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Full Research Article

Bio-based Business Models: specific and general learnings from recent good practice cases in different business sectors

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Abstract

Business models can be a perfect tool to meet the challenges in highlighting the competitiveness and sustainability potential of bio-based solutions, and facilitating primary producers to benefit from the opportunities offered by bioeconomy. In this work six concrete bio-based good practices that have succeeded in progressing from early ideas to a products on the market were analysed. These examples pose new insights that can be used by a wide range of experts and stakeholders for the analysis of benefits and challenges of value chains in the bio-based economy sectors. It is concluded that the traditional Business Model Canvas needs to be extended with additional factors related to sustainability and business ecosystem. In order to establish a practical framework promoting economic viability of bio-based business cases, the importance is highlighted for adjusting the exclusive focus on Technology Readiness Levels by introducing levels reflecting business or market readiness.

Keywords: Bioeconomy, Business Modelling, Business Model Canvas, Bio-Based Industry, Business Readiness Level.

1. Introduction

1.1 Special role of business models in bioeconomy - dissemination of good practices

The shift towards a circular economy and bioeconomy is one of the main focuses of political initiatives aimed at replacing fossil feedstock by renewable biological sources while still achieving economic growth.[1] Awareness raising activities, highlighting the potential of bioeconomy for competitiveness and sustainability are necessary for informing the general public as well as the different policy departments and business sectors.[2] Bio-based business models, the importance of which is clearly stated in the Updated Bioeconomy Strategy of the European Commission (EC),[3] can be a perfect tool to meet this challenge. According to this strategy, bioeconomy is sustainable and circular, and includes, among others, "economic and industrial sectors that use biological resources and processes to produce food, feed, bio-based products, energy and services".

One of the "pilot actions" included in the European Bioeconomy Strategy aims to better link national bioeconomy strategies and national strategic plans under the Common Agricultural Policy (CAP), in order to support inclusive bioeconomies in rural areas. It is also highlighted at this action that dissemination of good practices is among the most important tools to foster the deployment of the bioeconomy and enables primary producers to benefit from the opportunities offered by bioeconomy approaches.[3] A strong support for economic information is imperative for enhancing the convergence between bioeconomy and the CAP or other relevant agricultural policies and priorities.[4] When developing CAP strategic plans supporting the setting up of sustainable bioeconomy businesses in rural areas, particular attention has to be paid to primary producers because they play a key role in bioeconomy value chains. Countries with well-developed primary sectors have certainly many opportunities to develop downstream value chains.[5]

The bioeconomy's strength lies in its diversity, adaptability and close interactions with local and rural communities,[2] and business modelling can represent all of these aspects in a unified structure, taking into consideration the local economic and social environment where the business operates.

When talking about an innovative solution as part of the workflow in research and development (R&D) projects where companies or business oriented organizations (e.g. clusters, chambers) are involved, the first immediate question that arises on their part is whether deployment of the solution is economically viable. Further questions that arise are: What evidence underpins the real potential and economic feasibility of the technology solution? Has the technological viability been already demonstrated? Has the technology been operated on a large scale? How does the innovation fit into the business environment? No matter how eager the representatives of business-supporting organizations (e. g. clusters, farmers' associations, consultancy services, etc.) are to widely share the bioeconomy-related technologies and opportunities to their network, they are not able to make steps forward in qualitative terms without having answers to these questions above. Bearing in mind the precious trust gained from stakeholders they have been working with, representatives feeling responsible simply cannot afford to introduce these promising solutions, as long as it is not fully clear and proven that these innovations would not cause any economic disadvantage to these stakeholders. Involvement of farmers is especially essential, since this is the key to ensuring that farmers, instead of being mere biomass providers, benefit from the profit-creating value-addition that is achieved by the innovative transformation processes in bioeconomy businesses.

The study on the participation of the agricultural sector in the Bio-Based Industries Joint Undertaking (BBI JU) emphasizes that business models in the bio-based sector are worth highlighting.[6] An easy-to-understand business model is a great tool for several purposes, i.e.: awareness raising in different sectors, dissemination of bioeconomy good practices, involving primary producers. The model is expected to clearly explain the key components of a business and how they relate to each other in order to create value and a favorable balance of cost structure and revenue streams that can make the business model viable.[7]

This current work focuses on business aspects within the bioeconomy concept, which are of key importance for this industrial sector, and intends to show interlinks between these aspects and others considered essential for the successful implementation. The aim is to analyse real-life, concrete examples of 'bio-based concepts' that have succeeded in progressing from the early ideas to a final product placed on the market, and assessing their business models, in order to provide learnings that can be used by experts of consultancy services and other business-supporting organizations, clusters, research organizations, legal authorities, etc., for the development of innovative companies. The results contribute to developing a common and shared perspective of different sectors involved in bioeconomy developments, with special regard to academic or R&D organizations and industrial actors implementing bio-based industrial solutions in real life.

1.2 Business Model Canvas

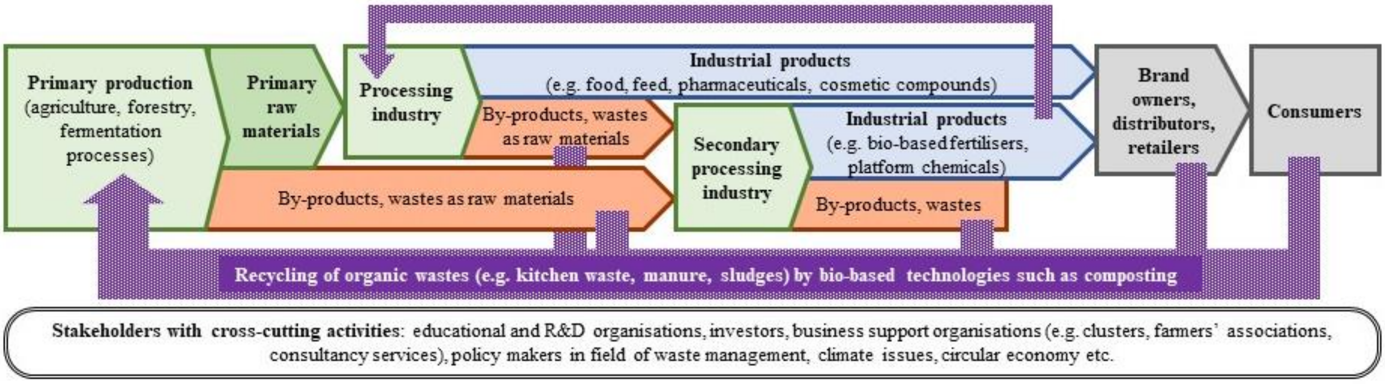
In very general terms, business models explain how enterprises work to deliver value to their customers. A competitive model represents a business activity that is better than the existing options or may offer more value to a discrete group of customers or may even completely replace the old way of doing things and become the standard for other entrepreneurs. Business Model Canvas (BMC) is a template framework identifying and addressing the nine most important so called building blocks of a business solution and its environment:[8, 9]

- Value proposition is the bundle of benefits that a company offers to customers. It is the concept at the heart of the model, including the product or service itself (or the combination of these), and also value factors being the reasons behind the customer's motivation to buy it.
- Key partners, Key activities, Key resources are the internal building blocks that are mostly under direct control of the Value proposition's owner, including all the operational components that make the Value proposition a reality.
- Customer relationships, Channels, Customer segments are the external building blocks, including all components related to the understanding and reaching people and companies representing the market.
- Cost structure and Revenue streams are the finance-related building blocks, describing the financial viability and feasibility of the business.

