood produced and thus combine the positive effects to the environment with economic aspects. The wood marketing from wet alder forests is recommended as an environmentally friendly form of land use. The formation of new forests by alder cultivation after rewetting on suitable sites is a recommendation that has meanwhile been incorporated into the revised peat protection concept for Mecklenburg-Vorpommern [5].
There are two possibilities to increase the economic use of Alnus timber on wet or rewetted areas in MV:

- Afforestation of new rewetted peatlands with alder
- Increasing the economic use of timber in already existing wet alder forests
  Already 53% of the alder trees are growing on marshy or wet fens in MV[6]. This means that 21.200 ha of wet area is covered with *Alnus* and can be used for sustainable timber production.

In this study we focus on the use of timber from the already existing wet forest areas.

In MV the site conditions for high forest management are generally favorable with valuable wood production. Over two thirds of the alder stocks are concentrated in productive wet locations. In order to increase the yield of wood (especially high-quality wood) and make it economically attractive, a good forest management is very important: In the context of young growth management, poorly formed individuals are first removed from the stand, which are pressing good alders. In the further course of the young growth care, a limited number of the best trunks are then selected which should grow into valuable wood. These trees must be specifically promoted by removing the closest neighbouring trees.

If the care management is performed in this way within the production period, annual volume increases of at least 8 m³ per hectare on average are expected[7]. Without care management, 348 m³ wood can be expected in 60 years per hectare, so the annual increase is 5,8 m³. So the optimal growth potential is far from being used for value-oriented trunk wood production currently.

[4] Ministry of Agriculture, Environment and Consumer Protection MV (2009): Konzept zum Schutz und zur Nutzung der Moore; Fortschreibung des Konzeptes zur Bestandssicherung und zur Entwicklung der Moore
[5] Ministry of Agriculture, Environment and Consumer Protection MV: (2009) Konzept zum Schutz und zur Nutzung der Moore: Fortschreibung des Konzeptes zur Bestandssicherung und zur Entwicklung der Moore
[6] Ministry of Agriculture, Environment and Consumer Protection MV (2012): Grundlagen und Empfehlungen für eine nachhaltige Bewirtschaftung der Roterle in Mecklenburg-Vorppommern
[7] Röhe, P., Schröder, J. (2010): Grundlagen und Empfehlungen für eine nachhaltige Bewirtschaftung der Roterle in Mecklenburg-Vorpommern, page 3

Thus, in the national forest, despite an overhang of older stocks, still about 90 % of the wood is industrial wood assortments. Even of the small proportion of trunk wood sold, only 3% belong to quality class "A" and is therefore valuable wood.

Vision

The aim of this report is to define and evaluate the optimal financial feasibility of a high-quality timber production in a special wet environment with commercial available technologies. Is it possible to use those wet peatlands in MV, which are already vegetated with *Alnus glutinosa,* in an economic way to evaluate, if the use of alder wood from peatlands can be raised in principle from TRL 5 to TRL 6?

On the basis of the data collected, considerations on the use of new peatlands for wood cultivation can follow at a later date to not only maintain the share of the alder area in the region in the long term, but to further expand suitable sites where possible.

Roadmap Elements / Action fields

The economic use of *Alnus glutinosa* from paludiculture includes two established economic sectors:

- Forestry: Classic forest management
- Agriculture: Economic use of peatlands

Thus the combination of both sectors, which is necessary in a wet environment, is the challenge and needs innovative solutions.

Classical forestry has been established for centuries. Although it has undergone changes over time due to new technologies, the care and harvesting of trees generally follows certain standards, depending on the region (different climate and soil conditions) and the composition of the forest stock. On the other hand we have the precondition “wet land”. The economic use of peatlands is also possible and is described in many publications. But especially the afforestation of these areas with trees, that tolerate marshy soils, is not established very well. So there are a lot of aspects, which will differ from the classical forest management and need adapted solutions.

The elements of the roadmap are illustrated in Tab. 1 and explained in more detail in the following chapter. The objective of the roadmap is to show the innovation strategy along a time line for a successful implementation of a business concept for the economic use of high quality timber from peatlands. The topics to be identified are those which on the one hand harmonise with this business model and on the other hand should be a key to successfully market the wood.

Tab. 1: Roadmap for use of *Alnus* biomass from paludiculture

		short term (up to 2021)	**mid term (up to 2030)**	**long term (up to 2080)**
	forest management			
Inventory	clarification of the ownership structure			
	condition of the test area			
	classification of the wood			
Legal Framework	legal requirements			
	funding programmes			
Strategic considerations	simulation models			
Operational considerations	technology			
	working method			
	amount of wood harvested			
	Sustainability			
Activities	recruitment of staff			
	agreements with the involved industry			
	forest care			
	harvesting and selling wood			

Considerations on strategies to manage forest care

Because tree growth is a long-lasting process, there is need for a short- as well as a long term strategy.

Active Forest Management:

Good wood properties are a precondition for a wide range of applications and correspondingly attractive remuneration. The sales and revenue opportunities are not only determined by positive technological properties. Equally important is continuity in the supply of high-quality timber. In order to be able to guarantee this, it is necessary to consistently care for the forest on the basis of guidelines. Alder management will only be economically profitable for forest owners in the future if it is possible to continuously achieve the production targets in terms of quantity and quality.

So the forest management has to be done permanently. It includes culture and young growth care, forest protection, stand treatment, wood harvesting and wood preservation.

The first year of forest management is the most time-consuming year in which an inventory on the preconditions of the investigated area should be made. Beneath preliminary considerations also strategic and operational procedures need to be clarified. The most critical point is the evaluation of the passability of the land for the machines: The more special technology is needed for care and harvesting, the more expenses occur and the lower the net income will be.

Inventory

Each selected business case has some given preconditions and regulations which cannot be changed, but which must be taken into consideration.

Paludí areas which are considered for wood utilisation can be in private hand (forest owners), belong to regional foundations or are in public ownership.

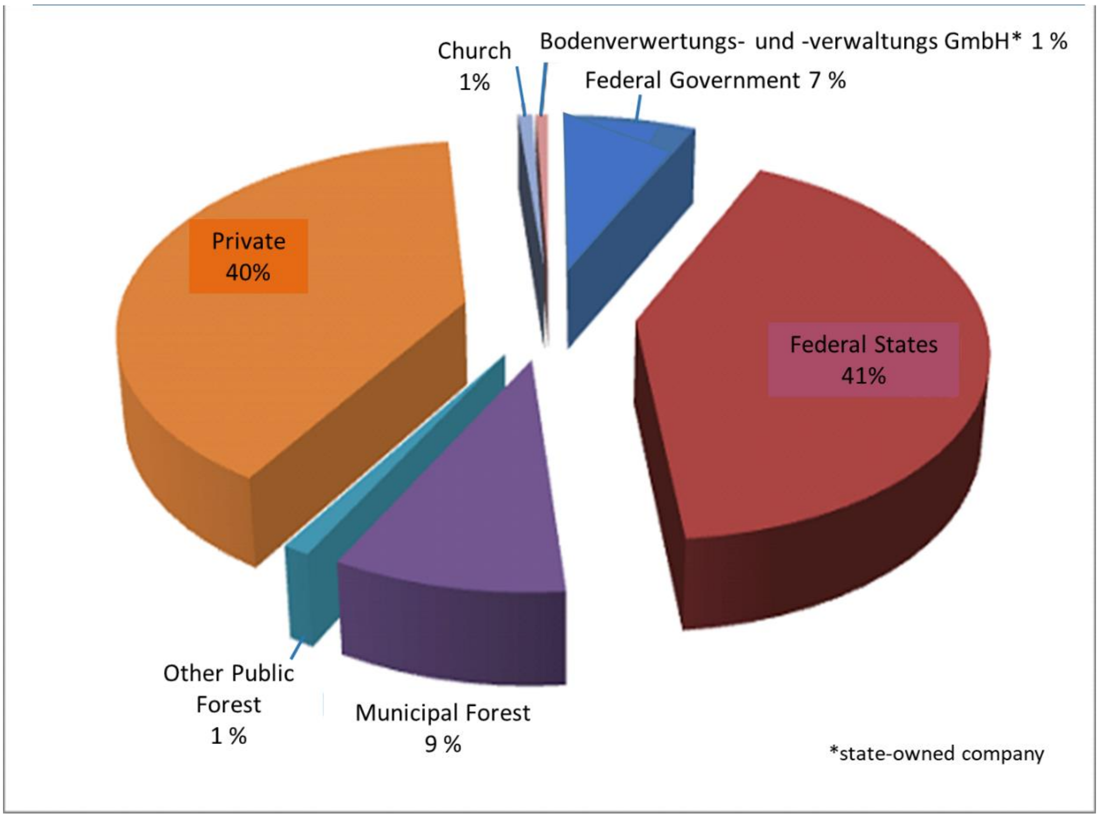

Fig. 1: Shares of forest ownership in MV; Source: Landesforst MV, status 07.02.2019

Different guidelines on income generation and taxation are relevant for the different ownership structures. Additionally, to make the planned forest use attractive for the owner, diverse approaches and consultations will be necessary to the different target groups so that the owners can be persuaded to implement the new concept.

Furthermore, the condition of the area should be checked: Soil composition and humidity, amount and age of the trees, distance between the trees and further vegetation are parameters that influence the quality of the wood as well as the harvesting costs and therefore the revenue. To calculate the quality of the timber it is necessary to classify the wood into different value categories[8,9].

Legal Framework

One of the first to dos for evaluation an economic use of alder wood on wet areas are the legal requirements: Alder forests on peat sites are often legally protected habitats and there are permit reservations by nature conservation authorities, which in many cases results in a great deal of bureaucratic coordination in the implementation of management measures.

If there is no legal argument against the use of wood, funding possibilities can be examined in addition to the possible revenues. They might differ from classical forest management and can give an innovative input to the financing possibilities.

Strategic Considerations

Both the long observation period (trees have a long cultivation time) and the relatively small areas make it difficult to assess the economic viability for the far future. In order to manage wet forest sites economically in the medium to long term, management models can be used that offer a long-term orientation. In order to assess the advantages of different management models, simulations for normal or sustainably managed operating classes can be used[10,11]. When using a "sustainable" operating class, the temporal succession of a forest stand is represented as a spatial coexistence in which each age class is represented by the same (or risk-related decreasing) partial area.

On the basis of the alder yield table[12] used in MV in the forestry facility, five different management models for alder trees were developed and economically examined[13].

Tab. 2: Five management models for the alder tree species depending on the production target and the trafficability of the site[14]

	I	II	III	IV	V
Target assortment	Trunk wood			Industrial wood / Firewood	
Soil conditions at the location	passable	hardly passable	not passable	passable	hardly passable
Production period	70 years	75 years	110 years	40 years	50 years
Wood harvesting technique	conventional harvester, forwarder	caterpillar harvester, special forwarder	rope crane	motor-manual felling, harvester	motor-manual felling, special forwarder

[8] Walther, M. (2016) Reihe Grundlagen der Forstwirtschaft: Vermessung und Sortierung von Holz

[9] Rahmenvereinbarung für den Rohholzhandel in Deutschland (RVR) des Deutschen Forstwirtschaftsrates e.V. und des Deutschen Holzwirtschaftsrates e.V (2015)

[10] MÖHRING, B. (1986): Dynamische Betriebsklassensimulation. Ein Hilfsmittel für die Waldschadensbewertung und Entscheidungsfindung im Forstbetrieb. Berichte des Forschungszentrums Waldökosysteme, Bd. 20

[11] Allgemeine Forst Zeitschrift für Waldwirtschaft und Umweltvorsorge 68 (2013): KWF-Thementage vom 1./2. Oktober 2013: Umweltgerechte Bewirtschaftung nasser Waldstandorte (http://www.fragen-an-den-fsc.de/wp-content/uploads/2018/02/AFZ_Thementage_komplett.pdf)

[12] LOCKOW, K.-W. (1996): Ertragstafel für die Roterle (*Alnus glutinosa*) in Mecklenburg-Vorpommern; Ministerium für Landwirtschaft und Naturschutz des Landes Mecklenburg-Vorpommern.

[13] Allgemeine Forst Zeitschrift für Waldwirtschaft und Umweltvorsorge 68 (2013): KWF-Thementage vom 1./2. Oktober 2013: Umweltgerechte Bewirtschaftung nasser Waldstandorte

[14] Modified from: Allgemeine Forst Zeitschrift für Waldwirtschaft und Umweltvorsorge 68 (2013): KWF-Thementage vom 1./2. Oktober 2013: Umweltgerechte Bewirtschaftung nasser Waldstandorte, page 21

Details of the trafficability were shown in a previous report[15]: The higher the water level, the shorter is the time interval on which conventional machines can be used and the more expensive is the harvest of the wood. In general, the harvesting periods should be scheduled in months with little rain, so that the use of special technology is kept to a minimum.

The first three forestry models (see Tab. 2) follow a classical trunk wood collection after planting, assuming different timber harvesting technologies due to the passability of the sites. For the target area, site conditions must be determined and the simulation must be carried out. Although the results for different management models are afflicted with a major error, they can nevertheless provide an important orientation for long-term (strategic) decisions.

All management models presented can contribute to covering fixed costs. On passable sites, positive net income can be achieved by managing alder forests. In a comparison of the first three models, variant I "Alder management on passable sites with the aim of trunk wood production" clearly provides the highest marginal income. This is mainly due to the comparatively low timber harvesting costs. As soon as the passability of the sites is restricted to such an extent that only special and even more cable crane technology can be used, the silvicultural contribution margins decrease considerably, depending on the amount of use of the special machines.

Operational considerations[16]:

Operational decisions focus on short-term success factors and concrete stocks to be processed. One critical point is the use of technique: Which machines are necessary for a conventional wood harvesting? Which additional technique is needed? How often must the special machines be used in comparison to conventional machines? How much more expensive are they? Where can they be ordered from? Should they be bought or rented? Is it also an option to share machines with other actors in the region? The replies enable the working methods to be determined.

Fig. 2: One special machine is the mobile rope-crane of type VALENTINI V 1000[17]

[15] BioBIGG (2020): pre-feasibility study “Material Use of *Alnus glutinosa* from Paludiculture as Construction Material in Mecklenburg- Vorpommern (MV)”
[16] Allgemeine Forst Zeitschrift für Waldwirtschaft und Umweltvorsorge 68 (2013): KWF-Thementage vom 1./2. Oktober 2013: Umweltgerechte Bewirtschaftung nasser Waldstandorte, page 22
[17] https://www.google.com/search?client=firefox-b-d&biw=1536&bih=750&tbm=isch&sa=1&ei=1NWAXYinFdHVwAKX367gCw&q=mobile+rope-crane+VALENTINI+V+1000&oq=mobile+rope-

The harvested timber will then be transported and further processed analogous to the classical forest management (processing and transport to its destination). No further new innovations have to be considered.

Sustainability considerations on deforestation management

In all these observations, the sustainability of forest use is the primary goal. The natural regenerative capacity of the forest should be preserved in which their productivity, rejuvenation capacity and vitality is improved or maintained. So one critical aspect is the amount of wood, which can be harvested in a sustainable way (see also strategic considerations). The following aspects must be considered:

- How and to what extent is the stock justification and maintenance carried out?
- How much wood can be harvested over the time to have a balanced amount of trees in the forest?
- What damage to the remaining stock or soil is acceptable?

To support the development of a sustainable selective afforestation and at the same time preserve the financial feasibility of the forest management harvesting and afforestation must be balanced: In a well-established alder forest, each year the oldest trees will be harvested and this area will be afforested with new alder seedlings (ideally, the trees have seeded themselves). It is important to have more or less the same amount of biomass so that the stock should be maintained even in the long-term.

Activities

After having checked all properties of the target area with the Paludi biomass and all possibilities for processing the target area to get a valuable product, the active part of the work begins.

- Recruitment of staff
  How many persons are needed (forest management during the whole period, additional staff during harvest time)? Should some work be outsourced? Which companies can do this?
- Contracts with the industry (wood purchaser, companies that sell or lease machines)
- Forest care
- Harvesting of wood
- Raw wood sorting and measuring
- Selling

The activities have to follow the guidelines of a classical forest management. Particular attention should be paid to the selection of those trees which are suitable for the production of quality wood (healthy trees, appropriate distance from neighbouring trees to allow the crown to develop well) and the optimal time for care and harvest to minimize the use of special technology[18].

Planning Implementation

crane+VALENTINI+V+1000&gs_l=img.3...48600.50606..52172...0.0..0.58.386.8......0....1..gws-wiz-img.tQY9J_AulSw&ved=0ahUKEwiI4Z328dfkAhXRKlAKHZevC7wQ4dUDCAY&uact=5#imgdii=IBYcvAy-WK9puM:&imgrc=rJGjX4Tu1d5f_M:

[18] See next chapter „Planning Implementation; Stand care”)

The routine silvicultural treatment of the alder stands is the most time consuming part of the management. It is carried out in three phases[19]:

1. Young growth care

   In the first 10 years of life the alders pass the young growth phase. The aim is to keep the stock closed and to promote natural branch cleaning. Through a one-time restrained intervention only extremely bulky adult and particularly badly formed specimens are taken.

2. Young stock care

   With the subsequent young stock care it is important to let the natural branch cleaning progress further. On the other hand, the strong growth in thickness during this period should be exploited and carefully directed to the best predisposed individuals. The first intervention here takes place already at a middle height of 10 meters. When the most vital and at the same time qualitatively suitable trees have reached a knot-free shaft length of 6-8 meters, the final selection of the later value timber carriers is made. Derived from the stand space requirements of a cut-ripe alder in the final stand, up to 120 trunks per hectare should be selected, distributed as evenly as possible over the area. These are now promoted in their growth by the consistent removal of harassers.

3. Stand care

   From a mean diameter of 20 cm (after about 25 years) of stand age the alders enter the tree-wood phase. From now on, the further measures are focused on the development of the crowns of the previously selected future trees. Vital crowns are characterized by a uniformly full structure on all sides. Slipping up of the crown attachment due to lateral shading should be prevented as far as possible. For this purpose, thinning operations are carried out as soon as new crown contacts of valuable wood trunks with neighbouring trees become apparent. The crown closure is thus permanently interrupted.

   Beneath the forest care there are additional elements which influence the implementation of the economic forest use:

   - Rewetted peatlands with traffic-sensitive soils have special demands on machines with adapted technology for care and harvesting[20]. Although these machines are already available, they are more cost-intensive and increase the process costs. Before afforestation *Alnus* trees on such areas it is urgently necessary to calculate the percentage use of special machines in comparison to conventional ones.
   - Because of the long cultivation time of trees before they can be harvested in contrast to the small area, the abovementioned management model, the "operating class simulation[21]" is to be used for decision-making on the management of the area.
   - Wet sites in all cases will have an economic disadvantage over drier soils. Economic use is easier through incentive programmes.
   - The more alder forests on wet peatlands can be included in timber production, the more political importance can be generated which will increase the influence on the politicians. So

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[19] 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.)

[20] Pre-feasibility study: *Alnus glutinosa* from Paludiculture as construction material

[21] MÖHRING, B. (1986): Dynamische Betriebsklassensimulation. Ein Hilfsmittel für die Waldschadensbewertung und Entscheidungsfindung im Forstbetrieb. Berichte des Forschungszentrums Waldökosysteme, Bd. 20, Göttingen

it is advantageous to identify all possible forest areas, come in contact with the owners and try to convince them to participate. In MV there are a lot of small private forest owners which alone are not able to implement the economic forest use. Joint forest management and marketing is therefore advantageous for them (e.g. forestry operating communities[22]). With the organization of forest owners' meetings and individual consultations (forest owners are entitled to them), forest owners can be supported.

Stakeholders:

Following actors are needed to implement the concept of alder timber use:

Research institutions

Universities, Stiftung Umwelt und Natur, DUENE
The Greifswalder peatland research groups are famous for their research, application-oriented projects and prominent scientists, which have influence on the regional as well as the trans-regional (Brussels) environmental development. This work must be continued and expanded to other regions. These peatland research scientists should also continue to gain public acceptance and teach students in the field of paludiculture. They should also be activated to inform forest owners about the economic use of wet alder forests.

SMEs

Involved companies can be the

- Timber harvester: timber entrepreneurs
- Timber purchaser: woodworking industry
  Sawmills, timber trade
- Seller of wood harvesting machines
- Companies, which lease wood harvesting machines
  Because special harvesting machines are required, companies in the surrounding should provide those machines. Which companies can purchase and process the wood (different wood qualities may result in different customers)? How does the wood reach its destination?
- Bioenergy plants (for low quality wood which is generated during forest care).

To identify competitors, other suppliers of wood in the region should be screened out and possibly contacted. Due to the high demand for wood, joint marketing strategies can be considered.

Decision makers

- Ministry of Agriculture and Environment MV[23]

  As the supreme forestry authority, the Ministry implements the National Forest Law and directs the lower forestry authorities of the National Forest Agency and the national park administrations.

- Forest authorities like the National Forestry Office (Landesforst MV, AöR[24])

  The Landesforst MV - Anstalt des öffentlichen Rechts is a public law institution with legal capacity in MV. It has its headquarters in Malchin and should protect and increase the forest.

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[22] http://www.fwv-mv.de/
[23] https://www.regierung-mv.de/Landesregierung/lm/
[24] www.wald-mv.de

The state of MV is the responsible body of the institution. Until the law on the establishment of the State Forestry Institute comes into force, the tasks of the State Forestry Administration and the State Office for Forests and Protected Areas will be transferred to the State Forestry Institute[25].

The State Forestry Administration maintains a Forest Research Institute for the implementation of forest science research and monitoring tasks at state level and for ensuring technical cooperation within the framework of national and international research networks. It is a departmental institution of the Ministry of Agriculture within the so-called transferred field of activity of the State Forestry Administration (Landesforst MV) and is located in Schwerin within the department of forest planning, experimental facilities and information systems.

The research activities of the Forest Experimental Service focus on current issues concerning forests and forest treatment with regional specific reference on the one hand, and on the other hand the participation in various monitoring and research projects in the research association of the federal states and the European Union. For this purpose, a nationwide, extensive network of various forest experimental plots is maintained.

In all questions addressed here, the focus is always on the rapid transfer of knowledge of newly generated results from research and monitoring for decision makers, forest owners and citizens.

In MV the forest authorities collaborate closely with the research institutions. They have the knowledge in all areas of the forest management and are able to identify suitable areas. The Landesforst MV has a well-established sales system with trans-regional marketing by the central office and regional marketing by the forestry offices.

Underline of Innovation Programme

Financing

Several factors influence the potential income from the timber business on wet sites:

- “normal” costs for harvest
- sale of the wood / timber price
- application of special harvesting machines
- funding and market incentive programs
- biotic and abiotic environment: weather conditions, fungal infection, wild infestation

There are several possibilities of financial support of non-state forest owners[26]. They can be supported because of the useful, protective and recreational function of the forest and are strengthened through structural improvement measures. This is done in particular by improving the economic framework conditions. An important instrument is financial support under the currently applicable German directives:

- Directive on the promotion of forestry measures within the framework of the Joint Task for the Improvement of Agricultural Structure and Coastal Protection[27] and the

[25] https://de.wikipedia.org/wiki/Landesforst_Mecklenburg-Vorpommern
[26] https://www.wald-mv.de/Forstbehoerde/Finanzielle%E2%80%93Foerderung/
[27] Forest GAK Directive 2019

- Directive on support for forestry measures under the European Agricultural Fund for Rural Development[28]
- Administrative regulation of the Ministry of Agriculture and Environment for the promotion of wooden backs with horses in Mecklenburg-Vorpommern (decree on wooden backs with horses).

Further measures may be funded to support sustainable development in forestry. The prerequisite is the safeguarding of the useful, protective and recreational function of the forest and the improvement of production, working and marketing conditions in forestry.

Revenues for weak wood assortments and trunk wood of poor quality at present are low. In addition, there are higher costs for the difficult timber harvest on wet sites (see above). Both preconditions lead to a management model for alder trees, where the focus should be on high quality timber.

Results

The rewetted areas in our region are not very suitable to generate revenues for timber in competition with common timber suppliers. But currently, the demand of wood in MV is higher than the supply. This applies to all categories - trunk wood, industrial wood and firewood[29]. So, competitors can be neglected if the price is not considerable higher.

Nevertheless it is possible to have more areas which can be used for forestry to generate additional biomass. This can only be achieved if an economic use of the forest area attracts forest owners that currently don't make business with their timber, and business stakeholder who like to invest in such a business model.

To sum up, it can be said, that the following preconditions make an economic use of alder forests on peatlands successful:

1. optimal relevant environment (not too wet so that only minimal special machines are necessary, but wet enough for an optimal environment for alder trees)
2. technological mixture between cheaper classical harvesting machines and more expensive special machines
3. constant forest care
4. well-chosen harvest times (to minimize the use of special technique)
5. sustainable balance between harvesting and afforestation

Whereas 1. and 2. can only be influenced marginally, constant forest care and well-chosen harvest times are the key factors to thriving business with alder trees.

The innovation is therefore not a new or elongated value chain, but the implementation of an existing value chain to a previously unused area to enhance the growth potential of usable biomass.

[28] https://www.wald-mv.de/Forstbehoerde/Finanzielle%E2%80%93Foerderung/
[29] https://www.welt.de/regionales/mecklenburg-vorpommern/article136642169/Preise-auf-hohem-Niveau.html

POSSIBILITIES FOR AN INTEGRATED WOOD PELLET PRODUCTION

COLOURBOX9818068

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Innovation Programme: Possibilities for an Integrated Wood Pellet Production

1 Introduction

Heating with pellets is one of the most environmentally friendly options for generating heat, as pellets have a very low CO_2 footprint. Since long transport routes by truck increase the CO_2 footprint, a pellet production with sales in the production region is the most sustainable option. Germany has a large wood supply and a high sawmill density and thus a broad raw material base for the production of pellets. This report evaluates the innovations needed to implement pellet production into an operating sawmill at regional level. The vertically integration of a pellet production into an operating sawmill offers a chance for small companies to be competitive at the market.

2 Innovation Roadmap

2.1 Purpose/Objective

The objective of this report is the evaluation of all innovations needed to integrate a pellet production into an already existing sawmill. A number of factors need to be taken into account to ensure that the local and regional implementation contribute to a sustainable bioeconomy. This includes a consistent availability of feedstock, reliable customers, short transport routes, use of existing energy sources (such as a combined heat and power plant or the waste heat of a biogas plant), weather conditions as well as existing competition in the area. [1] This report will highlight the remaining necessary steps required for a successful implementation.

2.2 Current situation

In Germany, either many pellet producers exist as a stand-alone facility or as a pellet production integrated into sawmills.[2] However, many of them have already been operating for several years and have built a strong customer base. Others are larger companies operating beyond the regional market. Very little information is publicly available about the pellet production implementation into sawmills in general, thereby this innovation programme fills the gap.

