Wood-Based Bioeconomy Solving Global Challenges

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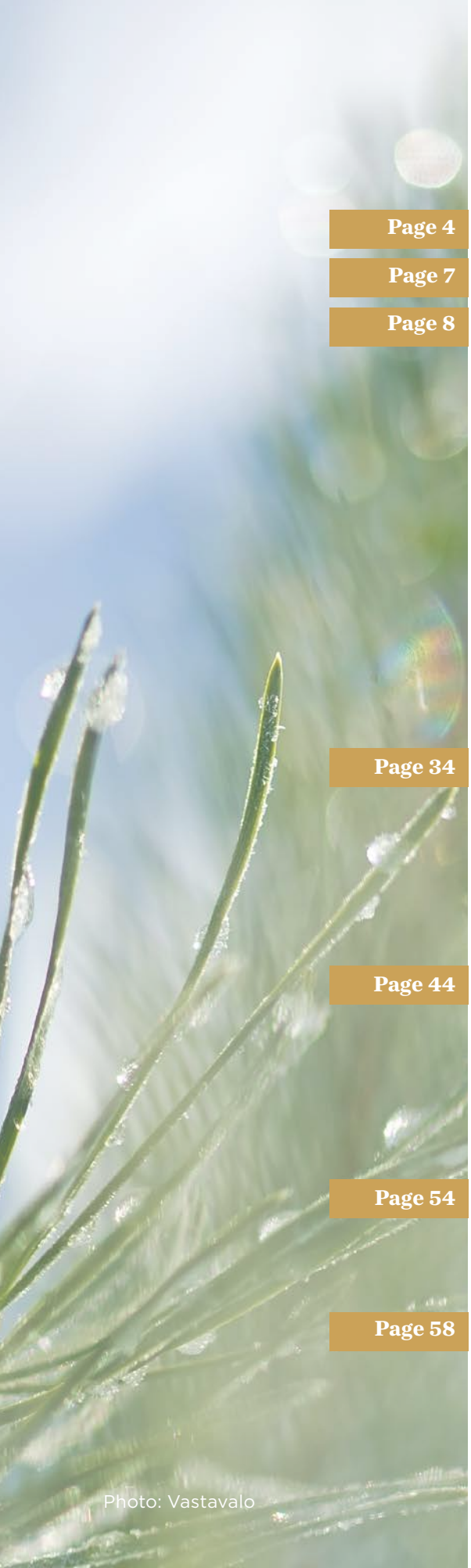

Photo: Vastavalo

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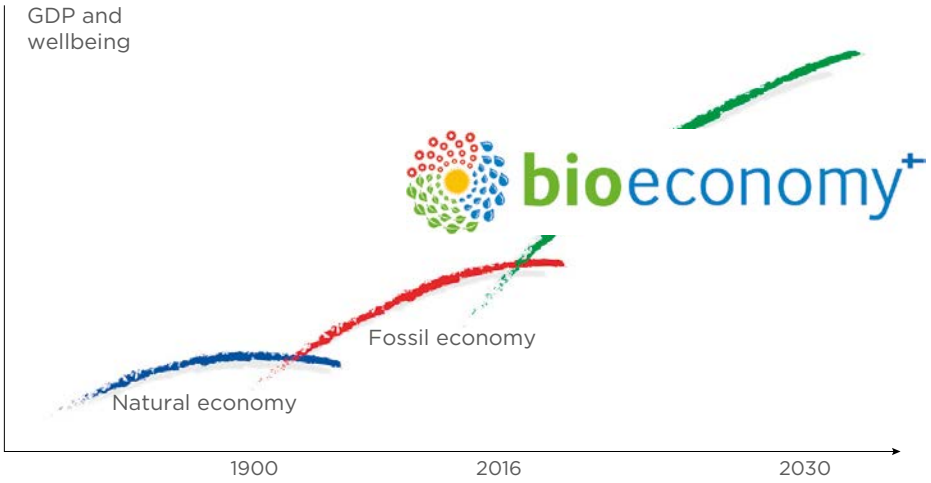
Radical innovations from wood

Companies, governments and individual consumers have awakened to the problems caused by global warming and waning natural resources. In Finland, forests provide a platform to tackle such global challenges, as wood raw materials contain ingredients that have only recently been detected and developed for new uses. As a renewable natural resource, ingredients from wood can be valorised in innovative bio-products, alongside a range of conventional forest industry products. In this new context, our vision is that each ingredient in wood should be refined into an end use that provides the best value-added on the market. To implement such a vision, major breakthroughs have been accomplished in Finland. Traditional mill sites of large forest industry companies are in the process of becoming biorefineries. The start-up boom, which began in Finland around the turn of the century in the ICT and game industry sectors, has also entered to the bio-based industrial field. Research-based spin-offs and start-ups constitute a core element in the business ecosystem of a biorefinery. Major

investments have been made in new pilot and demonstration facilities, helping start-ups and established companies to test their inventions and accelerate their transition from basic research to commercialisation. In the national innovation system, new multidisciplinary knowledge concentrations have been formed and they function as seed beds for radical process and product innovations and educate specialists for knowledge-intensive services. The areal coverage of forests in Finland is the highest among the EU countries. Due to the significance of the forest sector in the Finnish economy, forests are sustainably managed and certified. Individualised forest areas can be monitored by using digitalised databases that also inform forest owners and wood markets about the amount and characteristics of the growing wood resources.

No wonder that in 2014 the Finnish government published the National Bioeconomy Strategy, based on a major mobilisation of stakeholders. It has set the objective to push the bioeconomy output to EUR 100 billion by 2025 and to create 100 000 new jobs. To implement such objectives, we have identified in our governmental programme five strategic priorities, one of them being the bioeconomy and clean solutions. These strategic priorities are supported by the establishment of key projects and allocation of funding to them. To support the bioeconomy, it is important that wood raw material is available for the market, as the annual growth of forests in Finland is much greater than the volume of trees that are annually harvested. Wood is also one of the sources of renewable energy. The government intends to increase the percentage of renewable energy out of the total energy consumption in Finland beyond 50 per cent by the 2020s.

By extending the scope of actors in local business ecosystems, forest industry companies are developing their mill sites into biorefineries.



The bioeconomy will be the next source of economic growth. With the National Bioeconomy Strategy, Finland aims to push the bioeconomy to create new jobs.

Research-based spin-offs and start-ups accelerate the development of business ecosystems.

Customers from various parts of the globe are using the knowledge-intensive services that the laboratories and pilot centres in Finland provide, and different types of economic actors have become interested in the business opportunities that are embedded in biorefineries. Foreign companies have become shareholders in growing bio-based business operations in Finland, and they have set up their own production operations in existing biorefineries or have made equity investments in start-ups. For potential investors abroad, Invest in Finland (www.investinfinland.fi) provides relevant services.

We invite you to read further about Finnish expertise and innovations related to the emerging bio-based industrial field providing benefits to the entire world.

Mika Lintilä
Minister of Economic Affairs
Finnish Government

Photo: Vastavalo

Introduction

This publication presents insights into the renewal of the Finnish forest sector and the emergence of the wood-based bioeconomy field. Many innovations are in the pipeline, and existing logistical and production processes provide platforms for start-ups. Both large and small companies build their businesses on breakthroughs in research and piloting. To reach end users in the markets, new value chains are emerging. Further inspiration comes from evidence that business-based operations – new products and operating modes – contribute to the solving of major global societal problems. To reach such goals, a variety of initiatives have been implemented by actors in the Finnish business and innovation systems in close cooperation with each other.

The use of natural resources in a sustainable way, both environmentally and socially, is the fundamental principle. Agricultural land has not been switched to bioenergy production in Finland, materials are used and re-used as comprehensively as possible and biofuel is made from process waste. No fossil fuels are used in the production processes of a bioproduct mill. Globally, wood-based textiles may at least to some extent substitute cotton, which requires much greater amounts of water, chemicals and energy compared to the growth of forests. Consequently, the land now used for the cultivation of cotton plants could instead be used to grow food crops.

We have invited specialists in the bioeconomy field to compile articles for the present publication. In addition, interviews with key actors are included, representing the core of the ongoing transformation process in the bioeconomy field. On behalf of all who have contributed to the present publication, we hope that this information package will stimulate dialogue and contacts from a variety of stakeholders, both in Europe and more widely in the global context.

Kari Lilja and Kirsti Loukola-Ruskeeniemi
Editors of the volume

Mika Aalto, Jussi Manninen and Reima Sutinen
Members of the strategic planning team for the publication

Ministry of Economic Affairs and Employment

The Landscape for Radical Product Innovations

In Finland, the annual growth of forests is close to 110 million cubic metres of wood, out of which 60–65 per cent is utilised annually.

