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Innovation Ecosystems in a Sustainable Bioeconomy

A Finnish case study for OECD

05/30/2018

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1 Country: Finland, Case study: Innovation Ecosystems in a Sustainable Bioeconomy, Contact person: Christopher Palmberg

Case study “Innovation Ecosystems in a Sustainable Bioeconomy” with two development pathways: cellulose based textiles and bioproducts and biocomposites replacing plastics.

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2 Country position and policies for bio- and circular economies

a. Definitions of bio- and circular economies

According to the Finnish Bioeconomy Strategy, bioeconomy refers to an economy that “relies on renewable natural resources to produce food, energy, products and services. The bioeconomy will reduce our dependence on fossil natural resources, prevent biodiversity loss and create new economic growth and jobs in line with the principles of sustainable development.”¹

Circular economy, as defined by the Finnish Innovation Fund Sitra, “strives to maximise the circulation of products, components and materials and the value bound to them as much as possible in the economy. In a circular economy, production and consumption create the smallest possible amount of loss and waste.”²

b. Main priorities and drivers for transition to bio- and circular economy

According to a report published by the Finnish Ministry of Economic Affairs and Employment, population growth and the increasing standard of living are the two key megatrends that drive the increasing demand for natural resources, which is the key growth driver for bioeconomy. Additionally, consumer preferences can promote more sustainable solutions, especially when sustainability can be communicated clearly and reliably. These can include e.g. biobased plastics that can replace alternatives produced from fossil raw materials. The scarcity of natural resources drives towards resource efficiency and circular economy which subsequently can be used as competitive factors by manufacturers³.

The drivers for circular economy are twofold: The Finnish road map to a circular economy 2016 – 2025 lists both environmental and economic reasons that drive the systemic change towards circular economy. From the economic point of view, circular economy is estimated to create 75,000 jobs and provide Finland’s national economy with 2 to 3 billion euros in added value potential by 2030. Moreover, a road map to circular economy is seen to improve Finland’s ecological sustainability.²

c. Existence and main content of relevant strategies/visions/road maps

There are several relevant national strategies in place regarding the development of forest-based bio economy in Finland. The Ministry of Economic Affairs and Employment has launched the Finnish Bioeconomy Strategy in 2014, the goals of which are to promote: 1) a competitive operating environment for the bioeconomy, 2) new business from the bioeconomy, 3) a strong bioeconomy competence base as well as 4) accessibility and sustainability of biomasses.¹

For circular economy, The Finnish Innovation Fund Sitra has published a road map for years 2016-2025. The goals set out for 2025 in the strategy are that circular economy will be a new cornerstone for

¹ Ministry of Economic Affairs and Employment (2014) – The Finnish Bioeconomy Strategy

² Sitra – Leading the cycle – Finnish road map to a circular economy 2016-2025

³ Ministry of Economic Affairs and Employment (2017) - Growth and employment from sustainable solutions – A study into the dynamics of growth and employment in the bioeconomy, cleantech and circular economy.

the Finnish economy, that Finland is a model country for the challenge of scarcity, and that as a society Finland will be a pioneer rather than an adapter.²

Prime Minister Juha Sipilä's government is working towards its five strategic priorities by implementing 26 key projects. One of the key priorities is 'Bio economy and clean solutions', under which one of the key projects is labelled 'Wood on the move and new products from forests', and another 'Breakthrough to a circular economy and adoption of clean solutions'.

Wood on the move and new products from forests aims to increase, diversify, and grow the value of the wood used in Finland. Its goal is to create competitive and sustainable bio economy solutions in Finland as well as to create new business, employment and exports.

Breakthrough to a circular economy and adoption of clean solutions aims to leverage the growing opportunities enabled by circular economy and clean solutions. It promotes experiments, R&D and demonstrative projects to increase the reuse of materials and related cleantech business⁴.

The Academy of Finland, the governmental funding body for scientific research in Finland, has published its own strategy for scientific research concerning bioeconomy. The strategy lists 21 research priorities, including e.g. increasing the value of bioeconomy with multidisciplinary co-operation, bio-refineries, technically and economically sound biobased raw materials, tailored biomass, biobased compounds and substances, systemic changes in the bioeconomy / reforming value networks, dynamic bioeconomy, values and value networks (including the creation and adaption of innovations)⁵.