2.3 Roadmap Elements / Action fields

There are various factors, which need to be considered when implementing a pellet production.

<u>Preliminary considerations:</u>

First, the market situation needs to be investigated with a strong focus on the already existing pellet producers in the region. It must be determined how many sawmills are present within a 20-30 km radius. Their sawdust could potentially be pelletized, if their sawdust is not used otherwise and if it would be beneficial for them. Is the purchasing of sawdust from the surrounding sawmill economically feasible? Can the wood residues from the surrounding sawmills be used throughout the year or only during feedstock shortages? Which leads to the second point: the feedstock availability. It must be ensured that the raw material supply for the pellet production can be constantly guaranteed, so that the necessary amount of sawdust and chopped wood is available throughout the year. The lowest

[1] EUWID-Marktbericht für Holzpellets. Pelletpreise vor Beginn der Heizperiode kaum verändert. Hohes Angebot und geringer Verbrauch / Erstbefüllung entlasteten den Markt, in EUWID. Neue Energie. Erneuerbare-Energieeffizienz-Systemtransformation. Edition 41.2020, 07.10.2020 | Jahrgang 13, p. 11. [2020/11/17]

[2] DEPI. Deutsches Pelletinstitut (2020): Pelletproduktion. Pelletproduzenten. URL: https://depi.de/de/pelletproduktion. [2020/11/20]

quantity as well as the highest quantity of raw materials that can be produced over the year must be determined.
Based on the above criteria, it is also necessary to determine when pellet production is economically feasible. According to an email enquiry with representatives of pellet producers in Germany, the pellet production is only feasible with a feedstock availability between at least 15,000 t/a to 25.000 t/a. The number is strongly depending on the criteria mentioned above.

Another important point is the demand for pellets in the region. Are there large customers in the region (industry, communities) or private buyers with central pellet heating systems? Is the pellet furnace located in an apartment building, an office building or a single-family house?

Only a minor share of pellets is packed when sold. Since the purchase of a packaging machine is not always economically profitable, a sufficient demand for packaged pellets (15 kg bags for pellet stoves) is necessary. Mostly, pellets are sold loose. It is advisable to start pellets production with selling loose pellets, buy a packaging machine, when demand for packaged pellets is guaranteed by local sellers/wholesale, and retail markets (farmers markets, fuel traders).
The main advantage for the entire set up of the pellet production is the use of already existing energy sources. Is an energy or heating source available on-site or nearby? Like the waste heat from a block-type thermal power station or a biogas plant which can be used for the drying process. These and other energy and heat sources must be identified to maximize their benefits when integrating in a small-scale pellet production less than 25.000 t/a.

Table 1: Roadmap. Describing the integration of a pellet production into an already existing sawmill.

	Actions	Short term (up to 2022)	Mid term (up to 2025)	Long term (up to 2030)
Preliminary considerations	Market competition			
	Feedstock availability			
	Packaging machine			
	Existing energy sources			
Strategic consideration	Business planning by external experts			
Operational consideration	Technology			
	Working method			
	Wood processing			
Activities	Construction of additional buildings or access roads			
	Recruitment of staff			
	Find distributor			
	Securing a customer base			

<u>*Strategic consideration:*</u>

Leaving the planning to experts is of strategic advantage as they can make recommendations when selecting the appropriate machines. Their expertise is especially important when it comes to marketing strategies, which are of great importance when firstly entering the market. They can make connections to experts in the industry and establish contact with distributors of pellets.

Operational considerations:

Operational considerations focus mainly on the choice of pellet production machines. Evaluation is needed to see if sawdust from neighbouring sawmills can be used throughout the year or only when there is a shortage on company-owned feedstock. Will the other sawmills bring their sawdust or is it picked up? Which kind of wood is processed and whether a new or a used pellet press shall be purchased must be considered. The pellet press must be aligned according to the production capacity. How many employees are needed to operate this machine? Is it an option to share machines with other businesses/sawmills in the region?

After the pellet, production follows the pellet distribution. Will customers have the option to pick up the loose pellets from the production site or will the pellets be sold through a distributor? Alternatively, will both options be offered?

Activities:

For the vertical integration of a pellet press into a sawmill, construction measures must be expected. This may be the extension, conversion or new construction of a building or/and an access road. Are new employees needed or is retraining the employees enough? In case of a recruitment of new employees, it must be determined how many persons are necessary.

To push the marketing, distributors have to be found and contacts have to be made but the help of experts should not be renounced. Cooperation facilitates the business, as the company does not have to take care of it, but can leave this step to the distributor. The distributor knows the market and can help to build up a customer base. Customers will have to be convinced that regionally produced wood pellets offer a sustainability benefit.

2.4 Planning Implementation

The first step is to find a team of experts, which support the implementation of the project. They should retain their advisory role after the start of the pellet production to ensure continuous improvement. In case of problems, occurring within the first months or year of production, their expertise and connections to experts in the field can be helpful.

All preliminary considerations should be finished within the first year. An exception is the purchase of a pellet-packaging machine, which is not required immediately, depending on the size and production capacity of the company, and can still be purchased over time.

The rebuild or construction of buildings can immediately start after the completion of the plans. If retraining of the employees is desired, it can be commenced the beginning of the planning period. This is different when recruiting new staff, which only makes sense after the preliminary considerations have been completed.

In Germany, there is the chance to receive general economic support for companies that want to implement environmental and climate protection measures. The state invests in jobs created by environmental protection. [3] The KfW Banking Group offers concessionary loan programmes for environmental business activities.[4] Furthermore, companies can obtain investment capital via

[3] Umweltbundesamt. URL: https://www.umweltbundesamt.de/daten/umwelt-wirtschaft. [2020/11/20]
[4] KfW (2020). KfW-Umweltprogramm. URL: https://www.kfw.de/inlandsfoerderung/Unternehmen/Energie-Umwelt/Finanzierungsangebote/Umweltprogramm-(240-241)/#:~:text=Mit%20dem%20KfW-

crowdfunding or investment platforms, mostly from private individuals. Some municipalities even offer land, free of charge, if it contributes to the regional economy.

The search for a distributor and the establishment of contacts should begin immediately. However, a partnership can only be sealed when the possible production capacity has been estimated. Besides, the acquisition of a firm customer base is not feasible within one year. This takes time and is therefore an ongoing process.

2.5 Stakeholders

The following stakeholders are needed to implement a pellet production into an operating sawmill.

Consultancy Company:

The consulting company helps with the planning and establishment of contacts and the creation of management plans.

SMEs:

These include sawmills, pellet manufacturers, sellers of pellet presses and packaging machines, as well as supply stores and other distributors of wood pellets.

Decision- makers:

This includes forest owners and government authorities. Germany has 11.4 million hectares of forest of which 48% are private forests, 29% belong to the States, 19% belong to municipalities and corporations and 4% belong to the federal government. Their decisions may also affect the pellet production.

The Federal Forest Law (BWaldG) requires the preservation and sustainable management of forest because of their economic benefit for the environment and the recreation of the population (§ 1 and § 11 Abs.1). This regulation is implemented in the state forest laws of the federal states. In Germany, the state ministries of forestry (in state of Mecklenburg-Western Pomerania (MV) the Ministry of Agriculture and Environment MV[5]) are the responsible institutions. Furthermore, there are the State Forestry Offices[6], which are a public institution with legal capacity to manage the forest area. The Federal Nature Conservation Act (BNatSchG) prescribes an organic forest conservation and nature-based reforestation, a ban on large scale clear logging (clear logging limited to 20.000 m²) and a sufficient proportion of local forest plants (§ 5 Abs. 3).

When producing wood pellets, care must be taken to ensure that they comply with the air quality regulation to limit the release of pollutants (flue gas and dust) as well as noise pollutants from combustion and pellets plants, and from handling logs, wood chips, saw dust and pellets. The strict air quality requirements derive from the Clean Air Policy Package, which was adopted by the European Commission in 2013.[7]

Umweltprogramm%20f%C3%B6rdern%20wir%20Ihre%20Investitionen%20in,vermindern%20oder%20vermeiden%20Abfall%20vermeiden%2C%20behandeln%20und%20verwerten. [2020/11/20]

[5] MLU. Ministerium für Landwirtschaft und Umwelt-MV. URL: https://www.regierung-mv.de/Landesregierung/lm/. [2020/11/19]

[6] AöR. Landesforst MV. URL: www.wald-mv.de. [2020/11/19]

[7] European Commission. (Latest update 26/06/2020). Environment. Clean Air. URL: https://ec.europa.eu/environment/air/index_en.htm. [2020/11/20]

The construction of access roads needs to be approved by the state of Mecklenburg-Western Pomerania.

3 Conclusion

The purchase of a pellet heating system is a long-term investment and it is unlikely that consumers switch back to other heating systems. The main consumers of wood pellets in Germany are private households and small biomass heating plants. Where over the past 9 years, the purchase of wood pellet furnaces has consistently increased, which is expected to continue in the following years. Germany has a large wood supply and a high sawmill density, thus a broad raw material base for the production of pellets. There is a lively free competition with transparent pricing, forming a good basis for a regional pellet production. However, active customer acquisition will be required.

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Agro-industrial sector

KERATIN HYDROLYSATE PRODUCTION FROM POULTRY FEATHERS

COLOURBOX33938251

07.04.2020

Bioeconomy in the South Baltic Area

Biomass-based Innovation and Green Growth

Innovation Programme

Keratin hydrolysate production from poultry feathers

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1. Introduction

The European Union, in the strive to have the greatest impact on environmental protection and counteracting adverse climate change, places an increasing emphasis on the development of sustainable and circular bioeconomy. To meet this challenge, three principals have been introduced that can be followed during introduction of new bio-based solutions. These include a cascading approach, use of waste, leftovers and residues and finally the circularity. The cascading approach points to the production model, which is based on the production of high-quality products (drugs, cosmetics, food, etc.) first, and then the use of residues and waste for the production of fuels or energy. Organic products with the lowest value that can no longer be used should return to the environment as natural fertilizers. Thanks to this, the value chain of the utilization of a given raw material is extended and its availability increases. Cascading approach is strongly associated with the use of waste, leftovers, residues, and circularity because various types of bio-waste can become raw materials in other processes, and thus the circular economy is developing, which contributes to reducing the amount of generated waste and focuses on maximum extension of the value chains of processed resources and raw materials.

During developing new concepts for bioproducts and biotechnology, it is worth determining at what technological level the solution is currently located, and thus assess whether the concept is based only on observed phenomena and only various scientific studies are underway to describe them, or maybe the state of technological advancement is higher and technology is already known that in the future can be used in real conditions. Such an assessment can be made by assigning a given concept to one of the nine levels on the Technology Readiness Level (TRL), which helps to compare solutions from different fields with each other and gives an idea of what actions still need to be taken to implement the idea on the market.

2. Analysis of Technology Readiness Level of Keratin Hydrolysate Production from Poultry Feathers

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 [1]. 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 [2]. 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 5000 heads per hour) slaughtering enterprise generates about 7 tonnes of feathers per day [3]. 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), and 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. Keratin belongs to the group of proteins and can be used in the following industries:

- cosmetics (hair, nails, skincare products, etc.),
- pharmaceutical (a component of drugs that improve metabolism, prevent osteoporosis and delay aging),
- food (addition to bread, cakes, milk drinks, yogurt, energy drinks, a component of diets that improves digestion, especially in the elderly),
- packaging (production of biodegradable film and packaging materials).

2.1 Determination of current TRL of the project

Keratin is a protein, which is characterized by the highly cross-linked network structure with numerous disulfide and hydrogen bonds as well as hydrophobic interactions and tightly packed keratin microfibrils. The results are insolubility in water, solutions of weak alkali and acids, and most organic solvents which is a problem during converting it to soluble forms [4]. Research centers and institutions from various countries are researching the development of methods for obtaining keratin hydrolysate, thanks to which it will be possible not only to produce this component, but also to apply the method on an industrial scale. These methods include chemical hydrolysis (alkaline, acid or enzymatic), reduction or oxidation of the disulphide bonds, thermal treatment in some organic solvents, and hydrothermal methods [4-6]. The combination of the above-mentioned goals can be problematic, because some of the tested methods, although they lead to the production of keratin hydrolyzate, are not able to be used on an industrial scale due to the low efficiency of the whole process [4]. Other methods, in turn, require high energy demand, which may make their use in real conditions unprofitable [4]. However, Czech scientists have developed a method that is an easy process, taking place in a relatively low temperature range and at atmospheric pressure, and it is possible to use this process in a pilot or industrial scale [7]. This process is called a two-stage alkaline-enzymatic hydrolysis. A technological diagram of this process is presented in Figure 1.

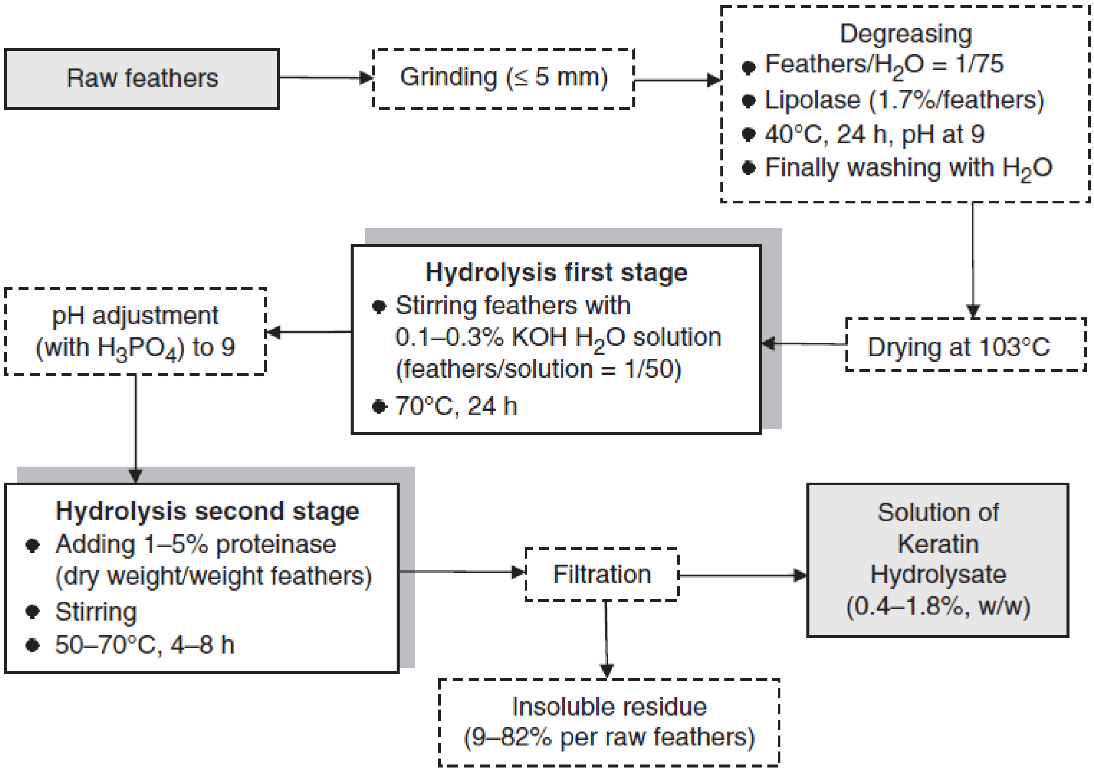

Fig. 1. Diagram of processing poultry feathers into keratin hydrolysate during two-stage alkaline-enzymatic hydrolysis [6].

At present, however, there is no installation operating on the industrial scale or that works in the near-real conditions. There are also no methods developed that would allow the transition from laboratory to serial production. An major obstacle is the fact that keratin contained in poultry feathers is highly insoluble, therefore more advanced methods of obtaining it should be used than in the case of keratin produced from cattle hooves [8]. It can therefore be concluded that the proposed concept is only confirmed in the laboratory scale and the target technology of production in the laboratory was mapped, therefore it should be assigned the number 4 in the TRL scale. Efficiency of production of keratin hydrolysate, however, should be improved.

2.2 Analysis of short-term TRL improvement of the project

In the short term (1.5-2 years), some barriers, for example legal issues, high investment costs, and a lack of similar installation in close-to-real environment, should be removed so that level 5 on the TRL scale can be reached. Improvement by only one level may seem insignificant, but TRL 5 refers to verifying the proposed concept in a simulated, close-to-real environment and achieving it would be a milestone which, if obtained, could help to collect information whether the production of keratin hydrolysate from poultry feather in real conditions is possible at all and what expectations it would have to meet to make it profitable. Only then further advancements can be planned.

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 benefits. The table below contains problems that may stand in the way of raising the TRL level of the proposed concept, together with some suggestions for their alleviation.

Table 1. The barriers and solutions of a short-term TRL improvement plan.

Barriers	Solutions
Issues related to the treatment of feathers as waste	• Introduction of legal acts and definitions related to the use of production residues as raw materials in other processes.
Obtaining keratin from poultry feathers requires a high investment costs.	• Increasing public awareness of the potential benefit of technology under development. • Cooperation with high-risk investment banks. • Own dispersed energy sources to reduce operational costs.
No installation that could become a demonstration plant for the production of keratin hydrolysate in the close-to-real environment.	• Development of a prototype pilot plant installation. • Implementing tests of the pilot to find out optimal with respect to efficiency and cost operational conditions • Attractive financial bonuses for making further progress in project development.

The first barrier concerns legal issues related to available waste. This is the most important barrier because no new solution that will not be supported by state and regional environmental policy will have an advantage over existing solutions. Therefore, the state needs to start promoting ecological solutions through appropriate legislation and to reward such practices to encourage entrepreneurs to use the principles of sustainable development and related. Feathers are currently treated as a waste and there are no legal regulations that would force to be managed in a manner consistent with the circular economy and cascading approach. Because feathers are a rich source of protein and it is possible to use them as a raw material in various processes, appropriate legal provisions should be introduced that would require the use of such practices to reduce the amount of unused products and extend the value chain. It would be easier to treat feathers instead of waste as production residues or by-products, that still need to be used.

The second barrier, as in most concepts, is the financial barrier. While testing on a laboratory scale does not have to seem excessively expensive, it should be remembered that these investigations are carried out on a very small scale, using laboratory equipment. However, if it is planned from scratch to develop an professional installation for production of keratin hydrolysate, then one should purchase apparatus that could also be used in these conditions to produce keratin hydrolysate from poultry feathers. This is associated with high financial outlays. It should also consider not only the apparatus but also the purchase of appropriate chemical agents that are used during the process. Also in this respect, the situation is similar – during tests on a laboratory scale, a relatively small amount is consumed. An important issue is also the cost of water consumption for the production of keratin hydrolysate – laboratory tests used a ratio of feathers to the water of 1:75 [6], which may indicate a high cost of water consumption incurred in conditions similar to real ones. The consumption of electricity and heat is another issue. The process is carried out at relatively low temperatures, but they do not occur at ambient temperature, which should take into account the use of different heaters and heat sources, and this also involves additional financial expenditure. Unfortunately, the above-mentioned problems are not negligible – each introduction of a new technology requires the purchase of appropriate equipment and taking into account indirect costs, such as the cost of water and electricity consumption. However, to reproduce the production process of keratin hydrolysate from poultry feathers in near-real conditions, it must be incorporated in these costs.

Most of breakthrough technologies are developed in the research centers, most at universities. The solution to this problem might be cooperation between such research institutions and private companies when the proof of concept has been reached and the prototype installation development is underway. It is worth adding that institutions and research centers should propose a method of obtaining keratin hydrolysate and provide substantive support, while to commercialize the project, it must be taken over by an external company interested in the development of such technology that has the appropriate budget and financing (for example support from investment banks but also own resources). Such company should have experience in taking investment risk and realistically estimate the costs of technology implementation. An example would be spin-off companies in which research institutions interested in commercializing their research cooperate with private investors who provide financing for the entire investment. Also, some auxiliary actions should be considered such, for example, to reduce energy demand costs, companies should take advantage of distributed heat and electricity sources (e.g. photovoltaics, heat pumps, solar thermal collectors) that will allow them to become independent of external supplies and increasing energy prices.

The next barrier is closely related to the previous one. Since currently keratin hydrolysate is not commonly produced from poultry feathers under non-laboratory conditions, no installation would reproduce similar to real conditions in which the selected concept could be tested. Therefore, the only solution is to design a new installation on which it would be possible to carry out tests on a larger scale for a given method of obtaining keratin hydrolysate or in such a way that different concepts can be tested on one installation. Thanks to this, it will be possible to determine how it is possible to switch from laboratory to serial production and what such production requires relative to laboratory research. In addition, companies that decide to invest in a given solution and will strive for its development should receive financial bonuses from the state or regional authorities, for example in the form of various grants, which will be a kind of encouragement and reward for further work.

2.3 Analysis of long-term TRL improvement of the project

The target level in the long term (about 3 years) is 7-8 on the TRL scale. It is based on testing the prototype installation in real conditions and proving that the presented technology is applicable in these conditions. If an installation is created earlier that allows mapping conditions close to real conditions in good quality, it will be possible to assess in which places improvements or changes in the design are required. Thanks to this, in the next steps it will be possible to use the improved installation in real conditions. At this stage, it will also be known whether the production of keratin hydrolysate from poultry feathers by a given method can be carried out on a scale larger than the laboratory and whether it can be profitable. However, in order to achieve TRL 7, some problems need to be solved that can block the development of the project over a period of several years. Possible barriers and suggestions for their solution are presented in the table below.

Table 1. The barriers and solutions of a long-term TRL improvement plan.

Barriers	Solutions
Lack of willingness to take investment risk.	• State incentives for investors to take risks in the form of various grants. • Promoting pro-ecological solutions. • Implementation of a good business plan, taking into account all risk factors.
Domestic educated staff is often looking for a rewarding job abroad because of higher earnings and career opportunities.	• Ensuring attractive working conditions in Poland and self-development opportunities. • Salary supplements under different grants to enhance employee's effectiveness.
Poultry feathers are still more often incinerated or turned into feather meal.	• Promoting good practices aimed at extending the value chains of products. • Increasing a public awareness about possible benefits of circular economy.
The higher price of keratin from poultry feathers may contribute to the lack of consumer interest in development of alternative ways of its production.	• A good marketing strategy pointing to an important environmental aspect. • Increasing public awareness about new emerging technologies.
Dispersion of the poultry slaughterhouse from each other – logistic issues	• Appropriate selection of the size and location of the prototype installation to ensure continuity of material supply. • Dissemination of the results to public. • Development of good practices.

The first barrier is related to some kind of investment practices in Poland. Investors rarely decide to finance risky investments because they are afraid of failure, and with it, the financial outlay that cannot be recovered. Also, the production technologies of keratin hydrolysate from poultry feathers belong to the area of increased risk - there are other technologies on the market that allow the production of keratin hydrolysate from other raw materials, which may prove to be quite a competition. The solution to this problem is comprehensive and requires a large involvement of the state, stakeholders and general society. First, as already mentioned before, appropriate legal regulations should be introduced, which mandate the conduct according to sustainable development principles and the enforcement of these rights by state institutions. Such restrictive regulations may encourage investors to become interested in the area of solutions in the field of bioeconomy. In addition, local authorities should reward (through various bonuses) successes in the developing of a given technology and introducing new products to the market. It is also important to prepare a detailed business plan that will minimize the risk of failures and take into account the risk that a given solution is burdened with.

The second barrier refers to the human potential in Poland. New technologies in the field of bioeconomy are characterized by the involvement of employees from various fields and specialties. Poland has very good universities that are well perceived in European and world rankings. Students are educated at a high level and graduates are well prepared to work in accordance with their field of study. Such good preparation affects the desire to find a well-paid job, which in the current reality is much more common available only abroad. Therefore, young people travel to other countries and develop their careers there, thereby developing the economy of the host country. This may result in a drainage of qualified staff in Poland who could deal with the introduction of innovative solutions not only in the Polish but also in the global market. Therefore, it should be provided to young people, who are ambitious and want to develop their careers, work that will allow them obtaining satisfactory salaries, in accordance with their qualifications. Here, once again, an important role is played by state policy, which should encourage young people to stay in the country and offer attractive and challenging working conditions in industries related to bioeconomy and offer them, for example, bonuses paid from special bioeconomy development funds (maybe only to the people who indeed contributed to the development of technology and not the company directors).

Another issue that can be a barrier over a longer period is the fact that feathers generated during the slaughter of poultry are usually disposed of by incineration or disposal in a landfill. These methods are among the cheapest and poultry slaughtering companies that willingly use them, thus getting rid of the troublesome problem. Because feathers are a valuable ingredient and can be used in other processes, their disposal through incineration or landfill should be reduced, and good practices related to their use should be supported. An example is the various subsidies and informing consumers, that the meat they buy, comes from a slaughterhouse, which ensures that post-production residues are further used to give them added value.

Public awareness should also be increased because consumers who are only interested in consumption of poultry meat do not show much appreciation to the meat production process and are not aware of the waste generated during it. Therefore, there is no pressure that would force poultry slaughterhouses to use processes that are resulting in the extension of the value chain for using residues from poultry meat production to show a “greener” label of the company.

The price of keratin hydrolysate from poultry feathers is also an important issue. Considering that a new technological line should be developed for the production of the selected component and employ qualified staff with chemical education, the cost of such keratin hydrolysate may be higher than the same component produced from other sources. Therefore, a good marketing strategy might play an important role, informing consumers, for example, about the origin of the raw material for keratin hydrolysate production. Society is increasingly willing to choose ecological products that have been created on the road of sustainable development, thanks to which such a marketing campaign can have the intended effect.

The last barrier, important in terms of determining the size of the planned installation and its location is a significant dispersion of poultry slaughterhouses relative to each other. The solution could be the design of a smaller installation that receives feathers from several slaughterhouses located closest to each other to ensure continuity of supply without high transport costs. A similar production line can also be made in companies interested in a given technology that is close to the poultry slaughterhouse or have the appropriate financial resources to ensure the transport of raw material from further locations.

3. Conclusions

Determining the TRL level for new solutions, in particular for those based on natural raw materials, which are treated as waste in various processes, is an extremely important issue. By determining at what level of development a given concept is currently and how much it can develop in the short and long term, it is possible to assess whether its further development is possible and profitable.

The concepts that use post-production waste as a raw material for the production of other materials are characterized by high uncertainty and risk. The most important issue that needs to be addressed when assessing a given solution is the availability of manufacturing technology for the given resource. In the case of the production of keratin hydrolysate from poultry feathers, only laboratory tests were carried out, which proved the appropriateness of using a two-stage alkaline-enzymatic hydrolysis method of obtaining keratin hydrolysate. Therefore, future considerations should focus on assessing the possibility of producing it in the near-real conditions, i.e. at the TRL 5 level, and building a prototype installation that corresponds to TRL 7.

Achieving the next stages of the project is associated with overcoming barriers that apply not only to the technology but also to law, investment financing or public awareness. In the production of keratin hydrolysate from poultry feathers, the biggest barrier is the technology for producing this ingredient, which at this stage is not confirmed on a larger scale. Therefore, the presented technology belongs to the area of greater investment risk, but developing a method that allows the transition from laboratory to serial production can affect the success of the entire project.

