Result Report Organisation and business models

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Imprint

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Project management

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This result report presents a compilation on the key findings provided by the partners working in the work package:

WORK PACKAGE 1 — Project management

WORK PACKAGE 2 — Project communication & PR

WORK PACKAGE 3 — Algae sources, cultivation and collection

WORK PACKAGE 4 — Fucoidan characterisation and database development

WORK PACKAGE 5 — Pilot developments in medicine and cosmetics

WORK PACKAGE 6 — Organisation and business models

The FucoSan project

Algae from the North and Baltic Sea serve as an important but yet under-exploited marine bio resource. Brown algae contain fucoidan - a polysaccharide with highly health-promoting activities that could be used in medicine and cosmetics. Fucoidans are also valued for their positive influence on inflammation, vascular supply and tissue regeneration.
With their antimicrobial properties, infections in the bone could potentially be treated. However, fucoidan varies in structure, composition and modifications such as degree of sulfation or molecular weight - depending on the origin and other factors. This leads to different, sometimes even opposing effects.

The FucoSan project aimed at generating systematic knowledge of fucoidans and their modes of action. In various test systems, the project partners investigated on the optimal fucoidan for each particular application. Over the last three years, the project established a network in the German-Danish cross-border region pooling the expertise of companies and research institutions. They are active in the fields of extraction and purification as well as in chemical and biological characterisation of fucoidans.

March 2017 – August 2020

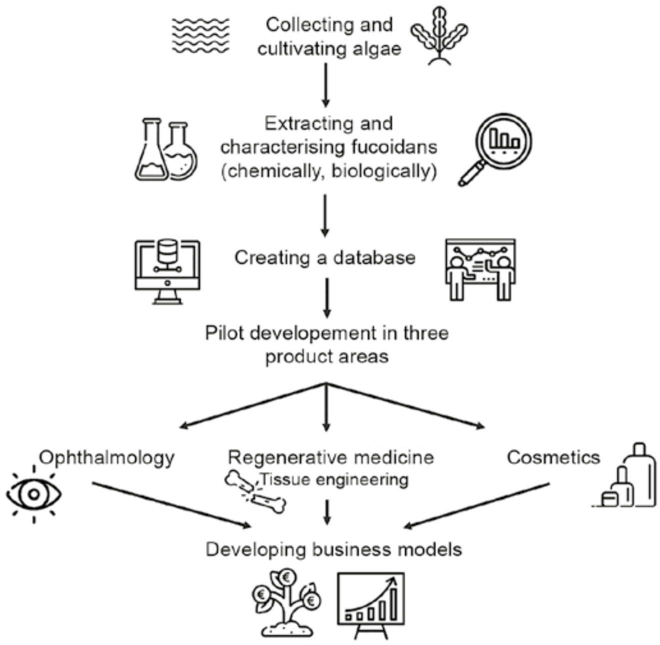
3.8 million Euros budget,
thereof 2.2 million Euros funds

8 partner organisations from
Denmark and Germany

Project aims

- ✔ Development of economically and ecologically sustainable processes to obtain brown algae from the Baltic Sea
- ✔ Setup of a database for the identification of suitable fucoidans
- ✔ Pilots for fucoidan-based applications in ophthalmology, regenerative medicine (tissue engineering) and cosmetics
- ✔ Establishment of a German-Danish value chain around the use of fucoidans

The FucoSan process chain



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Introduction

Substances derived from marine bioresources are often under-utilised. The use of biotechnologies to identify and produce new molecules has become a common method in the pharmaceutical industry (e.g. Krueger 2005). However, the use of marine bioproducts for high-value therapeutic applications remains the exception, despite their significant beneficial potential. We therefore aim to identify and discuss the challenges of the transition from research to commercialisation activities, and to initiate the establishment of a multifunctional innovation ecosystem for fucoidans, a group of sulphated polysaccharides that can be extracted from brown algae. We then turn to concrete business models along the process of value creation, presenting the final results in the FucoSan Technology Roadmap.

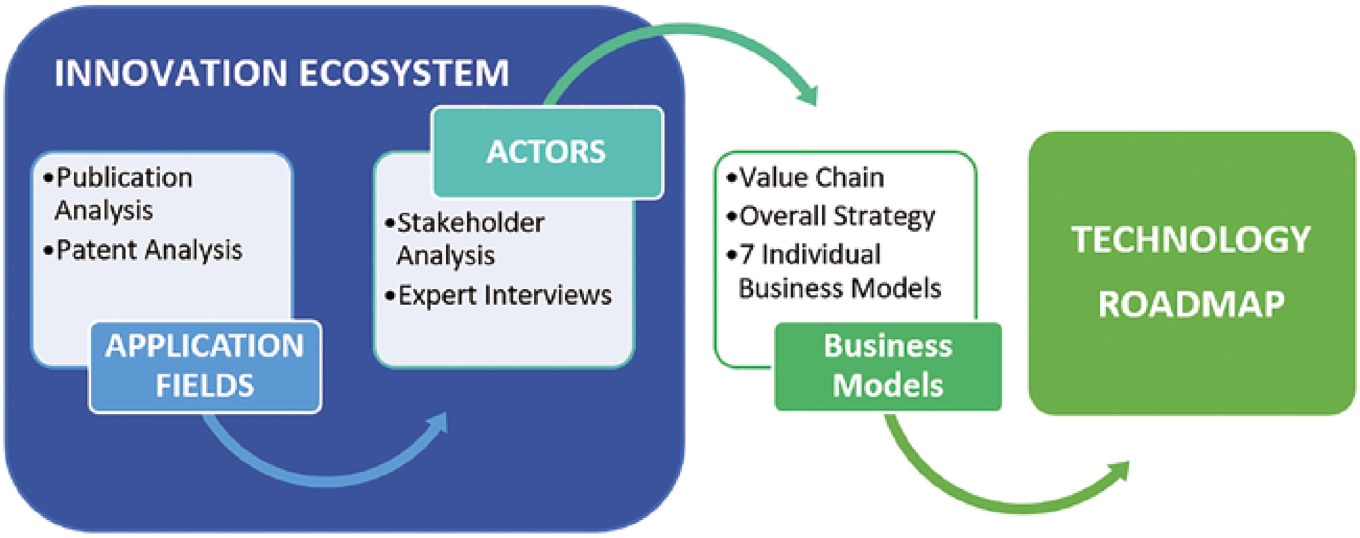

Figure 1: Structure of the report.

The structure of the report is shown in Figure 1: to provide an initial overview of the various application fields for fucoidans, we present the results of the publication and patent analyses conducted. The results are in line with our expectation of high research activity yet low commercial activity. We then turn to the identification of possible local key actors promoting and inhibiting the development and utilisation of fucoidans, and describe their individual roles and multilateral interactions among each other, on the basis of qualitative interviews. Afterwards, we describe how we created a common understanding of the innovation value chain, and present concrete business models within an overall strategy that were developed through the multidisciplinary collaboration of the FucoSan project team. The final FucoSan Technology Roadmap shows the development of technological subfields, application fields, and projected cashflows over time.

The scope of the fucoidan technology – results of the publication and patent analyses

Before we turn to local actors active in the development of fucoidan technology, we present an overview of international fucoidan activity. Bibliometric analyses of research publications and patent information are a suitable way to observe trends, to comprehend a technology including different sub-technologies, to identify research hotspot lead markets, and to study citation and collaboration activity. Whereas research publications display research activity, patent data reveals information on commercial activity. Figure 2 presents the research publication and patent activity over time. Research publications as well as patent numbers have increased noticeably over time, especially in recent years. We first present the results of the publication analysis and then turn to the patent analysis.