Finland is wll-known for growing forest resources that are managed in a sustainable manner and that are mainly certified. The utilisation of wood could be increased by approximately 20 million cubic metres per year by, for example, increasing its use as a source of energy, in construction, in the wood-product industry and for various bioproducts.

The forest sector plays an important role in the Finnish national economy: it accounts for a fifth of Finland's export income and produces around 70 per cent of the country's renewable energy.

Photo: Vastavalo

The role of forests in the development of the Finnish economy

The history of human influence on forests in Finland is long and varied. People have lived in and used forests in many ways. Game, berries and mushrooms have provided an important source of food. Here, the livelihood and cultural development of the population has been more dependent on forests than anywhere else in Europe. For several hundreds of years, the economy of Finland has been based on the exploitation of local forests: initially for hunting, slash-and-burn agriculture and tar burning, later for forestry and by the forest industry, and more recently also by the forest- and wood-based bioeconomy and related businesses.

In Finland, 86 per cent of the land area is covered by forest. This is the highest coverage in Europe.

The production of tar and sawn timber generated welfare for all of Finland from the 18th century. The industrial use of forests for paper products began in the late 19th century. A hundred years ago, forest industry products accounted for no less than 80 per cent of Finland's total exports of goods. Today, the forest industry accounts for 22 per cent of export revenues, amounting to EUR 11.5 billion, and forms one of the cornerstones of the national economy. Products of the pulp and paper industries account for about three quarters of the exports of all forest industry products, while the respective figure for the wood products industries is about 25 per cent. The gross value of manufacturing of the Finnish forest industry is about EUR 21 billion. Relative to its size, Finland is more dependent on forests and the forest industry than any other country in the world.

As a consequence, Finland has accumulated expertise in forestry and the industrial manufacturing of forest products that is unique in Europe. Modern pulp and paper mills operate with an integrated approach using industrial by-products (waste liquors and waste wood such as black liquor, bark, sawdust and process waste, and recycled wood) for the production of heat and energy. The new emerging bio-based forest industry is aiming at producing biofuels and other more value-added products based on wood.

New and existing wood-based products. (Diagram: VTT Technical Research Centre of Finland Ltd, Photos: Vastavalo, Metsä Group)

Forests are a truly renewable natural resource that is sustainably managed and certified in Finland.

The forest-based bioeconomy builds on the traditional forest industry, since new bioproducts are in most cases extensions to existing product portfolios in Finland. The role of the traditional forest industry is crucial, because it forms a solid platform for the development of new innovative bioproducts. The production of traditional pulp generates valuable streams that can be utilised for new value-added products. In other words, traditional production is a prerequisite for the rise of new value-added products.

The new bioproducts, such as wood-based textile fibres, provide possibilities for the eco-friendly fashion industry globally. For instance, the production of wood-based textile fibres may release cotton fields for food production.

Even in Finland, forest-based biomass is not a limitless resource. We need to utilize it in a sustainable way. We must develop technologies for the resource-efficient use of biomass, produce various products with different values and minimise waste.

Reima Sutinen
Ministerial Advisor
Ministry of Economic Affairs and Employment

The scope of innovations and new products

Sustainably produced wood and its components are the future bio raw material for versatile added-value products. Wood-derived products can open business opportunities for both current and new large- and small-scale companies. Wood-based materials and components are already now used, for instance, in paper, packaging, composite, textile and construction applications. In the future, wood fibres, biopolymers and molecules will be used to replace synthetic, unsustainable or diminishing materials, or to generate new functional, added-value products for the needs of the growing global population.

During the last ten years, the Finnish forest industry has been transforming into a bioproduct industry. Companies are actively searching for improvements in the properties of their current products and expanding their product portfolio to new value chains. New products such as biocomposites, paper mulches and biofuels have already recently been launched. Wood cellulose, lignin and bioactive components can also offer new product opportunities for companies that are currently using other raw material sources, or even for new companies. Guitars, interior design lights and health-promoting sap and phenolic extracts are examples of the already existing new generation products. Moreover, wood-based materials can be used as cost-efficient and biodegradable carriers for new diagnostic and other printed or hybrid functionalities. The true potential of new added-value wood-based products and applications is in the innovative use of the inherent unique properties of wood and its components in combination with novel production and conversion technologies, product design and the Internet of Things (IoT).

Biocomposites can be used in versatile end products, including guitars. (Flaxwood Ltd. Photos: Niko Jouhkimainen)

A new innovation, thermo-formable wood material, makes the form-pressing process more efficient and saves energy. (Photo: UPM Plc)

Ecological thermo-formable wood material used in interior decoration. (Photo: UPM Plc)

Micro- and nanocellulose possess unique strength and surface properties.

The future lies in active, intelligent, safe and sustainable wood-based products. The roadmap to the future includes the promotion of cross-industrial collaboration and the formation of new value chains. Furthermore, flexible demonstration environments for new products and their production technologies, "biorefinery hubs", are needed. In parallel, radical openings that combine wood-based materials, technology, digitalization and design should be generated and supported.

Examples of recent new wood-based products

In biocomposites, cellulose fibres have been successfully combined with either virgin or recycled polymers in order to produce materials suitable for interior, outdoor, construction and musical instrument applications. In comparison with glass fibre–reinforced polymer composites, cellulose fibre–biopolymer composites are light and have good performance and appearance, as well as better recyclability and a smaller environmental footprint.

Plastic waste is a global problem. It is disturbing ocean ecosystems, and through nutrient cycles, also affecting the well-being of mankind. The need to reduce plastic waste and at the same time retain efficient arable farming and prevent erosion have found a solution from paper mulch. Each year, approximately 90,000 square kilometres of arable land are covered by plastic mulch. In the spring of 2016, Stora Enso launched a mechanically laid paper mulch for large-scale farming, offering a well-performing and feasible option for farmers. The reduction of plastic waste in the environment is also aimed at by Paptic Ltd, a start-up that has developed a business model for innovative wood fibre-based bags for consumers. These new products are good examples of the potential new uses of paper machines and the benefits of converting extensive expertise in papermaking to new bio-based product solutions.

The natural properties of wood-based products can also be harnessed as such in new printed and hybrid functional products. The capability of paper to wick and transfer fluids has been used to develop cost-efficient, biodegradable paper-based diagnostic platforms with printed fluid-guiding structures. For instance, a start-up called The Active Paper Company (www.theactivepaper.com) offers a platform for easy-to-use everyday diagnostics. Furthermore, the integration of different electronic functionalities and components in wood-based substrates using printing-based and hybrid methods has been demonstrated in a roll-to-roll manufacturing process and forms a basis for new wireless communication solutions, e.g. for logistics and diagnostics. Moreover, wood-based materials can be used as a basis for a disposable microcurrent power source applicable for new cosmetic products.

The need for textiles and hygienic products is increasing globally due to population growth and the growing middle class. Because of the concurrent stagnating production capacity of cotton, it has been estimated that the gap between the demand for and production of cellulose-based fibres will be 7–9 million tons annually by the year 2050. This is an exciting opportunity for wood cellulose-based man-made fibres. The development of

The future lies in intelligent, safe and sustainable wood-based products. Wood lignin can replace fossil materials in many end products.

new textile fibre production technologies outperforming the current viscose and lyocell processes in sustainability, safety and feasibility is currently in progress in Finland. Textile fibres produced from virgin pulp or recycled newspaper with these new spinning technologies will offer opportunities in the future for companies in textile, hygiene and composite value chains.

Cellulose is the future super material. Nanocellulose, the smallest fibrous structure in wood fibres, possesses unique strength and surface properties that have a vast application potential. Nanocellulose is already used to improve the properties of paper products. It has high potential in various other applications, including biocomposites, packaging, filtering, hygiene, medical applications, electronics and construction. Novel additive processing technologies, such as 3D printing, allow the creation of cellulose-based structures designed for purpose.

Environmentally friendly biocomposite material used for decking. (Photo: UPM Plc)

Ecological thermo-formable wood material replacing steel sheets in cars. (Photo: UPM Plc)

Lignin is another valuable wood-based resource for novel bio-based products. Annually, approximately 60 million tons of lignin is extracted from wood as a by-product of the pulping industry. Wood lignin has a high potential for added-value applications, for instance in concrete, adhesives and other chemicals, in addition to its current energy use.

Nordic wood is a rich source of bioactive components. Some of these have already been commercialized, for example in health-promoting products, such as spruce lignans for prostate cancer prevention by Separation Research and spruce hemicellulose for helping to alleviate urinary tract symptoms by Montisera. Others components are waiting to come in health, medical, IT and cosmetic applications.