Looking from the point of view of bioeconomy and sustainable development, taking such actions is very important because it allows to minimize the amount of generated waste that arises as a result of satisfying the needs of humans, and thus contributes to environmental protection, which is currently one of the most important issues raised by countries around the world.

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BIO-PLASTIC PRODUCTION FROM POTATO STARCH POST-PROCESSING

COLOURBOX26675650

09.04.2020

Innovation Programme

Bioplastics production from potato starch post-processing

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1. Introduction

In recent years, an increase in interest for innovative development directions related to environmental protection is observed. It is due to introduction of extensive legislation changes, occurring not only at the national, but also at the global level, which are aimed at stopping the progressive degradation of the environment. The increasing consumption of raw materials and non-renewable sources forces entrepreneurs around the world to look for new substitutes, preferably of natural origin. Organizations such as EU have been taking action for years to steer the economy into circular economy model, which could help to reduce the negative environmental impact of industries. An idea, that fits in perfectly with circular economy, is the concept of cascading approach, which evaluates the methods of post-production waste management. It is essential to lean towards new methods of waste valorization, producing cosmetics, medicines, food products or biodegradable materials from them, instead using it as energy raw material.

One of the most intensively developed field is he bioplastic industry, due to its huge potential and opportunity to solve the problem of polluted ecosystems, especially aquatic ones. An especially attractive idea is to use existing waste for the production of bioplastics, because it provides a double benefit - it not only uses and reduces existing waste deposits, but also reduces environmental pollution. Technologies related to the production of bioplastics are still being developed, but the growing interest caused that in the coming years the growth of global annual production of bioplastics is predicted to raise from 2,11 million tons in 2019 to approximately 2,43 million tons in 2024 [1].

Each project, and in particular the innovative biomass projects, should undergo a technological readiness level (TRL) analysis. It is a useful tool for mutual communication between entrepreneurs, scientists and investors, that helps properly plan and track project progress. Since the production of bioplastics from post-production waste is not yet popular and widely used, it is worth analyzing the current and future TRLs to locate the weaknesses of the project and to ensure raising the level in a short amount of time.

2. Analysis of Technology Readiness Level of production of bioplastics from potato starch post-processing

Potatoes are one of the most popular and important crops grown not only in Poland, but also worldwide. Despite the rapid decrease of the area of potato cultivation in Poland in 1996-2005, since 2015 a relatively constant value of the growing area has been observed, amounting to approx. 300 000-341 000 ha [2]. Additionally, the location of large food processing plants and starch processing factories also supports the need for this production. It is forecasted that despite the decline in potato consumption, the cultivated area will not change significantly, so it is justified to introduce new technologies for potato waste management, due to their constant value.

In potato processing industry, a various waste is generated at every stage of production. The case of a large production plant located in the SBA region in Poland, which processes 220 000 tonnes of potatoes a year, was considered. The amounts of particular waste generated annually in examined plant are presented in Table 1.

Table 1. Waste generated during potato processing [3]

Type of waste	Amount [t/a]
Peelings	20 000
Sewage sludge	11 000
Wet cuttings	8 000
Overcooked potatoes	6 500
Mud	3 100
Dry cuttings	2 900
Starch	2 200
Soil	2 100
Stones	800
Crumbs	650
Unprofitable material	350
Wastepaper	160
Foil	55
Frying oil	40

The analyzed project is the production of bioplastics from potato starch, which is post-production waste from potato processing. Bioplastics are most attractive option for food industry, because it is the most dynamically developing in the sector of food packaging – according to the latest market data compiled by European Bioplastics and Nova-Institute, it remains the largest field of application for bioplastics with almost 65% of the total bioplastics market in 2018 [4]. It is promising vision for food processing sector.

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 [5]. 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, occurring in the temperature between 90-180^{o}C; evaporation of water from the starch solution; addition of plasticizer and other additives to improve properties of the final product [5]. 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 pelletizing, this quantity is reduced to 19,24 t/d. The next steps require extruder unit, surface treatment unit and distribution unit. It can also be assumed, that the price of final starch-based product is between 2,5 and 5 €/kg . A production line with such capacity would produce 6 734 tonnes of bio-plastic annually (Figure 2).

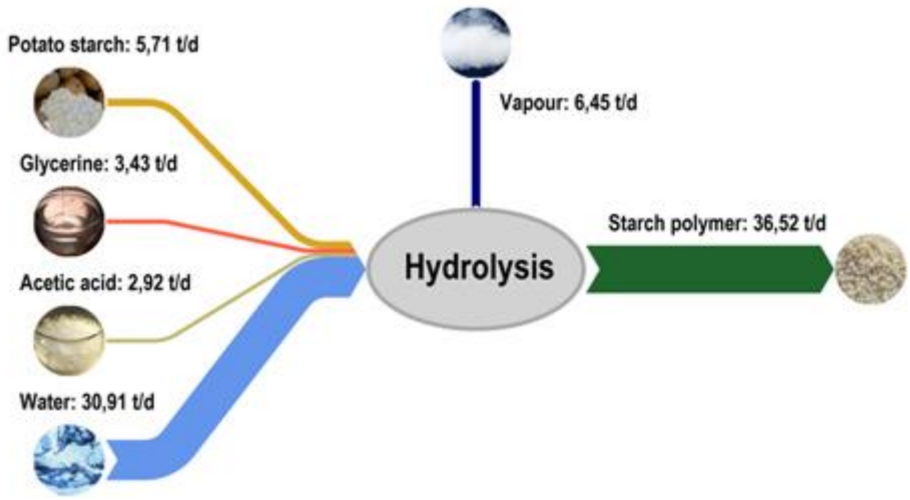

Figure 2. Material flow in starch-based bio-plastics production [5]

2.1 Determination of current TRL of the project

To define the current level of technological readiness of the above-described project, several aspects related to the current knowledge and market review should be investigated and compared with definitions of technology readiness levels. First level describes the lowest level of technological advancement and the ninth level means its full maturity and readiness for implementation.

Research on the usage of waste potatoes for the production of chemicals and materials has been documented in the prefeasibility study. Studies about valorization of cull and surplus potatoes were already carried out in the 1950s [6]. The range of researchers' interests developed along with the changing market situation. Due to the growing demand for technology of plastic production using waste biomass, a lot of basic research in this field has been and still is being carried out [7,8] and thus the level 1 criterion is met. A literature review shows that this research is quite common and new publications on this topic appear every year, which proves the constant development of technology. There are many publications confirming the possibility of using potato starch for the production of bioplastics in laboratory conditions [9,10] using the traditional extruders available on the market.

There are starch-based bioplastics production plants operating worldwide, however, they are still in the minority compared to production lines producing plastic from petroleum derivatives - the main reason is the higher price of the product. According to European Bioplastics and Nova-Institute, Europe is second main producer of bioplastics in the world, with 25% of global production [11].

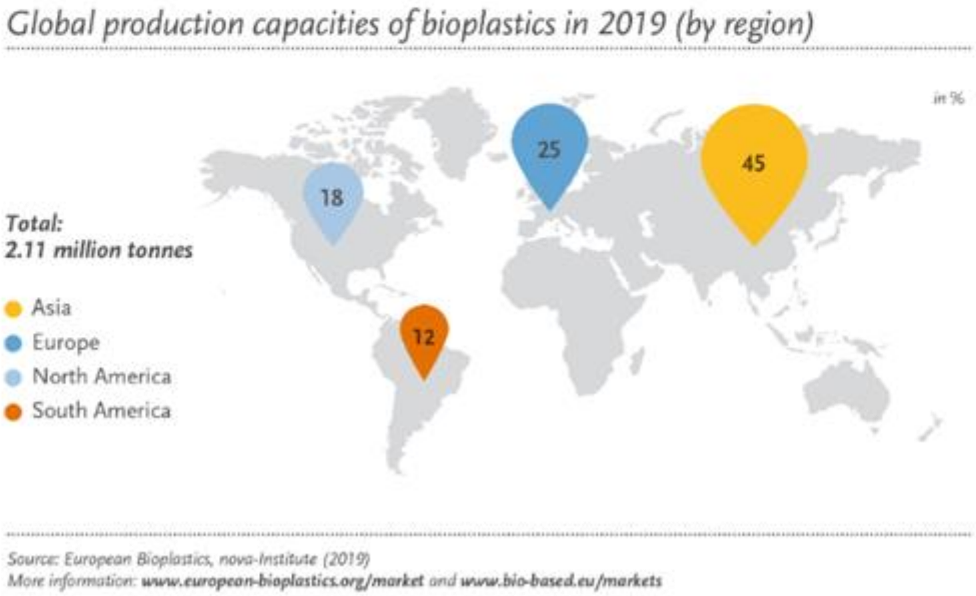

Fig 3. Global production capacities of bioplastics in 2019 [11]

In Poland, there are few companies producing fully biodegradable bioplastics. The most known is the Biotrem company located in Zambrów, which produces disposable dishes and cutlery from bran. Another enterprise is Maropak, located in Halinów, 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 Mazowieckie region. Also, none has a potato starch based bioplastics in their portfolio. In Pomeranian Voivodeship, 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 from the potato starch, and in particular from waste.

Present analysis indicates that the project is currently on the TRL 4/5 border. Numerous research and tests carried out in laboratories confirm the validity of the technology of bioplastics production from potato waste, however, for now there is no ready prototype installation with the possibility of its implementation in the SBA region in Poland.

2.2 Analysis of short-term TRL improvement of the project

For the analysis of predicting the level of technological readiness of the project in the short-term perspective, a period of 1,5 year was assumed. Based on recent scientific research and the market situation, it was assumed that TRL 6 is the realistic level to be achieved within 2 years. The current state of knowledge, together with the support of companies from the plastic production industry, would allow to launch an advanced prototype production line of bioplastic from potato starch in the near-real life conditions. This would later allow the development of mass production technology that will improve the economic parameters of the project.

There are several barriers that may delay reaching level 6 and which must be overcome to implement the project in Polish conditions. Table 2 summarizes the barriers and threats and proposes some solution strategies.

Table 2. Barriers and solutions for increasing TRL of the project perspective

Barriers	Solutions
Lack of standards, legal acts, national guidelines	• Change of waste/biomass management law, creating framework and standards
Low interest of entrepreneurs	• Encouragement through bonuses • Local grants awarded by state/province • Increasing society, as well as entrepreneurs awareness, of the potential benefit of technology under development • Promoting circular bioeconomy
Lack of communication between entrepreneurs and universities	• Tools for better information flow (dedicated research centers) • Comprehensive cooperation in many areas (electricity, heat, sewage)
No pilot demonstration plants in real-life conditions	• Development of a prototype pilot plant installation • Starting cooperation with entrepreneurs to conduct tests in real-life environment • Financial bonuses for this field of research

One of the main problems is lack of standards, legal acts, national guidelines regarding waste biomass management. Many entrepreneurs indicate that despite producing large amounts of valuable biomass waste, they cannot propose their reuse due to the lack of legal basis. It is therefore crucial to quickly introduce changes to the law and to create standards for biomass and waste from its processing. As demonstrated above in the description of technology, waste material from a single factory can be a raw material for the production of an innovative product desired on the market. It is crucial to develop a legal framework in which companies processing the waste into new products could operate.

Most entrepreneurs also show little interest in implementing new production lines in their plants that are not strictly connected with the main production profile. They emphasize too high investment costs, high risk, lack of human resources. SMEs usually do not have R&D departments to support the implementation of innovative technologies. However, without industry cooperation and willingness, there will be no way to develop the project and raise its TRL. The solution could be prizes and bonuses awarded at the local level (Marshal Offices) or national level (Governmental institutions) for enterprises that will support the development of bioeconomy and cascading approach in Poland and will operate in accordance with the principles of the circular economy. Such programs could encourage entrepreneurs to reuse post-production waste, or would result in the development of new companies, that would collect and process post-production waste from other enterprises into new products, attractive on the market. These types of grants should be combined with an information campaign on the attractiveness of innovative projects related to biomass processing. If the awareness of the society increases, it will encourage entrepreneurs to invest in ecological solutions that will be desired by consumers. It is important to increase awareness of the circular economy not only among the society but also among companies and entrepreneurs. The introduction of the cascading approach is primarily an opportunity and profit for the company, and well implemented with the help of a good business plan does not have to involve large financial outlays and risk.

There is a problem in communication between industry and universities. Often, entrepreneurs would like to undertake the implementation of an innovative project, but they do not know where they could find scientific support (due to the multitude of faculties, departments, specializations). The solution can be dedicated research centers focused on the most important developing fields. This solution was recently implemented at Gdańsk University of Technology, which has created 4 research centers, related to the development of innovative technologies. Specific areas of activity of centers can help entrepreneurs communicate with the selected center and find project partners. In the production of bioplastics, two existing centers can cooperate: the EcoTech Center and the Materials Center of the Future. Such solutions could simplify the communication of companies with universities and develop cooperation.

Entrepreneurs often claim that they have no conditions or resources to undertake the production of an innovative product. Therefore, cooperation with research centers in many fields is important. For example, problems related to the lack of some resources (water, electricity, heat) can be solved by using other technologies (the use of low-temperature heat in ORC technology, innovative technologies for wastewater treatment and reuse, renewable energy). Many production plants have a large unused potential in these fields, and their effective use can solve many problems related to the implementation of bioplastics production lines. This may ensure a reduction of some financial outlays.

To raise the level of technological readiness from level 4 to level 6, research on adapting bioplastic production technology to use in large-scale production in real conditions should be intensified. Locally-awarded grants to universities/research centers could lead to increasing number of projects related to environmentally friendly technologies and encourage researchers to develop solutions that are in demand and that have the highest priority (such as works on improving the bioplastic production process).

2.3 Analysis of long-term TRL improvement of the project

For the analysis of predicting the level of technological readiness of the project in the long-term perspective, a period of 3,5 year was assumed. The level of technology desirable after this time would be TRL 8, which would allow to start production on large scale as well as sales of the final product. Previous steps, considered in short-term analysis, aimed at starting the project, while long-term planned works require further changes, mainly from the government. Table 3 presents barriers and ways to solve them to achieve TRL 8 in 3-4 years.

Table 3. Barriers and solutions for increasing TRL of the project in long-term perspective

Barriers	Solutions
Problems with qualified staff	• Human potential in the region • Attractive innovative projects for young scientists and engineers
Price competitiveness	• Obligatory use of bioplastics • Providing new markets for producers
Threat of lack of market	• Campaigns on proecological solutions and raising public awareness • Market observation and intensive further research into other applications of bioplastics • Support of specialists in the field of risky investments, marketing, business plans
Long procedures	• Easier bureaucracy
Lack of standards, legal acts, national guidelines	• Change of waste/biomass management law, creating frameworks and standards

It is important not only to develop technology from technical side, but it is crucial to develop staff and specialists in a given field. Poland educates engineers in many fields at a very high level, also in topics related to the bioplastics production, such as biotechnology, industrial apparatus and materials science. An important problem is the outflow of young engineers and specialists abroad, therefore attractive jobs in a highly developed industry should be made available to them. Innovative, interesting projects and challenges will be an incentive to work in the region. Additionally, to stimulate the development of technology, salary supplements should be provided for employees who take part in such projects.

The use of human resources in the SBA region is also important. According to the data of the Statistics Poland [12], in 2017, 49 653 unemployed persons were recorded in the Pomeranian Region, of which 14,3% are persons with higher education and 20,5% with vocational education. This means that in the Pomeranian region alone a total of over 17 200 people could change the industry or be trained to work in the bioplastics industry. The situation is similar in the West Pomeranian Region and Warmia-Mazury Region. Human potential in SBA regions in Poland is shown in Table 4.

Table 4. Statistical data on unemployment in SBA regions in Poland in 2017 [12]

SBA Region	Number of unemployed persons	People with higher education	People with vocational education
Pomeranian	49 653	7 100	10 178
Zachodniopomorskie	52 600	5 786	9 678
Warmia-Mazury	60 578	5 997	11 873
	Total	**18 883**	**31 729**

Another factor that prevents such solutions from entering the market is the lack of price competitiveness. The bioplastics market is still growing and developing, and the forecasts are mostly good and show that prices will fall, however, action must be taken, which will allow for a faster decline in prices. 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 [13] - which is over 3 times lower than a starch-based polymer prices (2,5 to 5 €/kg) [14]. However, most consumers do not analyze the additional benefits of bioplastics, that are incomparable to traditional packaging, so these should be emphasized. It is a beneficial solution for the environment, which allows a reduction of ecosystem pollution and enables to reuse post-production waste, which is the basic premise of a circular economy. In recent years, some cities in Poland have introduced a ban on the use of traditional plastics during mass events and in public institutions. Extending these orders to the all regions of Poland would create a huge outlet for entrepreneurs from the bioplastics industry and could be a powerful stimulus for accelerating research into technology development.

Observation of the market situation and constant adjustment of the product to it are also important for product development. Due to the dynamically changing climatic conditions, it is inevitable to introduce new restrictions in many areas of life. Bioplastics are currently used mainly for disposable dishes, cutlery and packaging, but there may soon be orders to use them in areas such as medicine (to reduce huge amounts of plastics used especially in disposable items), toys, everyday use items, cosmetic accessories. Therefore, further cooperation of research centers and entrepreneurs, who could through their market observations report new research directions, is important. Entrepreneurs also need to take risks and invest in new types of bioplastic products, thereby creating new outlets, which can provide them large profits.

Campaigns on the innovation and attractiveness of packaging and cutlery made of bioplastics should be initiated by the government and institutions. Raising the awareness of consumers who, by purchasing products produced from waste from biomass, can contribute to environmental protection and at the same time support local industry, may be the key to success. Also, the solution would be providing entrepreneurs the support of specialists and advisors related to finance, marketing or risky investments, who would help them with a good marketing strategy and business plan. A good campaign, focused on additional product qualities such as environmental protection, reduction of pollution or supporting local entrepreneurs, will allow the product to be successfully introduced to the market and will encourage consumers to buy it even at a higher price, especially as there is a growing interest in *bio, eco-friendly* products.

A solution to many problems would also be a simpler path to implement ideas, i.e. easier administrative procedures. Many entrepreneurs claim that materials classified as post-production waste are difficult to manage. The lack of relevant regulations and legal provisions is also emphasized by reports from other Interreg projects regarding ecological packaging [15]. In 2019, the Council of the Ministers prepared the document "Road Map for transformation towards a circular economy" [16]. The map provides for the completion of works related to regulations regarding biomass products for 2021-2022. Close cooperation between the ministers of: environment, economy, energy and agriculture is planned, which will aim to create uniform biomass standards and amend existing laws: the Act of 20 February 2015 on renewable energy sources and the Act of 14 December 2012 on waste [16]. The rapid action envisaged in this document will significantly increase the TRL of biomass related projects.

3. Conclusions

Performing a TRL analysis is important in terms of implementing innovative technologies. It allows to set goals or milestones and enables more productive cooperation between specialists from various fields, who work together on a specific project. This is particularly important in projects related to the use of biomass, especially post-production waste, which requires cooperation at many different levels. Biomass waste management technologies are extremely important in the aspect of the circular economy. The undoubted added value of this type of projects is environmental protection, so despite high investment and maintenance costs, it is necessary to support entrepreneurs who want to create this sector in Poland.

The analysis indicates the key barriers and actions that should be taken to gradually increase the technology readiness levels of bioplastics production from potato waste in the SBA region in Poland. Most of innovative technologies are on TRL4 in Poland, which is caused by several obstacles, mostly in legislation. The technology itself is intensively developed both in the world and in national research centers, and some of the actions identified in the document could help to implement them more quickly. The prospects for the bioplastics market in Poland are optimistic - the development of technology combined with the rapid establishment of regulations and standards may soon create a new branch of business.

[1]*European Bioplastics: https://www.european-bioplastics.org/market/*

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BREWERS' SPENT GRAIN FOR LOW-ALCOHOL NOURISHING BEVERAGES

COLOURBOX13707495

04.08.2020

Interreg South Baltic

EUROPEAN UNION

BioBIGG
Bioeconomy in the South Baltic Area
Biomass-based Innovation and Green Growth

Innovation Programme

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

Gdańsk University of Technology
Paweł Dąbrowski
Dariusz Mikielewicz

1 Introduction

The brewing industry use about 0,061 kWh of electricity per every liter of beer [1] and generates rather large amounts of by-products and wastes, amongst which spent grain, spent hops and yeast being the most common. However, as most of these are products of agricultural origin, they can be readily recycled and reused. Thus, compared to other industries, the brewing industry tends to be more environmentally friendly [2].

The schematic representation of the brewing process is shown in Fig. 1. The main by-product which represents around 85% of total disposables generated during beer production is Brewers' Spent Grain (BSG). This lignocellulosic material is made during the mashing process (obtained during filtration) 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 [2,3]. The composition of the BSG is very promising and allows for 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 paper manufacturing, as an adsorbent, in biotechnological processes, as an additive in brewing or substrate for cultivation of microorganisms or enzyme production [2]. The potential applications are very wide. Nevertheless, BSG is still sold primarily as a nutritious low-cost feed for cattle [4,5].

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 [5]. 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 [6]. 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.

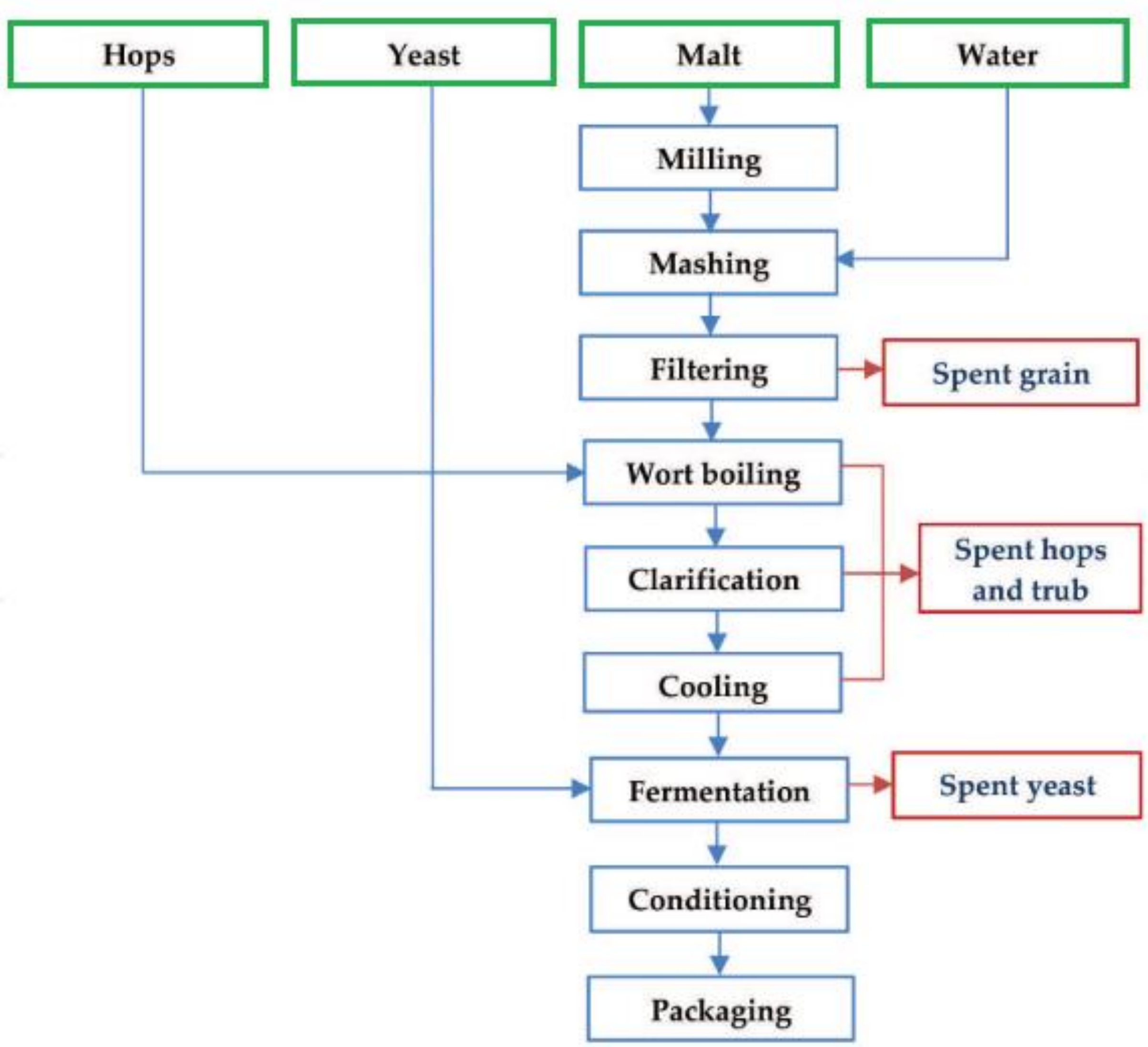

Fig. 1 Schematic representation of the brewing process (blue color) with main substrates (green color) and places where the main by-products (red color) are generated [7]

2 Analysis of Technology Readiness Level of Low-alcohol nourishing beverage with a high amount of fiber and protein production from Brewers' Spent Grain

Brewers' Spent Grain is generated in large amounts. Every 100 liters of beer produced in the brewery generates about 20 kg of BSG [3]. Assuming the annual beer production in Poland at the level of 40 million hectoliters [8], 800 000 tonnes of BSG is available for further processing every year.

Brewers' Spent Grain is a very promising residue and in fact it should be called a "by-product" or substrate for circular bioeconomy and cascading approach. Recent research on the evaluation of the BSG biomass showed results both in terms of the variety of classes of compounds and the quantity of the functional part. Even if BSG chemical composition is dependent on the intrinsic and extrinsic factors such as the barley variety and harvest time, malting and mashing conditions, type and quality of secondary raw materials added in the brewing process, it contains appreciable amounts of valuable compounds (proteins, lipids, carbohydrates, polyphenols, minerals) that remain unexploited in the brewing process [7,9–12] and very promising for further re-treatment.

It is an ideal situation for regarding BSG as a substrate for nutrient beverages. The idea arises by itself. Small breweries, which produce and sell their beer locally, in small quantities, could expand their offer with their own low-alcohol beverages, rich in nutrients. They already possess the capability for production of bottled beverages and experience with recipe creating so it would be much easier for them to start with a new product.

It often happens that companies do not want to deal with additional processes, and they want to get rid of the waste generated by them, often giving it away to external companies for free. But even in this situation, there is a scenario that can be implemented by creating new jobs and generating profits from material that was previously considered as a waste.