Another relevant strategy is the Forestry Research Strategy published by the Finnish Forest Association. It lists three strategic goals: 1. Finland is a competitive operating environment for forest-based business, 2. The forest industry and its structures are renewed and diversified, 3. Forests are in active, economically, ecologically and socially sustainable and diverse usage⁶.

3 Description of case study value chain

a. Name and key features of focus organization

Bioeconomy in Finland is based mainly on the structures that rely on the forest sector value chains. Due to development of new technologies and requirements on sustainable development, the forest based biomass is finding new higher value added applications when compared to applications that it has traditionally been used for, such as pulp and paper.

The aim of this study is to give understanding of innovation development pathways of two important new application areas in Finland that use forest based biomasses: 1) cellulose based textiles and 2) bioproducts and biocomposites replacing plastics.

Special emphasis in the study is given to the renewal of existing companies and the formation of new companies enabled by these development pathways and innovations. Thus, interviews were conducted with big multinational companies, startups and research organizations, the latter especially from the point of view of commercialization, as well as for policy perspective also with a public private partnership and a funding organization. Altogether 20 organizations were interviewed for this study, shown in Table 1 below.

⁴ <http://valtioneuvosto.fi/hallitusohjelman-toteutus/biotalous>

⁵ Suomen Akatemia: Biotalousstrategiset tutkimuskokonaisuudet – available at: <http://www.aka.fi/biotalous2014>

⁶ Metsäalan tutkimusstrategia 2025 – Kohti parempaa yhteistyötä ja kokeilukulttuuria - available at: <http://mmm.fi/documents/1410837/1504826/Mets%C3%A4alan+tutkimusstrategia/07e7935d-b27e-4736-910c-76c724a6f29b>

Organization	Most relevant development pathway
Aalto University	cellulose based textiles
Business Finland	both pathways
CLIC Innovation	both pathways
Elastopoli	bioproducts and biocomposites
Infinited Fiber Company /VTT	cellulose based textiles
Kotkamills	bioproducts and biocomposites
Marimekko	cellulose based textiles
Metsä Fibre	bioproducts and biocomposites
Neste	bioproducts and biocomposites
Paptic	bioproducts and biocomposites
Spinnova	cellulose based textiles
Stora Enso Biomaterials	cellulose based textiles
Sulapac	bioproducts and biocomposites
University of Borås/ Tampere University of Technology	both pathways
UPM	bioproducts and biocomposites
Welmu International	bioproducts and biocomposites
Valio	bioproducts and biocomposites
VTT	both pathways
Åbo Akademi Process Chemistry Center	bioproducts and biocomposites
Woodio	bioproducts and biocomposites

Table 1. Interviewed organizations with selected application pathways.

b. Type of biomass being refined, main biomass suppliers, refining techniques

In the context of this study, softwood and/or hardwood are the primary biomass sources processed further. Wood is refined by mechanical, chemical and/or thermal processing techniques to cellulose fibers, lignin and hemicelluloses which are used as raw materials for new biobased applications.

For cellulose based textiles, dissolving pulp is the main raw material used. Dissolving pulp is bleached wood pulp with high cellulose content dissolved in a solvent or homogenous solution. Dissolving pulp can also be mixed with other raw materials, such as cotton fibres. As special requirements, dissolving pulp needs to be extremely pure with low hemicellulose content. The kraft pulping process, predominant in Finland, has according to some interviews limited potential for biorefinery purposes. There is not, however, enough relevant funding for the development of alternative fractionation methods.

Specific refining technologies have been developed and defined by new applications such as the biomass based composite production. Also, when combining the cellulose fibres with polymers, compatibilization techniques are needed for the biomass, which is hydrophilic, to well mix with the normally hydrophobic polymers. Commonly, the specific refining technologies are trade secrets. Some companies utilize injection moulding to produce bioproducts and biocomposites. Also, new techniques to process biomass are under research and at laboratory/pilot state, such as technologies based on foam forming. Scaling up the production would require investments to demo-scale facilities and the supply of higher volumes than presently is available of raw material.

In Finland, forest ownership is fractioned and 2/3 of the forest is privately owned by a large amount of single owners. Private forest owners supply the wood biomass for saw mills as well as for the pulp and paper companies such as UPM, Stora Enso and Metsä, who also own forests. Most of the Finnish startups purchase wood from Finnish companies, but some use also global suppliers for wood chips. Many of the startups did not want to disclose their suppliers.