Anna Suurnäkki
PhD, Research Manager
VTT Technical Research Centre of Finland Ltd
(currently Development Manager at Metsä Fibre Ltd)

WOOD – what a wonderful raw material to improve the quality of life of a human being

Source: Ainomaija Haarla

UPM DogBone for global supply chain applications and radio frequency identification. (Photo: UPM Plc)

Interviews with

Markus Mannström
Chief Technology Officer
Stora Enso

Jyrki Ovaska
Executive Vice-President for Technology
UPM

Niklas von Weymarn
Vice-President for Research
Metsä Fibre Ltd

The ongoing transformation in forest industry companies

The large Finnish-based forest industry companies have grown and internationalised through mergers and acquisitions. Before the turn of the century, the focus for their growth was the printing paper segment. Thus, the decline in the demand for printing paper in the Western Hemisphere after the turn of the century strongly hit the turnover of the companies in the paper industry. The companies responded to this change in their business environment by closing down large numbers of paper production lines and several paper mills. In parallel with the restructuring of their business areas, they engaged in experimentation to produce radical product innovations. As a consequence, they have brought to the markets completely new bio-based products and have turned their mill sites into biorefineries, which have the mission to make use of every ingredient in the wood material and valorise them with the best possible value-added on the market. To develop new products and facilitate the use of every ingredient in wood, they have also been active in the formation of research-related ecosystems. Together with the aims to enter into the formation of new value chains, a core element in their transformation process is the commitment to finding sustainable solutions to severe global problems, such as climate change and the scarcity of non-renewable natural resources, together with other actors in their ecosystems.

In the following, we provide perspectives on the ongoing transformation process in the three largest forest industry companies via interview statements of the directors, who are deeply involved in the transition towards the bioeconomy.

'We are creating new business activities that are rooted in the use of wood-based biomass as a raw material. The infrastructure – in the form of wood raw material procurement and versatile mill sites turned into biorefineries – is for the most part in place, and new expertise has been built beyond the existing know-how. By doing so, the forest industry is expanding into fields that are new to it,' says Jyrki Ovaska, UPM's Executive Vice President for Technology. He continues: 'Developing new bio-based products requires long-term commitment, as no fast results are on the horizon. The path to finished products and new business activities takes both time and money. Funding and other resources are required upfront, well before the cash flow starts running in.' Fortunately, all three of the large forest industry companies are profitable in their existing businesses. However, for R&D in private–public partnerships in the new bioeconomy field, both national-level and EU-level funding is needed.

Bio-based product development is typically carried out by forest industry companies in networks comprising technology providers, research institutes and universities. Often, expertise must also be sought from further away.

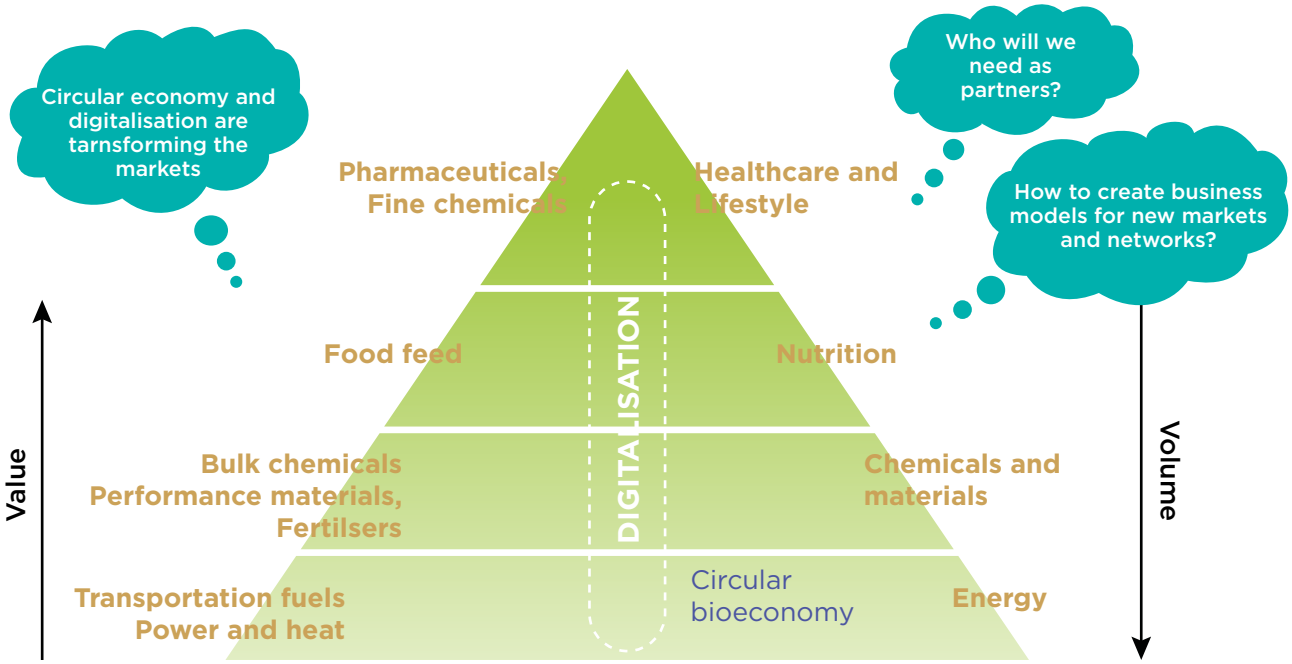
The wood-based bioeconomy is boosted by the efficient higher-education sector and free university-level education for students from all EU countries.

The first biomedical solutions and commercial applications made of biofibrils have recently been launched for cell cultivation. (Photo: iStockphoto)

GrowDex® is highly biocompatible with human cells and tissues. It provides a 3D culture to analyse how cancer cells react to medical treatment. (Photo: iStockphoto)

Wood-based biochemicals will open up completely new horizons and are an interesting, sustainable alternative for various industries and applications. (Photo: UPM Plc)

UPM Biochemicals has developed GrowDex®, a cellulose based hydrogel for 3D cell culture. GrowDex is a strong example of completely new applications for wood-based materials. (Photo: UPM Plc)



Bioeconomy value chains. The bioeconomy utilizes clean technology when sustainably producing products and services.

The Finnish forest industry brings to the global market recyclable products made from renewable materials.

The availability of suitable expertise, collaboration between the public sector and companies, and the correct allocation of funds are all factors that demand attention. The national innovation system in Finland has been oriented towards this new horizon of action by setting up open innovation companies that have the mission to develop thematic and systemic research programmes and organise the selection of partners for open innovation activities and company-specific projects. Private companies, universities and research institutes are owners of these public–private open innovation platforms. They obtain part of the funding from the state budget via TEKES, the Finnish Funding Agency for Innovation. In the R&D activities for the formation of the bioeconomy field, CLIC Innovation Ltd(www.clicinnovation.fi) is the core actor. It was formed in 2014 as a result of a merger between two former strategic centres for science, technology and innovation (FIBIC for Bioeconomy and CLEEN for clean tech and the circular economy).

'New, wood-based bioproducts are an excellent investment choice for both national and EU funds. But we must also invest in the existing business activities, which have already gained a foothold in the export market. We can still break new ground in these sectors,' says Markus Mannström, Chief Technology Officer in Stora Enso. As an example, he mentions the increases in production efficiency brought by digitalisation.

Bio-based materials and chemicals

As to the potential for radical product innovations, biochemicals have often been listed among the top. Biochemicals represent new and interesting territory for the forest industry. The sector is actively investigating new technologies for separating wood-based biomass into its constituent components, which can then be processed into finished products or used as raw materials in the chemical, food and medical

industries. For instance, for the chemical industry, 60 to 70 chemical components can be made from wood-based biomass and used in the production of a wide range of products, including paints, solvents, epoxy, resins, polyurethane insulation elements and transparent films. Biochemicals can thus be used as an alternative to numerous oil-based chemicals.

'Biochemicals will open completely new horizons. They provide numerous applications. Stora Enso recently began extracting lignin on an industrial scale with a view to using it as a replacement for fossil material-based glues,' Markus Mannström states as an example.

Biofibrils, which are also referred to as micro- and nanofibrillated cellulose, have recently been developed into an exciting commercial application by UPM. This biomedical solution can be used in cell cultivation and wound treatment products. UPM has launched a distinct product brand for this application area called GrowDex®. It is gel that is highly biocompatible with human cells and tissues. It provides a 3D culture to analyse how cancer cells are reacting to medical treatment. It is being used in pharmaceutical research and development by more than a hundred researchers.

Biocomposites

Biocomposites are another product area in the bio-product field. 'Biocomposites are composite materials comprising wood and plastic, in which wood is used as a replacement for plastic. Its applications include injection moulding and numerous end products, including furniture, electronics, vehicle parts and other consumer goods,' Jyrki Ovaska tells us. When using biofibrils and biocomposites together, the potential for more widespread utilisation of wood-based materials can emerge.

eCommerce, digitalisation and the boost for cardboard

Cardboard and wood-based packaging materials are among the traditional forest industry products. As living standards around the world continue to rise and online shopping increases in popularity, the demand for these renewable packaging materials will reach new heights and provide an alternative to many of today's packaging materials, such as plastic and aluminium.