BMC is a useful tool for facilitating the entrepreneurial process by breaking down the most relevant aspects of a business solution, and helping to understand and visualize the interplay of the different components creating value. While BMC might be helpful to understand existing business models, it is also suitable to design novel innovations.[7]

The internal building blocks of BMC can be more complex for bio-based industry than other industries. In most bio-based value chains biomass raw material comes from a sector different from the one where it is utilized in a bio-based process (Figure 1). This means that bioeconomy solutions evidently involve different sectors and thus require the cooperation of various and divergent players which rarely interacted so far, such as established chemical companies and small-scale farmers.[10] Moreover, the bioeconomy concept, as all holistic innovation systems, needs to involve all groups of stakeholders according to the Quintuple Helix Approach: economic, education and political systems, civil society and natural environment.[11]

Figure 1. Bio-based value chain structure demonstrating the stakeholders involved



In 2017, a systematic literature review was conducted by Reim et al. on research articles describing bioeconomy-related forest-based business solutions.[1, 12] The review assessed to which level of detail the BMC building blocks were investigated in these studies. The building block that is extensively covered in literature is the Value proposition, mainly by describing existing or potential offers related to bioeconomy. Key activities and Key resources are also well-discussed. Customer relationships block often mentions the need for reliable information to convince potential customers, however, there is not much written explicitly about Customer relationships. Channels is the BMC building block that is least addressed. Details about the cost structure can also be found in literature even though detailed calculations are currently missing. The most frequent explicitly addressed cost is related to the cost of biomass or feedstock.

1.3 Extension of BMC to meet sustainability and business ecosystem aspects

BMC is often chosen for business modelling, due to the ease of its practical application and worldwide recognition. However, applying the principles of the circular economy and bioeconomy exceeds the existing BMC components.

The potential contribution of the bioeconomy to sustainability and its social value generation (e. g. local employment, rural regeneration, energy security) are highly evident and well-described in the recent literature.[1] However, bioeconomy is not per se sustainable just because it is based on renewable resources, and sometimes it even brings about new challenges, despite the fact that it can be a way to solve sustainability problems and may contribute to the Sustainable Development Goals defined by the United Nations.[13] Besides competition with food and feed, increased use of biomass also has its effects on land use, water availability and on other sectors. For example, forest-based industries (such as production of pulp and paper, building materials, etc.) are affected by the increased use of wood for energy conversion.[14] As already seen in the context of bioenergy, rise of the demand for bio-based products will increase the pressure on limited biomass and land resources and thus may cause several sustainability conflicts.[13] To make sustainability as one of the key concepts behind bioeconomy supply chains noticeable, sustainability-related aspects can be added as extensions to the BMC. This extension enables the BMC to indicate/demonstrate that bio-based solutions are not aimed at merely replacing fossil resources by bio-based ones, but also generating societal and ecological values and contributing to a long-term structural change.[13] Various models based on the original BMC have already been published which suggest to add further blocks to the top, side and/or bottom sections to reflect a wider perspective.[15] An example is the framework presented by Antikainen and Valkokari, which shows how to create values also in environmental and social terms, which is particularly relevant in bioeconomy businesses requiring the cooperation of various and divergent players.[16]

2. Methodology

2.1 Selection and categorisation of bio-based solutions

The starting point for the selection was a collection of nineteen bio-based solutions which were described in detail in a study in the framework of the POWER4BIO project.[17] In the first step, this collection was screened to select good practice solutions having high technological maturity (TRL8 or TRL9, the highest Technology Readiness Levels used in H2020 Framework Programme for Research and Innovation[18]) and proven business potential. Additionally, sufficient quality and quantity of the data of the solutions should be available. In this step, knowing a reliable contact person at the company owning the bio-based solution who had permission for sharing necessary and relevant information for all nine building blocks of the BMC was an important aspect. The third step was to identify different solutions to cover the four categories as defined by COWI, Bio-Based World News and Ecologic Institute:[19]

1. Final product (product that can be sold to the end consumer, without any further processing, e.g. tableware, biofuel, mushroom grown on agricultural wastes, etc.);
2. Material (product that can be used as raw material to produce bio-based final products, e.g. bio-based fibers, bio-based foam for packaging applications, hemp-based insulation material for buildings, plant-based material for clothes, etc.);
3. General building block or biopolymer (chemical monomer or polymer to produce materials, e.g. bio-based 1,4-butanediol, an industrial chemical used as a building block for the production of plastics, elastic fibers and polyurethanes);
4. Technology licensing.

The authors selected six recently developed bio-based good practice cases and described them following the BMC modelling system.

2.2 Data collection

Intensive desk and literature research were carried out to extract the valuable information from publicly available sources such as webpages of the companies, (bio)economy news portals, press releases issued by the companies, conference presentations, economical/statistical databases, scientific articles, etc. Online or telephone interviews were conducted with the owners or experts of selected solutions. One person was interviewed per company. The company experts were informed of the aim and subject of the interviews in advance, during the appointment arrangement process. A set of relevant questions was compiled before the meetings, structured by the elements of BMC, to help covering all relevant details during the interviews. For the case when a company preferred to fill in a questionnaire rather than giving an oral interview, this set of questions was sent to its representative expert. The collected data were processed and organized using BMC structure.[8] Companies have checked and endorsed the business model descriptions.

2.3 Literature review

To learn from previous experiences and take into consideration bio-based business models elaborated earlier, a literature review was made to obtain an overview about the work already performed in the field of application of bio-based industry business modelling methodologies, especially BMC. Based on this review, the cases presented in the following studies were included to develop learnings about the bio-based business models and their development, together with the good practice cases described in this paper:

- The study on the participation of the agricultural sector in the BBI JU was carried out between March and August 2019.[6] Fifteen business models from European countries and five from non-European countries were studied.

- BE-Rural project, funded under the same H2020 call topic as POWER4BIO, delivered a report in November 2019, addressing business models for regional bioeconomies[20] which analyses four models based on BMC.
- In 2017 a one-day stakeholder workshop was organized in Lleida, Spain in the AgriMax project funded by BBI JU, to develop business models for valorisation of agricultural and food-processing waste. Farmers, agricultural cooperatives, food producers, investors and other stakeholders were invited, and BMC was used to elaborate three case studies and map existing and innovative ways to create value for the new supply chains.[15]
- In 2019 a report was prepared for the EC by COWI Group, Bio-Based World News and Ecologic Institute, in order to "provide concrete examples of 'bio-based concepts' that have succeeded in progressing from the early ideas to a final product placed on the market", to a fully commercial level, or close to that. Fifteen success stories are presented in this report.[19]

2.4 Framework for the extension of BMC to meet sustainability and business ecosystem aspects

In order to extend the traditional BMC with sustainability and business ecosystem aspects, authors used the framework offered by Antikainen and Valkokari,[16] which complements current business model tools by integrating the following additional factors: trends, drivers, stakeholder involvement (business ecosystem level), and environmental, social and business requirements and benefits (sustainability impact). A collection of examples for these additional factors was compiled based on the authors' own experiences and the work of Philp and Winickoff,[21] Biber-Freudenberger et al.[22] and Pavlovskaia,[23] and categorised as follows: drivers and stakeholder involvement tools; sustanability requirements; sustainability benefits.

3. Results

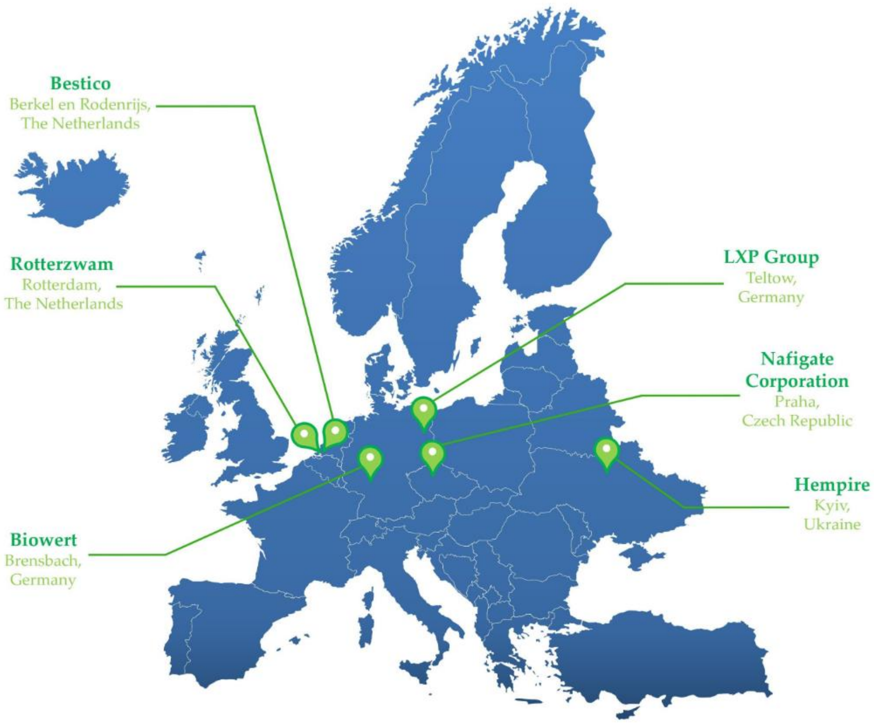
Table 1 summarizes the good practice cases presented in this article and Figure 2 shows the locations where these cases are being operated by the owner companies. Figures 3-8 present the business models in BMC format behind the analyzed solutions numbered S1, S2, S3, S4, S5 and S6, respectively. For each solution short additional background information is presented next.