As can be seen in Fig. 2, in Pomeranian region there are a lot (18) of small breweries. The largest cluster of breweries that produces up to 20 000 hectoliters of beer (marked with a red pin) per year is located in so-called Tricity (Gdańsk – 6 breweries, Gdynia – 1 brewery and Sopot – 1 brewery). Moreover, about 20 km from Gdańsk there is a large brewery (marked with a blue pin) – Browar Amber in Bielkówko which produces annually 200 000 hectoliters of beer. It can be estimated, that more than 4 000 tonnes of BSG can be obtained annually in an area with a radius of 30 km. At the same time, when taking into account only small breweries, the potential of BSG is up to 24 tonnes per year, which is much less but, small breweries may be much more willing to look for new opportunities of development, as mentioned earlier.

In authors' opinion, it is possible to build a new facility near the Tricity that would collect all the BSG from the neighboring breweries and utilize them in their own company. It would open opportunities for new jobs, for the region's development and for improvement of the bioeconomy situation in Polish SBA. The Pomeranian region itself is a very good place for innovative technology. There are many strong scientific centers in the area with which entrepreneurs and investors could establish cooperation to solve all problems related to BSG utilization. It is the science sector that generates ideas in the early stages of TRL and the science sector develops the idea to higher levels. In such an environment full of cooperation between business and science sectors, where BSG would be collected from individual companies from a larger area, the described idea would have a greater chance of success.

However, it should be emphasized that such an investment by its nature as an investment into innovative technologies and solutions involves a high investment risk. It should be noted that every company existence relies on self-supporting and obtaining financial benefits. Nevertheless, economic and political conditions must be created nationwide in such a way to enable investments into new technologies without unnecessary legislative and political hassle. It is the legislation related to bioeconomy that should be developed in the first place in such a way that investors are willingly involved in green, innovative technologies.

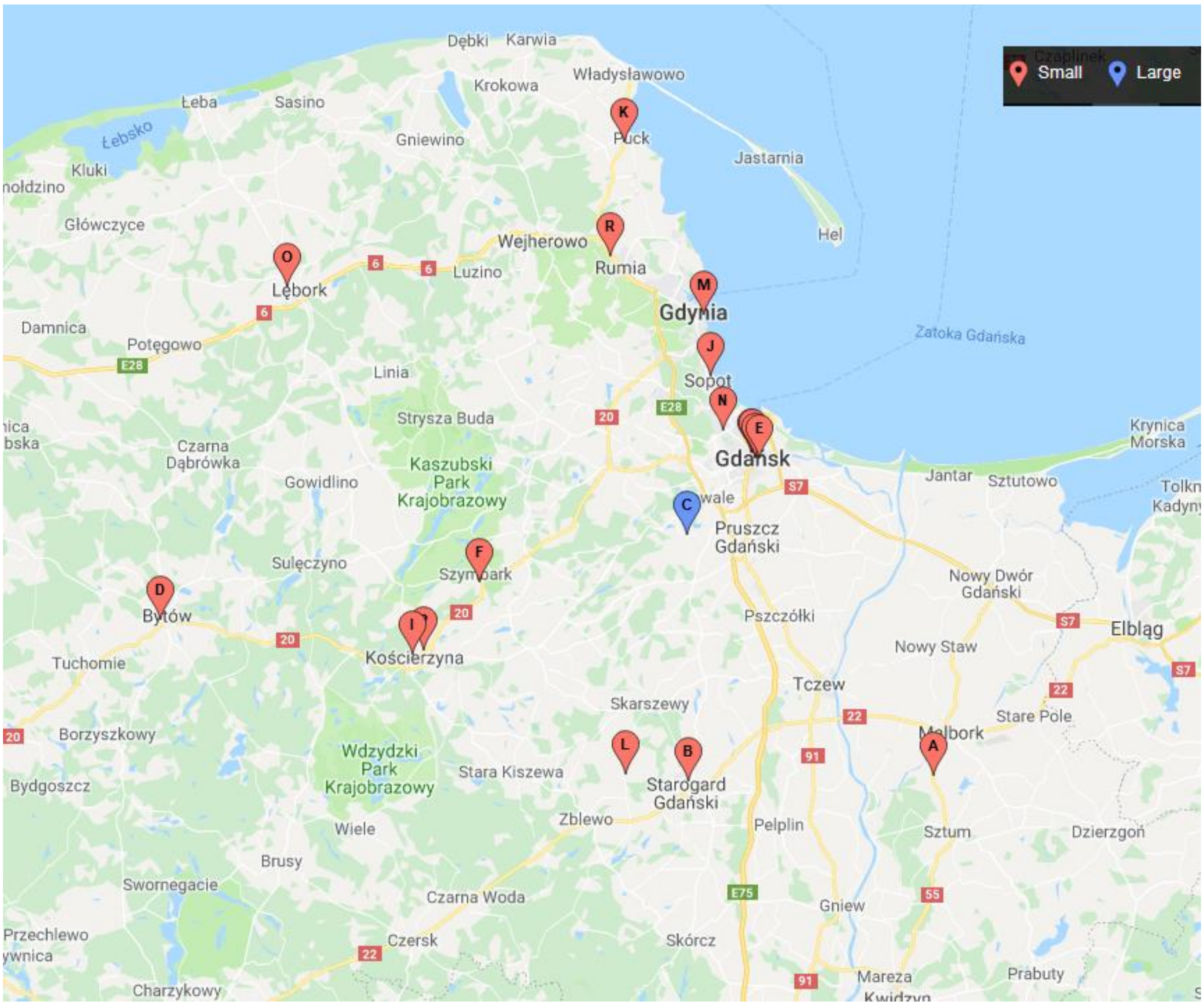

Fig. 2 Geographical distribution of breweries in the Pomeranian region. The red pins show small breweries and the blue pin shows a large brewery

2.1 Determination of current TRL of the project

There are a lot of studies that are dealing with BSG potential application, chemical composition and ways of utilization [2–5,7,9–12]. Scientists work in various institutions (universities, institutes, research and development units) in different parts of the world. The research is carried out independently for many years, and the results are published in world-wide journals, which prove the relevance of the problem of BSG utilization. The results of experimental research are very promising, and yet the main application for BSG is to use it as feed for cattle. The idea to use BSG for beverages is not totally new and unknown to anyone. There was one start-up company that has started to collect money on a crowdfunding platform in July 2017 for an alcohol-free beverage made of BSG. The beverage name was Canvas [13]. At the end of 2017, a limited amount of this drink was sent for sale in the United States as a pilot project. It is a kind of protein shake or smoothie in other words, in which cereals are fermented in very similar way milk is fermented to produce yogurt, and then supplemented with other organic ingredients such as fruits, nuts and spices [14]. The results of the experiment have not been disclosed to a wider publicity, nevertheless the product is not available commercially.

It can be assumed that it has not been very successful or is not yet fully developed and explored. This can be inferred from the fact that it is not even possible to buy the product on the manufacturer's website. All drinks have the status "sold out” and the latest reports about the company are from the beginning of 2018. Moreover, the mentioned Canvas drink [13] was an alcohol-free product and the biomass management proposal described here is based on a low-alcohol beverage, which was not found on the existing market.

The Polish South Baltic Area (SBA), which consists of Pomerania, West Pomerania and Warmia and Mazury regions has a big production of beer potential and hence high amount of Brewers’ Spent Grain that can be utilized in a new way. In Polish SBA there are 25 small breweries (annual production of beer up to 20 000 hectoliters), 1 medium brewery (annual production of beer at the level of 20 000 hectoliters up to 200 000 hectoliters) and 6 large breweries (annual production of beer over 200 000 hectoliters). The most of the small breweries (18) are located in the Pomeranian region.

There are installations on the market for mixing various ingredients as well as pasteurization or bottling for further sale. However, the use of a substrate (BSG) in the production of the beverage that is widely considered as a waste from the production of another beverage (beer) is a challenge due to a number of secondary aspects. The low Technology Readiness Level (TRL) does not result here from the lack of technology for production, but results from the use of an unusual by-product substrate and the related legal, logistical, marketing, bio-safety and taste difficulties.

That is the reason to assign the TRL 4. Technology components or basic subsystems were verified under laboratory conditions. The overall mapping of the target system under laboratory conditions was obtained. However, there is a need to develop lab-validated technology in a relevant environment. All the advantages of BSG, its rich nutritional properties, high fiber content and other valuable components content are indisputable. However, it should be not forgotten about other important aspects that needs to be considered when introducing a new food product for people. Difficulties that need to be overcome can be presented on three different levels. Those levels are legislation, production and sales. These aspects need to be developed both by scientists and entrepreneurs.

Any idea for a project, especially the one with a low TRL (at the pilot level) has many weaknesses, causes difficulties, problems, challenges and has some barriers. Similarly with the idea described here i.e. a new way to manage BSG by small local breweries or newly established entities by producing a low-alcohol nourishing beverage with a high amount of fiber and plant-based protein. This kind of beverage is not produced by any company nor available on the market. There are only reports from the scientific literature stating that BSG is a very promising material rich in nutrients, containing ingredients that can be fermented to produce alcohol. On the other hand, lack of such a product on a market can be a great opportunity for investors to fill a niche that is on the market which will result in good business and high profits. For that reason, there is a need for developing a new technology that would be feasible both from economic and ecologic point of view. To do so, it is necessary to identify and localize all the barriers and challenges in the present concept, providing new knowledge on what research and innovation should be done to implement the concept.

2.2 Analysis of short-term TRL improvement of the project

In the short term (2 years), it is estimated that work on the basic difficulties in implementing the described project will allow to increase the TRL to level 6. The culmination of TRL 6 is the demonstration of a prototype or model of the system or subsystem of the described BSG utilization technology in near real-world conditions, ready for another pilot demonstration product. Achieving TRL 6 means that a representative model or prototype of the system was tested, which is much more advanced than the one tested at previous levels, in conditions similar to real ones. Tests at this level include prototype tests in laboratory conditions reflecting real conditions with high fidelity or in simulated operating conditions.

To make it happen, in the next 2 years it should be focused on overcoming the barriers that are presented in Table 1. Most of the problems described here can be solved by intensive laboratory experiments both in scientific institutions (universities, institutes) and in Research and Development (R&D) centers or units of large breweries. The main goal should be to encourage entrepreneurs to invest in bioeconomy, and scientists to devote their time and energy to research on BSG and the possibility of its utilization by people, not just animals. To do so, there is a need of special financing programs for entrepreneurs in the form of tax vacations and additional funds for the development of biomass management technologies. Changes in the law that will allow the real competition of bio products with products based on classic solutions (oil-based products, plastics, food with artificial additives) are necessary for bioeconomy to be developed. These changes should start immediately and be developed at both regional and national level.

The world is changing fast and developing. Keeping up the pace with this world is of outmost importance. Changes in every field, starting with education are crucial. New fields of studies related to modern green technologies should be opened to train specialists in bioeconomy and related sectors. The same profile of specialists should be sought abroad and attracted to come to Poland to develop their passions and skills here, contributing to the development of the country and particular regions especially. Until now, talented Polish people seek their careers abroad, and Poland lost a lot of scientific and technical potential in this way. It is now time to change and reverse that trend, which is why legislative and related changes are necessary.

Moreover, the dedicated funds for projects connected with biomass utilization and green technologies should be created or expanded. The regional and national government should promote and reward ideas that significantly contribute to the development of bioeconomy. The new beverage should be healthy and eco-friendly to fit into the current trends of the society of European Union.

Table 1 The barriers and solutions of a short-term TRL improvement plan

Barriers	Solutions
The high cost of entering the market in the case of the construction of a brewery as a production plant.	Increasing public awareness of the potential benefit of technology under development. Development of existing installations. Involvement of investment banks.
High production costs and thus the high final product cost.	Development of cost effective technologies.

	Increasing the pressure on introduction of new ecologic technologies into compulsory practice. Subsidies from state institutions for new installations. Own energy source to reduce the operational costs.
A lack of tested recipes for new beverages.	Employment of experienced brewers and cooperation with producers of other beverages. Literature survey (historical).
Difficulties with obtaining the right taste, smell and color of products containing BSG.	Chemical and biological research on BSG.
Difficulties with maintaining the repeatable quality of products constituting a company's permanent offer.	Increased research on the composition of BSG and determining what affects the taste and smell of the product and its nutrient content.

The short-term TRL improvement should be primarily focused on solving difficulties occurring on the production level and starting to working on enforcing changes in law. The legal issues related to available waste are the most important barrier because no new solution that will not be supported by good policy will have an advantage over existing solutions. Moreover, the changes in law require time so it should be started at the very beginning. Therefore, the state needs to start promoting ecological solutions through appropriate legislation and to reward practices closely located in the field of bioeconomy to encourage entrepreneurs to use the principles of sustainable development and circularity.

It should be noted that entering the market with a new product is unpredictable. It may be that the new beverage will appeal to customers and will turn out to be a huge success, which will bring profits. It may also be that despite proposing a product of a very high quality, it will not appeal to customers and all investments made may not pay back. That is why it is worth paying special attention to costs and investing carefully. The cost of development of breweries is high. The solution to this issue is trying to find existing, old installations, that are often abandoned and to invest there and develop existing facility. It would be much cheaper and easier for investor to adapt existing building and machinery instead of buying a new one. Increasing public awareness of the potential benefit of technology under development should be also very profitable in broader perspective.

A completely new, innovative product requires greater financial outlays for its development and promotion. Demand is also lower (especially at the beginning), and hence the profits compared to products well known to the consumer are also lower. To reduce the impact of this phenomenon and to promote bioeconomy to a greater extent, there is a need of subsidies from state institutions for new producers or existing producers with a new bio-product. It would lower the final price and make it easier to promote for the customer. The company can also consider own source of heat and/or electricity, e.g. Combined Heat and Power (CHP) facility based on Organic Rankine Cycle (ORC) technology.

The next production difficulties is a recipes for new beverages which are not known yet and at the same time the main substrate (BSG) and people’s taste preference of it is also unknown.

To overcome this barrier, producers should rely on experienced craftsmen, look for inspirations in other branches of beverages, not only the beer and make a lot of tests, experiments and attempts in the field of finding new tastes which will delight their customers. They can also carry out literature studies. Very often it turns out that old recipe books carry a lot of useful information and inspirations.

The next barrier or challenge connected with the BSG is a taste and color of the products that have BSG in their composition. Brewers' Spent Grain (BSG) is brownish in color when moist and thus can only be used in off-white products or in such products that brown color would not affect. Moreover, because of alterations in the flavor only relatively small quantities of BSG can be incorporated [2]. This negative taste-effect is associated with high quantities of compounds such as 2-butyl-1-octanol, 3-methyl-butanal, 2-heptane, butanal, benzene and 2, 3-butanedione, responsible for its characteristic unpleasant odor. But there are studies that use supercritical CO_2 to mask the unpleasant and bitter taste and simultaneously to preserve the stability of polyphenols or other bioactive compounds.

Even if the recipe and taste of the final product would be finally satisfactory there is another aspect of production, i.e. repeatability of product's quality. The BSG chemical composition is dependent on the numerous parameters as said before. These parameters are connected with raw product (e.g. barley) itself as well as processes in brewery (fermentation, milling etc.). It is challenging to control all these parameters in such a way that the taste and properties of BSG remain unchanged. To achieve this, it is first and foremost necessary to have a clear description what affects the taste and smell of the product and its nutrient content. To do so, there is a need of more scientific studies in biological and chemical laboratories. The best solution would be the cooperation between the entrepreneurs and scientists.

2.3 Analysis of long-term TRL improvement of the project

In the long-term (4 years) improvement, it is estimated that work in regards of legislation and sales in the field of bioeconomy, especially in the brewery production, BSG distribution and utilization will allow the increase of TRL to level 8. It means that research and demonstration of the final form of technology are completed. It has been confirmed that the target level of technology has been achieved and the technology can be used in the conditions envisaged for it both in terms of technical possibilities to implement the project and legal and administrative possibilities. Practically, this level represents the end of the demonstration. Examples generated during long-term TRL improvement include testing of production, storage, distribution and consumption. Evaluation to confirm that the design assumptions have been met, including those related to logistic security and training.

To make it happen, in the next 6 years it should be focused on overcoming the barriers that are presented in Table 2. It can be achieved by changing the legal acts, introducing various long-term regional development programs, carrying out state campaigns for the promotion of biomass products, supporting the small and medium-sized enterprises. It can be noted that the majority of businesses do not have their own R&D department, so the role of universities and research institutes and the need for research and cooperation between entrepreneurs and scientists should be emphasized.

Table 2 The barriers and solutions of a long-term TRL improvement plan

Barriers	Solutions
More restrictive regulations on products made from residues	Unambiguous definition and differentiation between wastes, residues and by-products.
Investment risk can be too high for investors.	Various grants for investors to encourage them to take risks. Promoting pro-ecological solutions at national and regional level. Good business plan and risk assessment, taking into account all risk factors.
The need of good marketing	Create a social awareness of bioeconomy and local products by preparing appropriate campaigns.
Small, local market – low income	Establishment of a network of regional producers of beer and BSG products in order to promote bioeconomy.
The appearance of products of dubious quality on the market, "impersonating" for known craft products	Distinguishing regional products, bio products and tightening the law regarding the granting of such statuses to products.

The long-term TRL improvement should be still primarily focused on solving difficulties occurring on the legislation level and in addition at sale levels. The main issue in Poland is the lack of official definitions of waste, residue and by-product. Moreover, the regulations on products made from residues are very strict and out-of-date. Nowadays, it is more and more popular to utilize the residues from one process and make something useful in another. However, the legislation often fails to keep up with the changing world and still valuable products that are residues from one process are treated as waste and cannot be used in another. The unambiguous definition and differentiation between wastes, residues and by-products in regional or national law would be very helpful in that manner.

Investors rarely decide to finance risky investments because they are afraid of failure, and with it, the financial outlay that cannot be recovered. This is strong barrier that should be emphasized. The solution to this problem is comprehensive and requires an involvement of the national and regional politicians, stakeholders and society. Appropriate legal regulations should be introduced to promote pro-ecological solutions. They should be focused on sustainable development principles and circular economy. The state should promote businesses which have a courage to invest in bioeconomy. Such regulations and promotions may encourage investors to become interested in the area of solutions in innovative “green” technologies. It is also important to prepare a detailed business plan concerning a risk assessment that will minimize the chances of failures.

It is worth to be remembered that business should make a profit. To achieve it, there is a need of good marketing for new, innovative products. The role of politicians, lawmakers and stakeholders is creating a social awareness of bioeconomy and local products by preparing appropriate campaigns. Thanks to that, small and local market would get greater incomes which will result in better and cheaper bio-products. Another solution for low income and lack of marketing for bio-products is establishing a network of regional producers of beer and BSG products in order to promote bioeconomy and region.

3 Conclusions

Determining TRL and its short- and long-term development is crucial before attempting to develop innovative technology. Knowledge about the current state, locating all threats and defining an action plan for the coming years is necessary for the correct implementation of the project.

Projects based on the use of biomass from other manufacturing processes are specific. They require knowledge in various fields of science (chemistry, biology, economics, law), and their success depends on many factors. The technologies used in the area of bioeconomy are currently very expensive, they require many legal changes, cooperation between various industry sectors, and in addition there are restrictions related to the workers and scientific staff.

As emphasized earlier, the analyzed idea of producing a low-alcohol nourishing beverage with a high amount of fiber and plant-based protein from Brewers' Spent Grain may seem to be quite a simple technology to implement, but the difficulties are associated with something else than just producing the beverage. The main issue here is played by the type of substrate that is to be developed, i.e. BSG. It is still a resource treated as waste that can be used in feeding cattle. There is a need for an unambiguous law that will distinguish between waste, by-product and residue.

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PRODUCTION OF NATURAL COSMETICS BASED ON EXTRACTS FROM CARROT POMACE

COLOURBOX34760928

16.09.2020

Innovation Programme

Cosmetic beta-carotene extract from carrot pomace

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1. Introduction

In recent years, an increase in interest for innovative development directions related to environmental protection is observed. It is due to introduction of extensive legislation changes, occurring not only at the national, but also at the global level, which are aimed at stopping the progressive degradation of the environment. The increasing consumption of raw materials and non-renewable sources forces entrepreneurs around the world to look for new substitutes, preferably of natural origin. Organizations such as EU have been taking action for years to steer the economy into circular economy model, which could help to reduce the negative environmental impact of industries. An idea, that fits in perfectly with circular economy, is the concept of cascading approach, which evaluates the methods of post-production waste management. It is essential to lean towards new methods of waste valorisation, producing cosmetics, medicines, food products or biodegradable materials from them, instead using it as energy raw material.

Reducing the exploitation of the natural environment can take place through the maximum reuse of waste. In many industrial processes, especially in food processing, the residues in the form of fruit and vegetable waste contain a large part of valuable active ingredients that can be reused in a completely different industry – cosmetics – often in a very profitable way. The trend of organic cosmetics with plant extracts from sustainable crops, which is gaining considerable popularity, makes it necessary to create new lines of cosmetics that would meet the growing demands of consumers. Hence, it is a promising idea to recover from food waste extracts that can be used in cosmetics.

Each project, and in particular the innovative biomass projects, should undergo a technological readiness level (TRL) analysis. It is a useful tool for mutual communication between entrepreneurs, scientists and investors, that helps properly plan and track project progress. It is worth analyzing the current and future TRLs to locate the weaknesses of the project and to ensure raising the level in a short amount of time.

2. Analysis of Technology Readiness Level of production of beta-carotene extract from carrot pomace

Thanks to the long-standing tradition of carrot cultivation, Poland is one of the world's leading producers – in 2018 in European Union Member States, Poland, together with the United Kingdom, was at the forefront of the production of this vegetable. Both of these countries produced 0.7 million tons in 2018 (a combined 27.8 % of the EU total)[1]. This creates interesting possibilities for the management of waste arising from carrot processing, taking into account the possible large source of raw material in the form of post-production waste. The southern Baltic region, due to its mild maritime climate, much higher humidity and relatively lower temperatures than in southern Poland, allows for higher yields per hectare and high-quality carrots.

[1] *Agricultural production – crops*. Eurostat, 2019.

The example of a company producing vegetable juices without added sugar, preservatives and unnecessary chemical additives was taken for analysis. The main processed raw materials are carrots, apples, white cabbage, celery, beets and others, depending on what seasonal flavors were released on the market in a given period. Since the juices are produced without the addition of chemicals, the process produces waste in the form of pure carrots and good quality waste water. During production, organic waste remains, such as:

- carrot pomace,
- post-production vegetables (peelings from carrots, apples, celery),
- waste plant mass (vegetables unfit for production, damaged, spoiled).

Annually, the plant produces about 2 000 tons of pomace and about 400 tons of post-production vegetables. Carrot pomace was tested in laboratory, to check the content of specific ingredients. The composition of the carrot pomace is given in Table 1. It can be seen that valuable nutrients still remain in the waste, especially the carotenes, which have a positive effect on human skin and are widely used in cosmetics.

Table 1. The composition of carrot pomace

	Orange carrot root meal	**Orange carrot pomace meal**	**Purple carrot root meal**	**Purple carrot pomace meal**
Dry weight (%)	90.61	93.06	92.3	94.69
Crude ash (%)	7.36	6.72	6.06	5.26
Crude protein (%)	7.37	6.63	9.65	9.08
Crude fat (%)	1.58	1.01	1.02	0.81
Total carbohydrates, including fiber (%)	75.7	71.6	74.4	72.3
Fiber (%)	25.7	55.8	28.6	55.6
Acids phenols (lyophilisate, without chlorogenic acid) (μg/g)	71.02	42.41	601.73	200.87
Chlorogenic acid (mg/g)	0.47	0.17	11.87	2.53
Anthocyanins (mg/g)	-	-	12.85	3.06
Lutein (mg/100g)	2.56	0.81	8.32	2.71
Alpha-carotene (mg/100g)	17.36	8.67	-	-
Beta-carotene (mg/100g)	39.86	19.4	0.46	0.08
Total carotenes (mg/100g)	65.88	32.52	9.63	3.48

The analyzed project is the production of beta-carotene extract from carrot pomace, which could be used as an ingredient in natural cosmetics. It is a particularly forward-looking direction of development due to the dynamic growth of the cosmetics industry and the revenues it generates. Cosmetics and pharmaceuticals, according to the cascading approach pyramid, are the most profitable use of waste. The European cosmetics market was valued at 79.8 billion EUR in 2019[2]. Poland is the sixth largest national market for cosmetics products

[2] *https://cosmeticseurope.eu/cosmetics-industry/* Cosmetics Europe, 2019.

within Europe, valued at 4.1 billion EUR[2], it is therefore an attractive field of activity for new, innovative businesses. A particularly developing branch of the beauty industry, in which innovations in the use of biomass waste can be applied, are natural cosmetics. Increasing consumer awareness means that more and more cosmetic brands are introducing to their portfolio lines of products based on ingredients of plant origin and natural extracts, and some completely switch to the production of plant-based, environmentally friendly cosmetics.

There are known uses of waste from the food industry in cosmetics, however, these are few examples on the huge Polish market. This study considers producing beta-carotene oil extract from carrot pomace in order to use it as an active ingredient in cosmetics made in line with the less waste philosophy.

Mirheli et al.[3] proposed a method of obtaining beta carotene extract from carrot pomace using ultrasonic-shaking incubation method. In the research they examined several possible combinations of the duration of individual processes and indicated the most favorable conditions. According to the researchers, carrot powder mixed in the proportion of 1.5 g per 100 ml of ethanol solvent is placed in an ultrasonic bath at 50°C at a frequency of 20 kHz for 80 minutes[3]. Then it is placed in a shaker incubator at 30°C, at rotational speed of 150 rpm for 120 minutes[3]. Then the finished carrot extract is filtered from the carrot powder. The tests showed that the above conditions allow for obtaining an extract with a high beta carotene content, equal to about 54 ppm[3].

Assuming that all of the above-described powdered carrot waste from the juice factory is used to produce the extract, 2 000 tons of carrot pomace will be used in the final process. In Figure 1, the material flow for the production of beta carotene extract from waste is shown.