Some research organizations and small companies reported that there is a lack of supply for more specialized raw materials from current forest industry companies and suggested it to be due to lack of interest to develop their product portfolio to be more diversified than it is currently. For example, there is plenty of bulk cellulose on the market, however, it can be difficult to obtain certain side streams such

as hemicellulose and lignin as their fractionization requires variations to the bulk process. Thus, instead of developing and selling smaller amounts of high value products, a high volume of bulk products are being produced to few customers. Innovations related to raw materials are usually spun off from startups.

The new technology developers reported that the demand of recycled biomass (both paper/carton as well as textiles) greatly exceeds its supply. Thus, even though their technology could process these recycled materials and thus they could be used as raw material, the material is not available.

For the end product manufacturers in the cellulose based textile pathway, the limited amount of fabric available for prototyping poses a considerable barrier for further development. The fabric is currently procurable in laboratory level or from small pilots, whereas the required amounts would be at demo factory level.

c. Type of products/processes/services being developed

In the textile value chain, all types of new wood-based fabric products are being developed: fabrics for clothes and furnitures, technical and professional textiles, as well as hygienic textiles and medical textiles such as bandages. In general, cellulose fibers can be utilized in all textiles that can replace cotton and viscose. Viscose of course is also based on cellulose but its production process has sustainability issues and thus alternatives are looked for.

In the biobased plastics and composites value chain, virtually everything that is currently being produced from fossil-based plastics can be replaced with biobased ones. Examples include consumer packages (e.g. food and drink, jewellery, cosmetics), hygiene products, toys, consumer electronics (e.g. cell phone covers, loudspeaker frames) as well as air and water filtration solutions. Biobased composites can also be used as reinforcement material in the automotive and home electronic industries, the construction industry as well as e.g. in interior design. Light and durable structures can be made from nanocellulose fibres. In the auto industry, for example, lighter biobased composite structures that replace glass fiber enhanced synthetic plastics can have a substantial impact on mileage.

In addition to the cellulose, developments are ongoing to use pulp production side streams in very high value-added products, such as pharmaceuticals and other fine chemicals. Examples include barriers for food packaging developed from black liquor, as well as wood glue processed from lignin.

d. Main ecosystem companies, type of companies and relationship with these

Traditional forest companies are looking for partners with insight from a broader range of sectors than what their companies are traditionally representing. These new partner ecosystems with research institutes, startups and established companies from other sectors, are driving innovation in a way that corresponds to consumer needs. The Finnish bioeconomy ecosystem for cellulose based products consists of the traditional forest industry giants UPM, Stora Enso and Metsä Group and a number of innovative startups developing new bioproducts and biocomposites like Paptic, Elastopoli, Woodio, Sulapac and Welmu International, and for cellulose based textiles like Spinnova, Infinited Fiber Company, with very few mid-sized companies in between. Universities and research institutes have an important role in the commercial ecosystem, as many of them are focused not only on basic research but also applied research and commercialization. In the development of cellulose based textiles, Marimekko as the brand owner has been actively participating already in the development phase. However, over all, the group that is missing from the established innovation ecosystem are the clients.

Typical criteria for selecting new partners for industrial ecosystem include market knowledge from the business field or market area or substance knowledge about technologies or materials. For some companies, key value for partner selection is to enable quick market entry. Criteria might also be sustainability commitments or strategies and quality standards. Others target big volumes: global brand owners with big sales potential and then on the other hand producers with big production capacities to meet the demand.

4 Ongoing developments to extend value chain and diversify to new business areas in higher value-added sectors

a. Potentials for utilising biomass across a broader range of industries/sectors/higher value-added sectors, drivers to achieve these potentials

There is great potential for new and more sustainable biobased materials. The demand for both plastics and textiles is expected to increase heavily, and existing raw material sources – fossil-based oil for plastics and water-intensive cotton for textiles – are depleting or their usage is unsustainable. Forest-based biomass can be utilized in a variety of consumer product sectors where their value-added is considerably higher than in the traditional products, such as pulp, paper and bioenergy. Non-woven fiber market is estimated to be 47,7 billion euros in 2020⁷ and bioplastic market (especially drop-in-biopolymers) is estimated to be 3,4 billion euros in 2020⁸. Finnish government strategy aims to nearly double the current bioeconomy turnover from 60 billion euros to 100 billion euros before 2025⁹.