Table 1. Summary of the bio-based solutions selected for this study. Product types, defined in Section 2.1, are as follows: 1: Final product, 2: Material, 3: Building block or polymer, 4: Technology licensing.

No. of solution	Name of solution	Bio-based product(s)	Product type	Company (country)	Mode of data collection
S1	Production of feed quality protein meal and oil with high nutritional value by the bioconversion of residual organic streams using Black Soldier Fly (BSF) Larvae	feed quality protein meal, oil with high nutritional value; fertiliser	1	Bestico (The Netherlands)	personal interview (08.01.2020); desk research
S2	Local production of fresh oyster mushroom combined with the valorisation of the coffee ground residues	fresh oyster mushroom and processed products	1	Rotterzwam (The Netherlands)	desk research, email discussion
S3	Natural insulation material produced using hemp hurds and own-produced limestone-based binder	insulation material based on hemp hurd	2, 4	Hempire (Ukraine)	personal interview (11.11.2019); desk research

No. of solution	Name of solution	Bio-based product(s)	Product type	Company (country)	Mode of data collection
S4	Meadow grass silage biorefinery producing grass fibre reinforced plastic composite granulates and bio-based insulation material, combined with biogas plant producing electrical energy from grass juice and food residues	grass fibre reinforced plastic granulates, natural insulation material, electrical energy from biogas, organic fertiliser	2	Biowert (Germany)	data and descriptions provided by the company in written form by filling a questionnaire; desk research
S5	Production of bio-based chemicals, high-quality natural lignin, biogas and biofuels from 2nd generation biomass by cracking technology	biochemicals, natural lignin, biogas, biofuels	3, 4	LXP Group (Germany)	personal interview (24.02.2020) and email discussion; desk research; content of slides used by the company at public presentations
S6	Production of polyhydroxyalkanoates (PHA) using waste cooking oil	polyhydroxyalkanoates (PHA)	3, 4	Nafigate Corporation (Czech Republic)	personal interview (06.12.2019), followed by email discussion; desk research

Figure 2. Locations of the companies operating the good practice cases listed in Table 1.



S1. Production of feed quality protein meal and oil with high nutritional value by the bioconversion of residual organic streams using Black Soldier Fly Larvae (Bestico, Berkel en Rodenrijs, The Netherlands)

Bestico B.V. founded in 2013 focuses on the production and sales of Black Soldier Fly (BSF) (*Hermetia illucens*) larvae and their processing to protein for animal feed (especially aquaculture feed and pet food), insect oil and fertilizer agent (Figure 3). The efforts of Bestico B.V. are supported by its mother company, Koppert Biological Systems, an internationalized firm with subsidiaries in 27 countries which is a leading provider of arthropods and microbes for biological control of agricultural pests and has developed expertise in the production of insects since 1967. The company provides a tailored, scalable solution (being at TRL8 at the time of the interview) to use biomass by-products and convert this into feed-quality protein and oil with high nutritional value. When the data collection was performed, the production rate was around 6-12 tonnes of fresh larvae per week. The growing process takes about 14 days, and within this period the larvae reduce the feedstock weight by 40-60% while half of this, i.e., 20-30% of the feedstock weight is converted into larvae biomass, depending on the nutritional profile of the feedstock.

Figure 3. BMC of solution 'S1' (Bestico, The Netherlands)

Key Partnerships
- raw material providers ensuring biomass feedstock of appropriate quality
- industrial and academic partners to increase TRL and to find new applications for BSF larvae products and side streams

Key Activities
- feedstock reception (GMP+ grade for feed application) and strict quality control upon receipt (dry matter content, free of pesticides/insecticides)
- primary production of insects
- processing insects into concentrated protein meal, insect oil and natural fertilizer
- adapting the technology to fit into existing operations (scale-up of current process)
- continuous R&D for cost effective and higher quality production

Key Resources
- raw material feedstock (e.g. vegetable waste coming from potato and alcohol industries) of appropriate quality (very low content of insecticides) and uniform in physical and nutritional properties affecting the time required to larvae growth
- infrastructure for feedstock storage and quality control
- facilities comprising conditioned rearing cells and equipment for feeding of the insects
- equipment to isolate protein meal and insect oil
- know-how on BSF eggs production and insects growing
- sales competences

Value Proposition
- tailored sustainable solutions for growing and processing insects
- scalable solution to utilise excess biomass from potato industry, beer and alcohol industry into valuable feed-quality and storable protein and oil with high nutritional value
- protein from BSF (with protein content up to 60%) suitable for farmed fish, poultry and other livestock, providing essential amino acids which are low in feeds produced from plant origin and which are easily digested by most animals
- substrate remaining after isolation of protein and oil has value as fertiliser
- automated processing secures consistent and safe products
- BSF larvae system is adaptable to a wide range of residual organic streams, making food chain more sustainable

Customer Relationships
- Business to Business (B2B) and Business to Customers sales strategies
- using a sales force of 3-5 persons in Europe (France, United Kingdom, The Netherlands)

Channels
- reaching customers by company website, social media and YouTube channels
- conferences and presentations at fairs and other events
- cooperation projects

Customer Segments
- pet food industry
- pet food consumers
- aquaculture
- animal feed industry (farm animals)

Cost Structure
- CAPEX is estimated in the range between 3-5 million EUR;
- main long-term expenses: plant and equipment purchases, building and improvements, instrumentation and automation of the process;
- most important operational expenses: feedstock, energy/utilities and labour costs, with equal shares within OPEX being in the range of 3-5 million EUR/year

Revenue Streams
- sales of dry insects for animal feed and pet food;
- estimated price of dry BSF larvae as animal feed: 1-3 EUR/kg; price of pet food: 15-40 EUR/kg (based on the retail prices in the webshop)

S2. Local production of fresh oyster mushroom combined with the valorization of the coffee ground residues (Rotterzwam, Rotterdam, The Netherlands)

Rotterzwam B.V. is a private company, established in 2013. The company is dedicated to cultivation, production and sale of fresh edible mushrooms grown on coffee grounds and its application in other related products (Figure 4). Its mushroom nursery is the largest coffee ground-based mushroom farm in Europe and the company aims to develop it to be energy neutral and CO_2 negative. The cultivation units contain a modular and sustainable climate system, which is fully optimized for mushroom cultivation. These units, which are especially designed for an urban environment, can also be very well used in remote rural areas. Rotterzwam also provides services like workshops, educational activities and consultancy in the field of urban management through the radical renewal of chains. They work with local partners to find new ways to put products derived from coffee grounds and oyster mushrooms into the market, developing products such as oyster mushroom vegetarian snacks and beer.

Figure 4. BMC of solution 'S2' (Rotterzwam B.V., The Netherlands)

Key Partnerships
- local coffee grounds providers
- local industries for the development of new products: partners cooperating in the development and sales of products listed at the Value proposition (restaurants, supermarkets, breweries, bakeries etc.)