Only half of each mass unit of wood delivered to the mill site comprises the main product, pulp. The other half is available for other production streams.

Photo: StoraEnso Plc

Packaging products will undergo considerable changes because of new requirements related to the recyclability and reuse of materials, advances in sensor technology, and new coating materials. 'Digitalisation will enable the production of packaging materials that offer smart features, additional information and various ways to interact with consumers. It will also allow us to monitor and streamline the flow of goods and information. A smart food package can, for example, indicate whether the food within has gone off,' says Markus Mannström.

New materials and technologies, such as dispersion coating for cardboard production, will provide barrier properties that will reduce fossil plastics in food service end use applications, especially in paper cups, and will make the products fully renewable.

The world's most efficient bioproduct mill now under construction in Finland

Metsä Group is building a next-generation bioproduct mill in Äänekoski, Central Finland. It is the largest investment in the history of the Finnish forest industry, worth EUR 1.2 billion. A new generation pulp mill, scheduled to begin its operation in the third quarter of 2017, is at the core of the bioproduct mill. The pulp mill will produce 1.3 million tonnes of pulp a year as the main product.

Why did Metsä Group decide to invest specifically in Finland? 'In Finland, all the basic elements enabling the investment are in place. We have sizeable forest resources, additional investments are made in the infrastructure, and everything works. We also have an efficient higher-education sector and free university-level education that produces expertise and skilled employees. In competitive benchmarking, the mill sites in Finland are from a technological and environmental impact point of view in an excellent shape. For product development, research institutes and pilot facilities provide world-class services, and finally, we have a growing start-up landscape in the fields of bioeconomy and digitalisation,' explains **Niklas von Weymarn**, Metsä Fibre's Vice-President for Research, when listing the reasons behind the investment.

With its environmental impact effectively minimised, the new facility will be the world's most efficient

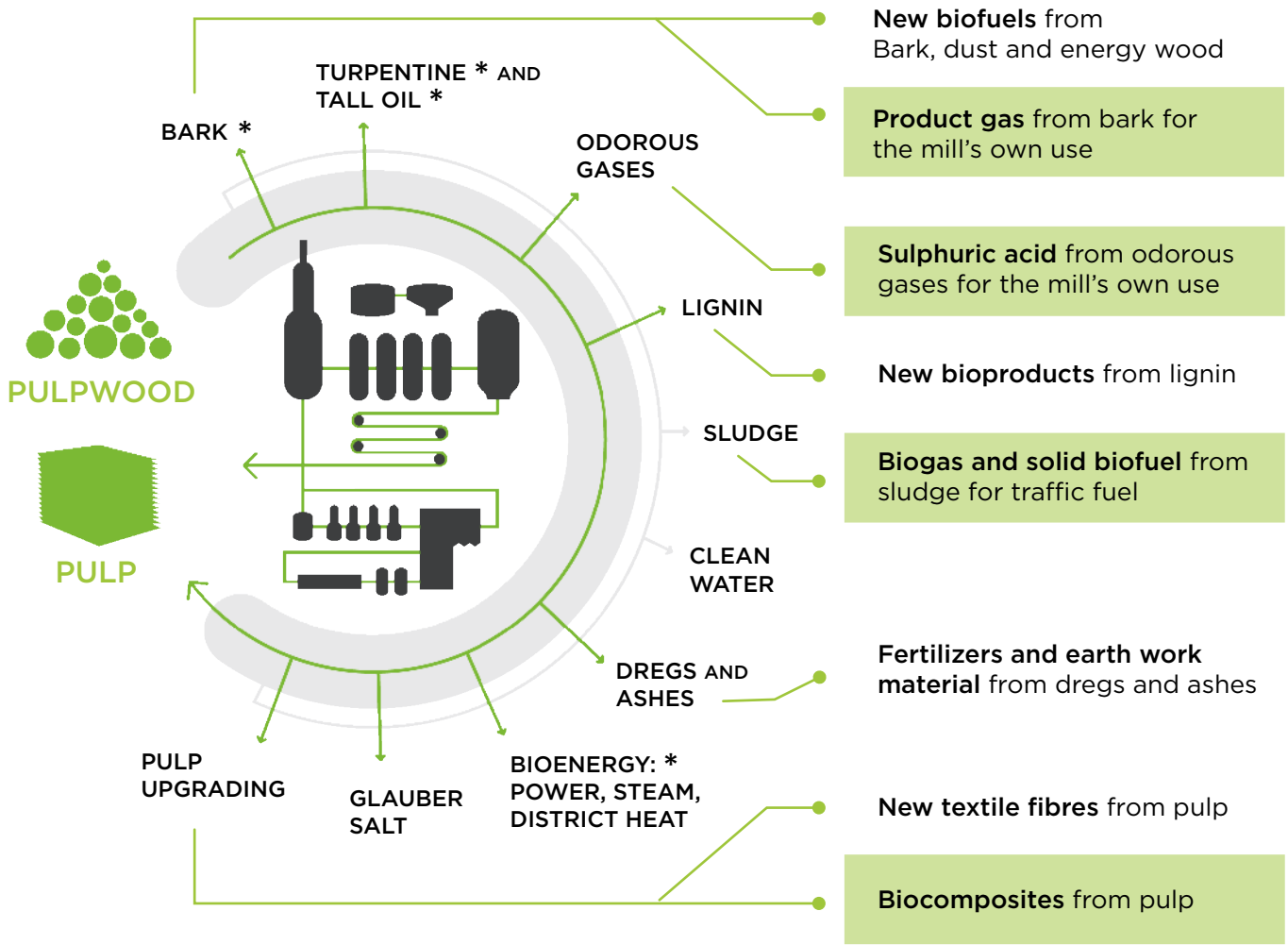
Traditional mill sites have been turned into biorefineries, where every component of the wood material is utilised for the production of innovative biomaterials and bioproducts.

Renewable packaging materials provide a sustainable alternative to many of today's packaging materials, such as plastic and aluminium (Photos: StoraEnso Plc).

bioproduct mill. Praising the authorities for their efficiency in the environmental permit process of the pulp mill, von Weymarn continues: 'The authorities met us halfway and tested a new, faster permit procedure, which worked out well. The entire permit process was of high quality, efficient and intelligently handled. The state has also made strong investments in the region's road and transport-route infrastructure.'

'From the word "go", the mill site has been planned in manner that enables the production of a wide and varied range of wood-based products developed by a unique network of operators in the field of bioeconomy,' Niklas von Weymarn tells us. For each mass unit of wood delivered to the mill site, only half comprises the main product, pulp. This means that the other half of the wood raw material is available for other production streams. With its partners, the bioproduct mill will refine these ingredients for end-uses that provide the best value-added. 'Taking this material to a landfill or simply combusting it would be a waste of natural resources and money. In the bioproduct mill concept, the resource efficiency will be maximised,' says Niklas von Weymarn.

The scope of products in the Äänekoski bioproduct mill. (Source: Metsä Fibre Ltd)



The Äänekoski bioproduct mill in Finland.
(Photos: Metsä Fibre Ltd)

Full use of wood through a partnership network

At the moment, the mill site where the new bioproduct mill is under construction contains a pulp mill that has reached the end of its life cycle. The mill site also contains Metsä Group's paperboard mill, which uses the pulp from the nearby mill as its raw material. In addition, the current ecosystem of operators comprises a company that manufactures chemicals from pulp, a plant that generates heat and electricity from tree bark, a cheese factory that utilizes the excess heat produced by the pulp mill for the drying of its cheese, and a company that produces pigments from carbon dioxide emitted by the pulp mill.

No fossil fuels will be used in the bioproduct mill's production processes. In addition to pulp, pulp mills have traditionally produced tall oil and turpentine. At Äänekoski, this product range will be extended to include novel bioproducts as a response, for example, to the targets set in relation to renewable energy sources in the EU. 'These bioproducts will be generated from the same wood fibre and wood biomass as the traditional forest industry products,' says Niklas von Weymarn.

The bioproduct mill, including partners, will produce, for example, bio-electricity, steam, district heat and solid biofuels. This co-production will enable the forest industry to contribute to the EU's goal of increasing the use of renewable energy. Up to 70 per cent of renewable energy in Finland is generated in connection with the forest industry's production operations. The bioproduct mill alone will increase the use of renewable energy in Finland by over two per cent.