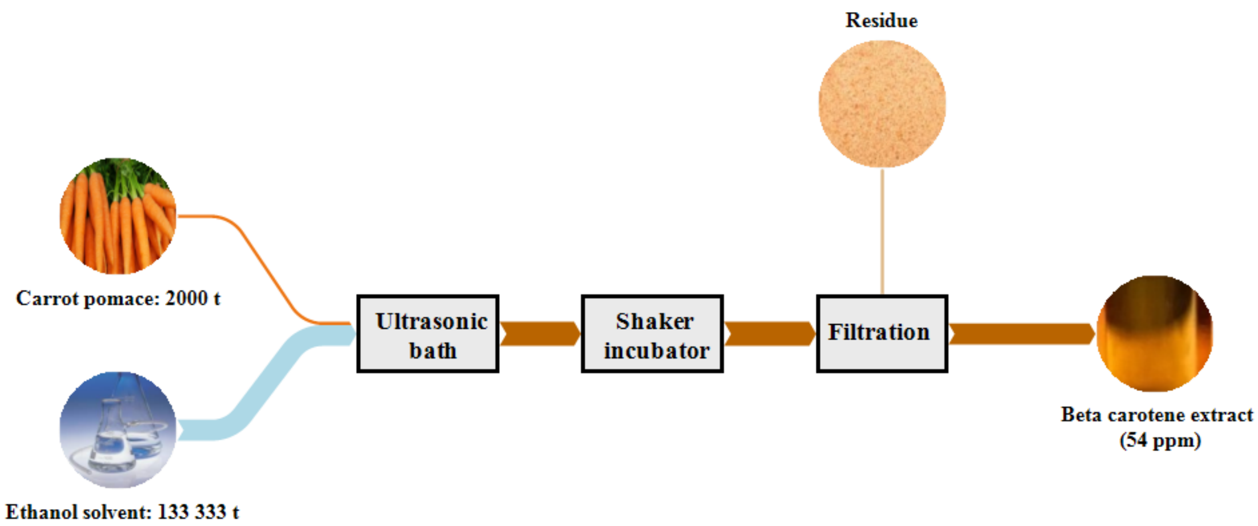

Figure 1. Material flow of beta carotene extract production (annual values)[3]

[3] Mirheli M., Taghian Dinani S.: *Extraction of β-carotene pigment from carrot processing waste using ultrasonic-shaking incubation method*. Journal of Food Measurement and Characterization, 12(3), 2018, pp. 1818–1828.

2.1 Determination of current TRL of the project

To define the current level of technological readiness of the above-described project, several aspects related to the current knowledge and market review should be investigated and compared with definitions of technology readiness levels. First level describes the lowest level of technological advancement and the ninth level means its full maturity and readiness for implementation.

Research on the reuse of waste carrot pomace has been documented in the prefeasibility study. Many studies conducted so far have focused not only on the possibility of extracting valuable ingredients from vegetable waste, but also improving and optimizing these processes. Previous studies with the use of laboratory equipment indicate the validity of the proposed methods. Therefore, it can be assumed that the proposed technology achieved TRL 4 as it has been validated under laboratory conditions.

The review of the Polish natural cosmetics market shows a few examples of products that use extracts from post-processing waste. An example of this type of products in Poland is the Blueberry C-Tox line by Bielenda, which uses blueberry seed oil obtained as a by-product of juice production. Another product is Paese's Nanorevit Natural Finish Longwear Everyday Foundation. According to the manufacturer, blackcurrant pomace from the production of the juice was used as an active ingredient. However, the presented examples are rare on the Polish cosmetics market, moreover – no products using extracts from carrot waste have been identified so far. This means that such solutions are not yet implemented. Neither of these companies are in the SBA regions either.

Presented analysis indicates that the project is currently on the TRL 4/5. Numerous research and tests carried out in laboratories confirm the validity of the technology of beta-carotene production from carrot waste. Moreover, the products available on the market show that it is possible in Poland to release a cosmetic product using waste ingredients. However, there are no reports of an industrial demonstration of the production of beta-carotene extract from carrot pomace and there is no ready prototype installation in the SBA region in Poland.

2.2 Analysis of short-term TRL improvement of the project

For the analysis of predicting the level of technological readiness of the project in the short-term perspective, a period of 1.5 year was assumed. Based on recent scientific research and the market situation, it was assumed that TRL 7 is the realistic level to be achieved. The mentioned technology of beta-carotene production from carrot pomace is relatively simple and does not require complex machinery. There are several steps that should be taken within 1.5 year to overcome barriers that slow down or prevent the implementation of this type of technology in the SBA region of Poland. Table 2 summarizes the barriers and threats and proposes some solution strategies.

Table 2. Barriers and solutions for increasing TRL of the project perspective

Barriers	Solutions
Long procedures	• Standardization and simplification of regulations on biomass waste • Faster procedures allowing changing the waste status
Unawareness of entrepreneurs about the available raw materials from waste	• Promoting circular bioeconomy • Possibility of easier access to laboratories • Reimbursement of research on the composition of waste • Creating a program associating companies from the biomass processing industry
No pilot demonstration plants in real-life conditions	• Development of a prototype pilot plant installation • Starting cooperation with entrepreneurs to conduct tests in real-life environment • Financial bonuses for this field of research

A significant problem is the problem of changing the status of a given product from waste to raw material and obtaining a permit to allow it for further processing. In order to change this status, each case must be considered separately, at the request of a given company, which significantly lengthens and complicates the process – there are no regulations governing this matter and all permits are issued based on the company's request and application. This is a kind of challenge that may discourage producers from taking steps regarding the use of waste in the production process due to the fact that each new component/waste will require a separate procedure. The small amount of products containing waste ingredients confirms this. The solution to this problem should be a faster, standardized procedure for all waste and introducing the definition of waste from biomass processing.

The problem is the lack of popularity of unusual solutions using waste - the Polish cosmetics market is huge, but so far only two companies have decided to release the product using waste material, and additionally only in a few products. Entrepreneurs in the cosmetics industry may be interested in new solutions in line with the idea of less waste, but do not know that biomass waste may contain such valuable ingredients from the point of view of cosmetology. This is due, among other things, to the fact that the waste is disposed of because manufacturers are not aware of the content of valuable ingredients in them. A solution could be a program associating biomass processors, in which they could obtain funding or priority for laboratory research on the chemical composition of the waste they generate. The results could be published in a public database, so that not only companies but also university researchers could know which waste to conduct research on in order to obtain valuable ingredients from it. A change of perspective is required - the residues from biomass processing should not be treated as "waste", but rather with the assumption that this component should be tested and reused.

To achieve TRL 7, a pilot plant must first be deployed in an industrial environment. Since the indicated technology does not require complicated equipment, its implementation will not require qualified staff, only financial resources for the construction of such installation may be a barrier. Most companies are concerned about the financial risk and do not want to invest in a given technology. In order to encourage companies from the cosmetics industry to cooperate, it would be necessary to propose initial funding for the equipment needed to start the installation. The cooperation should take place between the entrepreneur and local authorities and research centers, which should also take an active part in the process of implementing the installation in industrial conditions and cooperate with the company until TRL 9 is achieved.

2.3 Analysis of long-term TRL improvement of the project

For the analysis of predicting the level of technological readiness of the project in the long-term perspective, a period of 3.5 year was assumed. The desirable level of technology after this time would be TRL 9, which would allow to start production on large scale. Previous steps, considered in short-term analysis, aimed at starting the project, while long-term planned works require further changes. Table 3 presents barriers and ways to solve them to achieve TRL 9 in 3-4 years.

Table 3. Barriers and solutions for increasing TRL of the project in long-term perspective

Barriers	**Solutions**
Lack of standards, legal acts, national guidelines	• Change of waste/biomass management law, creating framework and standards • Changing the definition of waste
Possibility of lack of raw material	• Developing permanent cooperation with biomass producers through network • Optimization of the raw material transport/storage
Threat of lack of market	• Campaigns on proecological solutions • Support of specialists in the field of risky investments, marketing, business plans • Collaboration with research centers on new cream formulations

The biggest problem in Poland regarding the management of waste from biomass processing is the lack of legal regulations and a definition of such waste. This limits their reuse, as they must be disposed of as waste - the law will not allow it to be used as a raw material in another process.

A perfect example is not only the carrot pomace, but also the wastewater generated in the production of carrot juices - because the company does not use any additives or chemicals, the wastewater is exceptionally clean, which is confirmed by laboratory tests, and yet it cannot be used for irrigation of nearby of soils because of its status. It is therefore important to create a new legal framework and regulations that would apply precisely to this type of waste that can be successfully further processed or reused. The possibility of a faster change of the waste status, mentioned in the earlier analysis, will allow to raise the TRL of many innovative projects in a short period of time, however, a further change of the law regulating the functioning of biomass products on the market is needed. The provisions of the law should be rethought so that the waste status change procedure for certain types of post-processing biomass residues would not be necessary. In 2019, the Council of the Ministers prepared the document "Road Map for transformation towards a circular economy". The map provides for the completion of works related to regulations regarding biomass products for 2021-2022. Close cooperation between the ministers of: environment, economy, energy and agriculture is planned, which will aim to create uniform biomass standards and amend existing laws: the Act of 20 February 2015 on renewable energy sources and the Act of 14 December 2012 on waste. The rapid action envisaged in this document will significantly increase the TRL of biomass related projects.

One of the barriers may be the concern of the cosmetics company about the lack of continuity of supply of raw material from the factory processing carrots for food purposes. Therefore it would be necessary to establish cooperation with many entities using a dedicated network associating biomass processors in order to have several sources of raw material. It would be useful to involve government bodies that could facilitate “connecting” companies and indicate to interested companies the plants where the desired waste is generated (by, for example, having a database of plants and the waste they produce). Another way would be to optimize the transport and storage network of the raw material in an appropriate manner, so as to have constant access to the carrot pomace.

Another factor that prevents such solutions from developing is the lack of the market. As previously mentioned, natural cosmetics are very popular, but there are only few examples of using a waste component in them. On the large cosmetics market in Poland, the new line may go unnoticed, hence it is important to cooperate with marketing and promotion specialists in order to create a campaign that would provide the new line with a stable position on the market. The strength of the cosmetic would be not only the origin of the ingredient in line with the *less waste* approach, but also its regional and natural character. It would also be worth investing in the development of new cosmetic formulations based on this ingredient in order to develop innovative, effective cosmetics with a consumer-friendly formula - Poland is a well-developed country in the field of cosmetic laboratories, with experience in implementing innovations, so it is therefore worth taking advantage of the opportunities it offers.

3. Conclusions

Performing a TRL analysis is important in terms of implementing innovative technologies. It allows to set goals or milestones and enables more productive cooperation between specialists from various fields, who work together on a specific project. This is particularly important in projects related to the use of biomass, especially post-production waste, which requires cooperation at many different levels. Biomass waste management technologies are extremely important in the aspect of the circular economy. The undoubted added value of this type of projects is environmental protection, so despite high investment and maintenance costs, it is necessary to support entrepreneurs who want to create this sector in Poland.

The analysis indicates the key barriers and actions that should be taken to gradually increase the technology readiness levels of beta-carotene extract production from carrot pomace in the SBA region in Poland. The biggest obstacle is the change of the waste status and the preparation of a pilot plant on an industrial scale. Both of these obstacles can be overcome in a short time by coordinated action by legislators, entrepreneurs and scientists. The proposed technology will definitely need further refinement, however, the dynamically developing market of Polish natural cosmetics additionally stimulates the innovations in this area, therefore it is future-proof to invest in such ideas.

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

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Innovation Program: Processing and preparation of organic apple waste to produce high-quality proteins

1 Introduction

Globally, the demand for healthy, natural, and tasty processed fruits continues to increase. This also includes fruit-based products[1]. Nielsen, one of the world's biggest snack companies, reported that snack sales obtained $374 billion annually, increasing 2% per year[2], with an increased share of dried fruit chips. Recent research trends indicate a rise in apple pomace as a food processing residue to extract value-added items such as dietary fiber, nutrition, natural antioxidants, and biopolymers pigments compounds with specific properties[3]. Therefore, we can identify a growing supply of apple pomace and also apple cores globally. To counteract industrial livestock farming's various effects on the environment and climate and its consumption of resources, sustainability measures are necessary. One of those measures can be the utilization of apple cores as a basis for growing basidiomycetes. A growing awareness of the negative consequences of animal food production and the emergence of new biotechnological protein production processes has also led to increased investor interest and, in particular, to significant capital investment in the USA, Israel, France, and the Netherlands[4]. The production of microbial proteins or mycelium from higher fungi may be a key technology

[1] Elena Velickova, Eleonora Winkelhausen, and Slobodanka Kuzmanova, "Apple chips produced by osmotic-conventional dehydration," 2011.
[2] Hanna Kowalska et al., "Development of apple chips technology," *Heat and Mass Transfer* 54, no. 12 (2018).
[3] Shashi Bhushan et al., "Processing of apple pomace for bioactive molecules," *Critical reviews in biotechnology* 28, no. 4 (2008).
[4] Alexander Stephan, *Product development of innovative foods based on an alternative protein source from basidiomycetes* (Dissertation, Justs-Liebig-Universität Giessen, 2018), http://geb.uni-giessen.de/geb/volltexte/2018/13835/.

in the future, as various enzymes are secreted into the environment, enabling the degradation of hard-to-reach macromolecules and making the resulting nutrients available for growth. Furthermore, the biological value of mycelia from basidiomycetes is high compared to plant proteins. The cultivation and associated conservation of resources (consumption of water, area, and CO2 footprint) show that basidiomycetes mycelia are an efficient alternative protein source. The energy required for fermenters and drying plants could be covered by renewable energy sources such as photovoltaics, hydropower, or wind power[5]. While the pre-feasibility study and the business case focused on the process's direct application, this innovation program instead focuses on a holistic view of the Technology Readiness Level (TRL). Such an analysis is a useful tool, especially for projects that are not yet widely applied, as is the case here. By analyzing the current and future TRL level, the idea's weaknesses can be revealed, and thus the attempt to solve them can be started earlier.

2 Analysis of the TRL level of the production of mycoprotein in the basis of apple cores

The apple value chain's unique feature in Mecklenburg Western Pomerania was already pointed out in the business case: 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]. During the season, a local company produces 670 tons of apple cores, which has to be dried to reduce the risk of spoilage and results in 67 tons per season. In the context of the project outlined in the business case, it is necessary to investigate the extent to which the apple cores are suitable as a substrate for the production of high-quality protein. The resulting mycoprotein's physiological and metabolic properties also represent new requirements for the utilization of this unused by-product stream. It is also to be determined in which way the mycoprotein will be utilied further along the chain. One especially promising outlook is the production of a meat alternative. In the search for alternative protein sources for human nutrition, the developers of Quorn (Ranks Hovis McDougall, RHM) focused on using the filamentous fungus Fusarium graminearum in the 1960s. From the start, product development was geared towards its use as a foodstuff, with the substrate selection of glucose

[5] Alexander Stephan, *Product development of innovative foods based on an alternative protein source from basidiomycetes* (Dissertation, Justs-Liebig-Universität Giessen, 2018), http://geb.uni-giessen.de/geb/volltexte/2018/13835/.

[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.

from wheat or corn starch in food quality for the continuous fermentation process, an essential prerequisite for later approval food was created. The mycelium produced in the fermenter is harvested and processed into the finished product with spices and binding agents. The mycelium's fibrous structures ensure a very meat-like consistency of Quorn, which comparable products based on soya or wheat protein cannot currently offer. Since its launch in England a good 30 years ago, the product has established itself and is successfully marketed in many European countries, including Germany. A vegan variant, which contains potato protein as a binding agent instead of chicken egg white, is available in the USA. Quorn is so far the only commercially available mushroom-based meat alternative[7].

To establish the current level of technological readiness, several aspects relevant to the current knowledge and market analysis should be examined and compared with the definitions of the level of technological readiness. The first level describes the lowest technical development level, and the ninth level describes its maximum maturity and preparation for implementation. An in-depth literature review has been carried out during the pre-feasibility study and is supplemented by the business case. The research landscape also focuses on its valorization as a supplement for nutrition:

Figure 1 *– Mycoprotein research landscape, Web of Science categories*

To figure out the research landscape, a Web of Science search was conducted. Searching by the string "mycoprotrei*" resulted in 105 scientific articles. 58 (Food Science Technology;

[7] Ingrid Weigel, "Proteine nicht tierischer Herkunft als Fleischersatz - eine aktuelle Literaturübersicht," 2017, https://www.raps-stiftung.de/fileadmin/templates/default/dokumente/Projektbericht_Fleischersatz.pdf.

Nutrition Dietetics) can be directly associated with the food sector, while 36 (Biotechnology Applied Microbiology; Chemistry Applied; Allergy) are believed to fall into this section (Fig. 1). Looking at the publication years reveals a growing interest (Fig. 2):

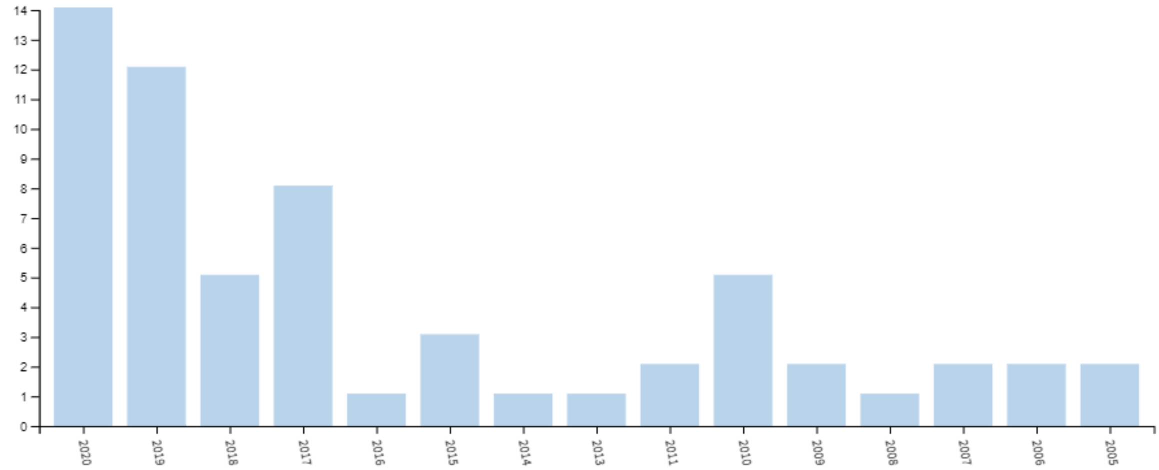

Figure 2 *– Number of published articles per year with the topic "mycoprotein", Web of Science*

This increasing research interest goes along with the growing demand for vegan products.

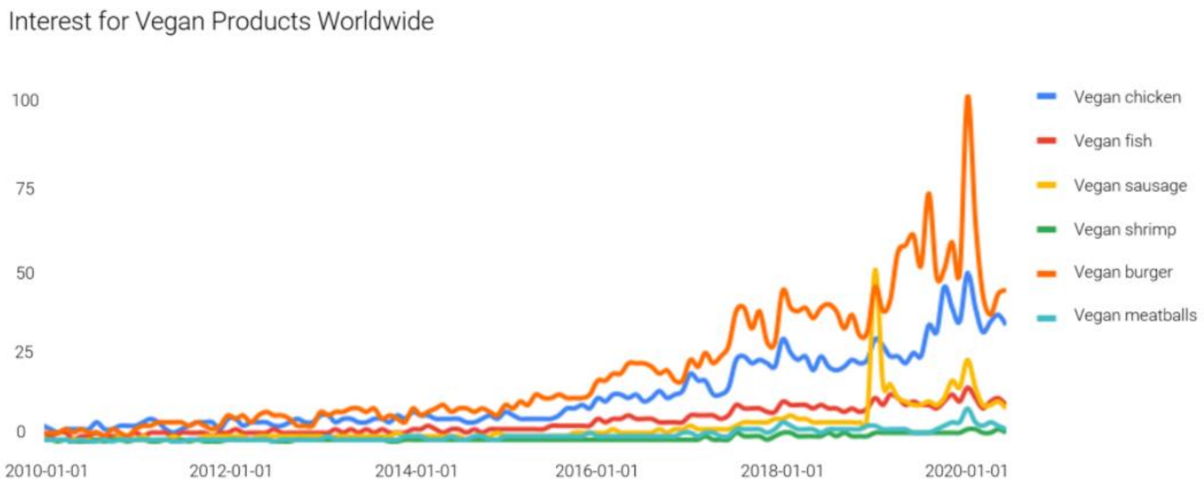

Figure 3 *– Interest for vegan products (Mycorena 2020, https://mycorena.com/mycoprotein-the-new-big-bang-for-the-vegan-market)*

The interest in mycoprotein worldwide is growing, especially in the UK and Ireland, mostly because of Quorn, but also in the US, Germany, Brazil, India, and the Philippines (Fig. 4)[8]

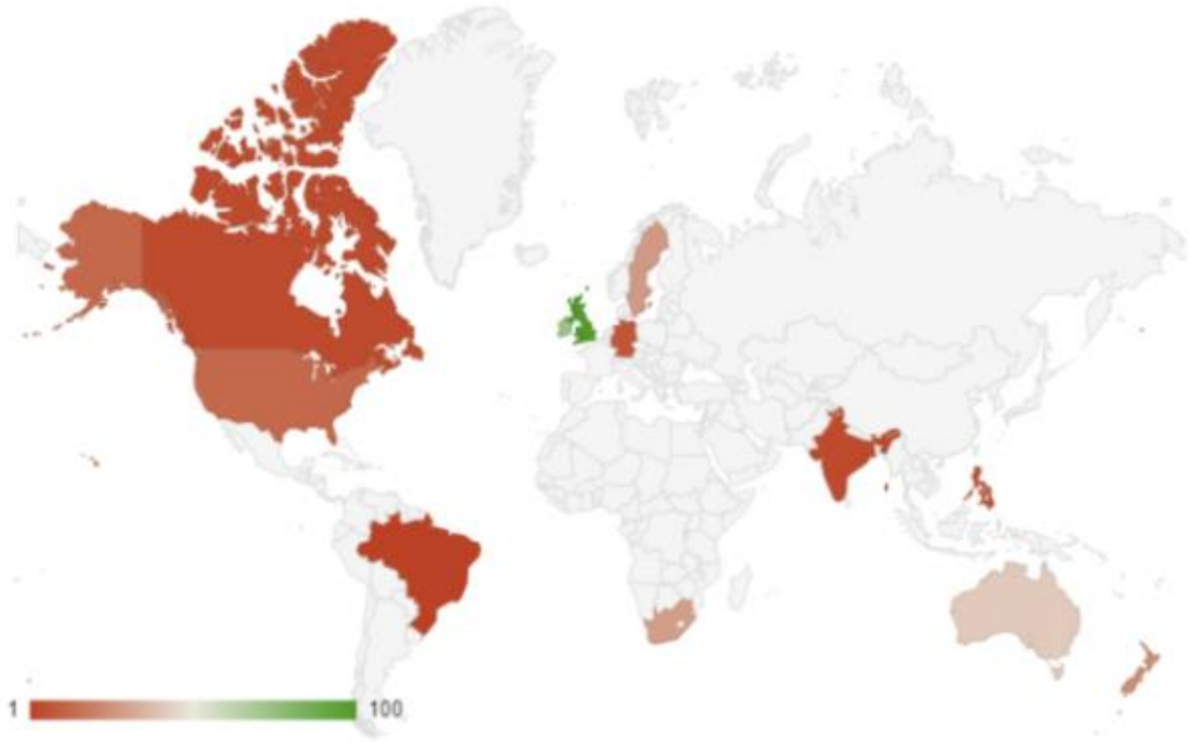

***Figure 4** – Geographical interest for mycoprotein (Mycorena 2020, https://mycorena.com/mycoprotein-the-new-big-bang-for-the-vegan-market)*

However, while scientific research and market demand continue to grow, there still is only Quorn that actively produces mycoprotein. Start-ups like mycorena do indeed look promising but did not enter the market yet. Thus, no company in Germany is producing mycoprotein, and none globally does so based on apple cores. Therefore, the comprehensive analysis in the two previously written papers and in this one comes to the conclusion that the project is currently on the verge between TRL 3 and 4. This means that the technology is not yet validated in a laboratory environment but is promising on the basis of multiple studies and thus can be expected.

A duration of 1,5 years was assumed to forecast the project's degree of technical readiness in the short-term perspective. Based on recent scientific studies and the business situation, it has been assumed that TRL 4 is the reasonable level to be achieved within two years. The current state of the research, coupled with the project's outline and ongoing scientific

[8] Mycorena, „Mycoprotein: the New Big Bang for the Vegan Market“, https://mycorena.com/mycoprotein-the-new-big-bang-for-the-vegan-market

evaluation, will make it possible to validate the technology in a lab and be in an appropriate environment under near-real-life conditions. Barriers and solutions to this are summarized in Table 1.

***Table 1** – Barriers and solutions for increasing the TRL-level in the short-term*

Barriers	Solutions
¬ Project initiative hindered by Covid-19	¬ Concrete planning of steps with the changed situation in mind
¬ Lack of communication between local actors	¬ outline clear communication plan with actors right from the start
¬ Miscalculation of the project	¬ Demand more funds

Due to the fact that the TRL level is, at the moment, only on a level of three and a project is well underway that will tackle the challenges, there is not much that can go wrong. In some way or another, all of the outlined barriers have to do with the project ending as a failed attempt. That is highly unlikely, given the official approach and funding from one of Germany's highest reputation-institutions. The ongoing global pandemic can be a hurdle during the next two years, but Germany and especially Mecklenburg Western Pomerania develop proven, effective countermeasures and continue to be a prime example of a reasonable approach to the virus.

Analyzing the long-term perspective of the TRL-level, a timeframe of five years was assumed. After this time, the project's runtime of three years would be over, and the resulting company founded and on the way to operation. A TRL-level between 7 and 8 would be realistic after this time, while between 8 and 9 would be an optimistic guess. Table 2 provides an overview of possible challenges and how to overcome them.

***Table 2** – Barriers and solutions for increasing the TRL-level in the mid-term*

Barriers	Solutions
¬ Legal certification problems	¬ early cooperation with the responsible institution

¬ Not enough raw material to fulfill market demand	¬ early market analysis; best during the project
¬ Lower than expected market demand	¬ early market analysis
¬ Fitting human capital	¬ Visible bottleneck during the project; early job advertisements
¬ higher than expected energy consumption	¬ close monitoring and development during the project
¬ problems during the founding of the company	¬ project progressing gradually with a precise aim
¬ Investment risk too high, no investor found	¬ aggressive approach during the project's runtime, investors to be early on found

Again, many of the barriers above can be mitigated by a proper and smart project and the associated participants' right mindset. The biggest hurdle can lay in certifying the mycoprotein as "safe to eat" or "safe to process further". In Germany, these kinds of legal certifications take hefty amounts of time, thus cooperation and communicating with the responsible institutions right from the start is a must. Also, investors for implementing the idea are needed after the project ends, thus starting to identify the needs to be the aim right from the start. Open communication with relevant actors across the board, skilled project management, and willing partners provided, the processing and preparation of organic apple waste to produce high-quality mycoprotein is believed to have tremendous success for the partners and the region itself and result in reaching a TRL-level between 7 and 9 in five years. Once established, the platform can be scaled to other by-products, thus fully integrating bioeconomic principles in the apple value chain in Mecklenburg Western Pomerania.

3 Conclusion

Performing a TRL analysis is essential for the implementation of emerging technologies. It allows deadlines or goals to be set and bolster more effective collaboration between experts from different fields who work. This is especially important in biomass projects, mainly by-products, which needs collaboration at several different levels. Biomass waste management technologies are crucial in the field of the circular economy. Environmental conservation is the undoubted added value of this form of project, so despite high investment and maintenance costs, it is essential to help entrepreneurs who want to build this sector. The study shows the main obstacles and measures to be taken to increase technological readiness for the development progressively. The prospects for apple cores as a basis for mycoprotein production are optimistic due to technological advancement and the project structure, which is believed to impact the regions' bioeconomic competitiveness significantly.