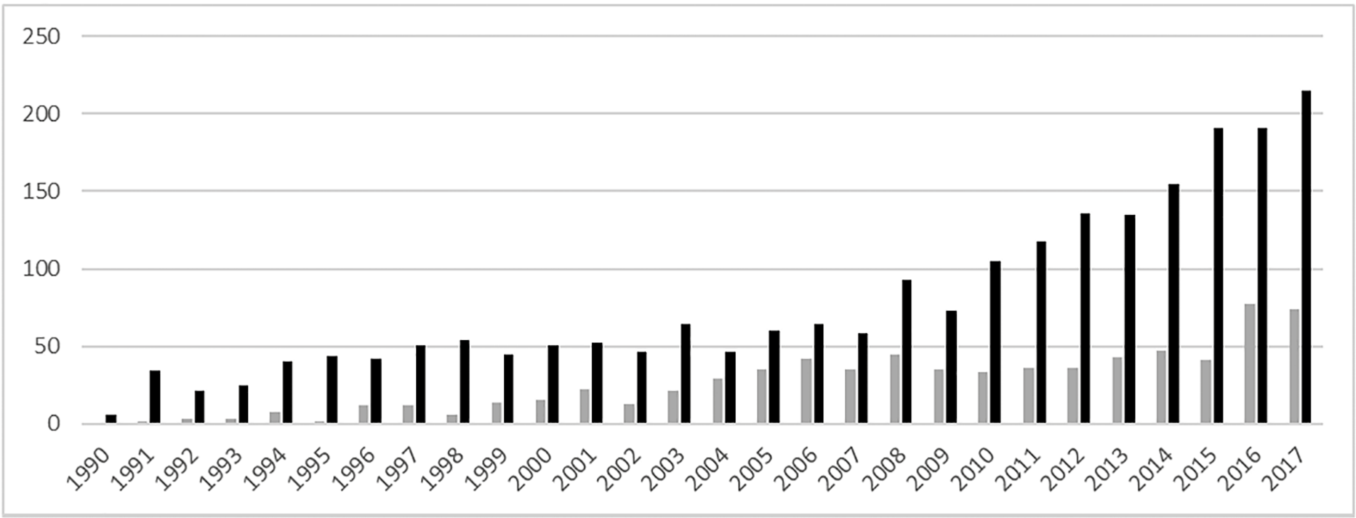

Figure 2: Number of fucoidan publications (black) and patents (grey) per year.

The publication analysis was carried out in February 2019, by extracting and redefining research publications from the Web of Science database. Searching for “fucoidan” and related terms in the titles, abstracts and keywords, we identified 2,421 research papers from 76 nations in 794 journals between 1950 and 2018. An overview of the top journals by publication count shows the diversity of research areas (Figure 3).

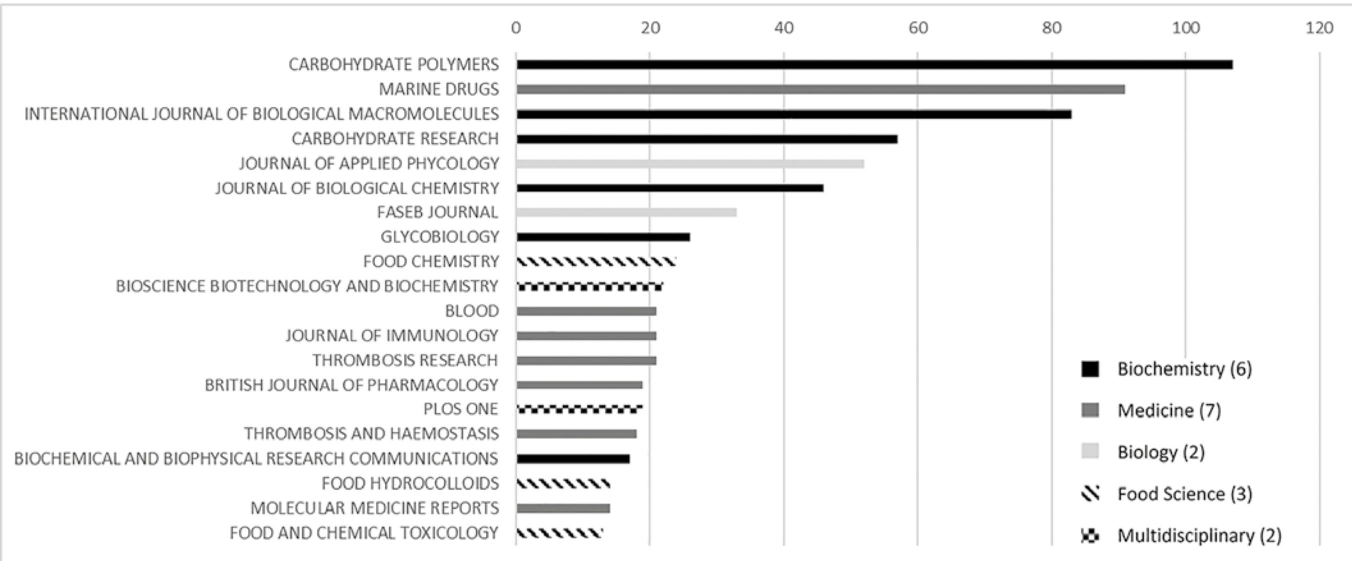

Figure 3: Number of fucoidan-related WoS research publications per journal. Top 20 journals according to the number of fucoidan-related research publications.

The diversity of journals and their respective scientific backgrounds already indicate the vast array of research fields fucoidans are studied in. To further investigate if these fields are separate or multidisciplinary, we took a closer look at the collaboration activity. We therefore focused on single research projects and studied the affiliations of the authors. The network structures display the scientific fields that are already connected (Figure 4).

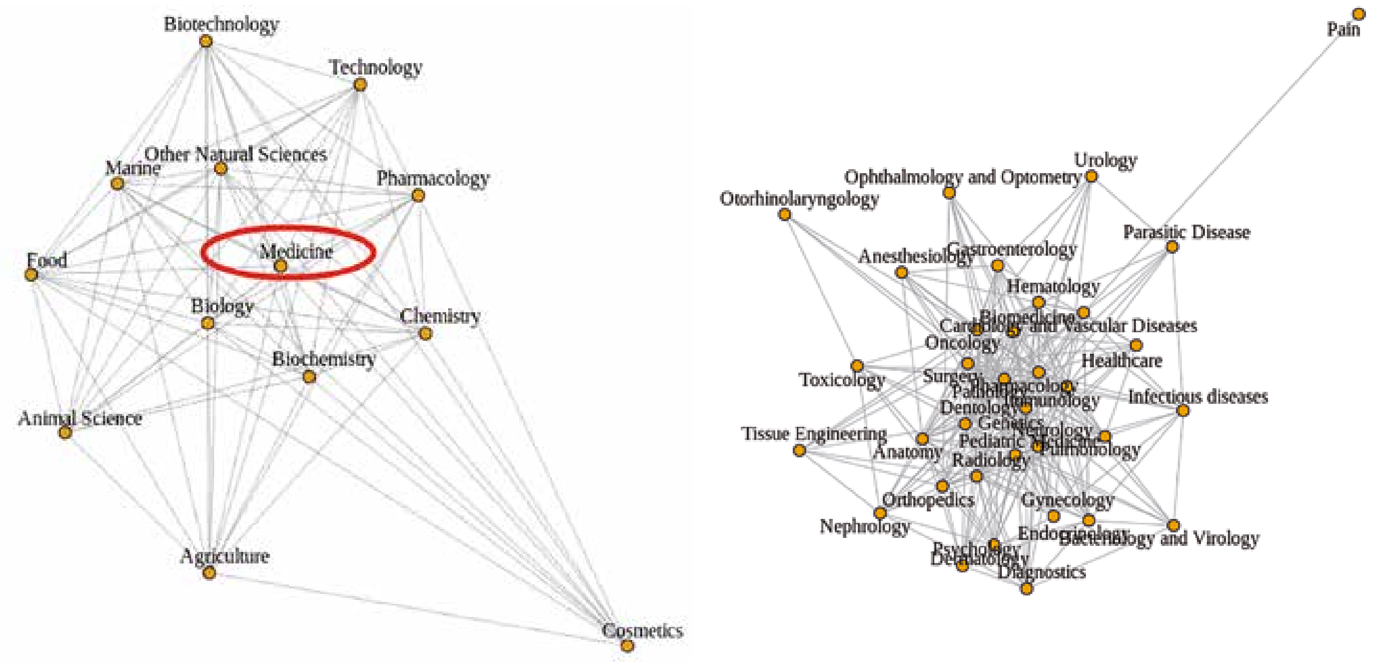

Figure 4: Network graph of researchers from different disciplines. Based on collaborations within research projects (= publications), the central disciplines are best connected within the network. The distance between the disciplines shows how closely they work together in the context of fucoidans.