For the biobased plastics and composites, the biggest potential volume-wise is in food and drink packaging. Other packaging, such as hygienic products, toys and consumer electronics are also potential. Additional industries include e.g. the construction industry, where biocomposites can be used in insulation as well as material for interior surfaces.

For biobased fibers, micro- and nanofibrillated cellulose have been developed into biomedical solutions, such as wound treatment products and cell cultivation, used in medical and pharmaceutical research and development.¹⁰ Moreover, biobased fibers can be combined with biobased composites to develop technical fibers that have even higher functionality and added value.

It has to be taken into consideration, however, that the product features of biobased materials need to be equal or better than the existing solution, e.g. the bio composite materials need to last long and should not brake or compost during the use phase.

b. Examples of ongoing biomass refining/utilisation experiments/ventures and related new cross-industrial collaborations to diversify to new business areas, foreseen economic or other impacts of these.

There are a few open-access pilot facilities in Finland for the forest-based bio- and circular economy. Pilot facilities focused on biofuels and thermochemical conversions are located in Technical Research Centre of Finland (VTT Ltd), University of Eastern Finland (UEF), and Kouvola Region Vocational College. Biomass processing and pulp production pilot facilities are located at KCL in Espoo, Mikkeli University of Applied Sciences (MAMK), VTT as well as Åbo Academy. Chemical process technology and industrial biotechnology pilot facilities are located only in VTT premises. Biobased material pilot facilities are located at KCL, VTT, Tampere University of Technology (TUT) as well as Lappeenranta University of Technology (LUT)¹⁰.

Examples of new ventures include e.g. the Ioncell-F technology for producing man-made cellulosic textile fibers, developed at Aalto University in collaboration with the University of Helsinki. A cross-industrial collaboration combining technical knowledge from the pulp and paper industry with the fabric industry, it provides an alternative to cotton. Another similar innovation is the method developed by Spinnova, whose patented spinning technology produces textile fiber from pulp without harmful chemicals. Moreover, Infinited Fiber Company has developed a technology for turning cotton rich textile waste into new fibers for the textile industry in pulp and dissolving plants. In the biocomposite value

⁷ Markets and Markets 2016

⁸ Markets and Markets 2015b

⁹ Finnish Government 2017

¹⁰ Ministry of Economic Affairs and Employment (2017) – Wood-based Bioeconomy Solving Global Challenges

chain, examples of new ventures include Aqvacomp, a new type of biocomposite that utilizes pulp fiber from the forest to reinforce plastic materials.

Relevant research programs include e.g. ACEL (Advanced Cellulose to Novel Products) which brings together universities, pulp and paper companies, as well as companies from the chemical and textile industries. The program ran up until the end of 2017, promoting wood cellulose fiber-based material opportunities in textile fibers, thermoformable composites and cationic chemicals. Another relevant research program under CLIC Innovation Ltd is the New Fiber Products, which aims to increase renewable materials usage by focusing on new cellulose modification methods: new enzymes and high consistency processes, on enabling foam technologies as well as on new product solutions in the area of antimicrobial products.

CH-Bioforce, founded in 2016, is delivering a new biomass fractionation technology to offer a new feedstock source for the chemical industry providing high end value products. The technology can fractionate biomass into its three main constituents: cellulose, sulfur-free lignin, and hemicellulose.

c. Examples of need for/already tested/new business models to facilitate extension/collaboration/diversification

The value creation logic is changing in the industry. From the forest industry point of view, the business logic of selling large volumes of bulk to few clients differs from the new model of selling small batches to many clients. Networking becomes crucial and subcontracting increases. New collaboration models are needed because the market (industry and clients) are new to the traditional players (forest industry). The new solutions are closer to the end-users so product development requires knowledge about end-user needs.

One of the key challenges in utilizing the biomass in new business areas is to understand the various value chains. It is important to define the right contact point to deliver the message at the end of the value chain (OEM, brand owner) and then get them to convince their own suppliers. There are a lot of educational points that need to be completed before introducing new material. For example, one must be familiar with polymer technology and processing opportunities in order to understand the end use opportunities well enough. Raw material must be processed in a way that is applicable to end use. For example, coffee cups and animal food packaging have different kind of quality criteria for raw material.

