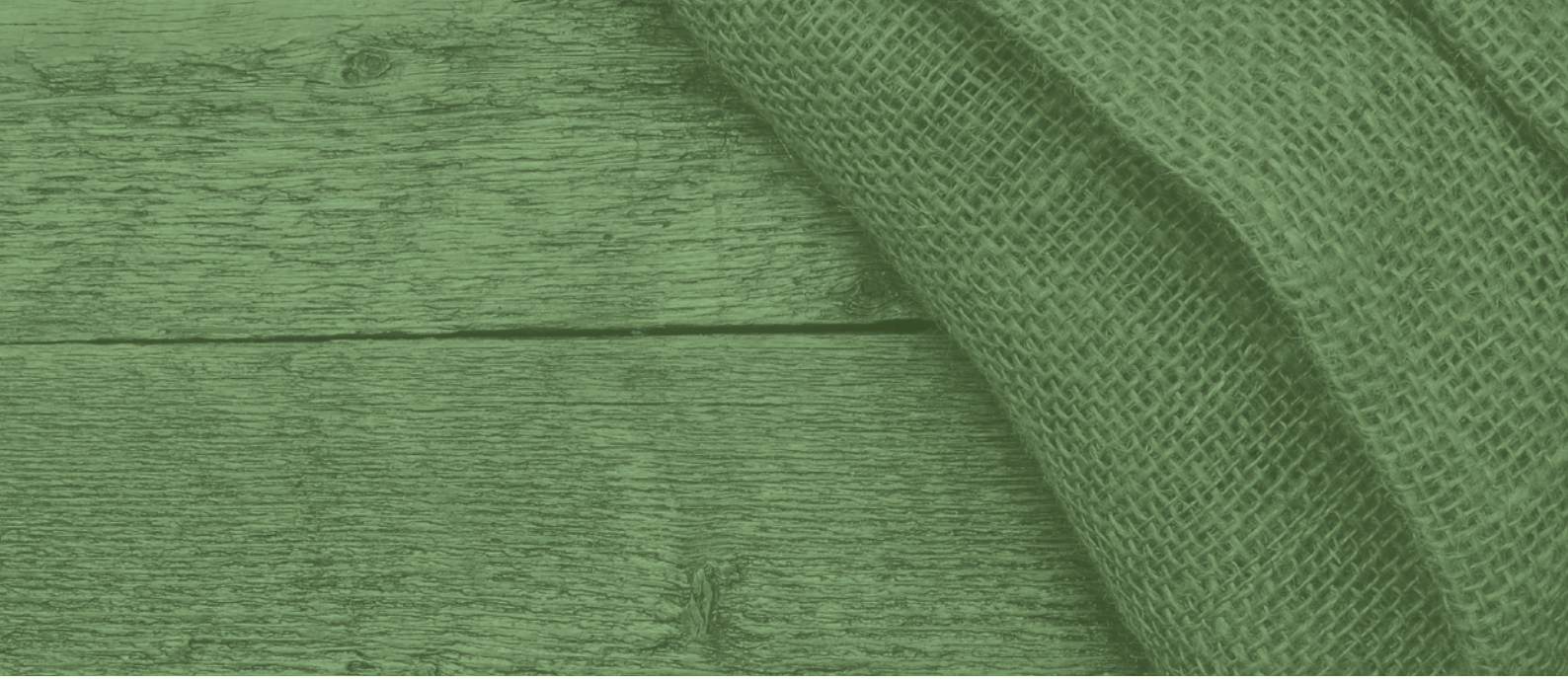

Added value materials and chemicals from cellulose – a Finnish approach

STRATEGIC RESEARCH AND INNOVATION AGENDA

Added value materials and chemicals from cellulose – a Finnish approach

STRATEGIC RESEARCH AND INNOVATION AGENDA

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Executive Summary

Finland has a fantastic opportunity to be a frontrunner in a forest industry -led bioeconomy. Wood is Finland's strategic resource and Finland's most significant renewable natural resource that is being processed on an industrial scale. Products made from wood, wood fibre, and other components of wood will replace non-renewable materials and fossil fuels as we move towards a low-carbon bioeconomy.

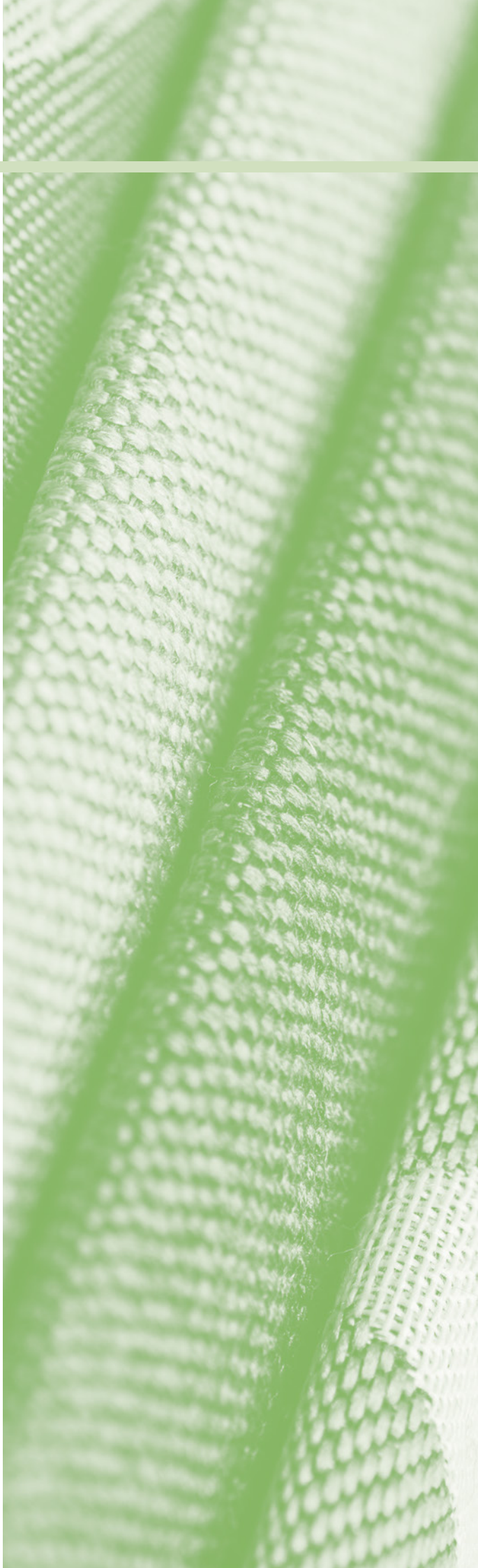
CLIC Innovation Ltd. is an open innovation cluster with the mission to create breakthrough solutions in bioeconomy, circular economy and energy systems with global business impact far beyond the capabilities of individual actors. The owners of CLIC Innovation have defined the development of new, high value fibre- and cellulose-based products as the main focus for the bioeconomy portfolio of CLIC Innovation. One of the main reasons behind this decision is the growing global need for sustainable materials giving significant rise to new business opportunities.

Our aim is to create a Public-Private Partnership (PPP) in Finland with the ultimate aim of developing new added-value cellulose-based products for the global market. Research and development have to be complemented with innovative efforts and measures that, in particular, take on the challenges of a bio-economy. The nature and scope of the challenges require extensive cooperation between the players and the sectors must work together to manage the complex issues and the solutions needed for the challenges.

There is a need to accelerate the development, verification and commercialization of new bio-based solutions and to continue supporting the demonstration of products, systems and services. There is also a need to support small and midsize companies in the commercialization of new technologies throughout the supply chain. This especially applies to cooperation between major companies, if development and innovation are to be accelerated. This entails offering incentives for collaboration on cross-industry research and innovation in order to develop and implement solutions that will contribute to a growing bio-based economy.

This research and innovation agenda was developed within the network of CLIC Innovation's owners and partners, comprising a broad group of stakeholders representing business and research. Supporters of this agenda include leading companies in the forest industry, chemical industry, textile industry, technology industry, as well as universities and research institutes. Consequently, there is strong collective support from both business and research organisations and a commitment to invest significantly in the Public-Private Partnership.