Key Activities
- collection of coffee grounds from companies or organizations that use at least 50 kg of coffee beans per month
- cultivation, storage and packaging of oyster mushrooms
- sales and marketing of fresh oyster processed products
- activities related to the development of processed products and to the services provided

Key Resources
- coffee ground material as the main feedstock
- know how on oyster mushrooms cultivation techniques on coffee grounds
- cultivation container units optimized for mushroom cultivation, especially designed for an urban environment
- infrastructure and adapted facilities for production of mushrooms
- vehicles for the collection and transport of coffee grounds and mushrooms

Value Proposition
- valorisation of coffee residues on a local scale into the best possible uses such as food products
- production of fresh oyster mushrooms
- mushroom-based and coffee ground-based processed products (beer, snacks, soap, fertiliser etc.)
- growkit for common people to convert their own coffee grounds into oyster mushrooms
- substrate remaining after mushroom production can be used as soil improver

Customer Relationships
- direct sales to local people, restaurants and shops
- attracting new customers and engaging entrepreneurs interested in mushroom growing and utilisation of coffee grounds
- unique marketing strategy and communication package on valorisation of coffee ground

Channels
- company's own website and Facebook site
- online shops
- catering wholesalers offering oyster mushrooms snacks
- network of local mushroom nurseries promoting the growkit
- social and traditional media
- online e-learning courses and seminars, presentations, workshops
- factory visits

Customer Segments
- strong focus on the citizens of the local municipality
- local shops, restaurants and markets
- local hospitality sector (food category)
- green consumers or entrepreneurs, with preference for local food production, environmentally friendly products and consumption of proteins of non-animal origin and concerned about the environment

Cost Structure
- 400 000 EUR from crowdfunding (Symbid) in 2018 to build the site;
- shares of investments: 34% for breeding units (8 containers), including climate system and installation; 16% for substrate preparation area, mixer, packaging machine, office space, cold room; 7% for installation of solar panels on the entire nursery; 7% for roll out quasi franchise; 8% for R&D; 8% branding and marketing campaign; 8% accelerated sales & rollout of new products and 12% for the other costs
- shares of the different costs within the OPEX structure are the following: staff costs: 33%, cost of sales: 29%, other operating costs: 34%, depreciation and financial expenses: 4%

Revenue Streams
- producers of coffee ground material pay for its collection (1-5 EUR/kg)
- fresh oyster mushrooms sales (8,5-10 EUR/kg)
- sales of processed products (beer – 9 EUR/litre; vegetarian snacks etc.)
- growkit for people to convert their own coffee grounds into oyster mushrooms: 15 EUR per kit
- E-learning courses and seminars on mushrooms growing (50-350 EUR per module)

S3. Natural insulation material produced using hemp hurds and own-produced limestone-based binder (Hempire, Ukraine)

Hempire is a company based in Ukraine and having a site in California, USA as well. The company was established to provide insulation technology based on hemp and lime (Figure 5). In the last few years, the company has been involved in more thatn 60 building construction projects and successfully developed its own lime-based binder material called "Fifth Element" which does not contain cement, sand or toxic components. The binder material is produced in the company's own facilities, both in Ukraine and in the USA. Through extensive R&D the company has created a very light insulation material called "Hempire Mix". This highly energy efficient material consists of three components, which are mixed on the construction sites using a special mixer: hemp hurds, water and the special proprietary binder mentioned above. Hempire Mix is applied on the walls and it can be used to insulate any wall, floor and roof inside a new or an existing building. It contains only non-toxic components and has numerous benefits: insulation acting as humidity and temperature regulator in the building; excellent thermal insulation properties resulting in significant savings on heating and cooling all year round; with vapor permeable walls there is no need to install a ventilation system; high thermal mass and thermal inertia help prevent temperature fluctuations; no rotting but protecting walls from fungus due to the regulation of humidity; excellent acoustic absorption due to high porosity; non-flammable material which repels rodents.

Figure 5. BMC of solution ‘S3’ (Hempire, Ukraine)

Key Partnerships
- raw material providers: hemp growers and lime provider
- logistic partners

Key Activities
- feedstock transport and storage
- producing lime-based binder
- binder transport
- mixing binder, water and hemp hurds on the construction site
- close cooperation with hemp growers
- design, planning and implementation services
- technology development for more cost effective and higher quantity production

Key Resources
- estate for the buildings and feedstock storage
- buildings and machinery for lime-based binder production
- high quality raw materials: hemp and lime (dust content of the hemp has to be as low as possible, it can’t be mouldy or wet, hurd particles shall be 1-4 cm long)
- vehicles for feedstock and product transport and handling
- know-how and knowledge for optimization based on own experiences

Value Proposition
- natural hemp-based insulation solutions using local ingredients for environment-friendly buildings
- building and energy cost-effective construction solution
- special lime-based binder material (free from cement, sand or toxic components) for the on-site production of insulation material
- processes to be done on the construction sites are easy-to-learn and do not require high level of skills
- wide range of services: consultation, services related to insulation, design, planning and implementation, quality control

Customer Relationships
- direct relationship and close cooperation with customers
- B2B and B2C sales strategies
- providing technical support
- informing the public about new buildings and construction solutions, to add more visibility to the solution

Channels
- marketing: company’s own website, Facebook site
- presentations and workshops to inform stakeholders about the company’s activities and current developments
- staying in contact with former customers

Customer Segments
- private persons, organizations, business companies, communities interested in making a hemp-based building
- consulting services: architects, designers, builders, contractors and other actors in the construction industry

Cost Structure
- CAPEX: building and equipment for a new facility: 2 million USD in USA or Canada, while around 1 million USD in Europe or Ukraine
- OPEX: price of raw materials: hemp hurds as main feedstock (120 EUR/t) and lime; energy costs; labour costs (4 people in the binder production facility and other 4 people working at the construction site); general & administrative expenses

Revenue Streams
- sale of binder material: 12 EUR per one bag, which contains 25 kg (480 EUR/t) and for a retail price of 32 USD per one bag, which contains 23 kg (1390 USD/t) in the USA
- revenues from sale of insulation material (180 EUR/m^3) and insulation services
- revenues from consultation and other services mentioned at Value Proposition

S4. Meadow grass silage biorefinery producing grass fiber reinforced plastic composite granulates and bio-based insulation material, combined with biogas plant producing electrical energy from grass juice and food residues (Biowert, Germany)

Biowert Industrie GmbH was founded in 2000 as a Swiss-German company. The first Biowert grass refinery which started its operation in 2007 is located in Brensbach, Germany. The "grass factory" system combines the biorefinery process, the multistage production of innovative bio-based materials and an affiliated anaerobic digestion facility with a CHP plant producing green electricity (Figure 6). The biorefinery is fed by meadow grass from their own permanent pastureland and arable land for crop production, and produces different innovative biomaterials: a fire safe blow-in insulation material for wall, roof and floor cavities which naturally controls the absorption and release of water vapor to ensure the ideal building environment and safe from rodents, insects and mould (AgriCell), a light, dimensionally stable and temperature resistant fiber-reinforced composite material with 30 to 75% natural fibers (AgriPlast) and an organic fertilizer made from biogas digestate (AgriFer). The facility has an annual throughput of about 2 000 tonnes of dry matter (equivalent to 8 000 tonnes of grass per year at 25–30% dry matter content). Grass juice, as waste of the biorefinery process and other co-substrates (biogenic residual materials such as local food waste, 15 000 tonnes/year) are used for biogas production (1 340 000 m^3/year) in the anaerobic digestion facility.

This solution is a good example of the case being quite specific for the circular bio-based business models, when the producer and converter of the biomass are one and the same party, i.e., producer directly uses its by-product as a feedstock for a bio-based process.