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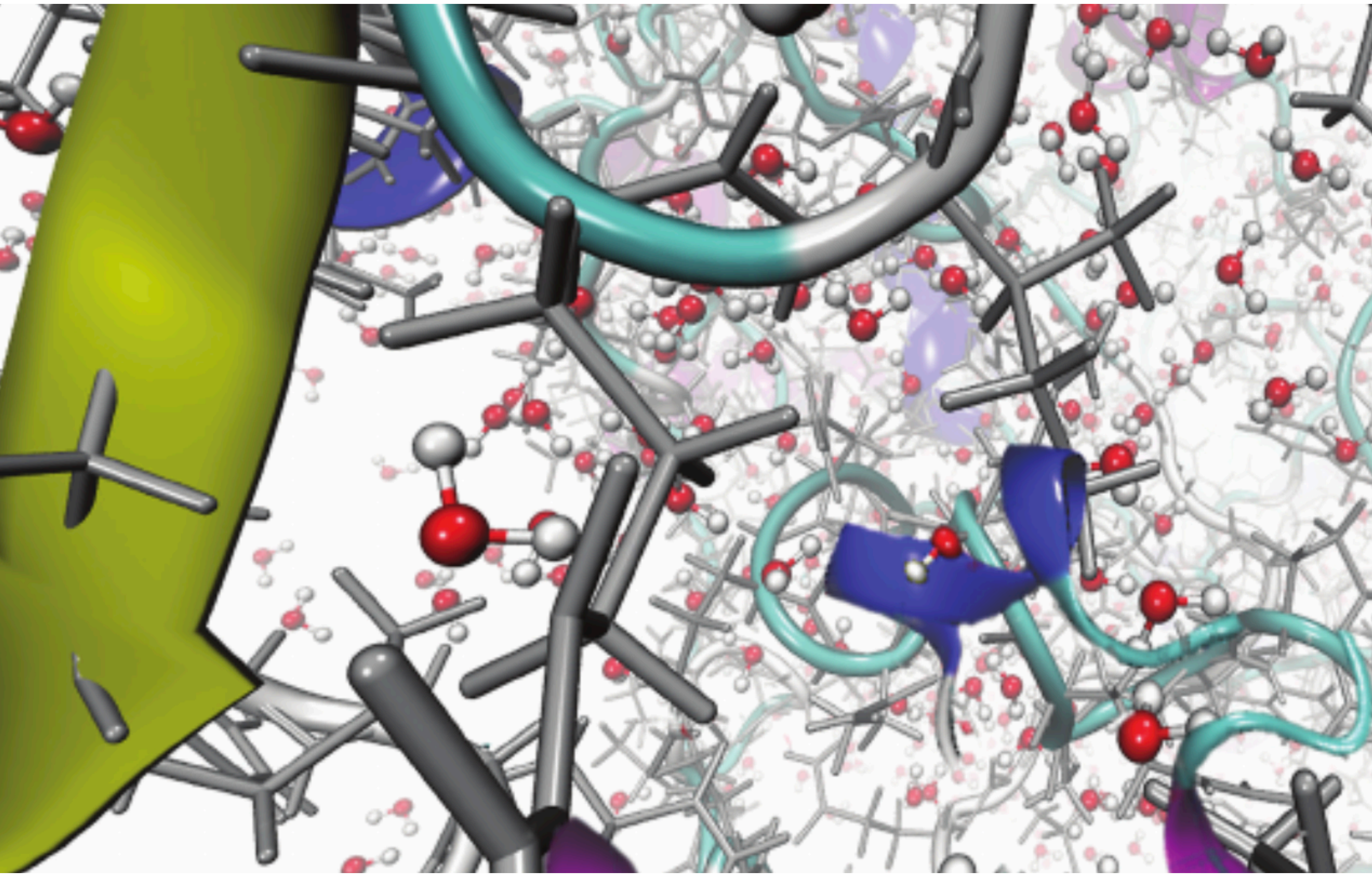
LEAF PROTEIN CONCENTRATE PRODUCTION FROM INTERMEDIATE CROPS

LEAF PROTEIN CONCENTRATE PRODUCTION FROM BROCCOLI AND KALE LEAVES

COLOURBOX1065531

PROTEIN-BASED SUPERABSORBENT POLYMERS



REPORT

INNOVATION PROGRAMS

- **PROTEIN CONCENTRATES FROM KALE AND BROCCOLI RESIDUES**
- **PLANT BASED PROTEIN FROM INTERMEDIATE CROPS**
- **BIOBASED SUPERABSORBANTS**

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Published by	BioBIGG

Summary

Generic models for sustainability and innovation are presented and applied to the three case of biobased resources. For sustainability, the Framework for Strategic Sustainable Development is used, including a back-casting method to allow for creative thinking about possible solutions. Innovation is defined as a solution with high degree of originality and high degree of market penetration. Except for the research findings, the market need and implementation drive have to be present to realise the innovation. To understand and confirm market needs, collaboration with internal and external partners, early in the process, is essential. As support to implementation, a guideline for how to form the organisation in the initial and coming steps of the innovation process is presented.

Three innovation programs are presented for protein concentrates from kale and broccoli residues, plant-based protein from intermediate crops and biobased superabsorbents. The programs are based on the pre-feasibility studies for the cases, and developed a result of several workshops in the research teams. Each innovation program contains a roadmap for the specific case, and a matrix with possible stakeholders, partners and customer.

For plant-based substances from kale and broccoli residues and intermediate crops there are many similarities when it comes to the innovation process, and for both cases it is concluded that a circular thinking including side-streams of the plants should be considered for achieving a reasonable business potential. For the biobased superabsorbents, the challenges are mainly in the product specification and manufacturing process, and how to compete with existing fossil-based material.

Each roadmap reveals necessary developing steps and timeline for idea (technology and product), need (market), drive (business and team), and funding. As for possible stakeholders and partners, it can be concluded that the food and agricultural business sectors, along with regional strategies for bioeconomy, are prominent in Skåne, providing a favourable soil for partnership for all three cases. Hence, the innovation programs, together with the documentation on implementation and business manuals, make up a good starting point for plant-based innovations.

1. Introduction

1.1 About the Innovation Program

The purpose of the Innovation Program report is to give both theory and practice for the process to transform research results into innovation. The structure of the report is as follows; In the theory section, the models for sustainability and innovation are described in some detail. This is the section where the Innovation Program is put in a context. Furthermore, an overview of the conditions for innovation in Skåne, including innovation ecosystems and regional strategies are outlined.

The applied theory results in the three specific Innovation Programs for the project cases. The Innovation Programs includes road map, suggested collaboration actors and an organisation outline for each case.

2. Theoretical Models and Tools

2.1 Framework for Strategic Sustainable Development

In order to be creative about new sustainable solutions for plant-based solutions, the Framework for Strategic Sustainable Development (FSSD)[1] is used. The Framework is a set of tools based on science and experience from organisations worldwide since the early 1990s.

2.1.1 The Funnel

The funnel (Fig. 1) is a metaphor for the decreasing resource capacity available for society. The access to diminishing resources, such as raw material, productive areas, biodiversity, assimilation capacity, clean air, fresh water are not matching the increasing demand for resources by society. This is not a sustainable development, but instead mankind needs to find ways and solutions that are aligned with the capacity of the ecosystems and the need for balance between nature and society.

The funnel shows the risk of running “business as usual”, where an organisation will eventually “hit the wall” in terms of e.g. legal restrictions or loss of customers. It also points out that the path for success is awareness of the limits and opportunities, where the ultimate goal is to be sustainable (i.e. navigate through the tunnel) and at the same time contribute to the opening of the funnel, i.e. a sustainable society. The UN sustainability goals can be used to describe how this sustainable society will be like.

[1] http://www.alliance-ssd.org/framework-for-strategic-sustainable-development-fssd/

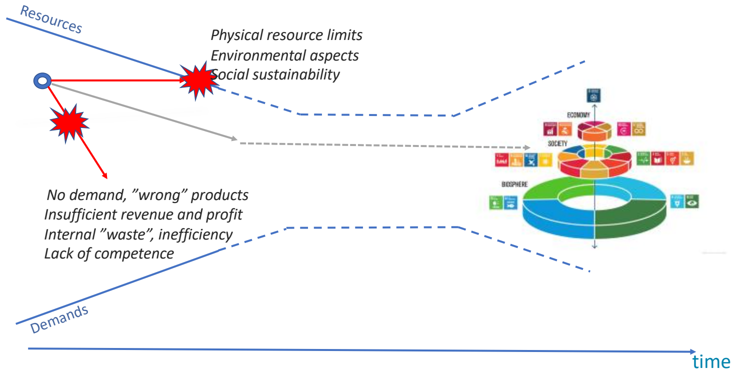
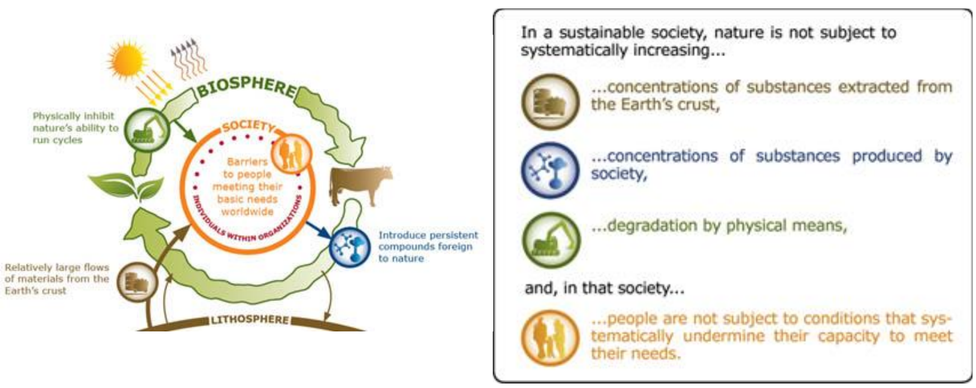


Figure 1. The funnel is a metaphor for the current non-sustainable society and the need for changing direction.

2.1.2 The Sustainability Principles

In order to navigate through the funnel in Fig. 1, there is a need to understand what in society contribute to the narrowing of the funnel (not sustainable activities), and what will lead to its opening (sustainable behaviour/activities). The sustainability principles are derived from the overall system functions in and between nature and society in a way that simplifies without reducing the complexity of the system. They are socio-ecological principles that can be viewed as the "rules of the game" for how society must work in order to be sustainable. The principles are based on established scientific models, such as the Laws of thermodynamics and the evolution.

Fig. 2 shows the principles in some detail[2]. The three first principles describes the ecological aspects of sustainability, whereas the fourth principles relates to social sustainability. The fourth principle has recently been further developed into five aspects for social sustainability; the necessity for humans of health, competence, influence, impartiality and meaning making[3].



Copyright The Natural Step 2011

Figure 2. The four sustainability principles, based on natural science.

[2] For more info, see for example https://thenaturalstep.org/approach/

[3] http://fssdsocialsustainability.weebly.com/uploads/3/9/7/7/39773758/missimer_et_al_2016_part_2.pdf

2.1.3 The ABCD-Method (Back-Casting)

The Framework includes the use of back-casting method. Back-casting is a well-established tool for strategic planning, in particularly valuable

- When there is need for ground-breaking change
- The problems are complex
- Existing trends are part of the problem
- The problems are caused by externalities
- There is time and room for planned changes

All these criteria apply to the need for sustainable solutions.

The ABCD-method is schematically shown in Fig. 3. The first step (A) is to create Awareness about sustainability. Understanding the sustainability principles is thus the starting point for strategic planning and helps to create an attractive vision that can be shared by many different actors on principal level. Secondly, the current state, or Baseline (B) is described. Knowledge about the present situation, with regards to e.g. resource dependence, competence, value chain, obstacles and advantages has to be transparent and known to all involved. The third step is to brainstorm on creative solutions (C) for what should be achieved. The solution can be a product, business, a service, a function or a system that can create value, solve a problem in a sustainable environment. The last step is to decide on priorities and make an action plan (D). It should be decided who is responsible and who needs to be involved in the different actions. Each step should facilitate the coming step to reach the goal, the vision.

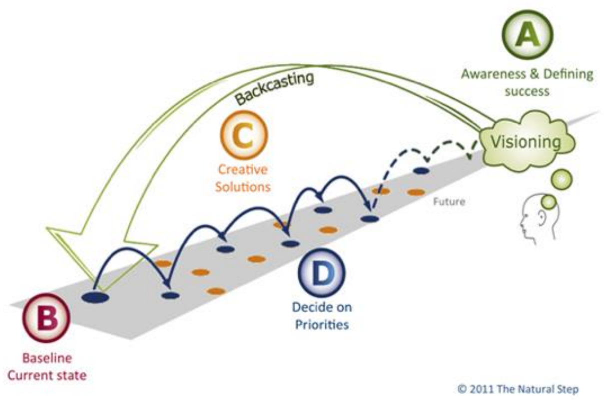


Figure 3. The ABCD-method based on back-casting

2.1.4 BioBIGG common framework for a sustainable and circular bioeconomy

The BioBIGG project has defined a common framework for sustainable and circular bioeconomy, based on the EU Bioeconomy Strategy. It contains three principles to guide the evaluation of potential innovation. The principles focus on resource efficiency through cascading (multipurpose use of biomass), use of waste and residues as well as circularity. These principles are aligned with the sustainability principles described in sec. 2.1.2 and serve as guideline for developing the innovation programs.

2.2 Innovation Models and Processes

2.2.1 Innovation models

Innovation is a concept that need some definition. One way to describe an innovation, as oppose to an invention, or an incremental change, is shown in Fig. 4[4] It is based on two important aspects of innovation; the degree of originality and the degree of impact, or market penetration.

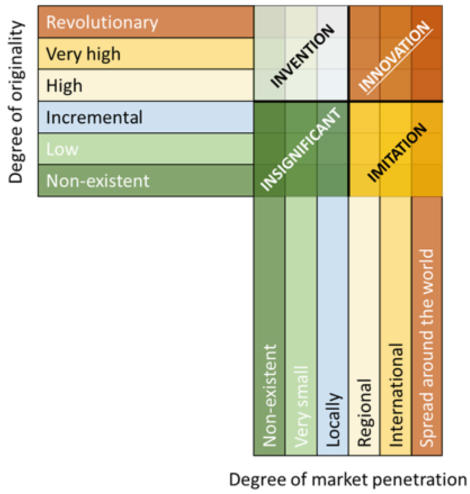


Figure 4. A definition of innovation, by Frankelius[5]

An innovation can be described as an idea is turned into reality, i.e. a product, service or solution is made available to the users. For this to happen, there are necessary roles, or ingredients, that has to be present, as schematically visualised in Fig 5.

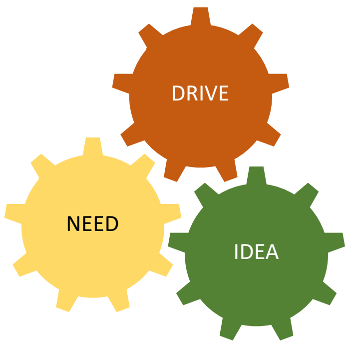


Figure 5. An innovation can be realised if there is a need, an idea and a drive to make it happen.

- The need represents the wish, or a market, addressed by the idea. The need creates a "pull", or demand, for a solution to fulfil the need. Without the need, an idea is not useful.
- The drive component is the entrepreneurial force to make it happen. To develop an innovation is a complex process that require determination and competence on how to involve the right actors, to overcome obstacles and seize opportunities to make progress.

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[4] http://www.frankelius.com

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

- The idea gives the solution to a problem or fulfilment of a need. The research result can be such an idea.

The purpose with this illustration is to state that it is seldom one person who can make an innovation. There often has to be a team and collaboration. “Open innovation” is a term acknowledging the advantage of collaboration in order to be successful when it comes to innovation. The model is applied in the case roadmaps in the Innovation Programs, to remind us that not only technology readiness has to be developed but that market attraction and driving team also need attention.

2.2.2 Innovation Process and Program

By applying the above (back-casting, and definition of innovation) the Innovation Program can be put in a context. It is the action plan that will take you from the current state to the goal, the realised innovation, or from a limited impact invention to a widely spread innovation (Fig. 6).

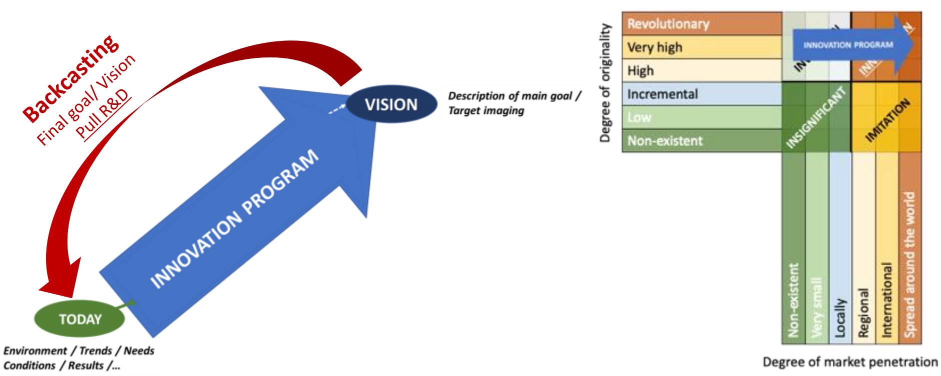

Figure 6. The Innovation Program is the action plan to reach the main goal. It turns an invention into an innovation.

The Innovation Program is based on a general innovation process (see Fig. 7 below);

- a number of action steps, developing the product, the market, financing and organisation/team.
- a number of actors that are involved in these different action steps, both internal and external.

Figure 7. The three general phases of the innovation process; Concept/Verification, Development, Commercialisation.

2.3 Organisation for Implementing the Innovation Program

The phases in the implementation of an innovation program requires different competences for each step of the process, such as technical competence, networking abilities, communication skills and business analytical experience. Thus, the team for implementation has to be well selected to match the competence need, and it will probably change as the process evolves.

As mentioned in section 3.1.3, the business potential and market demands need to be estimated and confirmed early in the process. This step of the process should involve both researchers from SLU and market representatives, i.e. the potential customers identified in the concept/verification phase in Fig. 12 above. A project team should be appointed next, to further verify the concept and drive the implementation according to the steps in first phase of the innovation process. The project team is likely to be formed by researchers with interest in commercialization, and some external persons with business and/or entrepreneurial mindset, linked to the innovation ecosystem around SLU and its partner companies.

When the innovation is mature enough, with proven business potential, it enters the development phase. It is now time to start a company and build the business. This is when the project team is converted into a company management team, and a company board is selected. The team, including the CEO, is responsible to make things happen. The board is responsible for contribute to the company development and support the CEO and team with experience and advise at strategic crossroads. The board work on behalf of the company owner and has the obligation to select, support and replace the CEO, if necessary.

The company team has preferably a mix of experienced entrepreneurs, product development skills and knowledge in financing. The composition of competences depends on the specific challenges of the project, and the persons available. Competences that cannot be included in the team can instead be found through collaboration. Members of the board can be chosen from the identified potential internal and external actors in the Innovation Programs (see case-specific sections below), and should have relevant experience, network and engagement to contribute to the company building.

Closer to commercialization, it might be relevant to change some of the team members to meet the challenges in scaling up and entering the market.

2.4 The Innovation Ecosystem in Skåne and Sweden

2.4.1 General finance support actors

There are several instances for public financial support in the Skåne innovation ecosystem, each one with specific aims, serving in different stages of the research and innovation process. In Fig. 8, some of these actors are shown, placed according to their focus at different phases.

- Research funding is provided by national organisations such as Swedish Foundation for Strategic Research (SSF) and Formas.

- For verification the university owned company SLU Holding AB is providing funding up to 300 000 SEK/project and also business advice and business development. In the early development phase SLU Holding AB could offer equity funding when establishing a company.
- Vinnova is the Swedish Innovation Agency and has support programs for both initial verification and later demo- and pilot plants in the development phase.
- EIP: The Swedish Board of Agriculture, Jordbruksverket, offers funding for innovation projects through the European Innovation Program, EIP.
- Connect is one of few private initiatives who are offering coaching and business development support as well as funding. Connect is a nationwide organisation, with strong regional branches, such as Connect Region Syd. Connect organise private "angel investors" who can support companies in start-up phase.
- Almi is a national public organisation which is, like Connect, providing both knowledge and financial support - the former through its regional office, Almi Skåne, the latter through the branch Almi Invest Syd.

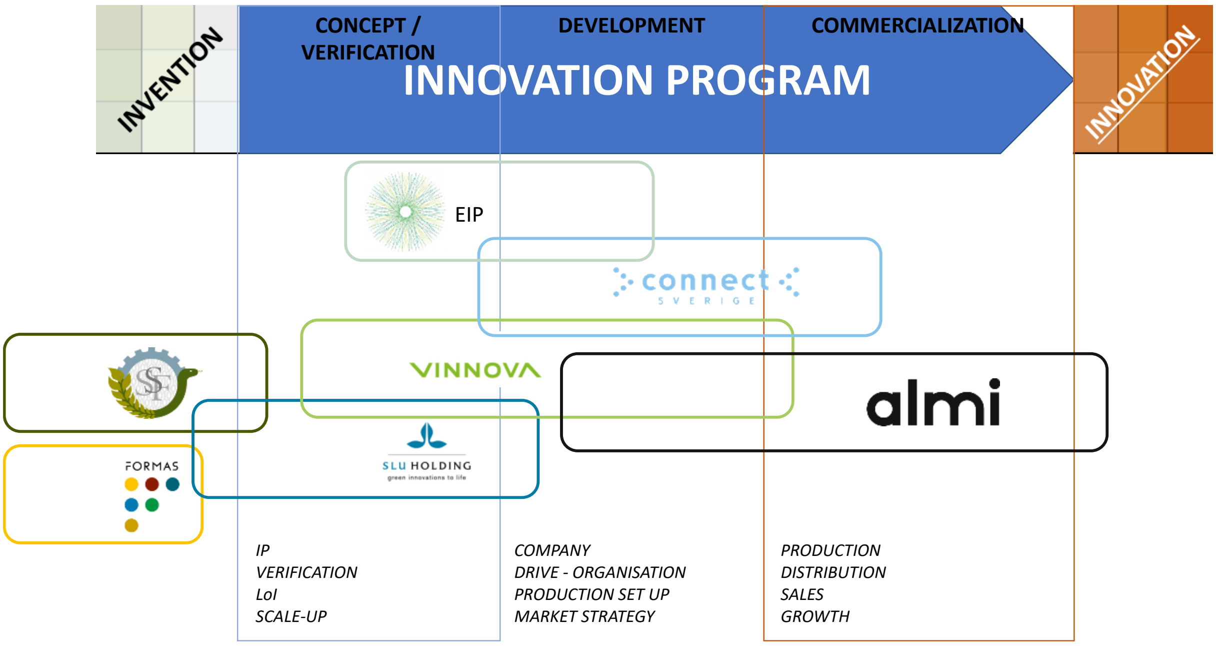

Figure 8. Some of the support functions in the innovation ecosystem in Skåne

2.4.2 Other regional support functions

As indicated above, the Skåne innovation ecosystem provides not only financial support. There are several Science Parks and incubators in the region. An incubator offers office space, coaching and network of special services. Science Parks and incubators are often located around campus of universities, in Lund (Ideon Science Park, Ideon Innovation, Medicon Village and Smile), Malmö (Minc and Medeon) and Kristianstad (Krinova).

In the region of Skåne there are some cluster organisations, centred around a specific industrial sector or societal challenges, such as Mobile Heights (ICT), Skånes Livsmedelakademi (food), Resillient Regions (resilience), Sustainable Business Hub (cleantech) and Packbridge (packaging). The cluster organisations have some different purpose, but in general they facilitate networking and collaboration and help to attract attention from e.g. investors and policy makers.

RISE[6] is the Swedish research institute, working on behalf of public and private sector as well as academia. It gathers technical expertise and research as well as labs and infrastructure within a broad range of industrial areas and functions, such as food, farming, packaging and manufacturing. Biobased economy is a special business area within RISE.

2.4.3 Regional strategies that links to BioBIGG projects

There are several regional strategies to support the innovation activities in the BioBIGG project and beyond.

- **"Smart food" – Skåne food strategy 2030**[7]. It is a strategy for food production related to health and sustainability, developed in dialogue with the regional industry and innovation system and established in 2017. "Circular and biobased food system" and "New knowledge, innovation and entrepreneurship" are two of five strategic areas for collaboration and co-creation.
- **Innovation Strategy for sustainable growth**[8]. The regional innovation strategy, decided in 2020, identifies six strategic areas for Skåne, where "food" is one of them. Furthermore, it points towards the need to develop attractive innovation environments and the support system. The strategy is presented by Research and Innovation Council in Skåne (FIRS). According to the strategy, FIRS will work to attract financing to support innovation in the strategic areas, including national and European funding.
- **Action plan for Skåne´s bioeconomy 2030**[9] was established in 2019 and aims to reduce greenhouse gas emissions, to strengthen regional industry and to increase innovation. Today, bioeconomy makes up for approximately 11 percent of the regional economy, but there is a potential to increase this share. The transition to a biobased economy involves trans-materialisation from fossil based to renewable resources, and more efficient use of resources. Region Skåne is responsible for the implementation and evaluation of the action plan, e.g. by dialogue with the regional actors.

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[6] www.ri.se
[7] https://utveckling.skane.se/publikationer/strategier-och-planer/skanes-livsmedelsstrategi-2030/ (in Swedish)
[8] https://utveckling.skane.se/publikationer/strategier-och-planer/innovationsstrategi-2020/ (in Swedish)
[9] https://utveckling.skane.se/publikationer/strategier-och-planer/handlingsplan-for-en-skansk-bioekonomi-2030/ (in Swedish)

3. Innovation Program for Protein Concentrates from Kale and Broccoli Residues

3.1 About the case: Protein Concentrates from Kale and Broccoli Leaves

The current trend towards increasing the content of plant based protein in diets has been recognized in North America, Western Europe and also other parts of the world. In the course of developing products to address this trend, new plant protein-based products are entering the market and contributing to an increase in the total volume of plant protein products used in the food industry.

In a corresponding pre-feasibility study the production of protein concentrates from kale and broccoli leaves was investigated. Kale and broccoli are currently grown in Sweden and especially in Skåne where the major part of the production is located. However, the production potential in Sweden is relatively low due to very low production volumes of broccoli and kale. Still, broccoli and kale leaves could become part of a feedstock portfolio of a plant protein facility.

The study concept aims at harvesting leaves from kale and broccoli or to collect leaves directly in the sorting facility for use as feedstock for plant protein extraction. Protein can be extracted as white protein aimed as a food additive and a secondary green protein fraction containing cell debris and chlorophyll-related components. The green protein and the fibre pulp are evaluated as animal feed.