Welcome to a future in which the forest-based sector is leading the way towards a circular bioeconomy!



Lyhyesti suomeksi

Puu on Suomelle strateginen resurssi ja merkittävin teollisesti hyödynnettävä uusiutuva luonnonvara. Puusta, puukuidusta ja muista puun komponenteista valmistetut tuotteet korvaavat uusiutumattomia materiaaleja ja fossiilisia polttoaineita, kun siirrymme kohti vähähiilistä globaalia biotaloutta.

Raaka-ainevarantojen lisäksi Suomessa on maailman kärkiluokan osaamista muun muassa metsäteollisuudessa: meillä on loistava mahdollisuus nousta globaalin biotalouden edelläkävijäksi. Ensimmäiset askelet on jo otettu. Suomalainen CLIC Innovation Oy on 30 kansainvälisen yrityksen sekä 16 yliopiston ja tutkimuslaitoksen omistama yritys, joka rakentaa ja koordinoi laajoja, yritysvetoisia tutkimusekosysteemejä. Edustettuina on kaikkiaan yhdeksän eri toimialaa, joiden osaaminen ja tietotaito on valjastettu ratkomaan biotalouteen, kiertotalouteen ja energiajärjestelmiin liittyviä haasteita. Tavoitteena on luoda Suomeen julkisten ja yksityisten toimijoiden innovaatiokumppanuus (public-private partnership, PPP).

Biotaloudessa keskitytään uusien korkean lisäarvon kuitu- ja selluloosatuotteiden kehittämiseen. Fokuksen valinta perustuu kestävän kehityksen mukaisten materiaaliratkaisujen globaaliin tarpeeseen, joka kasvaa vuosittain vauhdikkaasti ja luo näin merkittäviä uusia liiketoimintamahdollisuuksia alan toimijoille.

Meillä on kuitenkin ensin erinäisiä haasteita ratkottavana, mikä vaatii tiivistä ja laajaa yhteistyötä eri toimijoiden kesken. Uusien biopohjaisten ratkaisujen kehittämistä ja demonstrointia tulee kiihdyttää, tämä tarvitsee edelleen jatkuvaa tukea. Lisäksi uusien tuotteiden ja ratkaisujen kaupallistamista pitää vahvistaa. Menestyksekäs kaupallistaminen arvoketjun eri vaiheissa edellyttää pienten ja keskisuurten yritysten kaupallistamisponnisteluiden tukemista. Myös innovointi ja yhteistyön kehittäminen tarvitsevat tukea, etenkin kansainvälisten suuryritystemme kohdalla. Julkiset kannustimet ja monipuolisen, toimiala- ja yritysrajat ylittävän yhteistyön tukeminen tutkimus- ja innovaatiotoiminnassa nopeuttavat biotalouden liiketoiminnan kasvua.

Tämä tutkimus- ja innovaatioagenda on laadittu yhdessä CLIC Innovation Oy:n omistajien ja yhteistyökumppaneiden kanssa. Mukana ovat sekä metsä-, kemian-, tekstiili- että teknologiateollisuuden johtavat suomalaiset yritykset kuin myös yliopistot ja tutkimuslaitokset. Nämä toimijat ovat myös valmiita investoimaan merkittävästi sekä resursseja että rahaa PPP-kumppanuuden rakentamiseksi.

Kiertotalous on liiketoimintamalli, jossa raaka-aineita, tuotteita ja materiaaleja käytetään taloudessa mahdollisimman tuottavasti ja kestävästi. Tavoitteenamme on yhdistää biotalouden prosessit kestävään kiertotalousajatteluun ja rakentaa metsäteollisuuden johdolla kiertobiotaloutta. Tervetuloa matkalle mukaan!

1. Vision

Added-value cellulose is the preferred, sustainable choice in the growing global materials market.

In the future, many end-products will be efficiently manufactured with regard to the environment and energy and made of materials or chemicals that are based on renewable resources. These biomaterials and biochemicals have also been developed for a range of new functions and services that we are completely unaware of today. New manufacturing processes have been developed. Reuse and recycling processes are adapted to maximize the capacity of materials to store carbon dioxide and energy. Developed business models have resulted in in-depth cooperation between large and small companies.

The net value and export revenue created by the Finnish wood-based cellulose value network has increased significantly. New high-value products with long lifetime, thus acting as carbon sinks, are widely spread on the market. Finland is by 2030 the global innovation and knowledge community for cellulose-based innovations.

The vision also entails that the biomaterials' functions and attractiveness are so compelling that they have become the first choice of consumers. Welcome to a future, in which the forest-based sector is leading the way towards a circular bioeconomy!

2. The purpose of this document

Our aim is to create a Public-Private Partnership (PPP) in Finland with the ultimate aim of developing new added-value cellulose-based products for the global market.

The purpose of this document is to describe the background and reasoning behind the PPP and to describe the research and innovation actions needed to realize the vision and to reach the aim.

CLIC Innovation Ltd. is an open innovation cluster with the mission to create breakthrough solutions in bioeconomy, circular economy and energy systems with global business impact far beyond the capabilities of individual actors. CLIC Innovation aims at speeding up the commercialization of new knowledge by initiating and orchestrating solution-oriented project portfolios covering the entire field from basic research to demonstrations. The shareholders of CLIC Innovation include 30 companies as well as 17 universities and research institutions. In addition, a network of more than 20 small and medium-sized enterprises (SMEs) is connected to the activities of CLIC Innovation.

The owners of CLIC Innovation are prepared to invest significantly in the Public-Private Partnership both by co-financing applied research and by investing in demonstration and development projects.

The owners of CLIC Innovation have defined the development of new, high value fibre- and cellulose-based products as the main focus for the bioeconomy portfolio of CLIC Innovation. One of the main reasons behind this decision is the growing global need for sustainable materials giving significant rise to new business opportunities. It has, for example been estimated that the global wood-plastic composite market will double from 2016 to 2022 (from 4.4 billion USD to 8.8 billion USD) (www.grandviewresearch.com/press-release/global-wood-plastic-composite-market) and the man-made cellulosic textile fibre market shows annual growth rates of around 6%. In addition, the need for the forest industry to find new high-value and large-scale businesses to replace the declining graphic paper business boosts the development from the other direction.

3. Addressing global challenges

Global long-term development requires a controlled transition from the current, unsustainable fossil-based economy to a sustainable, circular biobased economy. This entails a conversion from an economy that is largely based on fossil raw materials to a more resource-efficient economy that extensively utilizes renewable resources in a circular way. The development of primarily forest-based materials, products and services is fundamental to such a conversion. Finland is in an excellent position to lead this change due to the solid foundation that we possess here in Finland, including education, R&D, industry, and most importantly a sustainable growing tree stock basis.

The transformation to a biobased economy helps to mitigate climate change by offering an alternative to the fossil dependent economy. An important basis for the transformation is the UN Global Goals for Sustainable Development (Figure 1) which are pointing towards a bio-based economy, based on resource efficient processes, renewable raw materials and principles of circularity.

In recent years, the bioeconomy has become an important component of both innovation and economic policy in many countries. The different political approaches share many common measures to promote technological innovation, economic growth, ecological sustainability and resource efficiency. Furthermore, the political focus has increasingly changed from promoting bioenergy as a stand-alone solution to fostering the value-added use of biobased natural resources. However, there is a great variation in the political aims and measures of the individual countries. They are characterized by the prevailing industrial and economic profiles of the countries and by the amount of resources they have, especially by their natural resources potentials. Their underlying motivations range from a desire to secure access to raw materials to comprehensive regeneration of the innovation system and the transformation of the economy.

Information about national bioeconomy strategies globally can be found at BioStep -project website (http://www.bio-step.eu/background/bioeconomy-strategies/.