Most multidisciplinary research activities can be observed between "Medicine" and "Biology" as well as "Medicine" and "Biochemistry". As the medical research field took a central network position and most collaborations were observed within this field, further investigation was conducted, which revealed thirty different specialisations that are also well interconnected (Figure 4). The research publication analysis supports the conclusion that researchers from various fields are already active in multidisciplinary collaborations. To study commercial activity, we analysed patents.

The patent analysis was carried out in January 2019 using the patent software Questel. Our patent portfolio covers all patents where the title or abstract contains the word element fucoidan or a synonym including the word family. We identified a total number of 776 patents, of which 356 are active. A noticeable increase in patent activity can be observed after 1990. Before this, only very few patents were filed (Figure 2). To investigate the diversity of the application fields, we investigated the IPC classes of the patents filed. As with research, the distribution of IPC classes in the fields of medicine, nutrition and cosmetic applications highlights the versatile utilisation of fucoidans (Figure 5).

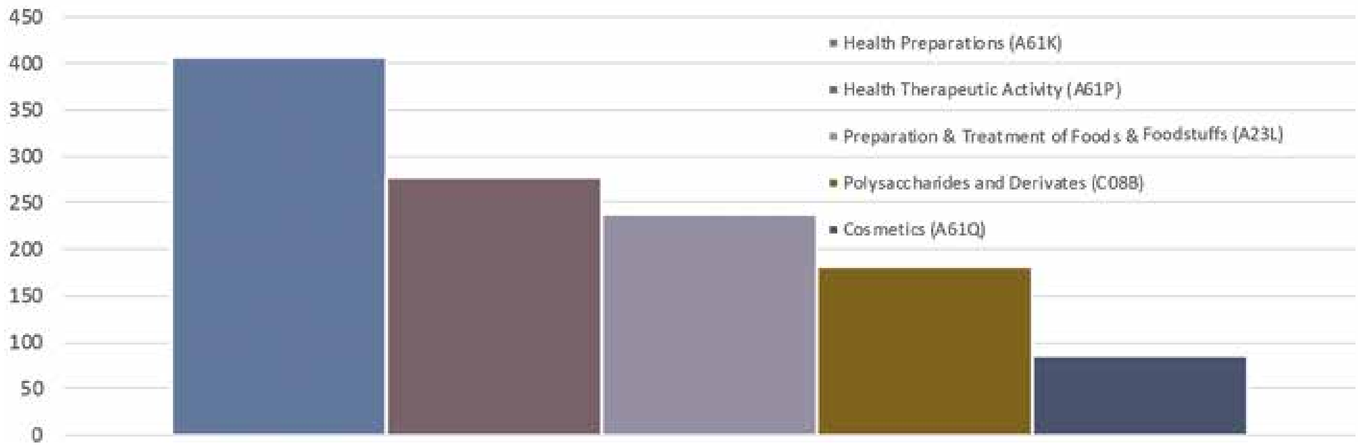

Figure 5: IPC classification patent analysis.

Figure 5 presents the five major IPC classes for fucoidan patents. The IPC class "Health Preparations" (A61K) is most common, followed by "Health Therapeutic Activity" (A61P), "Preparation & Treatment of Foods & Foodstuffs" (A23L), "Polysaccharides and Derivatives" (C08B) and "Cosmetics" (A61Q).

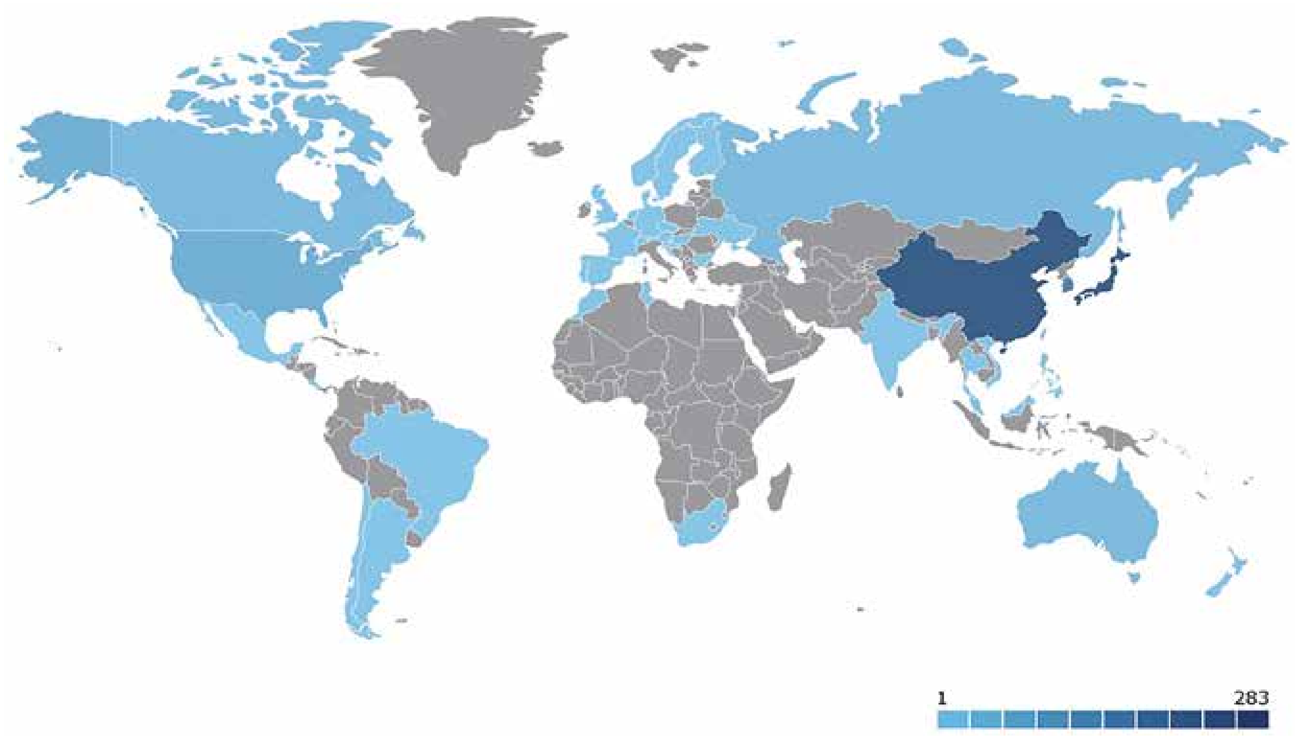

Figure 6: Patent activity map (the darker the colour, the higher the national patent activity, ranging from 1 to 208 patent(s), countries in grey don't show fucoidan patent activity).

A glance at the map (Figure 6) allows the most active regions to be identified. The highest patent activity observed in China, Japan and South Korea indicates good chances of these countries becoming future lead markets for the use of algal products, and hence the acceptance is also higher compared to Europe. The most active actors are universities such as Tottori University (Japan) and the China Ocean University, as well as companies such as Japan-based Takara Bio Inc. and Yakult Honsha. To reveal networks, we finally focused on citations and collaborations. A citation network is recognisable, but there is no evidence of large innovation networks, and instead only small collaborations (network of applicants who have at least 2 fucoidan-related patents and cooperated on at least one) are currently visible. In Europe, only one French cooperation with research character is currently visible at patent level.