The Äänekoski business ecosystem is still expanding: in the future, a partner company will use the sludge generated by the bioproduct mill to manufacture biogas for transport, a leading expert in the field has been selected to manage the wood yard, a large gas company will build an oxygen plant at the mill site, and sand containing tree bark is going to be utilised in the production of wood-chip mulch. Later, biocomposite production will be launched at the mill site. Other potential new products made from the side streams include lignin-based products and textile fibres.

'We'll have no fewer than ten partners operating as core actors in our business ecosystem. We don't ourselves have the knowledge required for the development of all existing and potential new bioproducts and serving the value chains, so we have invited partners to cooperate with us in this endeavour. This partnership network will enable us to get full use out of the wood and wood-based side streams. At the same time, we are developing the Finnish bioeconomy, creating new jobs and generating income from export,' von Weymarn summarises. 'The bio-based forest industry involves not only the emergence of new business activities, but also further development of the existing operations and the circular economy. We are innovating in each of these areas,' von Weymarn stresses.

No fossil fuels will be used in the production processes of Metsä Group's new bioproduct mill.

The forest industry in Finland has undergone a major structural change during the past decade. The decline in the demand for the biggest segment, printing paper, has forced the industry not only to restructure its existing businesses, but it has also been forced to develop entirely new products and businesses and to be active in forming research-related ecosystems.

Today, the industry brings to the global market sustainable and recyclable products made from wood. This helps to reduce the reliance on non-renewable raw materials such as oil and promote the development of low-carbon societies.

Interviews by
Miia Mikander
Senior Specialist
Communications
Communications Agency Woimistamo Ltd

Many start-ups have found their mission in the need to solve global environmental challenges, and by so doing have invented a role and an edge in global value constellations. In this section, we provide some highlights of the offerings provided by three start-ups.

Baby Tree-shirt, made from Spinnova's 100 per cent wood based fabric. (Photo: Spinnova Ltd)

Interviews with

Tuomas Mustonen
CEO
Paptic Ltd

Janne Poranen
CEO
Spinnova Ltd

Tuomo Kauranne
CEO
Arbonaut Ltd

Start-ups generating exciting innovations as partners in business ecosystems

An extensive business ecosystem has emerged in Finland around the forest industry. Many start-ups have found their mission in the need to solve global environmental challenges, and by so doing have invented a role and an edge in global value constellations. In this section, we provide some highlights of the offerings provided by three start-ups. One of the companies involved is Paptic. It has developed a business model by which retail chains can provide retail-brand-enhancing paper bags for their customers to replace plastic bags. By doing so, the retail chains improve their environmental footprint. Another example is Spinnova, a company that is developing technology to spin yarn from wood fibre, and by so doing allows arable land to be released for food production. The third start-up is Arbonaut. It produces detailed location-specific data on forest resources.

Paper bags replacing plastic bags

In Europe alone, around 100 billion plastic bags are used every year. This figure has to be multiplied many times over when the rest of the world is included. When this plastic waste ends up in seas and oceans, the waste gives rise to serious environmental and human health-related problems.

The EU recently passed a directive aimed at reducing the use of plastic bags. Many countries in Europe have already instituted restrictions on the use of plastic bags and imposed charges on them, thereby encouraging consumers to use paper bags or reusable bags instead. In response to the environmental challenges and the EU directive restricting the use of plastic bags, Paptic was founded. 'Whenever oil-based plastic can be replaced with renewable material, it's worth doing. With our technology, we can produce bags that combine the beneficial qualities of paper and plastic. Around 80 per cent of the raw material used for our Paptic bag is renewable and biodegradable. Because of this, the bag can be recycled with cardboard waste. The bag is reusable to boot,' explains Paptic's managing director, start-up entrepreneur Tuomas Mustonen.

Paptic has developed a business model grounded in a new paper production technology for which it has a licence. Around the world, there are several paper

Plastic waste in the environment can be reduced by replacing plastic bags with wood-based bags. (Paptic Ltd)

production lines whose owners are interested in upgrading their technology and are subsequently willing to lease these lines for the production of the material used in Paptic bags. Plastic-bag manufacturers have given a 'staggeringly warm' welcome to the new material, as have global brand owners and retailers, who are always on the lookout for more sustainable and environmentally friendly materials. 'We want to create a new market segment for paper and offer new applications for the existing plastic bag producers,' says Mustonen.

'Plastic bags are reusable, but, as they are made from oil-based material, both retailers and consumers are keen to find alternatives. There are other reusable shopping bags, but these too are made with non-renewable oil or environmentally harmful cotton and can't be recycled. At the same time, standard paper and cardboard do not meet all the requirements set for bags needed in shopping. The Paptic bag fills this gap and offers a product with a lot of strength. It is made from a renewable material and it is also recyclable and reusable,' says Mustonen, listing some of the benefits brought by the new material.

Having leased an upgraded paper production line for the new wood-based material to be used in Paptic bags, Paptic has the goal to offer an environmentally friendly alternative to polyethylene bags, plastic and reusable shopping bags. The Finnish-based clothing chain Seppälä is the first retailer to start using the environmentally friendly, recyclable and reusable Paptic bag. Paptic's goal is to bring its first prototype product to commercial-scale production in the latter part of 2017.

Textiles with minimum water, energy and chemicals

To a large extent, modern textiles are made from cotton and oil-based materials. The problem with cotton is that considerable amounts of water, chemicals and energy are needed for the cultivation of the plants. In addition, the land used for the cultivation of cotton plants could be used to grow food crops. Oil, on the other hand, is a non-renewable resource whose use the textile industry is striving to reduce.

Spinnova wanted to respond to this challenge. The start-up is developing a technology for the spinning of yarn from wood fibre in a sustainable manner. This means that the production process will be possible without work stages that consume large quantities of chemicals, water or energy. 'Our goal is to introduce an eco-friendly wood fibre-based material to complement or even replace the range of textiles, now mostly cotton and oil-based. Our production process is also cost-efficient and environmentally friendly,' says start-up entrepreneur Janne Poranen, who is Spinnova's managing director.

Responsible operations throughout the product life cycle

The research behind the new technology originated at VTT Technical Research Centre of Finland, where researchers were investigating paper production processes. The project gave rise to the idea of arranging the fibres one after another to produce an elongated, threadlike structure, instead of the criss-cross arrangement used in paper production.

The new wood-based textiles can easily be recycled and reused.

'Textiles have already been made from wood fibre, but the available methods involve extensive use of chemical processes. Our goal is to bypass these phases and produce yarn directly from the pulp fibre,' explicates Janne Poranen. According to him, leading textile brands are investigating solutions for more environmentally friendly textile-production methods. Ideally, the new textiles will also be easy to be recycled and reused. In addition to plastic bags, a considerable proportion of the waste ending up in seas and oceans comes from textiles. Spinnova's material can be recycled as easily as paper. 'Globally, this issue is high on the agenda. Our shareholders include the world's leading textile fibre manufacturer, which already produces textiles from wood but using a process that is not so eco-friendly. They want to collaborate with us because they see great potential in our technology. Our goal is to find the best international partners and start industrial-scale operations as soon as possible,' reveals Janne Poranen. While Spinnova is currently at the technology and product development stage and is preparing the move towards piloting, the first full-scale production-investment is estimated to be ready in the 2020s.

Innovative wood pulp design products made by Sukarwood: luxury package, evening bag, briefcase and hanger. (Photo: Matias Ulfves)