FIGURE 1. UN Sustainable Development Goals

4. Strong EU support for bioeconomy

The total European bioeconomy amounts to about 2.1 trillion EUR turnover and includes the food, feed and beverages sectors which are responsible for roughly half of the turnover. The total employment in the European bioeconomy is about 18.3 million persons with primary biomass production (agriculture, forestry & fishery) as the biggest contributor (58%). The biobased industries show a 600 billion EUR total turnover and employ about 3.2 million Europeans. Hence, the biobased industry is already an important part of the European economy and a pivotal element in the transition towards a sustainable, circular economy in Europe with renewable raw materials as key enablers (Piotrowski S et al., 2018).

Bioeconomy is an important driver in the EU's growth strategy. The EU adopted its own bioeconomy strategy in 2012 (European Commission, 2012). It is linked to Horizon 2020, the EU Framework Programme for research 2014–2020. Funding for research, development and innovation will improve European competitiveness and growth and create new jobs. The programme provides funding for food safety, sustainable agriculture and marine research, shipping and inland waters. Funding is also granted to safe, clean and efficient energy production, climate actions, resource efficiency and raw materials. The EU bioeconomy strategy will be revised in 2018 with the goal to move towards a sustainable and circular bioeconomy.

5. Finnish Bioeconomy Strategy

Finland has also set the course for a low-carbon and resource-efficient society and a sustainable economy. A key role in reaching this goal will be played by a sustainable bioeconomy. Thanks to our plentiful renewable natural resources, high level of expertise and industrial strengths, Finland is excellently placed to become a global pioneer of the new wave of circular bioeconomy. The bioeconomy will boost the national economy and employment in Finland and enhance the well-being of the Finnish people. The vision of the first Finnish Bioeconomy Strategy is that Finnish well-being and competitiveness will be based on sustainable bioeconomy solutions.

FIGURE 2. The Finnish Bioeconomy Strategy

The objective of the Finnish Bioeconomy Strategy (Sustainable growth from bioeconomy - the Finnish bioeconomy strategy, 2014) (Figure 2) is to generate new economic growth and new jobs from an increase in the bioeconomy business and from high added value products and services while securing the operating conditions for the nature's ecosystems. The leading idea of the strategy is that competitive and sustainable bioeconomy solutions for global problems will be created in Finland, and that new business will be generated both in the Finnish and international market, thus boosting the welfare of the whole of Finland.

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 resources, prevent biodiversity loss and create new economic growth and jobs in line with the principles of sustainable development. The objective of the Bioeconomy Strategy is to push our bioeconomy output up to 100 billion EUR by 2025 and to create 100,000 new jobs. In 2016 the output was 65 billion EUR, which was 16 % of the national output.

6. Market opportunities for Finland

The growing global need for sustainable materials and products provides a large market opportunity for biobased solutions. Broad end-use potential with biobased chemicals and materials as constructional elements for e.g. packaging, electronic products and durable goods opens completely new value chain opportunities for the Finnish industry. Currently the non-energetic market category within biobased product market opportunity, which includes bio-derived chemicals, bio-derived materials and bio-derived pharmaceuticals, is predicted to reach about 447 billion USD in 2021, up from 282 billion USD in 2016, representing an annual growth of 11%. This growth will result in a biobased solutions market penetration of 8% in 2021 within the fossil-based market, up from 7% in 2016 (BCC Research, 2017).

6.1 BROADENING THE APPLICATION FIELDS FOR CELLULOSE

An increasing number of global brand owners have announced their efforts for changing their raw material base towards biobased or recycled materials. For the Finnish cellulose community, a large potential lies in the development of novel chemicals and thermoplastics within the cellulose value chain as well as development of novel uses for the existing materials by developing their features and functionalities to meet with demands for sustainable solutions in e.g. packaging, textile and composite industries.

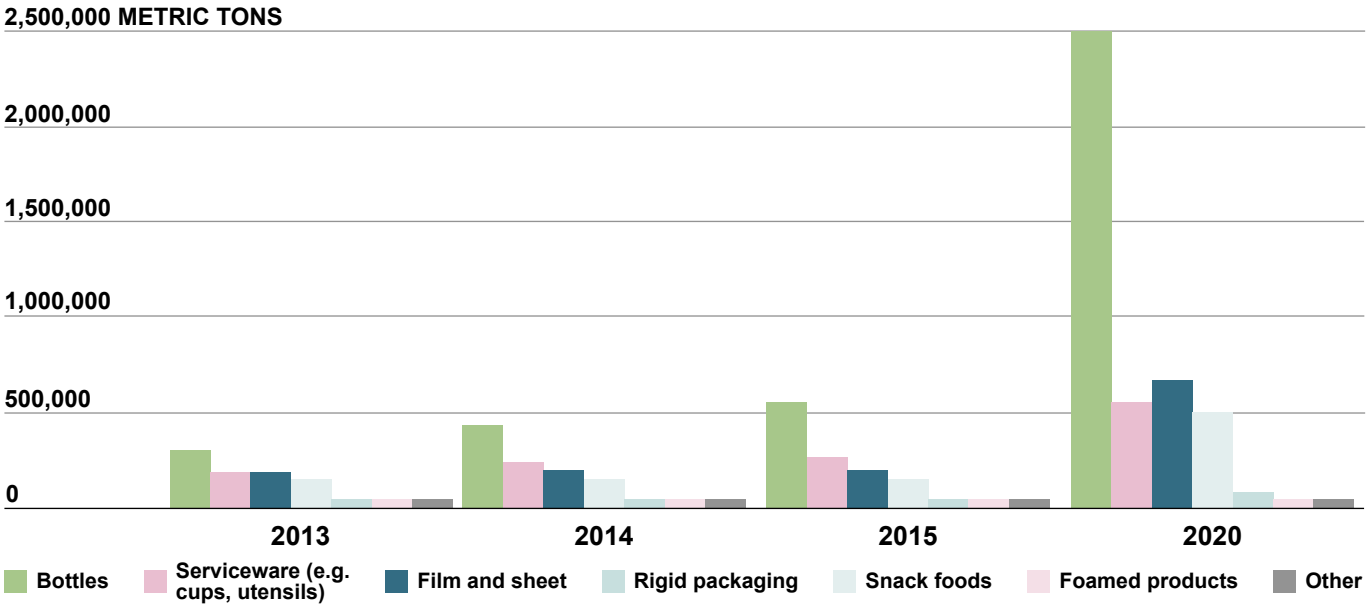


FIGURE 3. Global use of bioplastics in packaging applications, 2013-2020 (metric tons). (Bcc research, 2016)

As an example, it is estimated that demand for bioplastics/biopolymers will increase at an annual growth of approximately 10% over the forecast period to reach 29 billion USD in 2021 (BCC Research, 2017). The primary market for bioplastics remains packaging, but efforts to develop durable goods and other markets are rising. While bottles are predicted to be clearly the largest and fastest growing segment for bioplastics the use in films and sheets will also rapidly grow.

6.2 FIBRES FOR THE TEXTILE MARKET

In 2016, the global demand for textile fibres reached almost 100 million tons (Lenzing, 2016). The demand was dominated by synthetic fibres/polyesters (63%), followed by cotton (24%). The demand for wood-based fibres (i.e. the main category within 'man-made cellulosic fibres, MMCFs) was about 6.5 million tons (7%). Polyesters are predicted to take even more market share until 2030. The demand for MMCFs is also predicted to increase. It is assessed that if the development of new sustainable cellulosic fibres is successful, the growth rate of MMCFs will even exceed the forecast.

Especially the shortage of arable land and water needed for cotton cultivation increases the demand for MMCFs. The annual growth estimate for 2014-2020 is 6%. Importantly, in the long run the increasing MMCF demand cannot be satisfied with the existing MMCF production capacities. In 2030 this gap is estimated to be 10-20 million tons/year, and thus it offers a long-term growth opportunity for MMCF production.

The latest forecasts confirm the long-term growth potential for MMCFs. A recent sensitivity study for the period 2012-2020 reveals an annual textile fibre growth of 3.3% (average for all textile fibres), which predicts an annual textile fibre demand of 109 million tons in 2020 (CIRFS, The Fiber Year, 2013). With an estimated share of 36% of cellulosic fibres (including cotton), the annual demand of cellulosic fibres rises to 39 million tons by 2020. Assuming a maximum cotton supply of 26-29 million tons, a demand of 10-13 million tons of MMCF can be predicted. This means that the current MMCF demand would increase by more than 100%.