In conclusion, we can say that concepts from different areas are visible, but mainly regarding extraction processes, basics for the preparation of fucoidans, etc. so that it can be concluded that we are still at a very early stage of commercialisation. As we could not observe any patent activity in the Interreg Deutschland-Danmark programme region, we applied a qualitative approach to identifying local actors and stakeholders.

Databases as door openers for collaboration (Peters et al., 2020)

To enhance technology development, we would like to provide a further suggestion that could promote collaboration and foster interdisciplinary research and industry contribution. The increasingly data-intensive world of science allows new methods of data analysis. Access to high-quality data, and thus databases as interfaces, is gaining importance. Yet their establishment is often tedious, as it depends on diverging requirements of management, data generators as well as capturers and IT-systems. For the FucoSan project, a suitable setup of the database is crucial. Besides coordinating and fulfilling various requirements of different stakeholders, it is necessary to provide both relevant data infrastructure and data to foster data sharing. Incentives for researchers to contribute even after the end of the project must be identified to secure the future existence of the database. Our research investigates general factors which influence data sharing ambitions such as resources as well as organisational, technological, legal and political challenges. Despite several data sharing initiatives, shared data often remains unused. We examine which factors motivate or impede researchers with regard to data sharing. On the one hand, it is crucial to identify relevant data to be stored and used. This results in understanding data users' specific requirements. On the other hand, it is important to foster a sufficient data supply. Nevertheless, questions remain on whether motivation factors and barriers have changed due to rapid technological progress and the need for large amounts of data, e.g. to perform Big Data analyses or develop Artificial Intelligence. We have adopted a mixed method approach, starting with the identification of the pattern of database usage, followed by an explorative interview phase and an experiment. During the qualitative in-depth expert interviews, we uncover and discuss influencing factors from both the supply and demand side, and identify the most important ones for our field experiment. The first interviews are evaluated. Thereafter, the main determinants are analysed in a quantitative, empirical section focusing on the fucoidan technology.

Identifying local actors to set up an innovation value chain

A well-functioning innovation ecosystem fosters technological development. It includes all actors and external stakeholders, as well as their multilateral interactions that may have an influence on technological development. In order to identify all relevant local actors including stakeholders, and to reveal their roles and relationships, we systematically analysed the process of value creation. We therefore provide an in-depth analysis of the transformation, starting with the sourcing of brown algae right through to the utilisation in diverse final products, and present the innovation value chain. Furthermore, we conducted web research on local actors that are engaged in any activity in the algae sector. To understand challenges in the formation of a well-functioning innovation value chain within the innovation ecosystem - especially in the transition from research to commercialisation activities - we then present the results from the interviews conducted with actors at each stage of the value chain.

An active innovation value chain supports commercialisation opportunities for emerging biomarine technologies. An innovation value chain presents the innovation process and involves idea generation, idea development and the diffusion of developed concepts (Hansen & Birkinsaw, 2007). Each task such as sourcing, selection, development and spreading of the idea is a link in the chain. Along the innovation value chain, there may be activities which the collaborating partners fulfil without any struggles, whereas others require external guidance. To improve the development of innovations, the process of transforming ideas into commercial output must be viewed as an integrated flow, because this allows systematic analysis to detect challenges and weaknesses. The process as displayed in Figure 7 provides initial insights into the value creation of fucoidans, and illustrates the pathway from brown algae via processing to fields of application for final products on the market. In fact, the representation of the value chain shown interlinks the activities of the project participants, from the research-centric activities to the market-focused applications. It helps the participants to get a broader view of their contributions to the chain, and also to identify the key areas that connect the different actors in the industry.

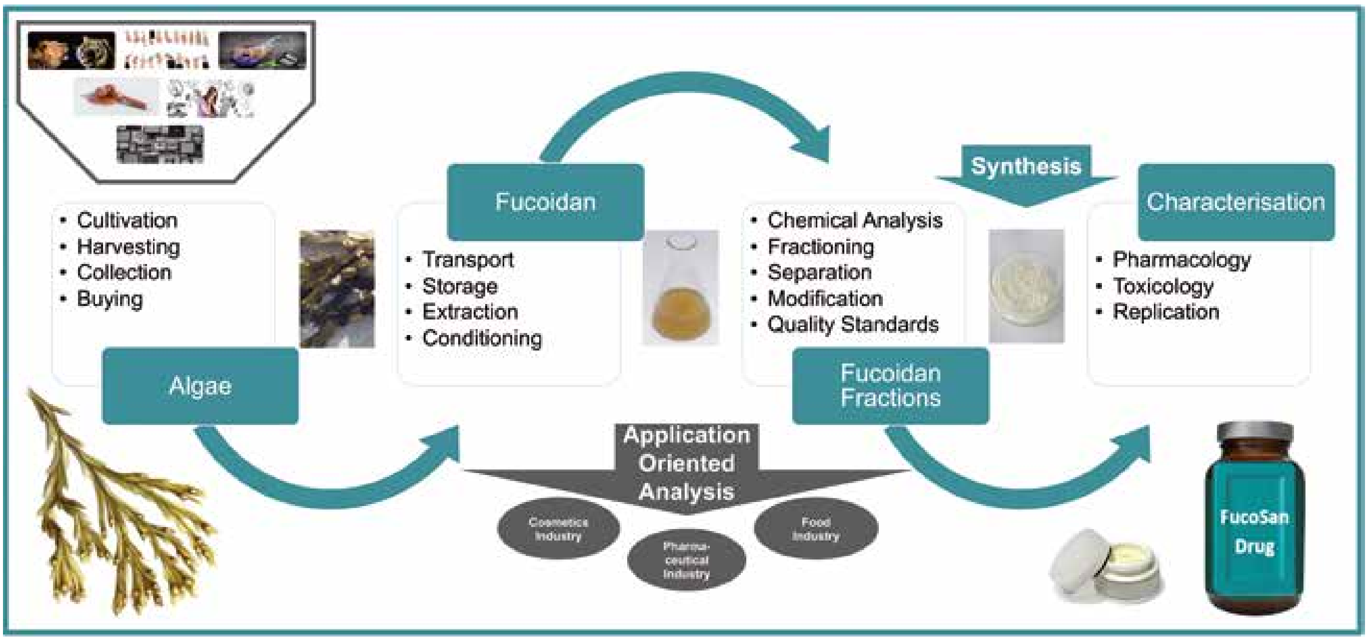

Figure 7: Process of value creation.

As we know, fucoidans are a group of chemical compounds of fucose-rich sulphated polysaccharides, which can be extracted from brown algae. To be able to make use of the substance, various actors from different disciplines must contribute and interact. This multidisciplinary set of actors is composed of marine scientists such as biologists who plant, harvest and collect algae, chemists and engineers who extract and separate fucoidans in various ways, chemists, pharmacologists, biologists and toxicologists who conduct an array of distinct in vitro and in vivo testing and studies, and the numerous applicants who aim to commercially use the substances in medical, cosmetic or dietary products. Depending on the field of application, the fucoidan crude extract must be further fractionated and modified according to high quality standards. In addition, further stakeholders from the fields of legislation, environmental protection, investors, competitors, media and customers may influence the development and acceptance of the use of fucoidans. The following paragraphs focus on the roles and relationships between the multidisciplinary actors.