Figure 6. BMC of solution 'S4' (Biowert, Germany)

Key Partnerships

- raw material providers: local farmers
- partners for transporting feedstock and products
- waste material handling companies to provide organic wastes feeding the biogas plant

Key Activities

- feedstock transport and storage (seasonality: meadow grass grows in spring and early summer, it can be harvested up to 4 times a year, but ensiling makes it durable, so it is available all year round)
- biorefinery process: cellulose fibres are separated from the grass using mechanical processing and then dried
- processing of the fibres into plastic based granulates or insulation material, using recycled plastic
- electricity and heat production by the biogas plant
- processing of digestate to a concentrated organic fertilizer
- keeping regular contacts with industrial customers and local farmers

Key Resources

- suitable biomass feedstock (mainly meadow grass, harvested before the panicle is pushed and ensiled, at a dry matter content of 25-30%)
- estate for the buildings and feedstock storage
- buildings and machinery for technology processes listed under Key Activities
- know-how and optimization based on own experience, included in patents as well
- specific-skilled workforce and high-quality experts

Value Proposition

- meadow grass processed into materials by a biorefinery process and green energy by an affiliated biogas plant, using food residues, other organic wastes and grass juice, ensuring energy needs (e.g. drying of cellulose fibres)
- products: grass fibre reinforced plastic granulates, insulation material, organic fertiliser
- positive environmental impacts: reducing the use of fossil-based plastics; reducing CO_2 footprint by using grass being a natural CO_2 adsorber; energy produced from wastes; agricultural and food industrial waste reduction

Customer Relationships

- sales strategy: B2B relations with industrial partners
- cooperation with local farmers

Channels

- marketing: company's own website and Facebook site
- presentations and workshops to inform stakeholders

Customer Segments

- grass fibre reinforced plastic granulates: industrial customers in a wide range
- insulation material: construction industry
- electricity and heat: own use and local electric service provider
- organic fertiliser: local farmers
- licensing the solution to actors interested in technology implementation

Cost Structure

- CAPEX cost estimated: 7-10 million EUR for biorefinery and 8 million EUR for biogas plant
- 18-24 months long period needed to install and optimise the technology (related costs also have to be taken into account)
- OPEX: feedstock (meadow grass: 140 EUR/tonne dry matter), energy and labour costs, general and administrative expenses
- energy costs depend on the share provided by the biogas plant

Revenue Streams

- selling of grass fibre reinforced plastic granulates (2500 t/year produced; price: 1,95-3,50 EUR/kg, depending on additives and final recipe)
- selling of insulation material (1400 t/year produced; 1,38 EUR/kg)
- energy sold to the local electric service provider, (price set by feed-in tariffs; CHP plant produces 5,2 GWh/year, the energy need of the biorefinery is 2,5-3 GWh/year, thus the surplus can be sold)
- by-product of the biogas plant is a nitrogen-rich material, sold as organic fertiliser (11000 t/year)
- indirect revenue: waste management costs are lower, as by-product of the biorefinery (e. g. grass juice wastewater, 2000 t/year) is processed in the biogas plant

S5. Production of bio-based chemicals, high-quality natural lignin, biogas and biofuels from 2nd generation biomass by cracking technology (LXP Group GmbH, Straubing, Germany)

The goal of the company, founded in 2009 is to optimize 2nd generation biomass value chains. They have developed and patented a pre-treatment technology (LX-Process) that "gently cracks" the lignin strands in 2nd generation biomasses (such as agricultural residues, forest materials, energy grasses, organic municipal solid waste, fibrous portion of digestate from biogas plants) into oligosaccharides, lignin, cellulose and other polysaccharides which are available for further processing in fermentation processes (Figure 7). Since no inhibitors are left after the cracking process, downstream fermentation does not require expensive, custom-tailored enzymes for hydrolysis. To be economically feasible, the capacity of the plant has to be at least 10 kilotonne dry matter of processed biomass per year. The LX Pre-treatment plants can serve as raw material producers for the chemical industry or the energy sector. The first industrial LX Demonstration plant is located near Straubing, Bavaria, Germany, it was inaugurated in February of 2020 and has a planned maximum capacity of 500 tonnes (dry matter) of biomass. Initially the plant processes biogas digestate and will test additional biomass types to prove that lignocellulosic biomass from agriculture, forestry and municipal waste are also suitable for the LX Technology. German-funded projects and an EU-funded project helped the development of the technical solution. The company is interested in own technology implementation (Product type 3) as well as licensing the optimized technology solution to other companies (Product type 4). The model presented on Figure 7 describes the own technology implementation activity.

Figure 7. BMC of solution 'S5' (LXP Group, Germany)

Key Partnerships
- raw material providers
- sales partners
- partners in waste management
- R&D partners cooperating in successful plant operation
- financial advisory service, investors

Key Activities
- feedstock transport and storage
- technology steps: LX chemical pre-treatment process, precipitation of cellulose and lignin, separation / filtration of each component
- enzymatic hydrolysis
- recovery of solvent and precipitant
- technical problem solving
- product transport
- technology optimization and design for scale up

Key Resources
- regionally available biomass feedstock (biogas digestate, agricultural and forestry residues)
- estate for the buildings and feedstock storage
- buildings and machinery for processes listed under Key Activities
- vehicles for transport and handling of feedstock and products
- specific-skilled workforce and their technical experiences

Value Proposition
- production of wide range of bio-based chemicals, non-toxic, sulphur-free, high-quality natural lignin, biofuels and biogas
- high feedstock flexibility: any lignocellulosic raw material can be processed (using only non-food biomass), meaning that the plant is not fixed to a single feedstock
- using the output materials from LX-Process technology, bioprocessing plants can produce sugars by enzymatic hydrolysis which can be then converted through microbial fermentation processes into a multitude of valuable end products (e.g. biogas, ethanol, lactic acid, etc.)
- LX-Process leaves little inhibitors (such as furfural or formic acid) the presence of which is a principle hurdle faced in downstream bioprocessing, as they cannot not be removed economically
- simple, modular technology system
- decentralized bio-based production is possible
- circular bioeconomy approach supported by legislation on EU and national level
- GHG reduction

Customer Relationships
- B2B sales strategy
- operating a large-scale pilot plant
- personal follow-up contacts with stakeholders showing interest after presentations at conferences or website visits

Channels
- marketing: company website
- presentations and workshops to inform stakeholders
- demonstration activities performed in the large-scale pilot plant

Customer Segments
- chemical industrial enterprises interested in 2nd generation biochemicals
- key players in development of bio-based, "drop-in" replacement of petrochemicals
- customers seeking natural lignin of unique quality
- cosmetic industry
- 3D printing market
- sectors of construction industry interested in green construction materials
- producers of biopolymers (resins, plastics) and adhesives
- bioethanol and biogas consumers

Cost Structure
- CAPEX costs highly depend on scale and integration scenario
- main OPEX items: feedstock, energy (heat / electricity)
- feedstock price: as cheap as possible, but up to 100 EUR/tonne
- simplicity of the process keeps operational costs low: low temperature, around 70°C, enabling use of residual waste heat; normal atmospheric pressure/tolerance/corrosiveness

Revenue Streams
- sales of the materials produced by LX-Process technology
- bulk products as lignin, cellulose, sugars generate revenue with relatively good margins but can also benefit from a wide market of niche products, such as vanillin, which generate high margins but in much lower volume markets
- 6-7 years long payback time is estimated for a plant with a capacity of 25 kt dry matter processed biomass per year
- deployment of the technology is already economical from ca. 10 000 tonnes of throughput (dry matter biomass) per year

S6: Production of polyhydroxyalkanoates (PHA) using waste cooking oil (NAFIGATE, Czech Republic)

NAFIGATE Corporation, a knowledge-based company founded in 2011 has developed HYDAL Biotechnology. This technology, as the first in the world on the industrial scale, uses waste cooking oil (mostly a mixture of different plant oils such as rapeseed and sunflower oil) to produce polyhydroxyalkanoates (PHA) by using a bacterial fermentation process (Figure 8). The pilot PHA production started in 2013 and the pilot of the downstream process (isolation of the polymer from microbial cells) in 2015. In 2019 the suitability of sludge palm oil was also verified by the company's research activity for PHA production.

The PHA family of biopolymers is unique to plastics from renewable resources, as it comprises the only group of polymers converted from raw materials into their final form directly by microorganisms.

Polyhydroxybutyrate (PHB), a specific type of PHA is similar in its material properties to polystyrene, has a good resistance to moisture and aroma barrier properties. It has a unique position in the PHA family, as it biodegrades within a reasonable timescale in a wide range of microbiologically active environments[24] such as soils, fresh water, aerobic and anaerobic composting, wastewater treatment plants. Currently, the PHB biopolymer's application is multifaceted, it can replace toxic substances in UV filters; microplastics in e. g. cosmetic industry, healthcare products or medical applications (e.g., covering for capsules, stitching of wounds, bone implants); synthetic plastics in different applications such as bottles, disposable cups, cutlery, lamination foils etc.; and materials in the agriculture sector for the slow release of fertilizers, insecticides, pesticides or fungicides in the soil.[25] Poly-3-hydroxybutyrate (P3HB), the final desired biopolymer has a purity higher than 99% and high molecular weight. NAFIGATE uses pure P3HB powder in cosmetic products (shower milk, sunscreen, etc.) which are sold by their sales and marketing partner company established in 2015. NAFIGATE is working on broadening the use of biopolymer into the medical and agricultural sector.