Viscose staple fibre (VSF) is currently the dominant MMCF. The high absorbency, high porosity, high mechanical strength, microfibrillity and softness are some of the advantages of VSF. The other important MMCF, Lyocell/Tencel®, adds to the list of advantages. The highest growth potential is actually attributed to the Lyocell-type fibres, mainly due to their better environmental footprint, in addition to better product qualities. As a consequence, it has been estimated that the Lyocell production capacity will be doubled in the next few years (i.e. from current approximately 250 kt/a to 500 kt/a).

In conclusion, the key MMCF production processes available on an industrial scale, Viscose and Lyocell, are both faced with challenges in light of significant production capacity increases, especially Viscose due to the heavy environmental burden it possesses. This situation, linked with the significant foreseen demand growth, opens an opportunity for the development of new, improved production processes, in addition to opportunities to become a player in this field via the traditional value chains based on Viscose and Lyocell.

6.3 BIOCOMPOSITES

According to Nova Institute (Carus M., 2014) the most important application sectors for biobased composites are construction (decking, siding and fencing) and automotive interior parts. 10 … 15% of the total European composite market is covered by Wood-Plastic Composites (WPC) and Natural Fibre Composites (NFC). The total production of composites in Europe in 2012 was 2.4 million tonnes and the production of biocomposites 352,000 tonnes. The level of market penetration of biobased composites varies between regions and from one application field to another.

Higher level of market penetration is to be expected in the future when NFC are starting to enter other markets than just the automotive industry. WPC granulates for injection moulding are produced and offered by global players and are becoming more attractive for clients that manufacture consumer goods, automotive and technical parts.

The development of applications will lead to WPC being increasingly used for applications beyond the traditional ones like decking or automotive parts. For example, WPC is increasingly used to produce furniture, technical parts, consumer goods and household electronics, using injection moulding and other non-extrusion processes. Also, new production methods are being developed for the extrusion of broad WPC boards.

Worldwide WPC production is estimated to rise from 2.4 million tonnes in 2012 with more than 15 % annually. Although North America is still the world's leading production region with 1.1 million tonnes, ahead of China (900,000 t) and Europe (260,000 t), it is expected that China will have overtaken North America by 2016. European production is estimated to grow annually by around 10%.

7. Finland´s position and areas of strength

Finland has a fantastic opportunity to be a frontrunner in a forest industry-led bioeconomy. Wood is Finland's strategic resource, and Finland's most significant renewable natural resource that is being processed on an industrial scale. Products made from wood, wood fibre, and other components of wood, replace non-renewable materials and fossil fuels as we move towards a low-carbon bioeconomy.

In relation to many other countries Finland has conditions conducive to the conversion to a bio-based economy. While the conversion from fossil- based to renewable raw materials could lead to competition for resources, it could also create new opportunities for supplementing traditional products with new products and services, with the aim of supporting and increasing Finland's competitiveness. The development of a bio-based economy will create excellent opportunities for increasing the usage of biomass raw materials in other industrial sectors, such as the transport sector, the automotive industry, construction sector, textile and chemical industry. Reusable and recyclable wood and fibre products can, at the end of their life cycle, be used for renewable energy together with biomass that is unsuited for further processing.

Finland has an advantage in terms of knowledge about and access to forest raw materials and their processing. Forest industry is one of our greatest export industries. According to the Finnish Forest Industries Federation, the annual production value is approximately 20.8 billion EUR. The industry's export value is nearly 11.4 billion EUR (2016), which corresponds to more than 22% of Finland's exports, and the industry collectively employs 41,000 people. In many parts of Finland, the forest industry is essential to employment and economic well-being. If the industry shall maintain its importance for the country a continuous forest and other biomass extraction at a minimum of current-day levels is needed, thus providing the basis for profitability throughout the supply chains.

This strategic research and innovation agenda for bio-based materials and products proceeds on the basis of existing opportunities in the forest industry and its significance in Finland and aims to create additional areas of strength for Finland through increased collaboration between various industry sectors and fields of knowledge. Although the forest is the basis for this area of strength, in the long term renewable resources from other farming will further strengthen this area and Finland's opportunities.

8. Building a Public Private Partnership (PPP) for added value cellulose products

Wood cellulose and fibre products have traditionally had a remarkable role in Finnish industry. By combining both large-scale and small-scale businesses together the Finnish cellulose community is expected to become even stronger in the global market in the future. In addition, the actors aim at covering the whole value chain from the raw material producer to the consumer, including pulp and fibre producers, converters, textile industry, composite producers and brand owners, as well as terchnology suppliers, chemical industry and the recycling sector.

The owners of CLIC Innovation are committed to create a Public Private Partnership that addresses the opportunity, which is created by the fact that the use of materials and especially the request of sustainable renewable raw materials is growing globally. Cellulose is a very good candidate to deliver the solution as it is abundant and can be sourced from sustainable forests. In Finland, we already have the world leading competence not only in cellulose production and conversion but also in doing the respective investments and selling the products. This enables a very competent platform, which is used for the further development of wood–based cellulose materials to novel application markets.

The PPP is expected to have a major impact on the renewal of the Finnish cellulose community and the generation of new networks in textile and composite value chains. A bold but still feasible impact could be a new, growing Finnish textile industry, which has the Finnish wood based raw material as a key competitive edge. The current textile fibre market is nearly 100 million tons annually. As the global population is growing as well as the general wealth especially in the developing countries, there is a projection for a steady and healthy market growth. Wood fibre and cellulose-based materials could have even greater impact in composites in terms of new market volume. Sustainable source of raw material is a key marketing aspect.

The industry owners of CLIC Innovation Ltd are prepared to co-finance 50 % of applied research within the PPP with a volume of around 10 million EUR annually if matching public funding is available. In addition, the companies will invest in demonstration and development projects with an aggregated annual budget of around 20-50 million EUR. Public funding will speed up the demonstration activities.

VISION AND TARGETS FOR THE ADDED VALUE CELLULOSE PARTNERSHIP

The vision is that the added-value cellulose is the preferred, sustainable material choice in the growing global materials market.

The target is to increase the net value created in Finland by the cellulose value network through developing new high-value products with longer lifetime (acting as carbon sinks). The target is also to be the leading global innovation and knowledge community for cellulose based innovations.

9. Research and Innovation Agenda

Research and development has to be complemented with innovative efforts and measures that, in particular, take on the challenges of a bio-economy. The nature and scope of the challenges require extensive cooperation between the players and the sectors must work together to manage the complex issues and the solutions needed for the challenges.

This entails offering incentives for collaboration on cross-industry research and innovation in order to develop and implement solutions that will contribute to a growing bio-based economy. Academic and research institutions have a pivotal role in linking such collaborations, but public- and private- sector players also have key roles. It is also important to stimulate the growth of environments for research and innovation, which will help in the compilation of relevant knowledge and create conditions conducive to innovations within the area.

There is a need to accelerate the development, verification and commercialization of new bio-based solutions and to continue supporting the demonstration of products, systems and services. There is also a need to support small and midsize companies in the commercialization of new technologies throughout the supply chain. This also applies especially to cooperation between major companies, if development and innovation are to be accelerated.

While development of the existing products with earlier established value networks within the Finnish cellulose community remains to be of great importance, the project topics in the PPP are focused on development of emerging business opportunities arising from new or emerging technological fields.

Close collaboration between the PPP for added value cellulose and the other activities currently being developed around the fields of packaging (Packaging Valley) and lignin will be crucial for a well-balanced and broad development of the forest-based industries. The in-depth development of packaging and lignin business will take place within those activities.

The basic material and process research has to be performed in close cooperation with academic research. The actual process and material development steps will be taken in public collaboration projects where major part of the development actions is performed within universities and research institutes in tight collaboration with the industrial partners. The industrial partners will be responsible for turning the public development project results into their own demonstration projects in which the new technologies and products made out of them, their business models and value proposition will be piloted in real end use cases.