We note that there are three ways of sourcing brown algae. The most common way is to harvest them in public waters, which includes - depending on the intended application - collecting parts of the plant from the shore. An alternative source that must be considered for setting up sustainable business models is the purchase of available biomass or extracts from regions with an abundance of wild brown algae, e.g. parts of the French coastline or the Arctic Ocean. The cultivation of algae in natural waters or breeding tanks is the third possibility. Seaweed cultivation and harvesting requires the expertise of biologists and marine biologists, who know the growth process and the ecological environment of the plants, and who can guarantee sustainable harvesting with the help of special equipment. Cooperation with analytical chemists and pharmacologists is important, in order to match the properties of the respective fucoidan obtained from the corresponding algae harvest (e.g. fucoidan content, chain length, degree of sulphation, branching) to the corresponding environmental conditions. External stakeholders include environmental and nature conservation associations as well as legislative bodies that strictly regulate the brown algae harvest, especially in German marine waters.

Turning to the processing of brown algae, the logistical hurdle of transport is negligible because brown algae are extremely robust. However, storage and preservation of the deep-frozen raw algal mass is worth mentioning, as the quantity is comparatively large compared to the powdered fucoidan extract, due to the different fucoidan content and the high water content. A raw material stock and an extract stock are required, to store and match substances and their effects for later test series. There are various methods for extracting the fucoidans, which differ for example in terms of extraction time, temperature, pressure, pH value and solvent. The extraction process influences the properties of the fucoidan, which is why it must be selected for the respective application. For the extraction and subsequent preparation, appropriate laboratories and the expertise of natural scientists such as chemists and laboratory technicians are required.

The fucoidan extract (powder) must be chemically characterised to ensure the quality of the product, so that more specific tests can be carried out. Even fucoidans of the same molecular weight differ, e.g. in terms of their sugar composition, sulphation and branching.
Due to the variety of fucoidan fractions within the fucoidan crude extract and the small yield for each fraction, it is necessary to determine beforehand which fucoidans can be used for which applications, and which requirements are thus imposed on the respective fucoidan. The sequence of pharmacological and toxicological tests must be determined, and documentation and communication of the results must be ensured. Above all, positive properties must be emphasised in order to verify the replicability of the results, to enable further, application-specific clinical studies. Databases are a suitable tool to document results and characteristics for later analyses.

Fucoidans must exhibit varying degrees of homogeneity, depending on their field of application. Commercial users of fucoidans can be roughly divided into the following industries: the cosmetics, food and pharmaceutical industries. While the requirements for the cosmetics industry are usually lower, the purity of the substance is of the highest relevance for medical applications. By identifying these potential industries, specific users can also be sought and addressed. In the cosmetics industry, for example, small and medium-sized companies that operate in the niche of natural cosmetics should be mentioned here. However, the patent activity of global companies observed in patent databases also suggests research activity on a larger scale. In the food industry, food supplements with a fucoidan content must be mentioned first and foremost. As a "health food", fucoidans could find new areas of application within gastronomy. The greatest, but also the most complex potential lies in preparations for therapeutic and medical applications, as completely new functionalities can be created here. For this purpose, fucoidan fractions must be standardised, analysed and categorised, according to their properties and the field of application in the body. Therefore, respective mechanisms of action must be uncovered in the best possible way, in order to meet the legal requirements for marketing a fucoidan preparation. The high degree of refinement and the absence of direct substitutes can result in a lucrative product.

To get an initial overview of actors involved in algae products, we conducted broad desk research, especially within the Interreg programme region of Northern Germany and Southern Denmark (Figure 8).

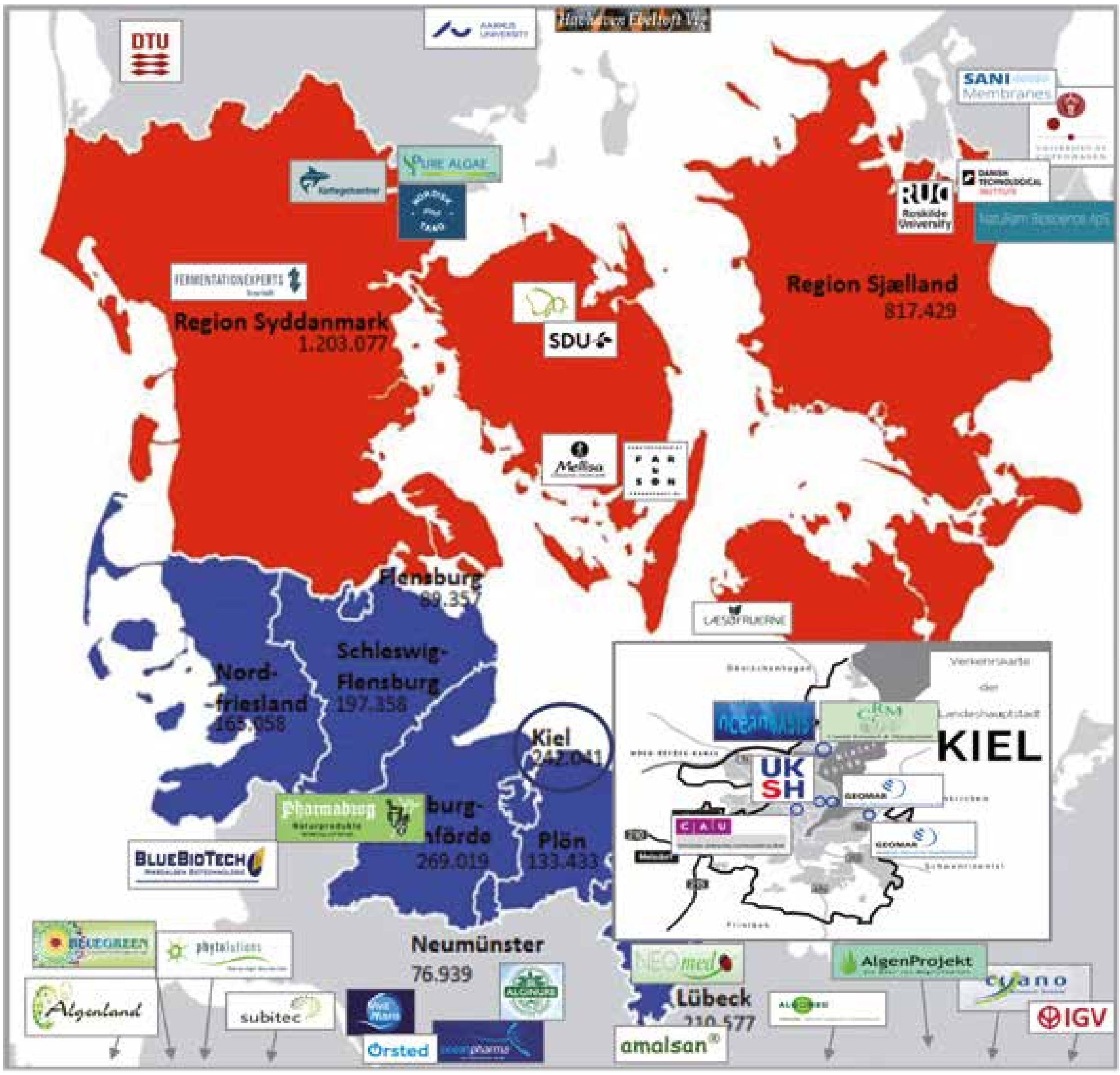

Figure 8: Danish and Northern German actors working with algae extracts.

The map already indicates that there are several companies making use of algal products, ranging from the sale of microalgae-based pharmaceutical products (e.g. Pharmadrog and ocean pharma) right through to energy production (e.g. Ørsted). There are companies and research institutions working along the value chain on the cultivation on land (Pure Algae), and investigations into the composition of microalgae are carried out by the Department of Food Science at the University of Copenhagen. Focusing on the programme region, we could identify more actors in Denmark.

In Germany, we could identify Kiel as the only city with a higher aggregation of active actors. Besides Kiel, most actors were outside the programme region.
The low density of actors confirms the absence of a local integrated innovation ecosystem. To understand the challenges that must be tackled in order to create a supportive innovation ecosystem which fosters the fucoidan innovation value chain, we conducted 17 explorative expert interviews. Qualitative content analysis of the interviews reveals six major challenges, which are presented in Figure 9.