Figure 8. BMC of solution 'S6' (NAFIGATE Corporation, Czech Republic)

Key Partnerships
- industrial feedstock providers ensuring large amount of waste cooking oil
- sales partner
- R&D partners providing laboratories and equipment needed for the production (if these resources are not owned by the producer)

Key Activities
- feedstock transport to the production site
- technology steps: microbial fermentation (transforming waste cooking oil into a PHA biopolymer, stored inside the bacterial cell); isolation of polymer from microbial cells; mixing with additives for stabilization
- production of cosmetics from P3HB
- product transport
- product selling activities
- continuous technology development and optimisation

Key Resources
- buildings, laboratories and equipment for processes listed under Key Activities
- know-how related to the specific bacterial fermentation process, based on own experience
- high quality experts and specific-skilled workforce

Value Proposition
- HYDAL biotechnology producing biodegradable PHA (polyhydroxyalkanoates) from waste cooking oils
- PHA: raw material in cosmetic or medicine industry for biodegradable microbeads, UV filter in sunscreens or bioplastics
- PHA product of the highest priority: poly-3-hydroxybutyrate (P3HB)
- production of cosmetics (e.g. peeling shower milk, sunscreen) from P3HB
- the technology does not use crops or other feedstock produced on agricultural land
- the technology contributes to reducing pollution caused by plastics and microplastics and to solving the problem of waste cooking oil utilization as well, and, at the same time requires less water and energy compared to PHB production from sugar beet, potato, wheat or corn

Customer Relationships
- close cooperation with industrial customers using PHA
- B2B and B2C sales strategies
- close cooperation with sales partners

Channels
- webshop of NAFIGATE Cosmetics to reach retail consumers directly
- marketing: company's own website, Facebook site
- press releases, presentations and workshops to inform stakeholders

Customer Segments
- PHA, P3HB: industrial customers (cosmetic and medicine industry, agriculture sector)
- cosmetics: supermarket chains, wholesalers and retail customers
- licences and know-hows: market actors interested in large scale PHA production

Cost Structure
- technology development was financed by own investment and public funding
- relatively high CAPEX costs purchasing equipment (new facility producing PHA on industrial scale would cost around 9 million EUR, according to the company's estimation)
- OPEX: cost of waste cooking oil as main feedstock (0,6 EUR/kg); rental costs of laboratory and equipment; energy costs; service costs (including the high cost of laboratory testing services that has to be purchased to provide certificates for cosmetics); labour costs; general and administrative expenses

Revenue Streams
- revenues from PHA, PH3B sales
- selling of cosmetics (60 EUR/litre, based on retail prices in the webshop)
- licensing of know-how

In the context of the extension of traditional BMC, Table 2 shows examples for the three additional factors[16] (left column) and good practice examples identified by authors in the reviewed business cases (right column).

Table 2. Examples for additional factors to extend the traditional BMC, and good practices identified in bio-based business models for these factors.

Examples for the additional factors to extend the traditional BMC	**Concrete good practice examples of bio-based business models**
Additional factor: Drivers and stakeholder involvement tools	
• identifying and informing "opinion formers" in different stakeholder groups • active participation and support of regional or industrial clusters, advocacy	• LXP Group: cooperation with Chemie-Cluster Bayern, a market-oriented development network of entrepreneurs and research institutions in the Bavarian chemical industry, acting as a catalyst facilitating the diffusion of innovative products into new markets[17]

forums and other organisations in stakeholder involvement, by action platforms to promote new technologies and innovations • knowledge exchange and development through networks and across value chains, involving learning activities, mostly on the emerging technologies • market formation involving activities that contribute to the creation of a demand for the emerging technology (e. g. taxation, procurement) • general policy instruments (e. g. long-term public strategies on industry regulations, incentives for product labelling, consumer information, industry collaboration) • public funding for early-stage research and competence building	• Rotterzwam: cooperation with many local partners to find new ways for marketing products from coffee grounds and oyster mushrooms[17] • Wilson Bio-Chemical: partnerships increasingly strengthened through R&D into higher value applications, anticipating delivering more economic, technical, environmental and social benefits[15] • AF Biomass: strengthening the supply chain network by exploring new end-markets such as for linseed straw in the paper industry in Spain and with a new straw pelleting plant in the UK[15] • Bio-Lutions received grant from the German government for upscaling their technology[20] • NAFIGATE Corporation started its operation with low investment amount and public support (most of these funds spent on R&D activities and know-how development)[17]
Additional factor: Sustainability requirements	
• energy and materials are conserved during the production process and the form of energy and materials applied are most appropriate for the desired result • work practices (including the use of chemical substances, physical agents or technologies) that present hazards to human health or the environment are continuously reduced or eliminated • products (including their packaging) and services are designed to be safe and ecologically sound throughout their life cycle • wastes and ecologically incompatible by-products are continuously reduced, eliminated, or recycled • non-food-competitive land use • biodegradability of bio-based materials in industrial, soil, or marine environments • avoiding health and ecological risks caused by improper use of technologies • management of companies is committed to an open, participatory process of continuous evaluation and improvement, focused on the long-term economic performance	• NAFIGATE Corporation: HYDAL technology transforming waste cooking oil into high-value biomaterial polymers does not use crops or other feedstock produced on agricultural land, moreover, requires less water and energy compared to PHB production from sugar beet, potato, wheat or corn[17] • LXP Group: LX-Process can be readily adapted for large-scale 2nd generation ethanol manufacturing[17] • Biowert Industrie GmbH: 'grass refinery' solution using agricultural and food industrial wastes[17] • Bestico: BSF larvae can transform nearly any kind of organic waste into high-quality protein[17] • Wilson Bio-Chemical: downstream reprocessing of recyclables[15] • AF Biomass: growing use of biomass for energy can positively contribute to energy security, the low carbon economy and 'green' jobs[15] • Hédinn protein plant: process requiring less water and energy than comparable technologies and thus economically and environmentally beneficial[20] • Spawnfoam renewable biocomposite: By creating sustainable and biodegradable products, fossil-based products are substituted[20] • Bio-Lutions: using local resources to produce biodegradable products, based on raw material being outside of the human food chain and other value chains[20]
Additional factor: Sustainability benefits	
• valorisation of biomass which would otherwise end up as waste • higher recycling rates • novel energy sources for households • increasing food production and lowering production costs • reducing greenhouse gas emissions and air pollution • decreasing the use of pesticides • generation of livelihood opportunities and income sources for farmers • health benefits due to medical applications • benefits in terms of energy provisioning and food security, for example, using waste as feedstock for insects or algae	• Rotterzwam: oyster mushrooms grown on coffee grounds, as source of proteins of non-animal origin with minimal footprint and food miles[17] • LXP Group: LX-Process reduces GHG emissions and enables 1st generation biorefineries and biogas plants to convert to 2nd generation feedstocks, thus reducing required acreage for 1st generation feedstocks[17] • Hempire: hemp-based building material reduces energy required for heating/cooling; 1 m^3 of Hempire Mix locks up 165 kg of CO_2 (negative carbon footprint)[17] • Biowert Industrie GmbH: their solution reduces CO_2 footprint by using grass as a natural CO_2 adsorber and the use of fossil-based plastics as well (and thus the consumption of fossil raw materials)[17] • Bestico: low environmental footprint of producing alternative protein sources for animal feeds by BSF larvae[17] • Wilson Bio-Chemical: biodegradable waste fraction diverted from landfill, reducing greenhouse gas emissions and freeing up land for other purposes whilst producing feedstock for renewable energy[15] • Soldebre: use of olive kernels as a low-carbon biofuel, environmental impacts are reduced such as achieving a reduction in carbon emissions by using less fossil fuel[15] • Small-scale pellet production: local pellet production reduces the dependence from fossil fuels, replaces them in households and CHP plants,

	etc., thus reducing overall logistics costs and emissions from fossil fuels[20] • Hédinn protein plant: more targeted fishing of cyprinids may help to reduce eutrophication which may have positive environmental impacts while supporting rural development at the same time[20] • Spawnfoam renewable biocomposite: solution facilitates decarbonisation for a range of products, reduces GHG emissions and prevents the deposit of waste in landfills or in the seas[20]