The European and potentially wider policy frame for novel cellulose-based products and value networks needs to be included in the work of the PPP for added value cellulose since the legislation may improve the business potential of cellulose products. In addition to potential legislative drivers, the environmental sustainability of new cellulose-based value networks needs to be assessed along with the research and innovation actions to ensure the sustainable competitive edge of the developed cellulosic products.

Opportunities for new business based on sustainable chemicals and materials will be looked into as they arise from research activities within the universities and research institutes. The development needs within the PPP for added value cellulose arise mainly from emerging business opportunities in the fields of biocomposites, sustainable textiles and other sustainable material solutions, e.g. for packaging.

Traditional gap preventing a meaningful collaboration between the large volume businesses and small-scale enterprises may be bridged by new digital tools and services. This may have widespread consequences in supporting a vast number of small businesses while at the same time making servicing small businesses profitable also for large businesses. Consecutively new business will be created also for the digital services developers and providers.

This research and innovation agenda was developed within the network of CLIC Innovation's owners and partners, comprising a broad group of stakeholders representing business and research. Supporters of this agenda include leading companies in the forest industry, chemical industry, textile industry, technology industry, as well as universities and research institutes. Consequently, there is strong collective support from both business and research organisations.

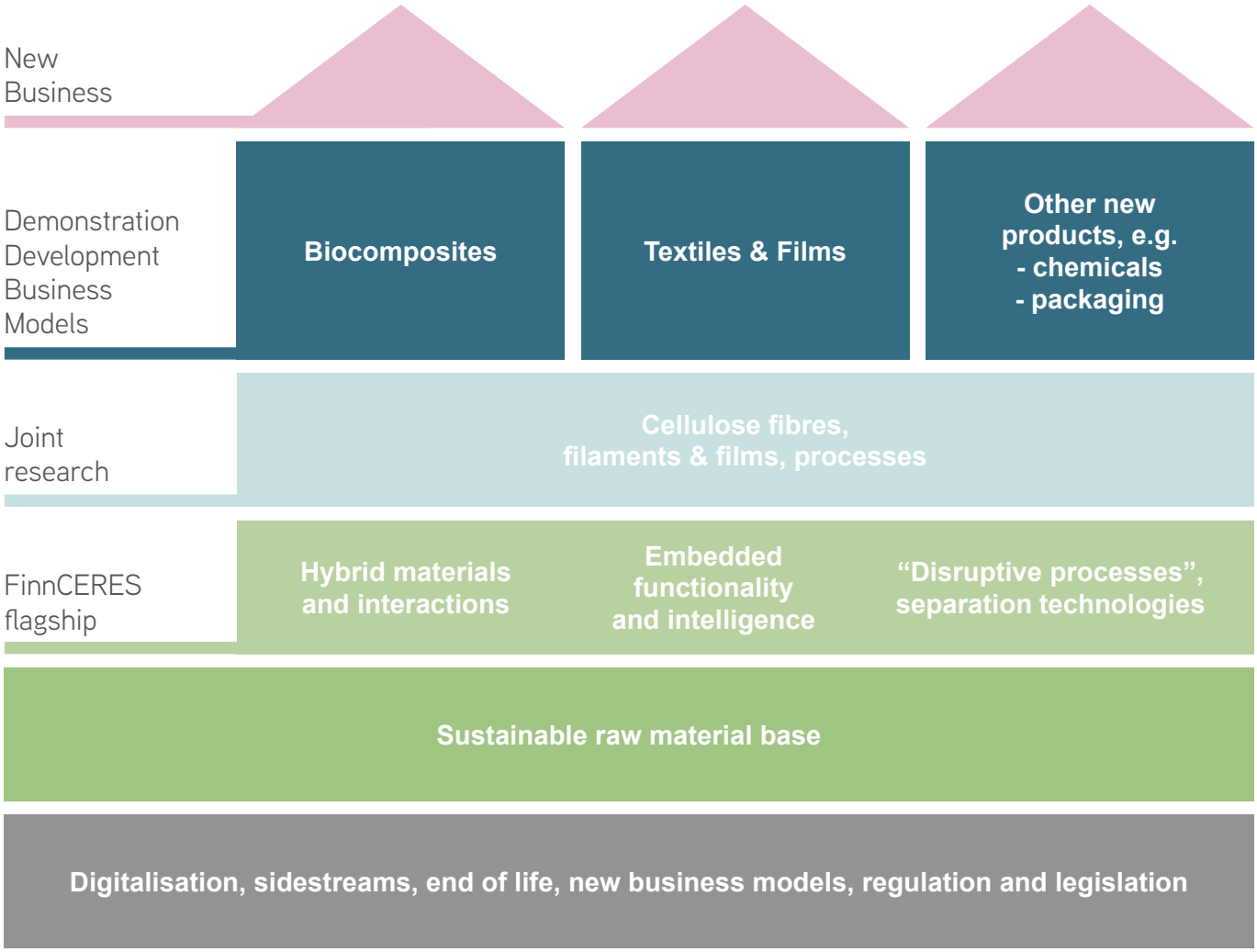


FIGURE 4. Structure of the Strategic Research and Innovation Agenda

9.1 BROADENING THE CELLULOSE PROPERTY SPACE

SUMMARY

For the Finnish cellulose community, a large potential lies in the development of novel chemicals and thermoplastics within the cellulose value chain as well as development of novel uses for the existing materials by developing their features and functionalities to meet with demands for sustainable solutions in e.g. packaging, textile and composite industries. For instance, it is estimated that demand for bioplastics/biopolymers will increase at a CAGR of 9.8% over the forecast period to reach 29 billion USD in 2021. The primary market for bioplastics remains packaging, but efforts to develop durable goods and other markets are rising.

OBJECTIVE

to explore the full potential of cellulose and related side streams in novel high value uses.

ACTIONS

In order to fully utilise the potential of the Finnish wood-based raw material new process and cellulose-based material innovations are developed for a broad spectrum of end-use applications. These actions include fractionation, separation, purification processes for wood-based biomass and its components, as well as derivatizing of cellulose. These processes and corresponding materials are developed to match the material properties for various end uses with technically and economically feasible processes. In addition, circular principles, where all fractions of the incoming biomass are valorised, are applied.

DESCRIPTION

Broad end-use potential with biobased chemicals and materials as building blocks or constructional elements for e.g. packaging, electronic products and durable goods opens completely new value chain opportunities for the cellulose industry.

The most lucrative research topics arising from academic research will be picked up and further advanced in the joint research projects by the academia and research institutes in collaboration with the industrial partners. The academic research may lead to new materials, processes and technologies which will be taken into use in the company led demonstration projects in any suitable field of use. Some of the new technologies may benefit the activities within the biocomposite and textile fields while other new technologies may open completely new business avenues within sustainable chemicals and packaging value chains.

The research to be conducted may comprise e.g. the following topics, which can lead to new openings for various different end uses:

- New types of cellulose based packaging materials, including biobased emulsion barriers
  - Use of cellulose and its derivatives in films and packaging coatings
  - Moisture tolerance, grease barrier properties, elongation, shrinkage
- Novel fractionation, separation and purification processes for cellulose and related processing side-streams
  - Target compounds: cellulose, hemicelluloses, lignin, hydroxy acids, wood extractives
  - Novel/tailored/modified separation matrices
  - Process concepts for fractionation and separation of the target compounds
  - Use of recovered biobased compounds in separation and purification matrices and in biocomposites
- New generation of cellulose derivatives and uses thereof
  - E.g. derivatives with multiple reagents
  - Combination of soluble cellulose derivatives/ particles with bio-based polymers and polyelectrolytes to form complex structures
- Recirculation and valorisation of processing side streams e.g. gases, wastewater and other waste and side streams in a mill environment
- Recyclability and recycling of the novel materials and their combinations
- Use of recycled materials and recovered biobased compounds as raw material for biocomposites and textiles
- Opportunities of industrial biotechnology and synthetic biology in the fibre value chain ■

9.2 SUSTAINABLE TEXTILES

SUMMARY

The global textile consumption is estimated to increase by a factor of three until 2050. Simultaneously existing technologies need to be replaced by more sustainable alternatives to reach the climate goals. The shortage of arable land and water for cotton cultivation increases the demand for man-made cellulosic fibres. Since traditional viscose process uses hazardous chemicals the opportunity for man-made cellulosic fibres is even bigger if a sustainable process can be developed. All the promising results with novel fibre manufacturing technologies within the Finnish fibre ecosystem have so far been created in a laboratory and semi-pilot scale. The development of an industrially viable fibre process requires a systematic process development across the whole process chain and up-scaling to a pilot plant scale. The key in capturing the potential increase in market demand for cellulosic fibres is to pilot and verify the properties of the newly developed fibres both within the textile industry's processes and in the end users' perspective.