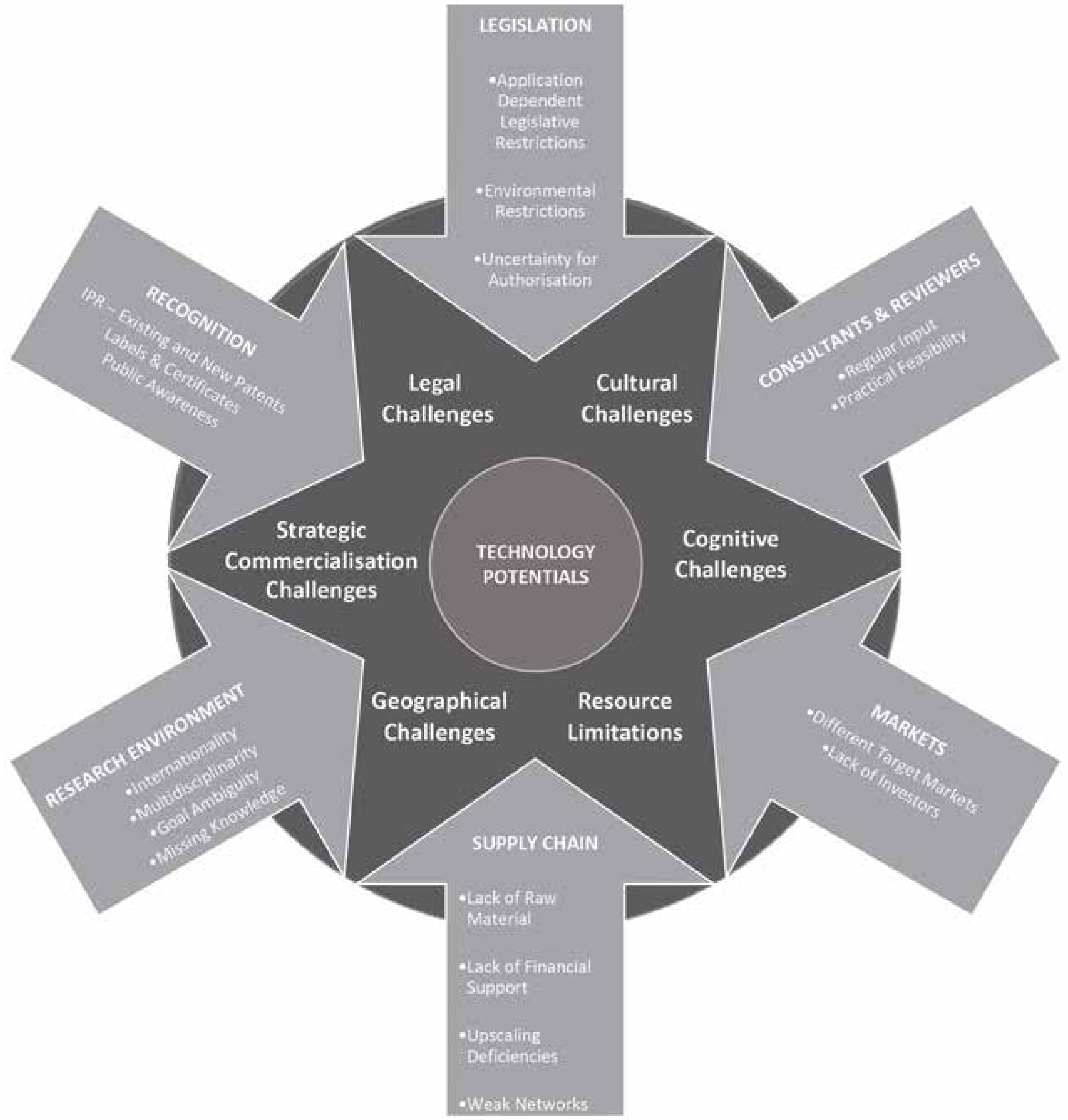

Figure 9: Challenges in the formation of a fucoidan innovation ecosystem.

After analysing the interviews from actors that are either involved in the Interreg FucoSan project or play an important role in the future of the innovation ecosystem, we summarised the major challenges facing the multidisciplinary collaboration activity. We propose that cognitive, cultural, strategic and geographical challenges between the stakeholders, as well as resource limitations, upscaling and legal challenges, impede the exploitation of marine biotechnologies.

For cultural challenges, we find the highest number of quotes in our dataset. We define cultural challenges as barriers that result from the different mindsets of the diverse groups of actors and stakeholders. Different working methods and habits of institutions involved in multidisciplinary collaboration require mutual understanding, to agree on a commonly-accepted procedure. The multiple fields of application require different extract features, such as the product quality. For potential users of the products, the researchers and actors interviewed highlighted substantial cultural differences in handling and adopting products across different regions. Therefore, the local market must be prepared to socially accept products of marine origin. The barrier of cognitive challenges summarises topics of individual mental hurdles in acquiring and applying knowledge, mainly due to its multidisciplinary nature. Goal ambiguities, different terminologies, and a lack of knowledge on the cause-effect relationship as well as on extraction and reproduction have been observed. Resource limitations result from a general lack of raw materials, and a lack of financial resources at company level. Regarding a potential business case, alternatives like seaweed farms are necessary to cope with the required biomass for upscaling: "If we find that one medical treatment which offers the greatest potential for fighting macular degeneration, we would have 196 million patients and need way more than we could cope with in the Baltic" (ophthalmology researcher, University Hospital). Resulting from the physical distance between actors, geographic challenges appear to be the most tangible barriers. Proximity to the sea is seen as a success factor. Comments on regional differences indicated that certain geographical locations are more suitable for successful technology development. The context of the emerging ecosystem is the German-Danish Baltic Sea. Despite the advanced research capabilities in the region, there are "natural disadvantages of the Baltic Sea Region". One of the university researchers pointed out that there are better conditions for seaweed growth in other locations. In addition, the eutrophication of the Baltic, limited stocks and the limited public coastline were critically discussed. From a market perspective, there are disadvantages such as high labour costs and difficulties in marketing the Baltic compared to tropical waters. In addition, there are advantages of other locations; the experts stressed an abundance of macro algae in other locations in Northern Europe, France and further afield, e.g. the Japanese or Korean Sea. According to one of the extractors, the quality of the material is also higher. Strategy depends on a clear focus and commitment, in order to reach a common goal. Unfortunately, strategic commercialisation challenges appear, mainly as we observe goal ambiguities between the actors: as one example, the high purity which medical applications require is too expensive for cosmetic products. Therefore, applicants rather aim at extraction processes that suit their individual business case. The topic of legal challenges covers the different aspects that regulate sourcing and applying fucoidans. Concerning sourcing, harvesting for example is regulated by different official departments, due to the environmental impact of brown algae.

To overcome these challenges, the literature suggests different actions for the success of the technology, which can be guided by external intermediaries. Overall, there is a need for multilateral collaboration among the various actors for the creation of a successful innovation ecosystem. The existence of these challenges highlights the value of policy interventions that support the creation of intermediaries for technology commercialisation (Li and Garnsey 2014; Clayton et al. 2018). An external intermediary can facilitate the innovation process. It should formalise the innovation process to reduce uncertainty and ambiguity, and improve communication by interconnecting suppliers and customers along the supply chain. Furthermore, an intermediary can actively promote the technology by obtaining government funding and by involving bigger industry partners.

Identifying business opportunities along the innovation value chain

After identifying the lack of a supportive environment for an innovation value chain and the challenges that hinder commercial activity in the fucoidan sector, our aim is to facilitate the multidisciplinary technology process and to initiate commercial activity. Figure 10 offers another perspective of the "Fucoidan Innovation Value Chain" by highlighting eight different business opportunities (blue circles) along the process that might be of interest to the FucoSan research group.