The common business model among start-up companies is to license their production technology – a relatively novel business model in the forest-based biomass industry. They sell their concept straight to the brand owners in contrast to current industry players who sell their products only to the next value chain level. Also, the production is often licensed to the existing vertical value chain companies (forest companies). Normally the challenge of material start-ups is that the required initial investment is considerable. This challenge can be tackled through licensing the production. Start-ups may also cooperate with the raw material suppliers and seek internationalization through collaboration.

d. Relevance of circular economy solutions and viewpoints for extending value chains and diversifying to new business areas.

Circular economy can be seen as inherent to the forest based industries, which are a core base for selected value chains and raw materials. The term circular economy has not been used by the industry, however, but rather strongly overlapping theme of “cascading use”. The cascading use of biomass is part of circular economy, where the target is to increase resource efficiency and decrease the use of primary raw materials. Selected bioeconomy value chains contribute to circular economy by utilizing side streams and waste fractions from forestry, cascading use of biobased products, composites and cellulose based textiles as well as returning biodegradable products to organic and nutrient cycles. The relevance of circular economy in the selected innovation pathways is keeping it as one aspect of product design.

e. Examples of how policies, agencies and their specific instruments have facilitated extension/collaboration/diversification.

Developing new technologies to enable the extension of value chains is costly, which entails high risks for the R&D investments. Consequently, public funding is required to alleviate the risk that private companies have to face.

Finland's Bioeconomy Strategy, Sitra's Finnish road map to a circular economy 2016-2025 as well as Prime Minister Juha Sipilä's government's key projects have given the forest-based industry a high profile in the Finnish society. Design Driven Value Chains in the World of Cellulose (DWoC) was a multidisciplinary research collaboration project funded by Tekes (the Finnish Funding Agency for Innovation) focused on finding new and innovative applications for cellulosic materials, thus promoting e.g. the development of biocomposites.

Tekes (Business Finland from 1.1.2018) has enabled technology development for start-ups and large companies alike. It has had several bioeconomy related programmes, such as the 81M€ Green Growth-programme from 2011 to 2015, 128 M€ Biorefine programme in 2007-2012, the 33M€ Symbio programme in 2006-2011, as well as the renewable energy Groove programme in 2010 – 2014 (53 M€). The Smart & Green Growth programme has focused on activating bio economy through projects such as BioNets, CleanWeb, Clean Soil as well as a number of pilot and demonstration projects. Additionally, bioeconomy projects are included in the following programs: Functional materials (2007-2013), Fin-Nano (2005-2010), Water programme (2008-2012) and Sapuska (2009-2012). Tekes has also contributed to the operations of Strategic Centres for Science, Technology and Innovation (known in Finnish under the acronym SHOK) in cooperation with Academy of Finland by combining the funding of leading-edge research with development and funding between 2008 and 2015. The SHOKs lead to a number of ideas which are currently being commercialized. The most relevant bioeconomy SHOKs were FIBIC and CLEEN, which have been merged as CLIC Innovation thereafter. The value for these programs have been 100 M€ in total including both Tekes support as well as own investments by the participating companies.

Academy of Finland has more recently focused funding to the bioeconomy sector through its programs and other applied research instruments. In particular, as one of its two first flagship programs, CERES – the Competence Centre for the Materials Bioeconomy: A Flagship for our Sustainable Future was selected for funding in April 2018.

On European Union level, the EU's plastic strategy has created interest towards biobased materials. In addition, energy efficiency requirements in the automotive industry creates demand for lighter materials, e.g. biocomposites. Many Finnish companies, have been active participants in the Biobased Industries Joint Undertaking BBI JU¹¹, a public-private partnership that operates under EU framework program Horizon2020.

f. Challenges related to extension/collaboration/diversification in general, specifically related to the regulatory/institutional regime.

The key challenges are related to sharing costs and risks, as well as variable standards. There is a need for public support to share the risks entailed by high pre-production development costs, to support ecosystem development and company demonstrations, to educate consumers about the benefits of biobased materials, as well as to unify and clarify the variable regulations, rules and standards.