OBJECTIVE

Upon successful piloting of various man-made cellulosic fibre production technologies at least one of them will reach industrial scale manufacturing. The industrial scale fibres will be proven to have market pull based on their functionality and proven environmental advantage. Recycling of process chemicals and utilization of sidestreams will make the business very profitable.

ACTIONS

In order to advance the novel textile fibre technologies, the key is to establish pilot scale production possibilities to provide the end use industries with adequate amounts of fibres to be tested in their processes and in end use. The detailed actions include:

- development of production processes, including chemical recycling to meet with economic and environmental demands
- setting up piloting infra to service multiple different technologies
- production of fibres for end user industries to test in industrially relevant processes
- end use testing of the fibres, both technological viability and usability
- development of new solvents for fibre dissolution
- understanding the process behaviour of solvents

DESCRIPTION

Since traditional viscose process uses hazardous chemicals the market opportunity is even bigger for man-made cellulosic fibres if a sustainable process can be developed. This challenge has been addressed for example in the FuBio Cellulose and ACel programmes of CLIC Innovation (former FIBIC). The new ionic liquid-based spinning process developed as a collaboration of prof. Kilpeläinen's group, University of Helsinki, and prof. Sixta's group, Aalto, (patent application US61/808415) has resulted in fibres with excellent appearance and strength properties, much better than those of the fibres obtained from existing commercial processes. This leads to a big opportunity for the Finnish forest industry and its network partners to develop a new brand based on the new ionic-liquid based fibre spinning process.

Other examples of a promising new technology for producing man-made fibres directly from wood fibre suspension by a wet spinning process have been introduced by VTT and Tampere University of Technology. In BioCelSol process the dissolution of cellulose is enhanced by means of mechanical and enzymatic treatments before dissolution in sodium zincate. In carbamate technology the dissolution is done in urea. A technology where the fibres are spun without chemical dissolution of cellulose has been spun out to a new enterprise, Spinnova Oy who is in charge of advancing the technology and commercializing its use.

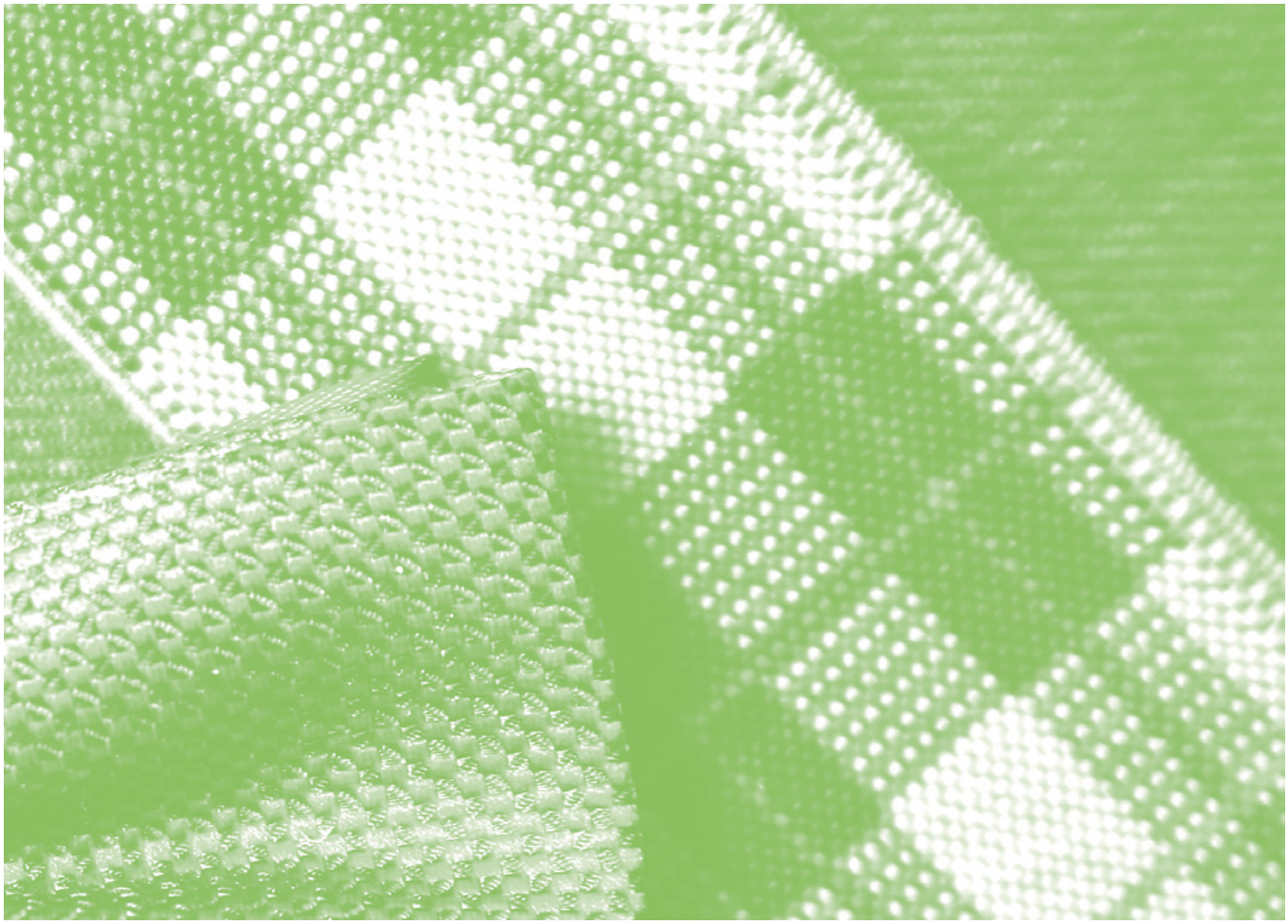
Advanced man-made cellulose fibres are expected to take market share from cotton. Additionally, one may speculate if also the strong share of polyester fibres could be targeted in selected high value segments, especially as there is a trend to move from fossil to bio-based products. This, of course, requires that the fibre properties have to be improved and the processes and raw materials have to be efficient and sustainable.

The starting point in Finland for establishing such new brands is excellent: high availability of raw material (pine/spruce and birch wood), best available technologies in sustainable wood fractionation technology for the pulp production (kraft biorefinery processes) followed by the refining of pulp qualities to the requested cellulose purity with e.g. the recently developed IONCELL-P process (US61/646383) and the conversion to regenerated cellulose fibres by means of the novel ionic liquid -based process.

Fibre innovations are essential for today's customers. It has been already shown that e.g. the new Ioncell-F fibres with good mechanical properties, moisture management and skin friendliness are expected to be fully competitive with commercial Lyocell fibres in the same textiles and nonwovens end-user segments and applications.

All the promising results obtained so far have been created in a laboratory and semi-pilot scale. The development of an industrially viable fibre process requires a systematic process development across the whole process chain and up-scaling to a pilot plant scale. A pilot plant would provide the scale-up design data and enable a sufficient production of fibres for customer evaluation and product demonstration.

The key in capturing the potential increase in market demand for cellulosic fibres is to pilot and verify the properties of the newly developed fibres both within the textile industry's processes and in the end users' perspective. This work will also build into determining the most potential market entry business cases for the fibre technologies and verify the value proposition. If the value proposition includes elements of environmental impact, this needs to be assessed in detail. The environmental advantages should be considered when developing business models for the new fibre technologies. The fast-developing circular economy can open opportunities for completely new business models which rely on a lower environmental footprint in the total operations cycle. ■



9.3 BIOCOMPOSITES

SUMMARY

Worldwide wood plastic composite (WPC) production is estimated to rise more than 15 % annually. New biocomposites with an attractive appearance, better long-term and short-term properties are sought after in the marketplace. In particular, lightweight, strong, durable materials that are also functional in terms of appearance, acoustics, tactility, and segment-specific properties are particularly desirable. The next generation of biocomposites should be tailor-made to suit intended applications.