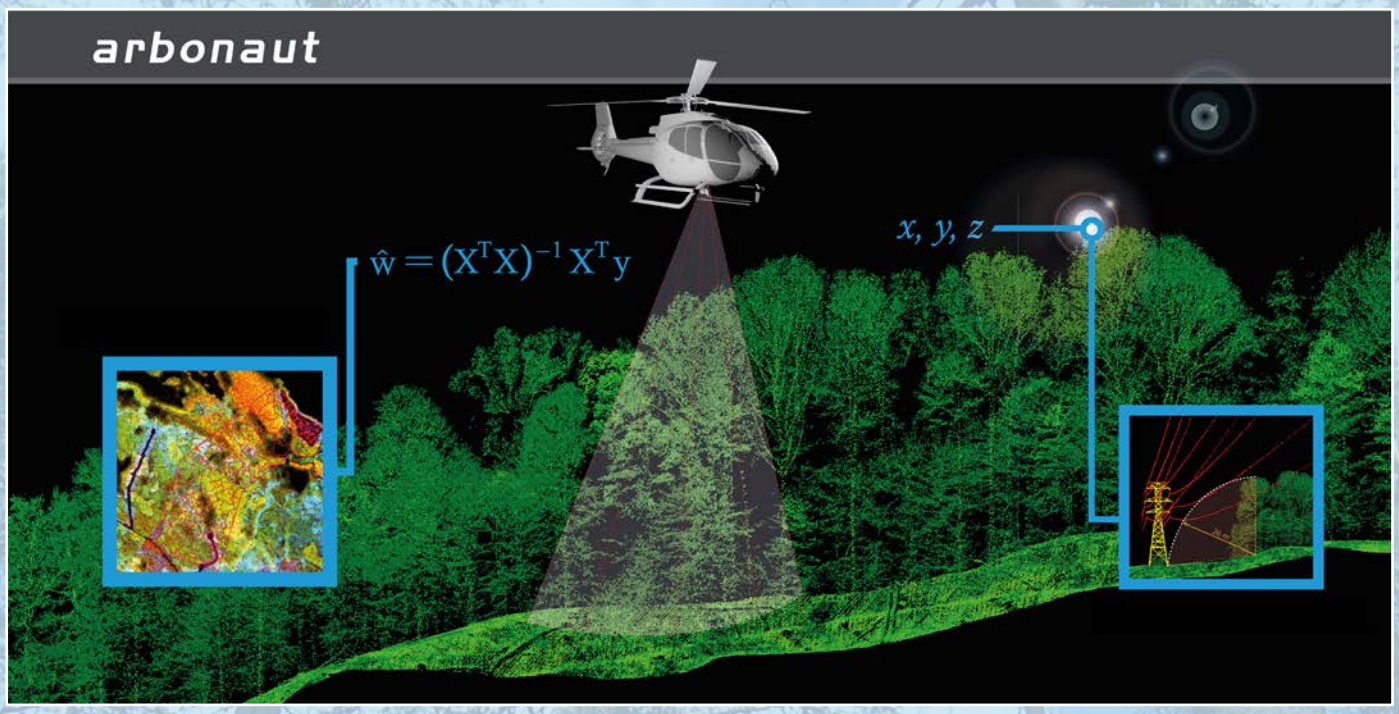
Arbonaut: a service business innovation for forestry and wood markets

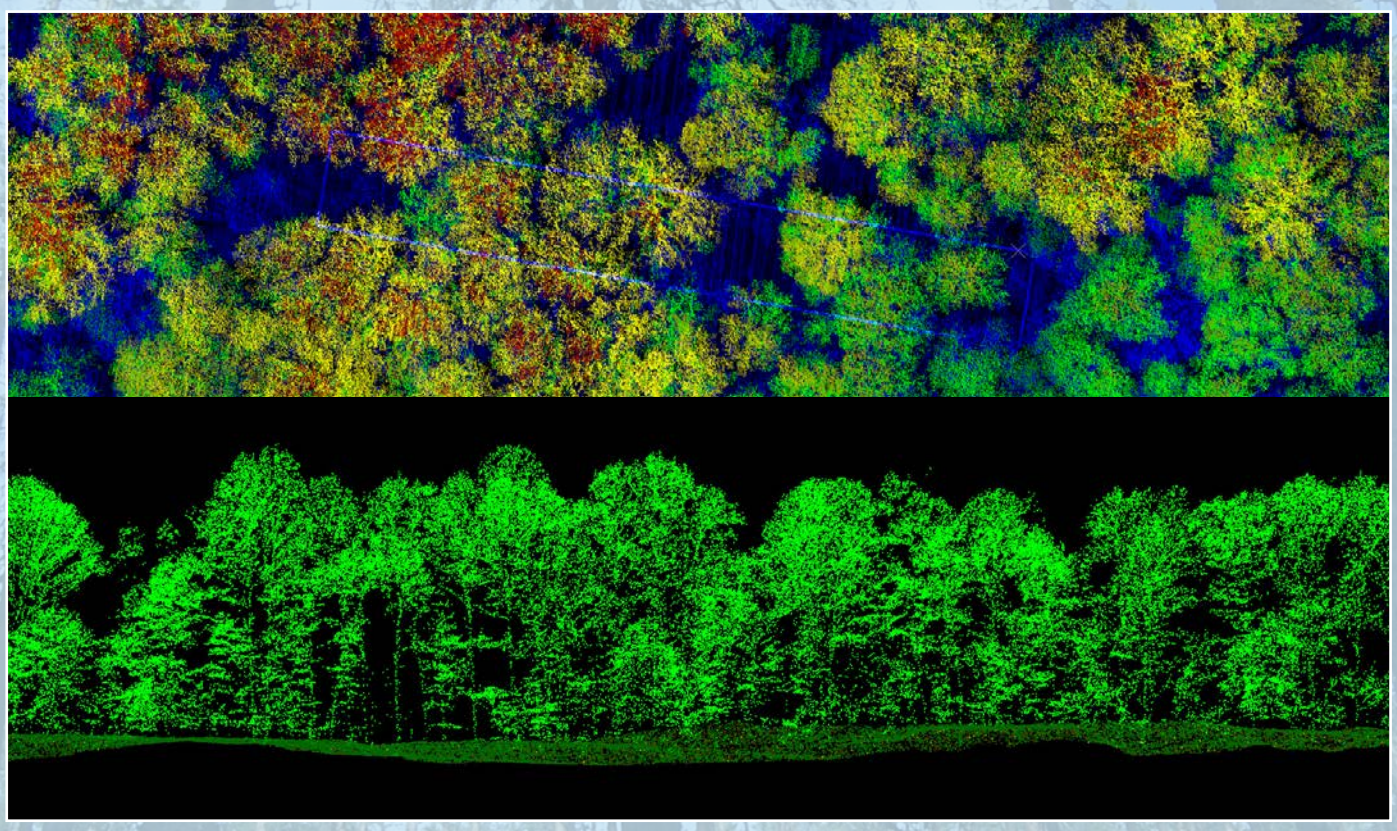
While Paptic and Spinnova have their roots in the research ecosystem of the Finnish forest sector, Arbonaut has its roots in the ICT sector. 'We realised that with our technology, we could measure two- and three-dimensional objects from aerial images. Initially, we created a new technology for the mobile phone industry. After the turn of the century, we developed the first ever map localisation phone in collaboration with the mobile phone manufacturer Benefon,' explains Arbonaut's managing director and owner, Tuomo Kauranne, telling about the roots of the start-up. The story goes on: 'The recognition that the method could be applied in forestry management emerged as a result of forestry related computer programmes that we developed in collaboration with university researchers located in Joensuu, Finland. We realised that if we know the diameter of the crown of a tree, we can predict the tree's volume.' After describing the procedure for such a measurement process, Arbonaut began to produce machine vision software utilising the method.

Airborne laser scanning

The Light Detection and Ranging (liDAR) survey method is at the heart of the technology that has now replaced field measurements. 'We fly at an altitude of a couple of kilometres in an aeroplane and use laser beams to generate three-dimensional point cloud data on an object. On average, you have one data point per square metre, and on the basis of these points, we use mathematical modelling to provide us reliable information on what the area consists of. We pretty much achieve accuracy down to a single tree,' Kauranne explicates the working process.

Now, with operations on six continents, Arbonaut has gained clients around the world, including both forest companies and government authorities. 'Forest inventories provide valuable information to facilitate sustainable forestry management, and they also indicate when and where trees should be felled. Assessments of carbon stocks in tropical forests are currently an area of strong focus. We can monitor carbon storage development and provide reliable measurement processes at the national level and for certifications,' says Kauranne. According to him, the measurement results become





Digital technology and the bioeconomy are combined to offer reliable information on forest resources. Source: Arbonaut Ltd

International investors are interested in Finland's start-up sector.

a financial asset for the state when Arbonaut's method is used to demonstrate the amount of carbon dioxide that has been removed from the atmosphere, entitling the state to payments for carbon capture via forests under the Paris climate agreement.

The decisive role of support and funding

The managing directors of Paptic and Spinnova, two companies that began life as spin-offs from VTT Technical Research Centre of Finland, praise the government for the role its various agencies have played in supporting R&D and for their investments in start-ups and related activities in Finland.

'Without the support from the state agencies, our resources would have been much more limited. It's also vital that, as a complement to the support from the state agencies, Finland's start-up sector additionally receives capital investments from international investors. Our domestic equity capital market is relatively small,' emphasises Paptic's **Tuomas Mustonen**. Both companies recently also received a major injection of funds from the EU. 'All these factors played a major role in enabling the development of our revolutionary technology,' says Spinnova's CEO, **Janne Poranen**.

In addition, **Tuomo Kauranne**, from Arbonaut, lists an open-minded attitude and belief in science and research as strong points in Finland: 'In the forest sector, things do not proceed as rapidly as investors might hope. This is a long-term project in which processes cannot be changed rapidly. It's clear that our start-up business wouldn't have remained viable without state backing.' According to Kauranne, Arbonaut has participated as a private sector partner in numerous international EU-funded research projects and framework programme actions involving forestry. 'These have helped us to gain access to international markets,' he says.