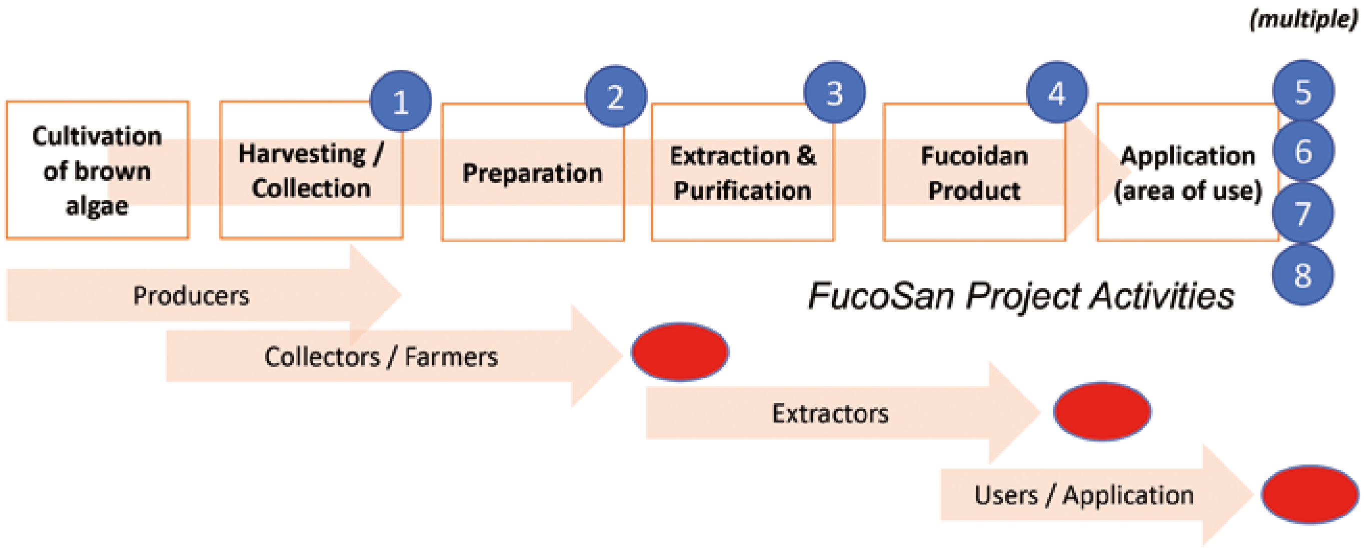

Figure 10: Business models along the innovation value chain. The numbers indicate at which "stage" different business models could be developed.

In two workshops, the FucoSan research group identified and assessed concrete business opportunities using different tools for joint business model creation. The aim of this chapter is to outline possibilities through business models (BMs) identified for commercialisation, using a business model canvas approach.

The first suggested BM is called "harvesting and cultivation", and the value proposition is to provide sustainable high-quality seaweed for different applications. Key partners of the FucoSan research group are governmental agencies and coastal authorities. The customer segment contains universities, research institutions, wholesalers and resellers, and the entrepreneur could create revenue by selling the harvested algae, or consulting to others on the cultivation methods. The second BM "extraction" deals with new technologies for chemical extraction processes. Extracts of different purities and characteristics could be sold to similar customers as in the first business model, but also to industrial users. The business would depend on a good seaweed supply, and revenue through selling the extracts, licensing methods and renting out equipment, all while ensuring sustainability. The high value of the extracts allows higher profits than selling raw materials (BM 1). BM 3 is the creation of a bigger "platform" for bioactive profiling, to offer easy access to information on fucoidan to other users in the value chain. Relevant information could be stored in a database, and limited access could be granted to customers. In this case, the key partners would be the suppliers and investors, as well as the researchers who share the information.

Revenue could be generated through licensing and a subscription fee, as well as consulting services. Our fourth suggested BM is called "food application" and comprises the efficient production and provision of a high-quality food supplement to boost health and prevent specific diseases, serving a variety of customers including restaurants, business-to-business (B2B) commerce and direct-to-consumer (D2C) commerce. The businesses would depend on suppliers, authorities and marketing, and create value through the sale of the product. The use of the positive effects of fucoidan for skincare and as a natural anti-aging solution is BM 5, called "cosmetics". The customer segments targeted include people interested in a healthy lifestyle, hotels, spas and dermatologists. The partners would be the suppliers, authorities and the customers who are not the end users. In this model, revenue would be generated through the sale of the product. The application as an adjuvant for faster and healthier bone regeneration is BM 6, "tissue engineering". The target customers are health-conscious patients and hospitals, and this model needs investors as key partners as well as cashflow through funding, because actual revenue can only be expected in the long run. As a promising therapeutic option in ophthalmology, the seventh business model named "eye treatment" targets doctors and patients with age-related macular degeneration (AMD). It has investors, researchers, hospitals and doctors as key partners. In this business model, we expect 6 to 8 years until the clinical phase is reached, and an even longer time without any return on investment. Therefore, we currently regard it as a business model for the future. This perspective highlights the need for a special strategy, which will be described in more detail using the technological roadmap in the next chapter. The following overview is the summary of a survey within the workshops, and shows the seven business models (Figure 11) as well as their respective market attractiveness.

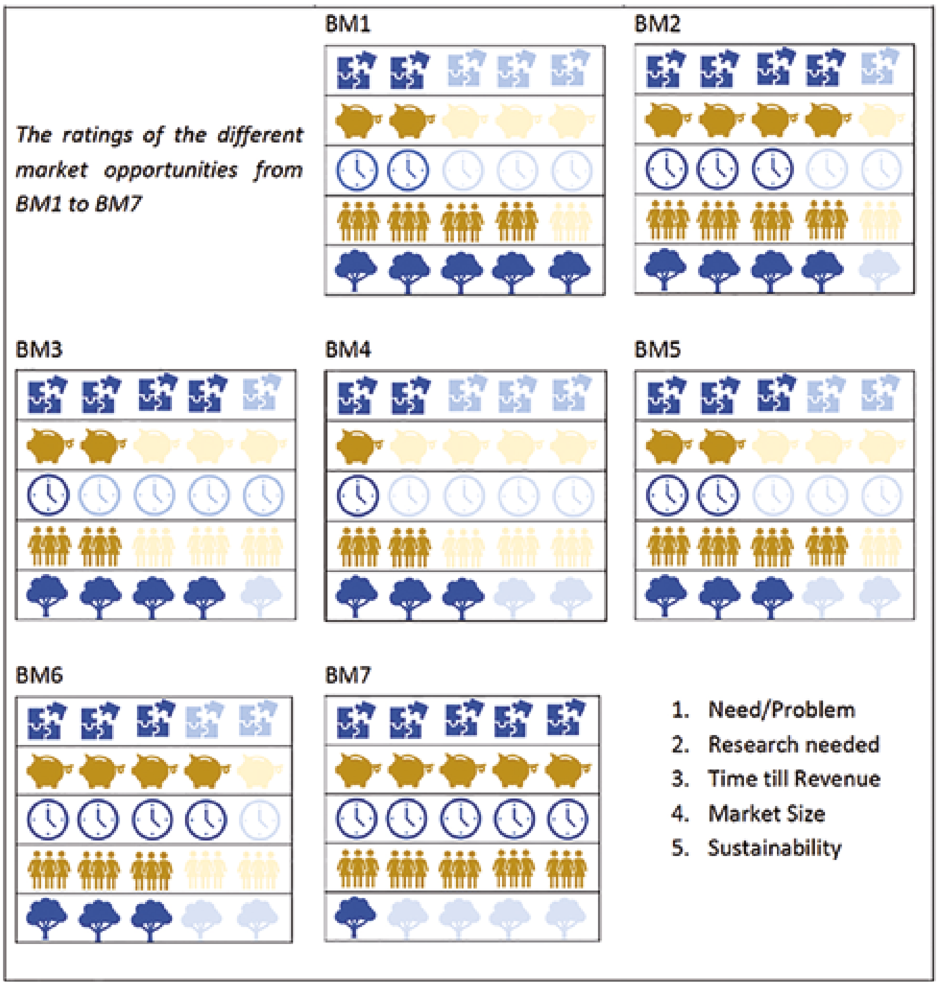

Figure 11: Evaluation of market opportunities for business models (BMs) in terms of their needs, research stage, time until revenue, potential market size and sustainability.