OBJECTIVE

Biocomposites will become a major material alternative in the markets currently dominated by plastics and non-natural fibre composites. The PPP will open up completely new ecological application fields for biocomposites utilising also innovative business models to increase the value for the whole value chain. Use of raw materials from sidestreams as part of a biocomposite will become a lucrative alternative approach for reducing the environmental footprint of biocomposites.

ACTIONS

Joint research projects with collaboration of universities, research institutes and companies will be conducted to: a) increase the functionality of biocomposites and b) develop design and planning tools to match the biocomposite properties with its end use requirements

These technological targets will be reached by developing

- new materials and their combinations,
- material modification methods,
- processability of the materials and material combination, and
- biocomposite production processes to be tailored for the requirements of biocomposites (not for plastics) and to exploit the full potential of wood-based cellulose fibres in composites.

Company led **demonstration projects** comprising a selection of different size of businesses in one project will be conducted to demonstrate:

- the technological viability of a business case
- the economic viability of a business case
- new business models, including utilisation of digital tools

All actions need to assess the life cycle effect of its approach and turn the LCA information into business value

DESCRIPTION:

Bio-based composites are a group of materials comprising many different materials that can be used in a broad range of application areas. Application areas range from low volume high value to high volume commodity products.

Fibre Reinforced Polymeric Composites (FRPC) are used for a whole range of conventional composites. Glass fibre is clearly the largest reinforcement fibre, polyester the most commonly used thermoset and polyethylene the most common thermoplastic used as matrix in the composites, but a range of polymers are used as matrix depending on the application requirements and manufacturing methods.

Biobased composites are often considered as a material class of its own, although they clearly belong to the FRPC group. The gap between non-renewable and renewable fibres is getting smaller as new biobased fibres are developed.

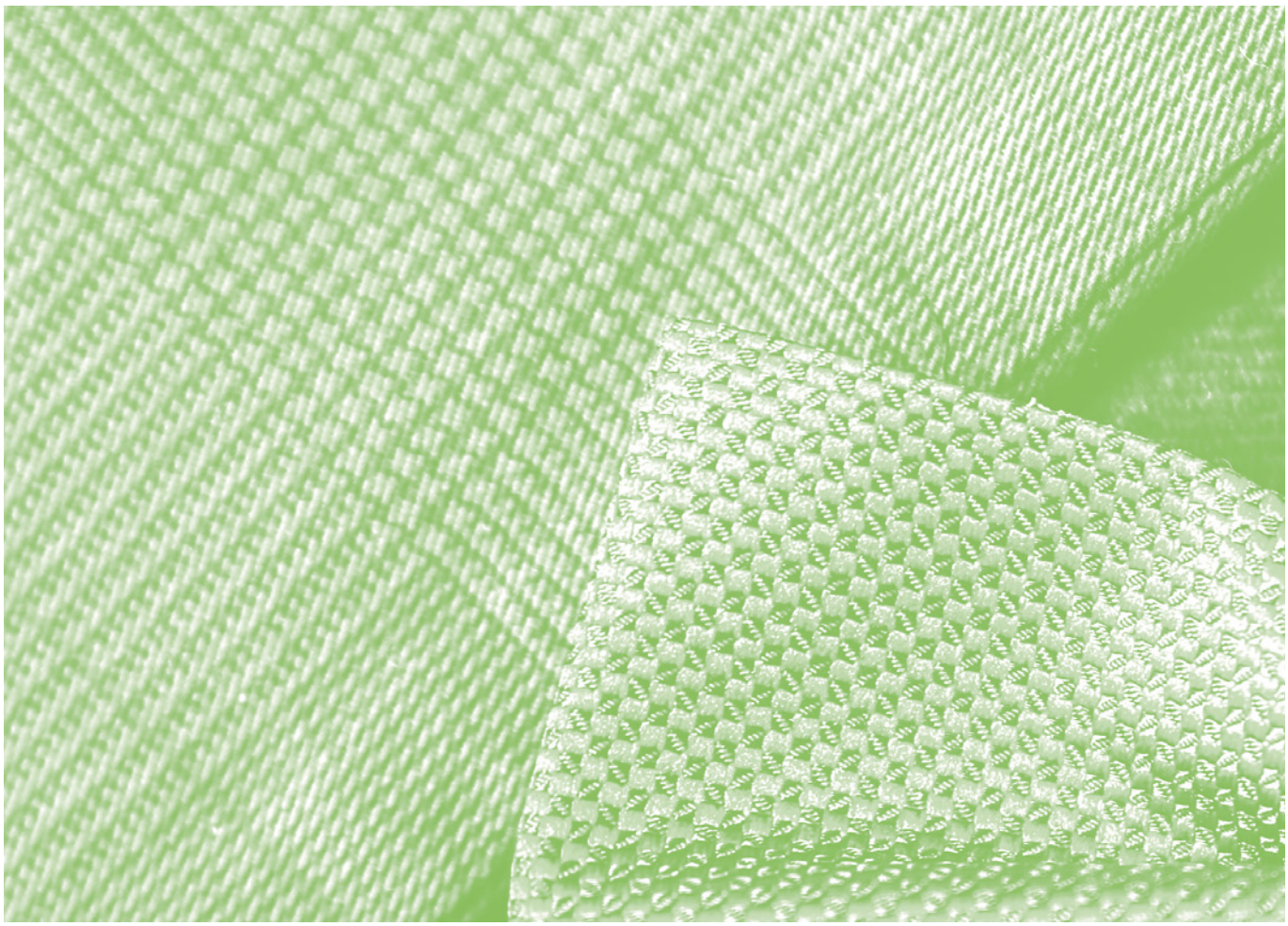
New biocomposites with an attractive appearance, better long-term and short-term properties and where processing is optimized for each application are sought after in the marketplace. In particular, lightweight, strong, durable materials that are also functional in terms of appearance, acoustics, tactility, and segment-specific properties are particularly desirable. Until now, biocomposites have been made using available materials. The next generation of biocomposites should be tailor-made to suit intended applications thereby ensuring the Finnish industry's competitiveness.

Cellulose fibres have properties and attributes that make them interesting as reinforcing elements in thermoplastics from both a technical and a commercial perspective. Low density, good specific stiffness, low abrasive nature combined with low cost, renewability, biodegradability, availability, end-of-life disposal and potential for modification are some of the advantages.

Some challenges remain, however, that need to be met when manufacturing cellulose-reinforced composites. For instance, the compatibility of fibre and plastic matrix is critical for the reinforcement effect. Another example of a potential challenge is the water absorbency of fibers at the cut surface which might cause problems in outdoor applications. New cost-efficient fractionation methods make potential development with hemicellulose an opportunity, also as a bio-based adhesive.

In addition to material specific development needs the key in meeting the demands for biocomposite performance lies in the processability of the materials and compatibility of the materials combined in a biocomposite. Development of biocomposite specific processes both in the pretreatment of the materials as well as in the final production step would benefit the whole biocomposite industry.