Mustonen also emphasises the significance of market pull for new bio-based forest industry products: 'New products must have stand-out qualities and market pull; otherwise, you can only compete in terms of price. But you don't have to do it all yourself. Networking and finding the right partners are essential, and such connections speed up the process.'

Interviews by
Miia Mikander
Senior Specialist, Communications
Communications Agency Woimistamo Ltd

In Finland, the number of engineers in relation to the population is the highest in the world. Research and innovation projects receive funding from the state.

Pilot and scale-up facilities for new wood-based innovations

Pilot and scale-up facilities offer tools for experimentation and demonstration, and by so doing speed up the commercialisation of inventions produced in companies, research institutes, and in universities. In Finland, the pilot infrastructure related to wood-based materials, fuels and chemicals builds on a long tradition, with a focus on process technologies and strong links with universities. Since the turn of the century, new cross-disciplinary constellations and strategic partnerships with universities and research institutes have opened a completely new opportunity scope that has also been supported by investments in new pilot facilities with the support of the state.

Pilot and scale-up facilities offer tools for experimentation and demonstration. The government is providing funding for such investments according to the roadmap of national research infrastructures. (Photos: VTT Technical Research Centre of Finland Ltd)

Full impact on the bioeconomy with new process and product innovations

In addition to nature values and the traditional use of wood, forests offer a sustainable raw material base for many new and existing industrial products. However, the development path and commercialisation often require a considerable amount of R&D, money and time. Experimental pilot production is often needed to speed up the development and to lower the technological and market uncertainty to an acceptable level for large investments. While uncertainty can be reduced with the piloting operation, the often-unrecognised challenge is that obtaining funding for the investments needed in pilot facilities and operations can be too difficult. This means that many good inventions may not pass the "valley of death".

To overcome such scenario, it is important that the costs of pilot facilities are shared. Open access shared pilot facilities, that are selling scale-up services, can offer a cost effective route to piloting. The scale-up professionals and state-of-the-art pilot equipment complement companies' own R&D resources. This is especially valuable for many growing SMEs.

New forest-based materials and bioenergy are Finnish strengths in piloting

From the European perspective, Finland has a versatile selection of open-access pilot facilities for forest-based bioeconomy processes. The pilot infrastructure builds on long R&D traditions in forest industry-related process technologies. As a response to the growing interest in bioenergy and novel cellulose-based materials, new pilot facilities have been set up in Finland for the testing of many innovative technologies. The service offering is complemented by scale-up facilities for forest biomass processing, separation technologies, chemical conversions, and for industrial biotechnology.

Many open-access pilot facilities in Finland are relatively small in size, although often large enough for scale-up purposes. Larger pilot plants exist in certain key technology areas, such as thermochemical gasification and pyrolysis, novel cellulose/pulp-based materials production, special pulping processes, biogas production by anaerobic digestion, bioethanol fermentation and process chemistry.

Finland has many leading companies specialised in manufacturing process equipment or producing

The open-access pilot facilities in Finland for the forest-based bio- and circular economy.

Focus Areas	Organisation	Contact information
Biofuels and thermo-chemical conversions	VTT, Espoo University of Eastern Finland, Kuopio Kouvola Region Vocational College, Biosampo	http://www.vttresearch.com/en/services/ http://www.uef.fi/en/services/commissioned-research www.ksao.fi/en/
Biomass processing and pulp production	KCL, Espoo Mikkeli University of Applied Sciences, Savonlinna VTT, Espoo, Rajamäki Åbo Academy	www.kcl.fi http://www.mamk.fi/services http://www.vttresearch.com/en/services/ www.abo.fi/facultetet/fiberochcellulosateknologi
Chemical process technology	VTT, Espoo	http://www.vttresearch.com/en/services/
Industrial biotechnology	VTT, Espoo, Otaniemi	http://www.vttresearch.com/en/services/
Biobased materials	KCL, Espoo VTT, Jyväskylä, Espoo/Otaniemi, Tampere Tampere University of Technology Lappeenranta University of Technology	www.kcl.fi http://www.vttresearch.com/en/services/ http://www.tut.fi/en/business-and-industry/index.htm http://www.lut.fi/web/en/cooperation-and-services

industrial products in the field of forest bioeconomy. These companies often have their own pilot and demo units for technology development, but the facilities are typically also available for use by partners and potential customers.

New cross-disciplinary constellations and strategic partnerships with universities and research institutes have opened a completely new opportunity scope.

The process development pilot plant for enhanced pyrolysis oil products at the new Bioruukki Pilot Centre. (Photo: VTT Technical Research Centre of Finland Ltd)

Bioruukki pilot centre and co-operation networks offer new opportunities

In recent years, research institutes and universities of applied sciences have invested in new pilot units, while science universities have reduced their capacity for pilot offerings. For example, VTT Technical Research Centre of Finland Ltd is heavily investing in the new Bioruukki Pilot Centre, which will have a notable impact on the development of new bio- and circular economy technologies. Bioruukki offers integrated pilot platforms for thermochemical conversions, energy storage, biomass deconstruction, cellulose fibre spinning and green chemistry technologies. Another example is the pilot facility of the Fiber Laboratory Innovation Centre of South-Eastern Finland University of Applied Sciences (XAMK), located in Savonlinna. The facility has a focus on advances in pulp processing technologies, including new expansion to a microcrystalline cellulose pilot.

The possibility to utilise the pilot and scale-up facilities speeds up the commercialisation of inventions.

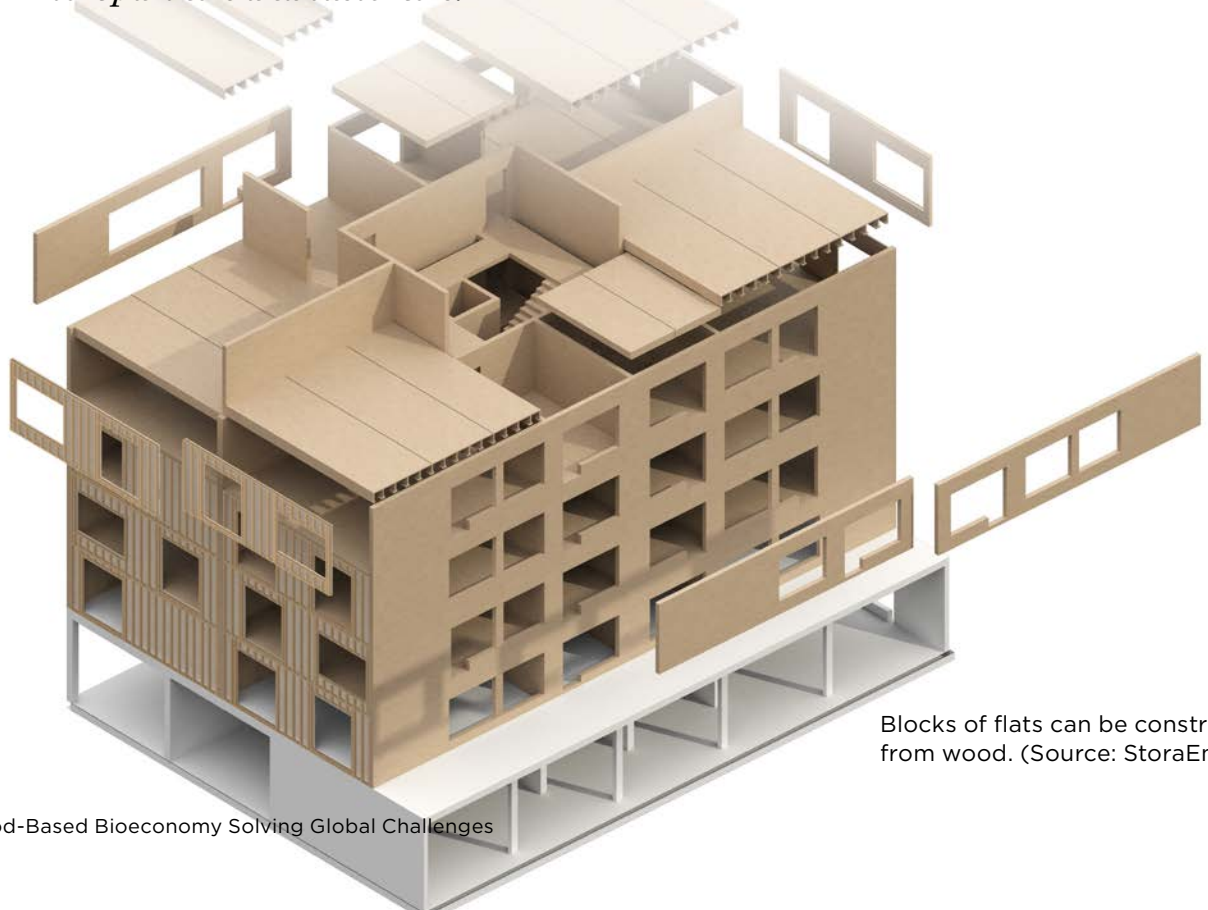
VTT and Aalto University have an agreement on the joint bioeconomy research infrastructure, and the alliance is listed in the roadmap for national research infrastructures. Research groups are actively cooperating in networks linked with the main Finnish and European pilot facilities. For example, VTT is participating in several European pilot infrastructure collaboration projects. This enables both large companies and SMEs to find the piloting expertise they need.