Cost wise, one of the key challenges is related to production costs. Especially when replacing plastics in packages, the new material needs to be competitive. Currently, the higher production prices are hindering the market demand and willingness to invest in large scale production. The question is how much the end user is willing to pay for the added value. The opinions of the price competitiveness of the new

¹¹ <https://www.bbi-europe.eu/>

biobased solutions varies between SMEs/start-ups and forest industry companies/brand owners, SMEs requesting for competitive price and larger companies allowing more expensive production costs.

The attributes of the products have to correspond to those of the existing materials. In composites, there are very strict end user specifications, which are difficult to fulfill. Some demanding application areas cannot bare risk in the durability, such as in heavy vehicles, trains, planes, sports equipment and building materials. Thus, one should focus on the markets where biocomposites fill the requirements, and where there is a possibility to gain competitive edge for the biobased material.

Commercialization is an issue especially for the research organizations. The entire innovation process might take 10 years or more and it is difficult to identify which organization should take responsibility of the commercialization. Commonly cooperation is done with big companies but there is a risk that all innovations are not interesting to them. After engaging with the big companies, a step back is needed to establish a spin-off.

There is also a need for new players and cross-industry collaboration. New industries do not evolve because big companies buy innovative SMEs when they succeed. Medium sized companies are missing, and the Finnish market consist of existing big companies and micro companies. Moreover, consortia covering the entire value chain are missing, more cross-disciplinary discussions would be needed. Discussion platforms (such as Biobased Industries Consortium BIC¹²), where different industries could meet each other and clients, would be useful. Business Finland's financing instruments are much needed; however, the fact that they are inclusive for only Finnish companies leads to a situation where cross-disciplinary development is not achieved. For example, parts of the value chain in the textile industry cannot be found in Finland and these parts are missing from the innovation ecosystem. This, however, is normal practice when using public national money and thus it is important to find such collaboration mechanisms that would allow to overcome this situation.

Standards are built for current materials, which might cause difficulties for producers of new materials who need to follow standards that do not fit in with their new material. The rules and regulations, as well as industry standards, are also considered too complicated, not only by smaller companies, but also larger ones. The competition of PEFC and FSC certificates poses also some challenges, which could be mitigated on a governmental level. Recycling rules and regulations vary even between EU countries, which is an issue when developing and commercializing new materials.

Certifications (forest land-use) are needed in order to ensure sustainability of the new biobased materials. Also, certifications for recycled materials are needed. In general, increasing public awareness about what is sustainable, should be done.

5 Overall synthesis of findings

The analysis framework adapted from the Hekkert et al.¹³ is used to synthesize the main findings of this case study. The analysis is based on two parts. The first part, structure of the innovation system, consists of actors and rules that make up the system. The second part, how the system is functioning, is validated through seven system functions. These system functions are: 1) entrepreneurial activities, 2) knowledge development, 3) knowledge exchange, 4) guidance of the search, 5) formation of markets, 6) mobilization of resources, and 7) counteracting resistance to change. The importance of the different system functions varies according to the different phases of the development. The functions can be used to identify any system problems that might act as barriers to the well-functioning of the innovation system. These barriers are manifestation of problems in the structure. Subsequently this analysis framework can be used to determine what kind of new policies are needed to overcome these barriers.

¹² <https://biconsortium.eu/about>

¹³ Marko Hekkert, Simona Negro, Gaston Heimeriks, Robert Harmsen: Technological Innovation System Analysis, A manual for analysts, Utrecht University Faculty of Gelsciences, November 2011

For the *entrepreneurial activities*, one of main findings is that the traditional business models do not match with the new needs: selling large volumes of bulk to few clients vs. developing higher value products to more fractioned market. The key players in this function are in particular startups and research organizations that commercialize their research results. Also, the traditional forest industry companies, food and textile brand owners as well as other relevant big companies are playing to some extent on the entrepreneurial field. The traditional forest industry companies control the beginning of the value chain. However, they concentrate mainly on bulk production and selling these large volumes to few clients rather than developing value-added products to a more fractioned market. The pulp being sold as raw material to the new application areas presents only a tiny fraction of their total production volume. Many times, the large companies are reluctant to produce raw materials from the side streams since it might require adjustment or even special production lines additional to their normal processes.