4. Discussion

4.1 Cross-cutting analysis

Based on the internal building blocks in the business models of bio-based solutions in Table 1 and described in the reports listed in Section 2.3, the following points were identified as especially important cross-cutting elements and also as factors that are specific to the bio-based industry in several aspects:

- Biomass feedstock as a key resource, local biomass suppliers as key partners and maintaining good relationships with them as a key activity, since the constant availability of biomass and solving the related logistic issues are of key importance. For bio-based companies it is essential to have close relation with farmers by offering them reliable and convenient services, e. g. secure and regular payments irrespective of harvest time, assurance of timely transport before new crop needs planting, access to financing opportunities within the business group to support farmers investing in straw storage facilities.[15]
- Logistic and quality assurance partnerships and activities, since keeping transport costs low is crucial for costs-efficiency, and so are the activities ensuring adequate biomass supply (e.g. handling seasonality and perishability, quality monitoring etc.). Volumes of resources, especially feedstocks from agricultural production can fluctuate, which represents a constraint for markets traditionally not subjected to large fluctuations in feedstock supply, like for chemical products, hence issues in logistics, storage and quality preservation should be constantly addressed.[26] Steady supply of the required seasonal feedstock, which may increase storage costs, is often reported as a weakness.[19] Challenges from seasonality are tackled by building appropriate storage capacity and technologies converting perishable biomass to a stable feedstock (e.g. ensiling).
- Research background (laboratories as a key resource or a key partnership, research-based developments as a key activity), since bioeconomy and industrial biotechnology are highly innovative and research-intensive sectors. Continuous R&D is part of business models for more cost effective and higher quality production as well as developing new applications for products and sidestreams.

The Value proposition is versatile since it can be extended to include social and environmental values besides the economic value the business creates. For example, in bioenergy producing solutions, the local production strengthens the local economy and reduces the dependence from fossil fuels at the same time.[27] Values that are generally recognized in all the business cases reviewed in this study include: valorization of wastes or untapped feedstocks; creation of more sustainable products; mitigating dependence from fossil fuels in the case of energy-producing solutions; local value creation by using locally produced feedstock; local job and income creation.

Public and private partners from diverse sectors need to be involved in order to establish strategic collaborations for bioeconomy initiatives.[26] For example, a biorefinery evolves in a territory with an economic, political and social identity, thus, the success of such a business model depends on the ability to form partnerships and collaborate with local players: (large number of) primary producers, agricultural cooperatives, industries, educational and research organizations, local authorities.[26] Showing them the environmental, social and business benefits as part of sustainability impact that the biorefinery project can bring to their local level can greatly improve this ability, and thus the chance for a successful and profitable project implementation. Business support organisations such as development authorities and clusters acting in the field of regional development or a specific industrial sector can play a key role in this integration process.

4.2. Readiness level of value proposition

The solutions analyzed in the present study comprise a technology and its bio-based product with just enough features to be subjected to customer feedback (i.e., suitable to build a demo plant on it or to be offered to customers) and to gain experiences in connection with actual market needs, forming the basis for future developments. The level of development of these solutions more or less corresponds to the stage of the "Minimum Viable Product" (MVP), a concept from Lean Startup that stresses the impact of learning for further product development. E. Ries defined an MVP as such version of a new product which may lack some or many features that may prove essential later on but allows the development team to collect the maximum amount of validated learning about customers with the least effort.[28]

The initial MVP and the abovementioned customer feedback loops with new versions of the MVP, developed in accordance with the feedbacks to the initial MVP, are two consecutive levels of the Business Readiness Level (BRL) scale defined by R. Ramsden; this scale can be used to benchmark the current status of a business proposition, from concept to mature business fully embedded in the market[29] Although TRL scale[18] is widely used to understand the current status of a technical innovation, even TRL9 does not entail by itself that the technology is ready for market. This is because business-related aspects are not necessarily taken into account when TRL is defined for a technology, moreover, TRL classification can be subjective. As put eloquently in a report produced under the framework of Access2EIC, the official network for H2020 National Contact Points for the new European Innovation Council:[30] "TRL level as commonly used in H2020 can be used to define if a technology is ready to go to market or not, but it does not capture properly how 'ready' is the business based on such technology to go to market." That is why it is useful to adjust the focus generally being on TRLs and involve BRLs when considering a technology being part of the Value proposition, in order to measure readiness in terms of creating real customer value in an objective manner.

4.3 Customer-related building blocks: Customer segments, Channels, Customer relationships

The customer-related building blocks can be a weak point of the business cases described. These building blocks could not be described properly in several cases in the BMCs due to the lack of relevant information, not because of insufficient data provision but because the owner of the Value proposition has not mapped all the possible segments yet. Grant-based subsidies covering the innovation costs as well as not fully market-driven developments focusing on increasing the TRL of R&D results mainly aim at the optimization of technology processes and reaching the MVP but fail to pay sufficient attention to customer-related building blocks, if any.

The results of a survey conducted with the participation of 66 companies from South-East Finland in 2012[31] clearly support the importance of external building blocks in bio-based industry: they show that two of the six measures investigated, i.e., "Customer value-added" and "Supply chain collaboration" had statistically significant effects on business performance, while the other four (i.e., "Opportunities from business environment", "Business forces", "Innovations", "R&D collaboration") did not show any remarkable statistical effect on expected business performance.[31] This finding demonstrates that it is useful to start the development of the BMC at the Customer segments building block where the Value proposition can be delivered to. Once there is a clear and thorough knowledge and understanding regarding who the customers are and what problems or needs they have, it is easier to define the Value proposition which is the value that can be added to these customers' activities.

Customer relationships building block includes, among others, identifying and tracking the specific customer segments and the customers' needs. Many customers are willing to pay slightly more for environmentally friendly, natural, chemical-free, local products, which aspects are easily discernible for products of bio-based solutions. Accordingly, companies clearly need to identify these segments[12] and products need to be tailored to "bioeconomy customers" identified.

Word-of-mouth promotion by personal contacts and providing continuously updated content online via e. g. company website, social media, blogs, newsletters sent by email proved to be crucial for the bio-based industry to deliver, communicate and sell value propositions and to raise the customer awareness of a company's products and services. However, Channels is the least addressed building block in the analysed models, probably because many applications for bioeconomy have not yet reached a stage where attention to distribution channels can no longer be ignored.

4.4 Finance-related building blocks: Cost structure, Revenue streams

From the business models described in Section 3, it appears that the main drivers for the innovation development from lower TRLs to the stage where the level of technology readiness allows the introduction of an MVP are:

- financial resources available to cover several CAPEX items, which can come from different sources, i.e. external ones such as EU funds or governmental support and the profit of the business, but for the majority of solutions presented in Section 3 it has been some kind of public subsidy so far;
- the cheap biomass feedstock material ensuring lower OPEX, meaning that the low price has to include logistic costs already.