Results of the assessment show that leaf biomass from kale and broccoli has a potential as a raw material in plant protein recovery for the production of protein-rich food and feed products. The white protein fraction contains essential amino acids and is suitable as a food ingredient or additive. The green protein and total recoverable protein fractions with essential amino acids and a likely efficient digestibility in mono-gastric and ruminant animals, can fulfil demand of locally produced protein-rich feed for e.g. horses and thereby reduce the need for imported protein-rich feed products.

Due to the need for additional harvest operations for recovering broccoli leaves, neither of the investigated production pathways is economically viable without an adjustment of the current practices of harvesting broccoli florets. Alternative harvest methodologies similar to the kale harvest could entail the harvest of the larger part of the broccoli plant and a facility based sorting procedure. It needs to be verified if changes towards such a harvest operation would be feasible and possible to integrate in the existing harvest methodology.

The simple process of drying and milling the leaves to formulate a health product seems to be an interesting option mostly for kale leaves, since the current production setup does not require costly field operations for additional harvest, but with simple process adjustment can provide the feedstock with only transportation costs straining the economic balance.

Technology readiness is generally high (TRL 6-9) for the feedstock supply steps, however, the protein extraction process and product formulation, needs to be adapted and verified to produce fractions with high protein yields and quality. Concrete scaling tests are currently being performed on the investigated crops outside the scope of the BioBIGG project. These tests will allow a more detailed and concise economic feasibility assessment.

3.2 Innovation Development Steps based on the Back-Casting Method

3.2.1 Current situation (Baseline)

The current (animal) protein-based food industry is associated with several environmental aspects due to inefficient resource use, large land area demand and linear, not circular, flows of matter;

- nutrients leakage
- loss of land and biodiversity
- greenhouse gas emission
- food losses

Inefficient resource use is also manifested by the fact that large productive areas are used for producing animal feed, not human food, and that food that are good for humans are used as animal feed instead. From a social sustainability perspective, resilience and food security as well as public health need to be addressed.

3.2.2 Vision

To create a better environment and move towards a sustainable society, plant-based protein could to a large extent replace meat and animal protein-based food and feed. This will result in reduced environmental and climate impact, but will also have positive impact on people and society. Increased use of plant-based protein food can lead to a healthier population and hence reduced cost for health systems. Furthermore, there are vast business opportunities for new innovations in the area of plant-based food due to increased market demand and investor interest in the sector. For academia, success in this field can bring positive impact such as increased funding, improved reputation and career opportunities for researchers.

The innovation task will be to bridge the gap between a sustainable vision and the current situation;

- To develop kale and broccoli leaf- or other residue-based products for feed and food to compete with current products from animals and plants.
- To produce protein products from these residues with high nutrient value.

3.2.3 Roadmap elements and actions

The roadmap for the kale and broccoli leaf protein concentrate case is shown in Fig 9.

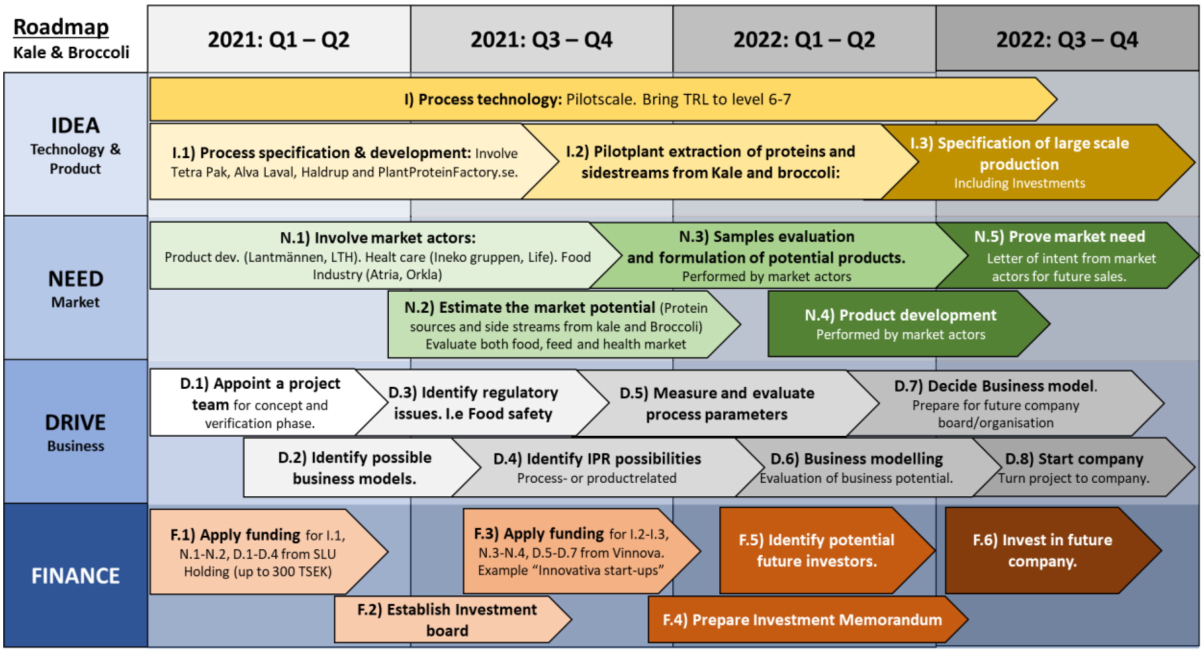

Figure 9. Roadmap for commercialisation of protein concentrates from kale and broccoli residues.

A brief description of the steps shown in the figure are listed below[10]:

Concept and verification phase

- Appoint a project team (D.1) to run the concept and verification phase.
- Apply for funding from SLU Holding (F.1).
- Involve external market actors (N.1) according to the mapping in fig 10 below.
- Involve process equipment companies (I.1) and specify potential pilot plant.
- Estimate the business and market potential (N.2) and identify market partners/customers for the different products and compounds.
- Elaborate on possible business models for the different value chains together with external partners[11](D.2).
- Establish an Investment board (F.2) together with external partners for future investments.
- Set up pilot plant (I.2) and start to extract nutrients and proteins from kale and broccoli residues.
- Run pilot plant to identify potential products and high nutritional compounds for different side-streams of kale and broccoli residues (N.3), and make a simple evaluation of customer acceptance/interest (N.4).
- Continuously screen potential future financing opportunities (F.3). Monitor Vinnova's announcements and contact the Swedish Board of Agriculture regarding EIP financing. Apply for funding when relevant.
- Identify regulatory issues (D.3) with impact on the potential businesses, e.g. in the areas of food safety or cosmetics.

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[10] For more detailed information about the different steps on how to implement the innovation program, see "The Implementation Model" document.

[11] For theory and examples of business models, see documents "Business modelling – examples".

- Identify potential process- and/or product related IPR (D.4). Perform a novelty search.
- Measure process parameters and identify process related costs (from harvesting to extracted samples from kale and broccoli residues) (D.5).

Development phase

- Develop products with verified business and market potential, identified in the previous phase (N.4).
- Evaluate and specify future large scale production units including investment level (I.3).
- Evaluate and decide suitable business models (D.6) and prepare for transforming the project into a company (D.7).
- Make a business plan and prepare an Investment Memorandum for future investors (F.4). Prepare a sales presentation to attract partners, customers and investors.
- Contact potential customers and receive Letter of Intents (LoI) for future sales (N.5). This will increase the possibility to attract investments, since the LoIs prove the market need.
- Identify future investors to offer the investment opportunity (F.5).
- If the technology development is successful and the project attracts proven interest from customers and investors: Start company and appoint management team and board (D.8).

Commercialisation phase

- Set up supply chains of contracted producers (farmers) to secure delivery of raw material
- Determine sales channels by contracting distributers/retailers who bring the product to the customer.
- Identify and communicate the benefits with the new products compared to the existing to attract interest from consumers, customers and investors.

3.2.4 Planning implementation and prioritising action

The matrix in Fig. 10 shows actors to involve in the different stages of the innovation process for protein concentrates from kale and broccoli residues. The proposed internal and external partners (roles and/or specific companies) is the result of workshops with the research team at SLU. The list of actors is helpful when selecting a project team and potential collaboration partners (and eventually customers and investors) along the innovation development path.

INVENTION	CONCEPT / VERIFICATION	DEVELOPMENT	COMMERCIALIZATION	INNOVATION
	IP *VERIFICATION* *LoI* *SCALE-UP*	*COMPANY* *DRIVE - ORGANISATION* *PRODUCTION SET UP* *MARKET STRATEGY*	*PRODUCTION* *DISTRIBUTION* *SALES* *GROWTH*	
INTERNAL ACTORS SLU	SLU Holding AB Plant Protein Factory Product quality group Harvesting & collecting broccoli/kale Project management	SLU Holding AB **Board member:** **Process development / Quality assurance:** Gun FoodLab	**Board member:**	
EXTERNAL ACTORS (Roles & Companies)	**Farmers:** Sydgrönt, Grönsaksmästarna **Process equipment:** Tetra Pak, Alfa Laval, **Transportaition/Logistics:** Food Hill **Scale-up/testbed companies:** RISE, Biobased Europé, Norups gård, Knisslinge, RME-companies **Product development:** Lantmännen, Svenska foder, Gasum, Gaia, LTH Foodtech **Health care stores:** Life, Inekogruppen **Food industry:** Orkla, Findus, Atria **Financing actors:** Vinnova, **Harvesting tech:** Haldrup, RJ-maskinerBjuv **Licencing knowledge:** **Market analyzing companies:**	**Financing:** Almi, Connect, VentureCap companies **Market development/strategy:** Marketing agencies, life style coaches (tareq effect), **Company management:** **Process installation & service companies:** **Legal issues:** Novelfood, IP, agreements **Technical consulting firms:** **Process companies:** Food hills **Packaging companies:**	**Sale/distibution organization:** **Purchase organization:**	

Figure 10. Internal and external actors to involve in the innovation process.

3.3 Conclusions

To develop a research result, or invention, to a commercial product, an innovation, requires a verified market and business potential, collaboration and determination. The results from the prefeasibility study of protein concentrates from kale and broccoli leaves show promising results on technology but need to be investigated further when it comes to the market interest and business potential. To do so, external actors, such as market representatives and investors, should be involved at an early stage. The food and agricultural industry sectors are strong in Skåne and the South Baltic Region, which brings favourable conditions for collaboration to develop innovations built on protein concentrates and other products from kale and broccoli residues. However, efforts have to be made in order to run the critical first steps to prove the innovation potential. A small team of dedicated resources, with research/technical competence and entrepreneurial skills, would be needed to drive the innovation according to the innovation program presented in this report.

4. Innovation Program for Plant-based Protein from Intermediate Crops

4.1 About the case: Plant-based Protein Concentrates from Intermediate Crops

The current trend towards increasing the content of plant based protein in diets has been recognized in North America, Western Europe and also other parts of the world. In the course of developing products to address this trend, new plant protein-based products are entering the market and contributing to an increase in the total volume of plant protein products used in the food industry.

In a corresponding pre-feasibility study the production of protein concentrates from various crops grown as intermediate crops (IC) was investigated. ICs are currently grown in Sweden and elsewhere in Europe as catch or cover crops in order to decrease nutrient leakage after harvest of a main crop or as a measure to prevent erosion or weed problems when the field usually would be bare soil. ICs are usually incorporated into the soil before the next main crop is established. Instead, we propose aboveground IC biomass can be harvested and plant proteins extracted.

The project concept aims at harvesting intermediate crop aboveground biomass and use it as feedstock for plant protein extraction. Protein can be extracted as white protein aimed as a food additive and a secondary green protein fraction containing cell debris and chlorophyll-related components. The green protein and the fibre pulp are evaluated as animal feed.

Results of the assessment showed that green biomass from intermediate crops has large potential as a raw material in plant protein recovery for the production of protein-rich food and feed products. The white protein fraction contains essential amino acids and is suitable as a food ingredient or additive. The green protein and total recoverable protein fractions with essential amino acids and a likely efficient digestibility in mono-gastric and ruminants, can fulfil demand of locally produced protein-rich feed and thereby reduce the need for imported protein-rich feed products.

In the economic assessment for recovery of protein concentrates from green biomass, crop nitrogen content affects the protein yield and therefore is an important factor for high profitability. Furthermore, the low DM content observed for some ICs affects transportation and processing costs negatively. The wide span of production costs indicates the need for further studies to lower the variability and corresponding risk for production, e.g. by optimizing biomass production of IC regarding the above-mentioned production factors.

Technology readiness is generally high (TRL 6-9) for the feedstock supply steps, however, the protein extraction process and product preparation, needs to be adapted and verified to produce fractions with high protein yields and quality. Concrete scaling tests are currently being performed on the investigated crops outside the scope of the BioBIGG project. These tests will allow a more detailed and concise economic feasibility assessment.

4.2 Innovation development steps based on the back-casting method.

4.2.1 Current situation (Baseline)

There current (animal) protein-based food industry is associated with several environmental aspects due to inefficient resource use, large surface demand and linear, not circular, flows of matter;

- nutrients leakage
- loss of land and biodiversity
- greenhouse gas emission
- food losses

Inefficient resource use is also manifested by the fact that large productive areas are used for producing animal feed, not human food, and that food that are good for humans are used as animal feed instead. From a social sustainability perspective, resilience and food security as well as public health need to addressed.

4.2.2 Vision

To create a better environment and move towards a sustainable society, plant-based protein could to a large extent replace meat and animal protein-based food and feed. This will result in reduced environmental and climate impact, but will also have positive impact on people and society. Increased use of plant-based protein food can lead to a healthier population and hence reduced cost for health systems. Furthermore, there are vast business opportunities for new innovations in the area of plant-based food due to increased market demand and investor interest in the sector. For academia, success in this field can bring positive impact such as increased funding, improved reputation and career opportunities for researchers.

The innovation task will be to bridge the gap between a sustainable vision and the current situation;

- Can we produce a highly nutritional protein that
  - has a low climate impact that replaces meat-based protein?
  - contains all essential amino acids?
  - that causes no allergy problems?

4.2.3 Roadmap elements and actions

The roadmap for bringing innovation from the plant-based protein from intermediate crops case is shown in Fig 11.

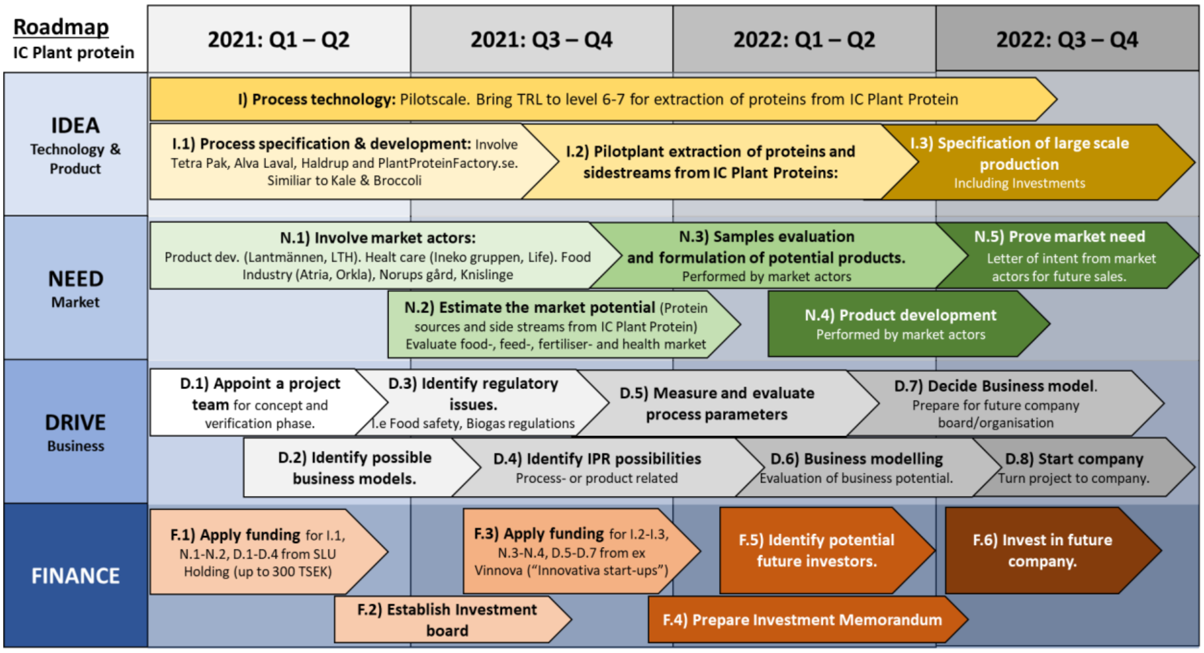

Figure 11. The roadmap for case plant-based protein from intermediate crops

A brief description of the steps shown in the figure are listed below[12]:

Concept and verification phase

- Appoint a project team (D.1) to run the concept and verification phase.
- Apply for funding from SLU Holding (F.1).
- Involve external market actors (N.1) according to the mapping in Fig. 12 below.
- Involve process equipment companies (I.1) and specify potential pilot plant.
- Estimate the business and market potential (N.2) and identify market partners/customers for the different products and compounds.
- Elaborate on possible business models for the different value chains together with external partners[13](D.2).
- Establish an Investment board (F.2) together with external partners for future investments.
- Set up pilot plant (I.2) and start to extract nutrients and proteins from intermediate crops. Evaluate side-streams.
- Run pilot plant to identify potential products and high nutritional compounds for different side-streams of intermediate crops (N.3), and make a simple evaluation of customer acceptance/interest (N.4).
- Continuously screen potential future financing opportunities (F.3). Monitor Vinnova's announcements and contact the Swedish Board of Agriculture regarding EIP financing. Apply for funding when relevant.
- Identify regulatory issues (D.3) with impact on the potential businesses, e.g. in the areas of food safety.

[12] For more detailed information about the different steps on how to implement the innovation program, see "The Implementation Model" document.

[13] For theory and examples of business models, see documents "Business modelling – examples".

- Identify potential process- and/or product related IPR (D.4). Perform a novelty search.
- During extraction of nutrients and proteins from intermediate crops: Measure process parameters and identify process related costs (from harvesting to extracted samples from intermediate crops) (D.5).

Development phase

- Develop products with verified business and market potential, identified in the previous phase (N.4).
- Evaluate and specify future large scale production units including investment level (I.3).
- Evaluate and decide suitable business models (D.6) and prepare for transforming the project into a company (D.7).
- Make a business plan and prepare an Investment Memorandum for future investors (F.4). Prepare a sales presentation to attract partners, customers and investors.
- Contact potential customers and receive Letter of Intents (LoI) for future sales (N.5). This will increase the possibility to attract investments, since the LoIs prove the market need.
- Identify future investors to offer the investment opportunity (F.5).
- If the technology development is successful and the project attracts proven interest from customers and investors: Start company and appoint management team and board (D.8).

Commercialisation phase

- Set up supply chains of contracted producers (farmers) to secure delivery of raw material
- Determine sales channels by contracting distributers/retailers who bring the product to the customer.
- Identify and communicate the benefits with the new products compared to the existing to attract interest from consumers, customers and investors.

4.2.4 Planning implementation and prioritising action

The matrix in Fig. 12 shows actors to involve in different stages of the innovation process for proteins from intermediate crops. The proposed internal and external partners (roles and/or specific companies) is the result of workshops with the research team at SLU. The list of actors is helpful when selecting project team and potential collaboration partners (and eventually customers and investors) along the innovation development path.

INVENTION	CONCEPT / VERIFICATION *IP* *VERIFICATION* *LoI* *SCALE-UP*	DEVELOPMENT *COMPANY* *DRIVE - ORGANISATION* *PRODUCTION SET UP* *MARKET STRATEGY*	COMMERCIALIZATION *PRODUCTION* *DISTRIBUTION* *SALES* *GROWTH*	INNOVATION
INTERNAL ACTORS SLU	SLU Holding AB Plant Protein Factory Product quality group Harvesting & collecting intermediate crops Project management	SLU Holding AB **Board member:** **Process development / Quality assurance:** Gun FoodLab	**Board member:**	
EXTERNAL ACTORS (Roles & Companies)	**Farmers:** Sydgrönt, Grönsaksmästarna **Process equipment:** Tetra Pak, Alfa Laval, **Transportaition/Logistics:** Food Hill **Scale-up/testbed companies:** RISE, Biobased Europé, Norups gård, Knisslinge, RME-companies **Product development:** Lantmännen, Svenska foder, Gasum, Gaia, LTH Foodtech **Health care stores:** Life, Inekogruppen **Food industry:** Orkla, Findus, Atria **Financing actors:** Vinnova, **Harvesting tech:** Haldrup, RJ-maskinerBjuv **Licencing knowledge:** **Market analyzing companies:**	**Financing:** Almi, Connect, VentureCap companies **Market development/strategy:** Marketing agencies, life style coaches (tareq effect), **Company management:** **Process installation & service companies:** **Legal issues:** Novelfood, IP, agreements **Technical consulting firms:** **Process companies:** Food hills **Packaging companies:**	**Sale/distibution organization:** **Purchase organization:**	

Figure 12. Internal and external actors to involve in the innovation process

4.3 Conclusions

To develop a research result, or invention, to a commercial product, an innovation, requires a verified market and business potential, collaboration and determination. The results from the prefeasibility study of plant-based protein from intermediate crops show promising results on technology but need to be investigated further when it comes to the market interest and business potential. To do so, external actors such as market representatives and investors, should be involved at an early stage. The food and agricultural industry sectors are strong in Skåne and the South Baltic Region, which brings favourable conditions for collaboration to develop innovations built on protein concentrates and other products from intermediate crops. However, efforts have to be made in order to run the critical first steps to prove the innovation potential. A small team of dedicated resources, with research/technical competence and entrepreneurial skills, would be needed to drive the innovation according to the innovation program presented in this report.

5. Innovation Program for Biobased Superabsorbents

5.1 About the case: Biobased Superabsorbents

Superabsorbent polymers (SAPs) consist of polymeric chains, which allow the material to swell large amount of liquids within the polymeric network. Such hydrogels are capable of swelling large amounts of water and saline solution per gram of dry SAP.

These properties have led to the extensive use of these materials in products requiring high liquid absorption and retention capacity, e.g., sanitary pads, diapers, medical pads, agricultural soil conditioners, among others. Since the 70's, the most representative application where SAP have been traditionally used is diapers, where the SAP represents up to 40 % of the product's dry weight. The SAPs contained in diapers are based on petroleum-based sodium-neutralized polyacrylic acid, which besides their non-sustainable nature are not biodegradable.

SAPs based on renewable resources, bioSAPs are discussed as potential replacements for these conventional petroleum-based absorbent materials in order to reduce use of fossil resources and reduction of greenhouse gas emissions. Consequently, this pre-feasibility study investigates different bioSAPs based on residual protein by-products from starch production in terms of their greenhouse gas emissions from production and end-of-life treatment.

This pre-feasibility study has shown that biobased superabsorbent polymers (bioSAP) produced from food industry residual products have the potential to reduce emissions when replacing fossil-based SAP based on sodium polyacrylic acid.

The raw materials used for the production of the bioSAP are readily available on the market and in relatively large amounts. The economic costs of replacing conventional SAPs with bioSAPs have to be further studied in the next step of the development, but raw materials are relatively low cost at prices below that of the fossil SAP counterpart.

Utilization of the residual streams from wheat and potato starch production will add an additional value to the value chain and strengthen the food production system with increased resource use efficiency and additional income. As residual by-products, utilization for bioSAP production will not affect the food production system negatively, by avoiding direct competition with resources needed in the food and feed industry.

5.2 Innovation development steps based on the back-casting method.

5.2.1 Current situation (Baseline)

Today, diapers and personal care products contains superabsorbent polymers (SAPs) based on fossil petrochemicals.

The products often end up in landfills, and are estimated to make up for 10-15 percent of the global landfill volume. The low degradability of acrylic acid-based SAPs and the large volume adds to the problem of filling up the remaining landfills. When these SAPs very slowly degrade in landfills, acrylic acid is leaching out and causes environmental and potentially human health problems.

5.2.2 Vision

To create a better environment and move towards a sustainable society, fossil-based materials have to be substituted by renewable materials. The vision is to replace the petrochemical based SAPs with protein material obtained from biomass (e.g. gluten or potato protein). This will result in reduced environmental and climate impact, and reduce the volume of landfills around the world.

Furthermore, there are vast business opportunities for new innovations for biobased SAPs due to increased market demand and investor interest in the emerging bioeconomy. For academia, success in this field can bring positive impact such as increased funding, improved reputation and career opportunities for researchers.

The innovation task will be to bridge the gap between a sustainable vision and the current situation;

- Can we develop
  - new reactions/methods to modify biomolecules with performance features suitable for SAPs?
  - methods to make bio-based SAPs products to compete with conventional fossil-based SAPs, regarding performance and cost?
  - a pilot testbed to test different applications where bioSAPs can replace fossil-based SAPs?

5.2.3 Roadmap elements and actions

The roadmap for bringing innovation from biobased superabsorbents is shown in Fig 13.