Other findings for the *entrepreneurial activities* are that research organizations are still closely involved in the ecosystem. The new applications may not be on the priority list of traditional companies and thus innovations are mostly commercialized through startups directly from the research organizations even if big companies have participated in the preceding research phase. This creates also IPR problematics and together with the lacking production capacities of the startups slows down the innovation process.

Also, a finding for the *entrepreneurial activities* is that many startups have a business model based on licensing: new concepts are sold straight to the brand owners. Medium-sized companies are missing and there is a lack of investment decisions on industrial scale demo factories which is slowing down the commercialization process. As their business model, at least some of the startups have outsourced almost everything else than portfolio management and marketing. Their strategy is many times to utilize the existing linear value chain to develop and produce new applications which would allow prompt large scale production of innovations. However, few startups are yet at this stage of the scaling process. At the same time, big companies buy innovative SMEs when they succeed and this inhibits the evolvement of new industries and results in the market consisting mainly of big and micro companies with the missing sector of mid-sized companies. Also financing for R&D is overall not sufficient for implementing mid-sized production facilities (between 1M€-100M€). Subsequently investment decisions for demonstration infrastructure is crucially needed and it should be located nearby the companies.

In terms of *knowledge development*, networking is crucial to increase knowledge about new business areas and customer need: cooperation throughout the value chain is important in order to ensure meeting the client needs. The main knowledge gaps are related to the end of the value chain: lack of market knowledge of the new industry. Thus, networking within the extended value chain is critical and cooperation with the brand owners is needed. The market knowledge can be increased if target market players are included as participants and partners already at the product development phase.

For the *guidance of search*, new standards and EU regulations are needed to fit the new materials and products: industry standards should be renewed to base on functionality and not on materials used, recycling issues vs. materials used in processes should be cleared, and also more uniformity is needed. For example, the new EU biocomposite definition and how it states about the materials recycling possibilities can drastically change the business potentials for an industry.

A finding for the *market formation* function is that product development focus is on consumer segment and the importance of industrial solutions is overlooked. The consumer market is many times more familiar to the investors and other funders than the industrial solutions market. This even if the latter has a huge potential that might be accessed easier than the consumer market due to that price many times is a less decisive factor.

As overall synthesis of these findings, when considering the phase of development on a scale of Pre-development – Development – Take-off – Acceleration – Stabilization, from main functions present, a conclusion can be made that the phase of development in Finland for the cellulose based textiles and bioproducts and biocomposites replacing plastics is at the end of the Development-phase and at the beginning of the Take-off-phase.

When considering policy implications and needed instruments, the following recommendations are suggested:

1. Foster the growth of mid-sized companies.
2. Promote funding for demo-scale activities.
3. Encourage and build capacities to renew current business models.
4. Enhance networks and capacities to understand the entire value chain and the client needs.
5. Pave the way to widen market view from consumer products to possibilities in the industry sector.
6. Promote at national and international level uptake of standards and regulations accustomed to the specific needs of the sector.

The two first recommendations call for especially public funding instruments as well as policies that promote supportive private investments that would take into consideration the particular challenges that the startups face in the bioeconomy sector, which is very different than for example when fostering startups in the ICT sector.

The third and fourth recommendations call particularly for example for program actions in such a manner to motivate the established industry in the field to extend its will and capabilities to make business with different means than has been and is still very much the state-of-the-art. Such program actions might also be the best means to enhance networks and support measures that would help build capabilities to understanding the value chain and the client needs.

The fifth recommendation calls for similar network enhancement and capacity building actions as for the fourth recommendation. Widening of market view might also be achieved by such policy actions that would promote and enhance the consciousness of sustainability improvements in various industry sectors and the capabilities of these industries to use these improvements as their competitive advantage in the market.

The best way to approach the sixth recommendation might be to take the development of needed standards and regulations as a strategic goal in national as well as international policy work and subsequently ensure that there are means for appropriate actions by the right organizations.

Overall there has been many effective practices and policies in use in Finland over the years that have forwarded well the development of the bioeconomy in general and the two development lines discussed in this report in particular. Finland has invested in research activities for a long time and promoted collaboration between research organizations and companies. The startup funding has allowed creation of spinoffs. In general, a lot of actions are promoted in the commercialization space. All these have given a good ground to grow new business of the developments in the bioeconomy. What is needed now are the activities according to recommendations above. Also, orchestration of the ecosystems will need specific effort, something that particular should be paid attention to.



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