The availability of the financing needed for the main CAPEX items is a determining factor because the development and implementation of new technologies in the bioeconomy in most cases requires large upfront investments. Moreover, uncertainties inherent to bioeconomy hinder these investments,[1] that is why many initiatives in this sector are dependent on grant subsidies. For example, Clariant is investing more than 100 million EUR in a commercial-scale cellulosic ethanol production plant in Podari, Romania and this plant receives more than 40 million EUR funding[32] from the EU and BBI JU within SUNLIQUID and LIGNOFLAG projects, although this multinational large company has been successfully operating a first pilot plant since 2009 and a large-scale pre-commercial plant in Straubing, Germany since 2012.[33]

When the COWI report was launched in 2019, 13 out of the 15 technologies mentioned were at TRL9, meaning an actual system proven in operational environment,[18] or about to reach that level in the very near future.[19] Among these 13 bio-based solutions, only 3 success stories were characterized by an investment requirement below 5 million EUR, while the success of 2 companies out of these 3 was based on financial support from H2020 SME Instrument funding and European Structural and Investment Funds (ESIF). Most of the large companies involved in the study developed their bio-based product as an addition to a wider set of products, and they have thus been able to mobilize the finance internally through leveraging on profits generated elsewhere in the business. All these large companies are reported not having received public funding for the set-up of the bio-based production plants, but all of them have benefited from EU funds in the initial phase of their bio-based developments (the bio-based development included in the report and/or others) which funds have been available to support R&D phases preparing the ground for the investment in the industrial scale plant.[19]

Utmost attention should be paid to logistic costs among OPEX items, as most waste and by-product streams used as feedstock for bio-based processes are bulky, making transportation a significant cost driver.[34] The largest distance for profitable transportation of raw materials to a bio-based industrial plant depends on the density of the feedstock and the actual products produced out of it. However, based on our own development activities and also participation at relevant workshops, the highest distance from which the transport of raw materials to the bio-based industrial plant is profitable is maximum 60 km. This relatively low value means that the place of a new plant has to be very carefully planned, in consideration for the logistic aspects.

In many cases, the production of value-added products from specific agricultural wastes and by-products may not be economically feasible mainly because of the low quantities and seasonality, high transportation costs, water content of raw materials and low market price of products. In order to overcome these problems, bio-based sidestreams can be treated on-site by the same producing industry, in order to produce intermediate products that can be more easily stored than the original raw material and more economically transported to the place of further processing.[34] For example, Hédinn protein plant can be run by fisheries or fish processing companies; in this case, products are processed at the feedstock source and sold on-site to customers.[20] Another example is Melodea technology producing 'Cellulose Nano Crystals', which can be deployed at on-site pulp mills, where the feedstock, the necessary infrastructure and utilities are already in place.[19]

The outcome of a good practice case, even if the solution is technologically mature enough, cannot be turned into a real consumer product without marketing and public relation (PR) activities like e.g., a campaign including advertising, promoting by social media, press releases etc. The costs that have to be allocated for marketing and PR activities often exceed by a factor of several times the technology development costs. However, usually neither activities nor actors related to marketing and PR do appear in the Key activities and Key partners blocks, respectively. Furthermore, the related costs are not indicated in Cost structure, because solution owners give low priorities to sales development activities and customer segment analyses. (See also Section 4.3 for this weak point of the business models.)

As a basic principle, a long-term sustainable bioeconomy needs to be economically self-sustaining through the provision of marketable products that are independent from long-term subsidies.[13] Currently, many ongoing bioeconomy-related development activities are heavily dependent on grants and other subsidies, especially for SMEs, and they are quite far from reaching economic profitability, even if their bio-based technology is reported to be on high TRL and BRL. Generally, the income from bio-based product sales is quite low, at least during the initial stages of market introduction, especially if compared with the total development and investment costs. A typical indirect revenue resulting from the bio-based industrial processes comes from the utilization of wastes produced by other activities of the same company E. g. by-product of the Biowert biorefinery is processed in their biogas plant (S4 in Section 3 and Figure 7), and thus decreasing costs associated with the disposal of these wastes.

It is relevant to add here that waste management costs are often reduced on the side of feedstock providers, such as the olive-producing farmers selling olive stones to Cooperativa La Carrera (Spain) using this feedstock as fuel for biomass heaters.[6] This saving on the feedstock provider's side can be included in the Value proposition, as in the business model of Hédinn protein plant described in the BE-Rural project, though Value proposition is meant to be delivered for Customers, not Key partners, so this aspect is difficult to interpret by BMC. It is mentioned in the BMC of Hédinn plant that fisheries, processing industries, etc. can save on their fish waste disposal costs.[20] However, these feedstock producers are key partners in this model, so this saving can be regarded as an indirect revenue only when the protein plant is run by the feedstock producer itself, using its own wastes.

When it comes to revenues, it is often stated that the products connected to bioeconomy are not profitable as long as they have to be sold at the same price as the non-bio-based product. Higher price of bio-based products compared to fossil-based solutions causing a deficient market pull is one of the most important basic limitations to the bioeconomy development.[6] It can be difficult to justify higher market prices for bio-based products, since many of them are commodity products and end-consumers rarely care where the original raw material comes from. Moreover, even if they are conscious "bioeconomy customers", they cannot distinguish the end-product from earlier, non-bio-based products. In this regard, products need to be tailored to these customers, and this specific customer segment has to be kept in the focus, since they are willing to pay higher but competitive price if the products fulfil their special demands while achieving similar functionality.[31] Similarly to farmers, brand owners are are less involved in the development of the bio-based economy. However, they consider climate challenges, sustainable production and consumption to an increasing extent[35], and can play a key role in supporting market uptake of bio-based products and to influence consumer choices in relation to these products.[36]

With a very few exceptions, only large companies have the financial means to develop the technology, invest in the necessary infrastructure and commercialize the product exclusively through internal financing, and without putting the entire company at risk.[19] Size of the company can be a determining factor when defining internal building blocks Key resources and Key partnerships: larger companies are usually able to finance the human and financial resources to do long-term development work in-house concerning their products and processes, while SMEs' ability to extend their knowledge and competence base is significantly more limited. Smaller companies are much more dependent on external networks and the ability to create such networks,[31] which is reflected in their cost structure as well.

Bio-based solutions have to be market-driven in order to achieve market viability, become independent from external financing in the long-term and that subsidies should focus on providing a learning curve in order to establish competitive business.

5. Conclusions

Assessment of six bio-based solutions using BMC allows to present all general or sector-specific business-related aspects to interested stakeholders in an easy-to-understand way. This way of presenting provides new insights for the relevant stakeholders in the bio-based economy and facilitates mutual understanding by different bioeconomy actors which often operate in different sectors like agriculture, industry, government or R&D. Increased understanding of how bioeconomy businesses work not only facilitates SMEs and large enterprises to benefit from replicating bio-based businesses, but opportunities for other type of stakeholders increase as well:

- producers of bio-based wastes or by-products can transfer these materials to bio-based industry, thus reducing their waste management costs or even generating income;
- rural communities benefit from local industrial development, job creation and local renewable bioenergy or food production;
- investors may profit from mapping attractive investment opportunities as they can be instrumental in meeting environmental and climate challenges;
- policy makers may benefit from identifying industrial initiatives supporting their existing objectives related to sustainability and climate policies.

This study shows that many bioeconomy business models developed thus far have in common that especially the customer-related building blocks have been weakly elaborated. At the supplier end, involvement of 'rural entrepreneurs' like primary agricultural producers, forest owners, their associations and other small rural businesses is prerequisite for success of the emerging bio-based economy. As proven economic feasibility is essential for acceptance of innovative solutions, well-developed, easy-to-understand business models such as those presented in this article can serve as a helpful tool to bring the good practice cases closer to primary producers, by making these cases more comprehensible and realistic.

At the same time, BMC can serve as a useful and effective tool for enhancing the replication of existing good practice cases, even if the business model always needs to be individually tailored to each local deployment situation. For such tailoring, the business models have to be elaborated in much more detail than presented in this study.

These findings point to the usability of BMC to identify strengths and weaknesses in the business concept at early stages of business planning. Near market introduction, scaling systems such as BRL can facilitate linking technology innovation (as the main part of Value proposition) and the often under-elaborated Customer segments. BRL can be difficult to define, but it can describe the actual business potential of bio-based solutions in a more exact and objective manner, reflecting to which extent the customer may be willing to pay for the Value proposition. The introduction of a scaling system such as BRLs in the assessment of bioeconomy solutions and alignment of TRLs and BRLs can create a practical framework to direct the development of bio-based start-up companies as well as funding instruments for technology developments and business acceleration.

The traditional BMC benefits from extending with additional factors related to sustainability requirements and benefits as well as factors related to the business ecosystem such as drivers and stakeholder involvement tools. The additional factors can show how to create short-term or longer term structural values also in environmental and social terms, which is particularly relevant in bioeconomy businesses requiring the cooperation of various and divergent players.

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