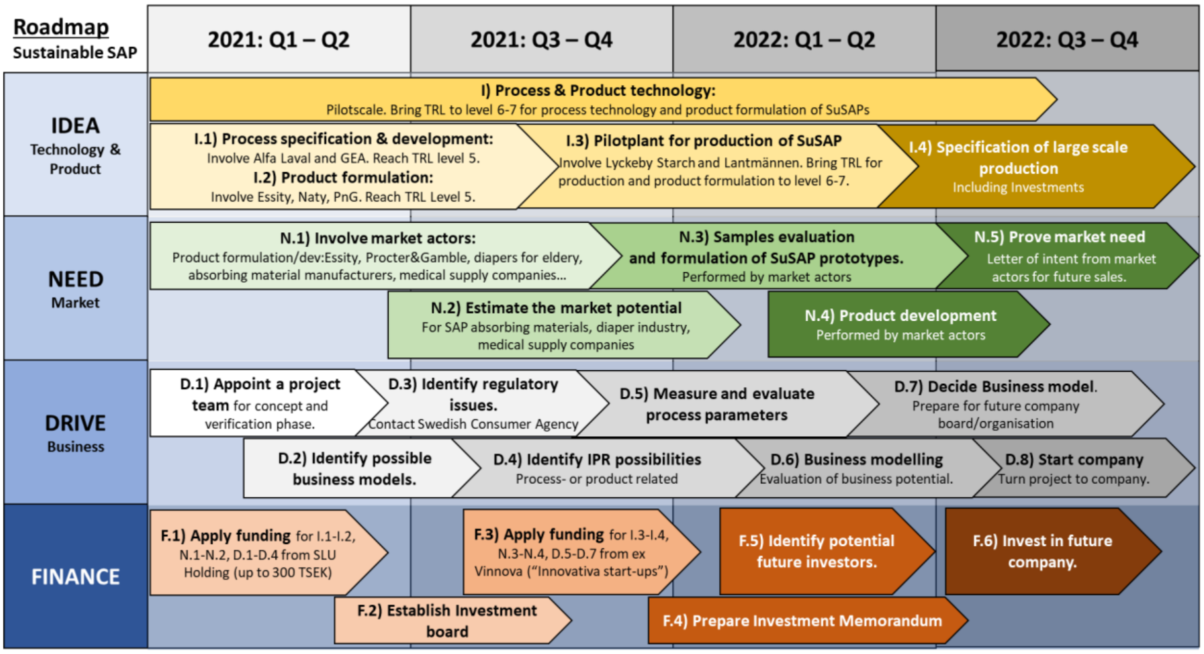

Figure 13. Roadmap elements for innovation on biobased superabsorbents

A brief description of the steps shown in the figure are listed below[14]:

Concept and verification phase

- Appoint a project team (D.1) to run the concept and verification phase.
- Apply for funding from SLU Holding (F.1).
- Involve external market actors (N.1) according to the mapping in Fig. 14 below.
- Involve process equipment companies (I.1) and product formulation actors. Reach TRL level 5 for both process technology and product formulation.
- Estimate the business and market potential (N.2) and identify market partners/customers for the different products and compounds. Make market analysis regarding diaper (SAP) industry and medical device industry.
- Elaborate on possible business models for the different value chains together with external partners[15](D.2).
- Establish an Investment board (F.2) together with external partners for future investments.
- Set up pilot plant (I.2) and start to produce samples of sustainable superabsorbents.
- Samples evaluation and prototyping of SuSAPs (N.3). Send samples to market actors for evaluation and together with market actors develop prototypes of potential SuSAP products. Evaluate prototypes.
- Continuously screen potential future financing opportunities (F.3). Monitor Vinnova's announcements and contact the Swedish Board of Agriculture regarding EIP financing. Apply for funding when relevant.
- Identify regulatory issues (D.3) with impact on the potential businesses. Contact Swedish consumer agency for regulations and also investigate regulations connected to medical devices.
- Identify potential process- and/or product related IPR (D.4). Perform a novelty search.
- During pilot production of SuSAPs: Measure process parameters and identify process related costs (D.5).

Development phase

- Develop products with verified business and market potential, identified in the previous phase (N.4).
- Evaluate and specify future large scale production units including investment level (I.3).
- Evaluate and decide suitable business models (D.6) and prepare for transforming the project into a company (D.7).
- Make a business plan and prepare an Investment Memorandum for future investors (F.4). Prepare a sales presentation to attract partners, customers and investors.
- Contact potential customers and receive Letter of Intents (LoI) for future sales (N.5). This will increase the possibility to attract investments, since the LoIs prove the market need.
- Identify future investors to offer the investment opportunity (F.5).

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[14] For more detailed information about the different steps on how to implement the innovation program, see "The Implementation Model" document.

[15] For theory and examples of business models, see documents "Business modelling – examples".

- If the technology development is successful and the project attracts proven interest from customers and investors: Start company and appoint management team and board (D.8).

Commercialisation phase

- Set up supply chains of contracted producers (farmers) to secure delivery of raw material
- Determine sales channels by contracting distributers/retailers who bring the product to the customer.
- Identify and communicate the benefits with the new products compared to the existing to attract interest from consumers, customers and investors.

5.2.4 Planning implementation and prioritising action

The matrix in Fig. 14 shows actors to involve in the innovation process for protein from intermediate crops. The proposed internal and external partners (roles and/or specific companies) is the result of workshops with the research team at SLU. The list of actors is helpful when selecting project team and potential collaboration partners (and eventually customers and investors) along the innovation development path.

INVENTION	CONCEPT / VERIFICATION *IP* *VERIFICATION* *LoI* *SCALE-UP*	DEVELOPMENT *COMPANY* *DRIVE - ORGANISATION* *PRODUCTION SET UP* *MARKET STRATEGY*	COMMERCIALIZATION *PRODUCTION* *DISTRIBUTION* *SALES* *GROWTH*	INNOVATION
INTERNAL ACTORS SLU	SLU Holding AB Product quality group Process development Project management	SLU Holding AB **Board member:** **Process development / Quality assurance:**	**Board member:**	
EXTERNAL ACTORS (Roles & Companies)	**Rawmaterials:** Lyckeby starch, Lantmännen, BioExtrax, Arla Ingredients **Process equipment & design:** Alfa Laval GEA **Market/Product development/verificat.** Essity, Procter&Gamble, Naty, Mölnlycke, Nelson Seed **Diapers for eldery:** Tena, Attends **Absorbing material companies:** **Medical supply companies (sanatary pads):** **Patent agencies** **Leagal:** Konsumentverket	**Market/Consumers:** Region Skåne, Region Stockholm, Region Västra Götaland, Region Uppsala. **Distribution:** Hygienshoppen, Apotea, Hjärtat **Financing:** Almi, Connect, VentureCap companies **Market development/strategy:** Marketing agencies **Company management:** **Process installation & service companies:** **Legal issues:** IP, agreements **Technical consulting firms:** **Process companies:** **Packaging companies:**	**Sale/distibution organization:** **Purchase organization:**	

Figure 14. Internal and external actors to involve in the innovation process

5.3 Conclusions

To develop a research result, or invention, to a commercial product, an innovation, requires a verified market and business potential, collaboration and determination. The results from the study of bio-based superabsorbents are promising and should be looked into some more detail to examine the innovation potential. To do so, external actors, such as market representatives and investors, should be involved at an early stage. The biomaterial sector attracts large interest from investors and customers, looking for alternatives to take effective actions against climate change and enhance sustainable development. Skåne and the South Baltic

Region have great opportunities for collaboration to develop innovations built on bio-based superabsorbents. A small team of dedicated resources, with research/technical competence and entrepreneurial skills, would be needed to drive the development according to the innovation program presented in this report.

Household sector

PYROLYSIS WITH THATCHING MATERIAL COMMON REED (PHRAGMITES AUSTRALIS) IN MECKLENBURG-WESTERN POMERANIA OR MECKLENBURG-VORPOMMERN

COLOURBOX31721058

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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 5.2: Pre-feasibility and innovation programmes for innovative value chains
Copyrights:	All rights reserved to the partners in BioBIGG. Copyright © 2020 BioBIGG.
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1. Introduction

Common reed (from this point forward only referred to as “reed”) is a typical wetland plant found all over the world with an ancient history of utilisation - mostly for thatching. In fact, there are references providing evidence that the use of roof thatching in northern Europe occurred during the last ice age,[1] and in some regions, homes are still famous for their thatched roofs today.

Mecklenburg West-Pomerania (MWP) has a broad coast with wide marsh regions and reed beds, allowing for the tradition of reed thatching to still prevail today. Thousands of houses contain roofs produced from this renewable resource, whereas each roof must be renewed every 30-40 years. After accomplishing its primary purpose in providing shelter, the used reed is redistributed in two ways. Overall, typically half of the used material will be sent to incineration plants, while the other half will end up in composting plants. The used material is not overly welcome in either approach, however, due to some problems in the further processing, as was explained in chapter 4.2 of the Pre-Feasibility Study (PFS). [2]

The PFS investigated possible alternative options of afteruse for used thatching reed. Pyrolysis was identified as a promising technique for the reutilisation of used thatching read, and thus was selected as an approach to be further investigated. One pyrolysis plant with biochar as main product already exists in MWP - the GreenCarbon GmbH near Schwerin. Investigations were made based on establishing a potential processing method of used thatching reed in this plant.

This innovation programme will take a closer look at the next steps necessary for the realisation of this project.

2. Innovation Roadmap

2.1 Vision

The idea behind the project was to find a more sustainable purpose for previously used thatching reed. Pyrolysis with biochar als main product seems to meet this aim perfectly. The idea would be to establish transportation in order to deliver the old thatching reed from locations in a range of 100km maximum, to the pyrolysis plant in Uelitz (a small town neighboring Schwerin). This could add a great deal of value to the reed and make the entire material chain more valuable.

[1] Schaatke, W. (1992): Das Reetdach - Natürliches Wohnen unter sanftem Dach - Von der Urzeit bis heute (The Reed Roof - Natural Living Under a Soft Roof - From Primeval Times Until Today). Christians Verlag, Hamburg, 264 pp.

[2] Nitzschke, J. (2020). Pyrolysis with thatching material Common reed (Phragmites australis) in Mecklenburg-Western Pomerania/MWP (or Mecklenburg-Vorpommern/MV) – a pre-feasibility study, Interreg project Bioeconomy in the South Baltic Area: Biomass- based Innovation and Green Growth – BioBIGG.

2.2 Current situation

Current situation reed: Common practice in the region is to transport the old thatching reed to the nearest block heating station or composting plant. A detailed description about the handling of old thatching reed can be found in the PFS (chapter 3.3).

Current situation pyrolysis plant: The plant produces biochar as main product in a batch process. It has not been using old thatching reed for pyrolysis so far, but various other organic materials, e.g. green waste and different types of wood. Tests with fresh reed have been conducted successfully. A detailed description of the plant's conversion methods can be found in the PFS (chapter 1). [2]

2.3 Roadmap Elements / Action fields

Table 1: Roadmap

	Actions	Short term (2 years)	Mid-term (5 years)	Long term (10 years)
Feasibility Study	*Legal requirements*			
	Market research			
	End-product research			
	Financing			
	Logistics			
	Amount of reed available			
Pilot phase	*Testing*			
Stakeholder Mobilisation and Engagement	*Finding research partners*			
	Establish contact with thatching companies			
	Rising regional interest in reed thatched roofs			

Feasibility study: A feasibility study serves the purpose of displaying what costs would be generated during the whole process. Especially during gaining knowledge about important details about logistical costs and possible end-products, a financial control should constantly accompany the process.

Legal requirements: An in-depth examination of regulatory requirements is advised in order to consider any legal and regulatory circumstances that may need to be considered, in terms of implementing the new value chain. Adhering to waste disposal regulations is one key aspect.

Market research and end-product research: Research on market conditions should be conducted by a suitable research institute or consultancy. This can also be included in an in-depth feasibility study. The GreenCarbon company produces "Terra Preta" as soil activator which contains around 10 % biochar. The soil activator finds markets in agriculture and gardening. The most conceivable solution for the reed char is to add it to the same process. At the moment, only small amounts of thatching reed can be expected to be transported to the pyrolysis plant. This is due to the location of the plant, which is located rather far away from the coast. Most reed-thatched houses can be found along the coast.

Financing: At this point, it is unclear how further financing of a possible implementation project will be carried out as the BioBIGG project will end on 30 June 2021. The market volume for used thatching reed will not allow several competitors within a region.
The Green Carbon company is already aware of the old thatching reed option and could pursue further trials on its own or with support from public fund. Going for public support on a European level to explore this new value chain further would imply that there are several potential users in different regions/countries. In that case, at least some roadmap elements like stakeholder engagement, research and a feasibility study could be financed through public funding. Still, any technical or logistical adaptation necessary to implement the process at specific plants would require private co-financing.

Logistics: Communication with reed thatchers is essential here. The transport from the construction site, where old thatching reed becomes available, to the pyrolysis plant is very expensive due to personnel costs and rental costs for the van (see chapter 4 in the PFS). [2]

Amount of reed available: Has to be verified together with the thatchers of the region. Given calculations in the PFS are estimates (see chapter 4).

Pilot phase: The pyrolysis plant(s) would lead the efforts for the tests with old thatching reed. Several batches in different states of decay should be tested. Cooperation with thatchers is needed during this phase.

Finding research partners: CARBOnet is an international cooperation network researching for the economic and ecological utilisation of biomass and other alternatives through carbonisation. The network is funded by the German Federal Ministry for Economic Affairs and Energy as part of the funding programme Zentrales Innovationsprogramm Mittelstand. Coordination is led by Innovations und Bildungszentrum Hohen Luckow e.V. [3] Another contact could be the 'Fachverband Pflanzenkohle': https://fachverbandpflanzenkohle.org/. The Greifswald Mire Center might be an interesting partner, too: https://www.greifswaldmoor.de/home.html. The EU H2020 project examines one related value chain, the conversions of low nutritional quality grass from the wetlands into biochar[4]. Synergies could be exploited.

Establish contact with thatching companies: One of the first steps for the further process is the need to establish contact between the pyrolysis plant and reed thatching companies in MWP. They can be contacted through the MWP guild of reed thatchers. An online research brought up two reed-thatching companies within 50km radius of the pyrolysis plant. More companies in larger distance of up to 100km should be contacted to offer them the opportunity of discarding their reed there. A long-term contact and cooperation between the plant and research institutions might result beneficial for the plant if new possibilities of using the bio-char appear.

Rising regional interest in reed-thatched roofs: Rising regional interest may help rise general interest in reed, paludiculture and circular economy. As environmental awareness is growing among the population, advertising the reed-char products regionally may help not only improve product sells but also motivate more people to decide for reed thatched houses.

[3] CARBOnet. Index page. Source: http://carbonet.ibz-hl.de. Last access 2020-09-29.
[4] https://www.go-grass.eu/germany/

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Schaatke, W. (1992): Das Reetdach - Natürliches Wohnen unter sanftem Dach - Von der Uhrzeit bis heute (The Reed Roof - Natural Living Under a Soft Roof - From Primeval Times Until Today). Christians Verlag, Hamburg, 264 pp.

SUSTAINABLE BIO-BASED ALTERNATIVES AS A SUBSTITUTE FOR PLASTIC PACKAGING, DISHES AND CUTLERY IN THE CATERING SECTOR ON THE BEACHES OF ROSTOCK

COLOURBOX47342830

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Project Title:	Bioeconomy in the South Baltic Area: Biomass-based Innovation and Green Growth. For information on the project, please check https://biobigg.ruc.dk/
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1 Introduction

With the implementation of the EU Directive 2019/904 of the European Parliament and the Council, many disposable single-use plastic products are banned from the market. This includes plastic cutlery, stirrers, straws, plates, to-go cups made of styrofoam, cotton swabs and balloon sticks. The introduction of this law calls for drastic changes and fast action, including the packaging and catering industry. Furthermore, the implementation of this law is an important and long-awaited step towards a sustainable lifestyle. Among many other things, it supports the approach of keeping beaches plastic-free.

Promising alternatives for fossil-based packaging, cutlery and dishes are biodegradable dishes and packaging material. This report focuses on the innovations needed to ensure a successful substitution of plastic packaging and dishes through biodegradable ones.

2 Innovation Roadmap

2.1 Vision

This report aims to reveal the steps still needed to guarantee the sustainability of beach visits with the overall approach to reduce single-use plastic products and packaging and to furthermore replace those materials with biodegradable products. The necessary measures to fulfil this approach include the reduction of waste, the improvement of recycling systems and waste management. The focus of this innovation program lies on the usage of bio-based and biodegradable packaging products as a solution to reduce plastic litter caused by packaging for food and other catering products at Rostock's beaches. A detailed analyses of each measure will be provided which lists all further implementation steps.

2.2 Current situation

The pre-feasibility study "Sustainable bio-based alternatives as substitutes for plastic packaging, dishes and cutlery in the catering sector on the beaches of Rostock" identified four measures as sustainable alternatives for fossil-based packaging, cutlery and dishes. These measures will be shortly introduced together with their current situation identified beforehand in the pre-feasibility study.

Designing bio-based packaging to increase sustainability:

The reduction of packaging waste and single-used fossil-based products is connected with a great deal of self-initiative and can be listed in each person's innovation plan. However, packaging cannot always be dispensed with. It is therefore of great interest to see how far the packaging industry is progressing with its research on sustainable packaging. There are several alternatives, such as plastic cups made of bio-based plastic, mostly polylactic acid (PLA), which according to research papers is not yet suitable for industrial compost because it does not fully decomposes (Hobbs et al. 2019). Another option is the use of coated paper cups where it is not easy to identify whether the coating is biodegradable. If no completely fossil-based free method can be found, compromises are made. This means that the product is manufactured with biodegradable products to the greatest extent possible and the fossil-based portion of the product is kept to a minimum. Yoghurt cups are a great example, they are made of a very thin plastic layer wrapped with thin cardboard to stabilize the cup. The lid is made of aluminium. By using cardboard, the fossil-based material amount has been reduced.

Biodegradable packaging, cutlery and dishes:

A sustainable alternative to plastic single-use packaging, dishes and cutlery are bio-based and biodegradable ones. There is a broad variety of biodegradable dishes, cutlery made of wood, paper, cardboard, cellulose fibres, bamboo as well as palm, and banana leaves. Some restaurants even use noodles as straws.

The listed measures already exist at the beaches of Rostock and will be further analysed in detail in the course of the innovation program to estimate the necessary steps for the implementation towards a more sustainable application.

Improve waste and recycling management:

As the material composition changes, waste systems also have to change and adapt. First, a proper recycling system is needed. This means, on the one hand, the presence of waste bins at regular intervals. The feasibility of waste separation at beaches is not self-evident at this time. However, it has been ensured that a waste bin can be found on Rostock's beaches at regular intervals. Lockable ashtrays can also be purchased on beaches or are distributed fee-free. These prevent cigarette jams from being distributed unconsciously into the wild but can be disposed of properly.

2.3 Roadmap Elements / Action fields

It should be kept in mind that waste reduction is the overall objective regardless of all the other approaches. In any case, these methods are intended to achieve this objective of an overall waste reduction.

Table 2: Roadmap for the use of biodegradable packaging, dishes & cutlery at beaches. Orange describes measures needed for the category "reduction of packaging

	Actions	Short term (up to 2022)	Mid term (up to 2025)	Long term (up to 2030)
	Waste management			
Preliminary considerations	Legal requirements			
	Involved industry			
	Market research			
	Labelling			
	Funding			
Strategic consideration	Test phase			
Operational consideration	Technology			
Activities	Recruitment of staff			
	Project promotion			
	Distribution waste bin			
	Setting up signs			

Biodegradable packaging, cutlery and dishes:

When using bio-based products, it is important that their packaging and delivery is also environmentally friendly and that the materials are not packed in superfluous plastic foils. The kiosk and stall owners should also pay attention to this. Furthermore, an eye should be kept on the state of research and innovations entering the market, in case innovations are available.

To get the most out of the biodegradable packaging, cutlery and dishes can be added into biomass for the production of bioenergy. Therefore, changes have to be made.

Labelling of biodegradable products

Regarding the project considered in the pre-feasibility study "Sustainable bio-based alternatives as substitutes for plastic packaging, dishes and cutlery in the catering sector on the beaches of Rostock", not all kiosk and restaurant owners have agreed to switch from fossil-based to biodegradable packaging, dishes and cutlery. Therefore, to avoid mixing the biodegradable materials with the non-biodegradable materials, labelling is of utmost necessity. Especially when it comes to waste disposal. Confusion about proper waste disposal must be avoided. This step depends on political decisions, since the affixing of such labelling cannot simply be decided in this way, but must be aligned with the production process, the recycling process and national as well as international requirements. The labelling of products should, however, be designed to be consistent and therefore suitable for a global application. Uniform transposition in Europe can be achieved for example by means of an EU directive of the European Parliament and the Council.

Additional waste bin

An additional waste bin is needed at the beach for the rightful disposal of biodegradable packaging & dishes and their further use as feedstock in the biogas production. The most suitable solution is the introduction of the bio bin, which is known by German citizens and collects all kind of biomass.

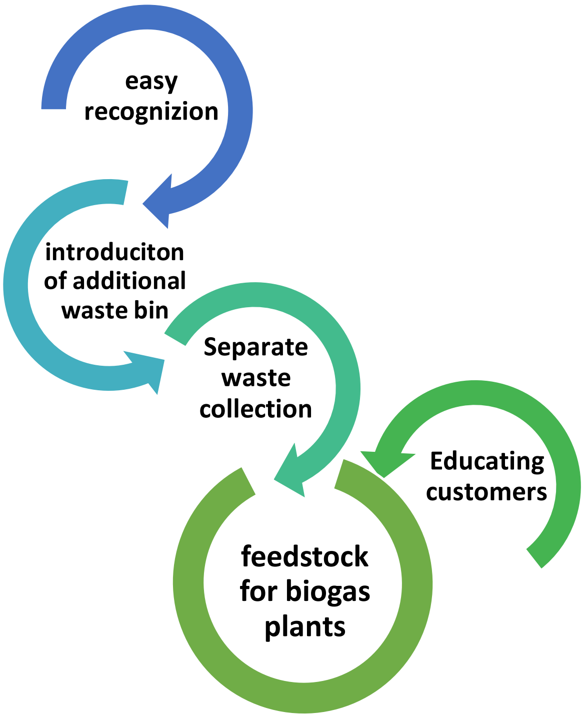

Figure 2: Steps of innovation needed to use biodegradable packaging and dishes in the biogas plant

Separate waste collection

The next step is the possibility of a waste separation at the beach, which should be designed as simple as possible so that all beach visitors can easily understand the concept of waste separation, regardless the language they speak. Giving the possibility to distinguish between the main categories, which are paper and cardboard, packaging waste, residual waste, the bio-in and the collection of bottles. The biodegradable materials should be disposed of in the bio bin. This step facilitates the sorting of the waste later on.

Figure 3: Possible waste disposal at the beach. Colour coding and graphics clarify the rightful waste disposal. The blue bin collects paper and cardboard, black is for residual waste, the yellow bin collects packaging waste (plastic material, Styrofoam, aluminium packaging, screw caps, and cans), the green bin is for the biodegradable materials. The cate collects all kind bottles (glass bottles as well as returnable ones).

In general, a test phase is of great use, which tests the bottom-up approach of a composting process to identify possible changes as well as barriers. The bottom-up approach refers to the reversal of the composting process. Does it make sense to first have the material composted and then remove those materials that cannot be decomposed? Is the bottom-up approach of the composting process economical beneficial? What needs to be changed until this approach can be applied nationwide and what effort is required to be able to implement this approach in the waste disposal plant? A second test phase is needed to evaluate whether the long composting time of biodegradable materials can be solved by sieving the materials, which have not biodegraded yet and feed them into a new composting pile. The evaluation of the exact cycles needs until when the material has been completely decomposed and whether this step leads to an additional effort in working hours and costs is necessary.

The last two necessary changes mentioned are important when feeding the biodegradable materials into biogas production.

All waste bins must be collected separately. This results in additional efforts and costs and must be taken into account by waste management authorities and service providers. The collection of individual waste bins leads to additional transport costs. Are the public waste authorities willing to pay for the extra service? Will the waste disposal company pick up the collected waste from the beach or will it be delivered to the waste disposal company? If latter, is the case, who will be responsible for the waste delivery? The frequency of the weekly waste collection needs to be tested and adapted if necessary. The labelling of the biodegradable materials should also be of use for the sorting machines in the waste disposal plants. The problem here is that the machines often cannot distinguish biodegradable packaging from fossil-based packaging when separating waste. This is an issue when the biodegradable material was not deposed of into the right bin. During the separation process, the material might not be recognized as biodegradable and is fed into the residual waste were it will be incinerated. Hence, labelling is needed which is easily understood by humans as well as waste separation machines.

Frequent distribution of waste bins is an important precondition to guarantee successful waste management. Without a proper waste separation, recycling is very difficult.

Educating customers
Another important step is raising awareness among consumers. Without their contribution, the project will not succeed. For this reason, a clear concept has to be developed on how to inform consumers about the rightful use and disposal of biodegradable packaging and cutlery. The danger lies in careless disposal, which results in the mixing of different materials in one waste bin, leading to expensive separation steps. Valuable biomass can get lost as it is burned together with the residual waste.

2.4 Planning Implementation

Step one of the implementation process is the acquisition of project participants, more specific restaurant, and kiosk and stall owners located near the beach. In order to maintain competitiveness, a type of agreement or contract should be concluded in which all parties declare and can prove that they only use biodegradable dishes and packaging. Clarification is needed whether the kiosk owners themselves are responsible for procuring the biodegradable material or if a person responsible is designated to take care of all the parties involved.

The promotion and marketing of the projects on websites and flyers as well as the setting up of all signs and waste bins shall be achieved within the first year of the project. For this part of the project, it is also possible to consider how many additional helpers are needed for the organization and management to form a small team. A large part of the money will be needed for marketing purposes within the first step of the project.[1]

The labelling of the biodegradable products must be actively promoted and demands the involvement of the government, as it concerns national and international production and disposal processes and not only individual companies.

Recruitment of sponsors can be started early. As this project could involve many people, as well as authorities and ministries being actively involved as it sheds a good light on the region and promotes tourism in the area. The test phase with the bottom-up approach of the composting process is tested as well as the decomposition time of the biodegradable material is started as early as possible, as project partners have to be found for this. In this case, waste disposal companies can carry out these tests in practice. Test run number 1 requires a more time-consuming planning phase, in which a cost estimate has to be prepared and the composting process has to be re-planned. Additional staff may have to be recruited for this purpose. This task is the responsibility of the waste disposal company.

Market research has to be conducted throughout the entire project to be informed about innovations regarding biodegradable products and waste disposal processes and technologies.

2.5 Stakeholders

Following actors are needed to implement the concept of replacing fossil-based single-use plastic packaging and dishes with biodegradable materials.

<u>Restaurants, kiosks and stalls near the beach and the tourism sector</u>

The project is based on own initiative on volunteering basis. However, this project is also in the interest of the restaurant, kiosk and stall owners as they are forced to act due to the ban on single-use plastic products by the Directive (EU) 2019/904 of the European Parliament and the Council. To approach this step together in a project gives the participants the chance to exchange ideas and learn from each other.

With the help of the hotels and holiday flats, beach visitors can be informed about the new arrangements on the beach.

<u>Waste disposal companies</u>

Without the active help of waste disposal companies, the project cannot be conducted as planned. Both test runs have to be carried out in waste disposal companies. In addition, the collection and disposal of the garbage on the beach cannot be carried out without their help.

<u>Decision makers</u>

The Federal Government of the European Parliament, especially regarding the labelling or the biodegradable products, partly depending on the regulations and laws passes the success of the project.

Renovations and construction work on the beach and the surrounding area always need to be coordinate with and approved by the state of Mecklenburg-Vorpommern, e.g. B if access to the beach needs to be expanded so that the garbage collection has enough space.

[1] Telephone interview with a representative of the Tourismuszentrale Rostock + Warnemünde. 18.09.2020

3 Conclusion

A barrier for the project states the involvement of the public. Without a good waste separation at the beach, the following project steps (e.g. waste separation and recycling) are very difficult to conduct. This may jeopardize the approach to use the biodegradable packaging, dishes and cutlery for the biogas production. Hence, great importance lies in the education of customers and beach visitors.

The extent to which the material is biodegradable also depends on the development of the products and is therefore linked to the success of the search for sustainable possibilities. Furthermore, the project's success also depends on the waste companies' willingness to cooperate and contribute with practical research. The politic can be beneficial or hindering for the development of the project with laws and directives on waste disposal, waste management or the labelling of biodegradable materials. Thus, the degree of success of the project depends on various factors.

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