One of the key perceived value propositions for biocomposites bases on their environmental benefits, including reaching a required performance level with a lighter structure and/or with lower environmental footprint. The end of life use of biocomposites depends on polymer base, whether polymers are thermosetting or thermoplastic. Recyclability of both material classes is good compared to glass fibre reinforced composites which have very limited reuse possibilities while cellulose or other natural fibre reinforced composites can be recycled to novel materials. It is of utmost importance to quantify the environmental advantages of biocomposites in given applications and benchmark against competing solutions. Correspondingly important is to find the most suitable business and use cases for biocomposites and explore the potential for new business models which rely on the value proposition of biocomposites and could potentially open up new market for biocomposites. Tight and functioning collaboration between different size of enterprises as well as start-ups and research groups throughout the whole value chain from material producer to the end user will ensure a successful and fast capture of the business potential the new end products and new business models will open. Agile small and medium sized enterprises will be in key role in introducing the new material technologies in the end use cases. ■



9.4 ACCESSIBILITY OF SUSTAINABLE BIOMASS

SUMMARY

The sustainable use of forest resources is the core of a successful forest-based bioeconomy. Sustainable multifunctional forest management aims to balance the complex and sometimes conflicting sets of demands on forests, for the benefit of all. Finland is one of the most forested countries in Europe. The growing stock in Finland has steadily increased over the last 50 years. The demand for wood is estimated to increase markedly in the near future, due to the growing bioeconomy. To secure the future sustainable biomass supply and the multipurpose use of the forests, the annual growth of forests needs to be increased. New methods in forest management and wood supply are needed to increase the profitability of wood production, increase the cost-efficiency of wood procurement and logistics.

OBJECTIVE

To increase the annual increment in the Finnish forest to 150 million cubic meters to meet demands from the growing bioeconomy and simultaneously secure the sustainable multipurpose use of the forests.

ACTIONS

Joint research with collaboration of universities, research institutes and companies will be conducted to:

- Enhance the availability of improved forest regeneration material
- Improve the efficiency of the supply chain
- Remove the bottlenecks of regeneration and young stand management
- Boost growth of high quality wood with forest fertilization in a sustainable manner
- Develop sustainable and resource-smart management of peatland forests
- Evaluate the impacts of activities on the amount and properties of produced raw material
- Evaluate the socio-economic impacts to different actors and stakeholders
- Evaluate the environmental impacts and ecological sustainability

Company-led activities include:

- Deployment of improved forest regeneration material
- Implementation of novel operational models among the actors

DESCRIPTION

The sustainable use of forest resources is the core of a successful forest-based bioeconomy. Managing forests sustainably means to manage and use the forests in such a way that future generations will benefit from forests as much as, and possibly even more than, we do now. Their biodiversity, productivity, regeneration capacity and vitality are maintained while leaving all interconnected ecosystems intact. Forests that are managed sustainably will maintain their potential to fulfill relevant ecological, economic and social functions.

The functions of forests are manifold and often the same forest area needs to provide a mix of functions simultaneously. Forest management practices are adapted to diverse policy goals and social expectations. The main focus of a forest's function does not mean that other essential functions are neglected. Sustainable multifunctional forest management aims to balance the complex and sometimes conflicting sets of demands on forests, for the benefit of all.

Finland is one of the most forested countries in Europe. Three quarters of Finland (about 23 million hectares) is forest, representing about 10% of the forest area in Europe. The growing stock in Finland has steadily increased over the last 50 years, being now 2 464 million cubic meters (annual increment 110 million cubic meters). Since beginning of the 1970's increment has been higher than the total drain. In recent years, the annual fellings have been on average 68 million cubic meter per year (62 % of the increment). In recent years, the annual net carbon sink of forests has been about 38 million CO2 equivalent tons.According to a study made by the Natural Resources Institute Finland, the sustainable felling potential of the Finnish forests would be 85 million cubic meters of stem wood per year for the years 2015–2024.

The demand for wood is estimated to increase markedly in the near future, due to the growing bioeconomy.

To secure the future sustainable biomass supply and the multipurpose use of the forests, the annual growth of forests needs to be increased. New methods in forest management and wood supply are needed to increase the profitability of wood production, increase the cost-efficiency of wood procurement and logistics.

Topics

- Deployment of improved forest regeneration material
- Enhancing the availability of improved forest material
- Improving the efficiency of the supply chain
- Removing the bottlenecks of regeneration and young stand management
- Boosting growth of high quality wood with forest fertilization in a sustainable manner
- Sustainable and resource-smart management of peatland forests

Viewpoints

Impacts of activities on the amount and properties of produced raw material

- Socio-economic impacts to different actors and stakeholders
- Environmental impacts and ecological sustainability

Activities

Research and development

- Implementation of novel operational models among the actors (piloting, cooperation, training)
- Communication (stakeholder networks and events, media) ■

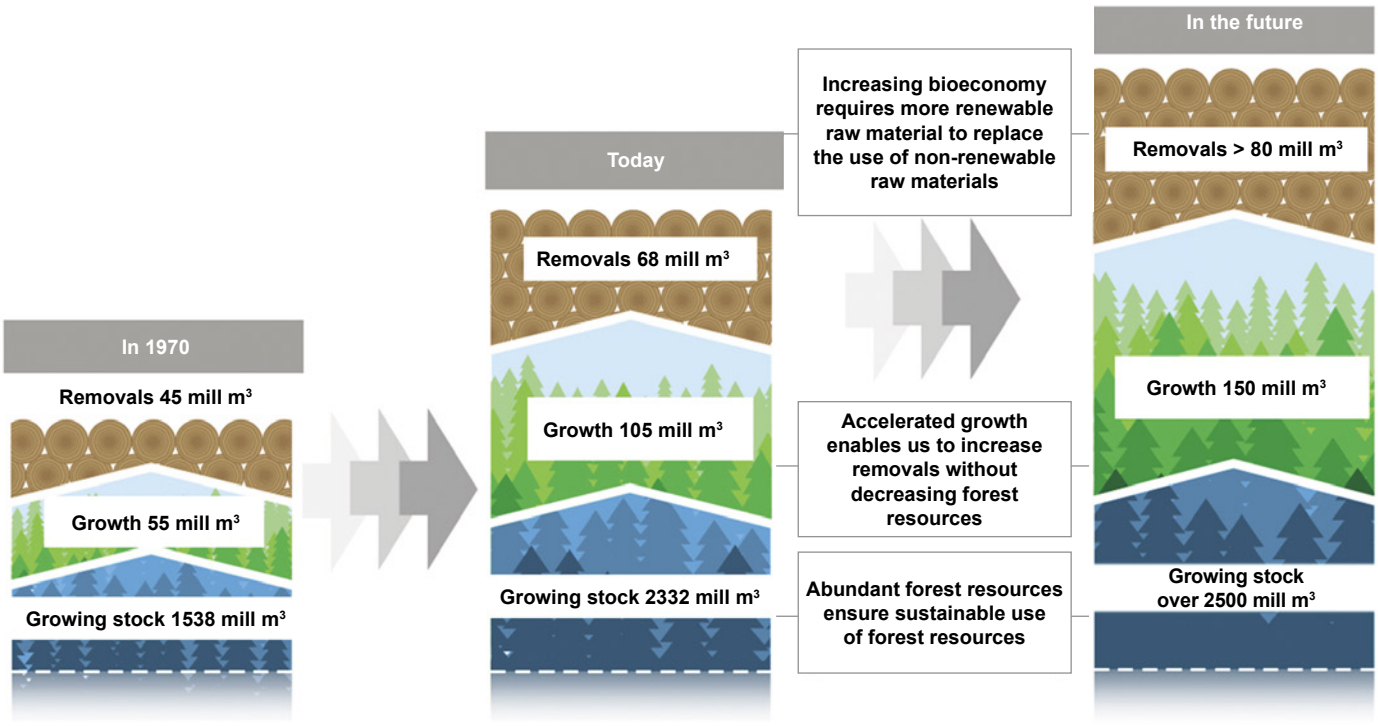


FIGURE 5. Increase of forest growth is prerequisite for increasing cutting removals sustainably.

10. Call to action

Finland has a fantastic opportunity to be a frontrunner in a forest industry-led circular bioeconomy. Wood is Finland's strategic resource, and Finland's most significant renewable natural resource that is being processed on an industrial scale. Products made from wood, wood fibre, and other components of wood, replace non-renewable materials and fossil fuels as we move towards a low-carbon bioeconomy.

Our aim is to create a Public-Private Partnership (PPP) in Finland with the ultimate aim of developing new added-value cellulose-based products for the global market. The owners of CLIC Innovation are prepared to invest significantly in the Public-Private Partnership both by co-financing applied research and by investing in demonstration and development projects and the Partnership is open for all actors who want to join.

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Notes

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https://clicinnovation.fi/