The seven business models have been evaluated regarding their needs of the end customers, the amount of research necessary for implementation, the estimated time until the first revenue, the expected market size and sustainability measures. We show that business models 1, 3, 4 and 5 can already be implemented soon without much further research, while they are expected to generate revenue quite quickly. These would be possible models to implement immediately, whereas BM 6 and BM 7 require more time and investment, and represent business models of the future. We integrate the business models into a coherent strategy in a technology roadmap in the following chapter.

Channelling the efforts into the FucoSan Technology Roadmap

According to Garcia and Bray (1997), a technology roadmap identifies critical system requirements, product and process performance targets, and technology alternatives and milestones for meeting those targets. The purpose of a roadmap is to precisely show objectives on an aggregated level, to inform about a given situation and to support the process of decision making, for example regarding resource allocation on critical technologies, regulatory requirements or monetary flows. Monitoring all factors required to meet these objectives allows a more efficient use of limited R&D investments.
One of the main challenges of the commercialisation of radically new biotechnology products is the high number of multidisciplinary actors. The success depends significantly on the successful integration of knowledge, tools and activities from distinct disciplines, in accordance with regulatory, environmental and social norms.

The visualisation of the technology roadmap is the final result of our explorative multimethod approach, combining the results from all prior steps of the report including publication and patent analysis, the analysis of actors and stakeholders, and content analysis of the interviews conducted. We further use the results to identify technology and fields of application, current trends, relevant white spaces and the need for freedom to operate. We also integrate technology-based forecasting tools, like long-term trend prediction and scenario formulation, to assess possible alternative futures - especially with regard to fields of application.

To develop the FucoSan Technology Roadmap, we built on the “lily pad” strategy (Sinfield & Solis, 2016). According to this strategy, the integration of short-term oriented cash returns lowers the risk of the long-term oriented establishment and commercialisation of major innovations: applications with a relatively low value creation can be developed and adopted more easily, and may lead to quicker returns on investment. These applications are regarded as “lily pads” on which the innovation (as a frog) could metaphorically “land” and generate new resources to jump further up the value chain. By pursuing a series of lower risk initiatives, short-term profits are used to achieve long-term goals. Early “adopters” must be found, which find a use in the current stage and thereby provide earlier returns and an easier diffusion of technology.

Figure 12 shows the final FucoSan Technology Roadmap as a window into the future. On a timeline starting today and running until the year 2033, it comprises relevant milestones, business models, technological developments and the expected market share and projected cashflow.

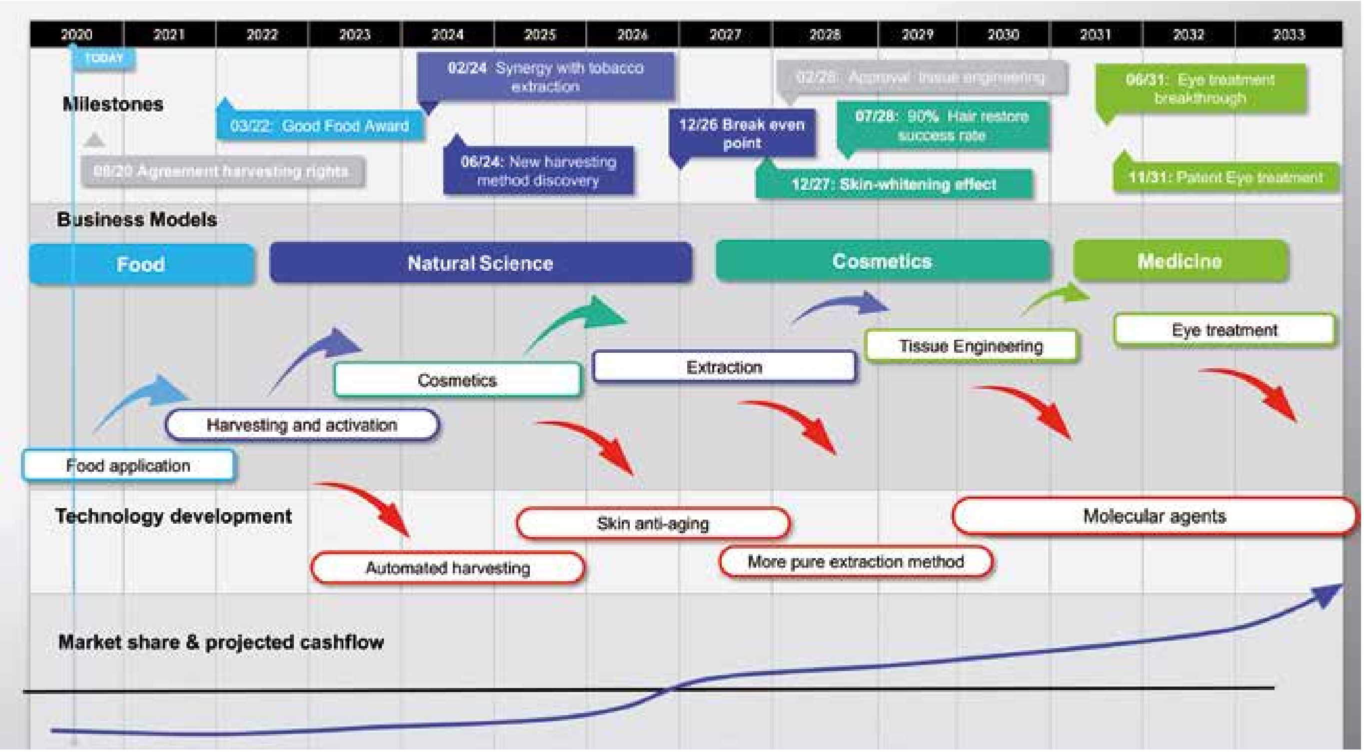

Figure 12: FucoSan Technology Roadmap.

Starting with predicted milestones on the vertical axis, important events on the way to commercial success are displayed in the colours of the business model area they stem from (Figure 12). The grey squares represent government actions including laws and regulations, like the approval of tissue engineering. Other important milestones like synergies, patents and the discovery of more efficient technologies add up to a rising projected cashflow overall. Synergies with other technologies must be taken into consideration. As one example for upscaling, idle extraction facilities from the tobacco industry could be used (blue square), as we observe a decline in the need for tobacco extraction facilities but a potential use of these facilities for extracting fucoidans.

The squares representing "food", "natural science", "cosmetics" and "medicine" lead down the road towards commercialisation, and are filled by the business models described in the chapter above. The representation of these models is by symbolising each one as a lily pad, from which the next model can be reached. Below the business models mentioned, arrows point towards "technology development". Here, the key improvements based on a technology are shown with the respective business models. For example, the models of tissue engineering and responsible medicine significantly rely on the development of molecular agents. As the application of molecular agents reaches far into the future, we expect relatively high uncertainty concerning the timing, which could even be outside of the time period in focus until 2033.
The last category on the vertical axis is labelled market share and projected cashflow, and shows a negative return at first which changes into a positive return further down the road. In conclusion, the FucoSan Technology Roadmap is a suitable overview that summarises the potential of the promising polysaccharide – but the time to reap the financial rewards still lies in the future.

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