Mika Härkönen
PhD, Principal Scientist
VTT Technical Research Centre of Finland Ltd

Pilot plants for forest residue and waste gasification at the new Bioruukki Pilot Centre.
(Photo: VTT Technical Research Centre of Finland Ltd)

New Business Ecosystems and Value Chains

In addition to many radical wood-based product innovations that are in the innovation pipeline, many relatively new products based on wood are already on the markets. Some of these will cause disruptions in existing value chains, especially if regulatory changes supporting new bio-based products are widely implemented as part of the fight against climate change. In this section, the potentials of timber construction and biofuels are opened up with the implications for the construction industry and for the use of oil. The section also highlights the role of the chemical industry, which is actively involved in bio-based value chains as producers, ecosystem partners and customers.



Blocks of flats can be constructed from wood. (Source: StoraEnso Plc)

Status and possibilities of timber construction in Finland

The forest sector is very important for the Finnish national economy. It accounts for a fifth of Finland's export income, five per cent of the gross domestic product of the entire country, employs some 200,000 Finns, and produces around 70 per cent of the renewable energy in Finland.

Every year, Finland's forests grow and produce nearly 110 million cubic metres of wood, of which 60–65 per cent is utilised. The utilisation of wood could be significantly increased (by approximately 20 million cubic metres per year) by, for example, increasing its use as a source of energy, in construction, and in the wood-product industry, as well as in various bioproducts. Approximately four-fifths of the sawn timber consumed in Finland is used for construction purposes. Housing construction plays a key role in construction: residential buildings account for about 65 per cent of Finland's building stock.

Timber construction in the fight against climate change

As global climate, environmental and natural resource issues gain in significance, new markets are being sought for timber construction, even in Finland. The biggest opportunities for growth in timber construction in the country are in multi-storey houses, in public buildings, warehouses and industrial buildings, silos, yard construction and landscaping, as well as energy upgrades of façades in suburban houses, in adding storeys to buildings, and in complementary construction.

Pre-fabrication in indoor facilities markedly shortens the construction time at the site. (Source: StoraEnso Plc)

Timber construction provides inspiring opportunities for high-quality architecture and interior design

Photo: StoraEnso Plc

Research-based evidence is available for the claim that the use of wood in interior solutions has health improving effects and is more relaxing to the eye.

Building with wood provides a long-term storage for carbon captured from the atmosphere by growing trees. This, in conjunction with the substitution effect – when emissions from other building materials are avoided – represents the most climate friendly use of forests.

New energy-efficiency regulations took effect in Finland in July 2012. These regulations aim at the construction of more energy-efficient buildings, and at encouraging greater use of renewable energy in the heating and cooling of buildings. The Ministry of the Environment has begun to compile a roadmap to reduce greenhouse gas emissions originating from the manufacture of building materials and products. The roadmap will be ready in 2017. The goal is to take the carbon footprint of buildings into consideration in building regulations by the mid-2020s. In this respect, wood – as a domestic, local, renewable, environmentally friendly energy source and construction material – will be an increasingly competitive raw material.

Small-scale construction favours wood

In Finland, there are half a million summer cottages, and the number is growing, as some seven thousand new vacation homes are built every year. Of these, almost 99 per cent are made of wood. The dominant position of log-based building in the construction of cottages is secure.

There are 2.95 million registered residences in Finland, and over the past twenty years, some 30,000 new residences have been built every year. Detached houses – i.e., single-family and two-family houses – account for slightly less than half of the production of new housing. More than eight out of ten detached houses have a timber frame and some three-fourths have a wooden façade.

Wood is aesthetically pleasing. (Source: StoraEnso Plc)

The breakthrough of multi-storey wooden buildings in Finland

Finland has the second highest proportion of multi-storey buildings in Europe, right after Spain. About 44 per cent of all residences in Finland are in multi-storey buildings. Between 14,000 and 16,000 residences are built in blocks of apartments each year.

Since the early 1990s, wood-based construction has undergone intense development in Finland, through close co-operation with other EU countries. Development efforts have particularly focused on large-scale timber construction and on enhancing the energy efficiency of buildings. Finnish fire-safety regulations were changed in September 1997 to allow the use of wood in building frames and façades for buildings of up to four storeys. Fire codes were again changed in April 2011 to also allow the use of wooden frames and façades in residential and office buildings of 5–8 storeys in height. In addition, the possibilities for using wood were extended to cover repairs of and extensions to suburban concrete buildings.

In Finland, wooden buildings of more than two storeys must be equipped with automatic fire extinguishers (sprinklers in each apartment). The most recommended of these is the high-pressure fog technology developed in the shipping industry. Compared with conventional sprinklers, only ten per cent of the amount

of water is used in extinguishing fires with sprinklers based on the high-pressure fog technology.

In 2017, approximately 5000 new apartments in multi-storey timber-based buildings will be constructed in Finland. New school buildings based on timber are under construction or in the planning phase in ten municipalities. In the quest for a healthy and pleasant indoor climate, the use of timber in day care centres and school buildings is clearly becoming more common.

Several construction methods exist for multi-storey wooden buildings

Several timber-based frame systems are available for multi-storey construction, and sufficient production facilities and manufacturing capacity for them exist in Finland. In particular, CLT (cross-laminated timber) and LVL (laminated veneer lumber) technologies have made a breakthrough. CLT products are made from massive timber sheets in which adjacent layers of boards are glued crosswise to each other. Such massive CLT beams are especially used as vertical and horizontal load-bearing elements in multi-storey buildings. LVL technology is based on rotary-cut lamellae of round wood glued into beams that are also used as structural elements. The width of an LVL product can be 2.5 metres, and they can be produced to lengths of up to 25 metres. The thickness can also be adjusted according to the end-use requirements. Owing to the easy coupling technique, air-tightness and good rigidity, both CLT and LVL are competitive, especially in tall wooden multi-storey buildings. An additional advantage in the use of pre-fabricated structural elements is that they facilitate the making of modules, which are then used in the construction of multi-storey houses. Ninety per cent of the contents of a module, for instance for bedrooms, kitchens and bathrooms, can be built at a dry and well-lit factory site. This shortens the construction time in an open-air context by 50 to 60 per cent, and thereby reduces the total costs of construction.

National wood construction programmes during 2011–2015 and 2016–2018

In Finland, the Ministry of Economic Affairs and Employment implemented a National Timber Construction Programme under the Strategic Programme for the Forest Sector in 2012–2015. The goal of the timber construction programme was to reduce the carbon footprint of construction by significantly increasing the use of domestic wood in construction. The intent has been to promote high-quality architecture and design with environmentally aware, energy-efficient construction that employs intelligent building technology. New targets for timber-based construction have constantly been sought in connection with the programme, in collaboration with Finland's most notable developers: construction companies, municipal decision-makers in growth centres and town planners. Rather than focusing on individual buildings, the aim has been to initiate construction projects for larger entities where wood is used in an appropriate and competitive manner.


Source: StoraEnso Plc

Education in timber construction has been updated at all levels of the educational system in Finland in order to be able to respond to the growing demand for large-scale timber construction. Project, research and development activities for timber construction on a national scale have also been honed, unified and enhanced to make them more efficient, by increasing cooperation and communication among the players in the field.

The government also wants to advance timber construction from the points of view of the regional economy and employment. By expanding timber construction, it is possible to increase the demand for and export of wood products and thereby create nearly 6,000 new jobs in Finland.

The interior design for a lobby in WoodCity, under construction in Helsinki. (Source: StoraEnso Plc)

Kupla Observation Tower Helsinki. (Photo: Jussi Tiainen)

The Sibelius Hall in Lahti, Finland. The concert hall was named after the famous Finnish composer Jean Sibelius.

The design for WoodCity houses in Helsinki. (Source: StoraEnso Plc)

A competitive edge is a basic prerequisite for the internationalisation of companies engaged in the wood products field. To promote internationalisation and growth, a shared service platform has been established for companies in the business (www.woodproducts.fi). It supports the advancement of know-how of the companies engaged in the wood products sector in production, R&D, networking and marketing practices. The promotion of exports has been systematised and enhanced in government–corporate cooperation supported by Team Finland.

During 2016–2018, this work is continuing as one of the strategic priorities in the Government's programme "Bioeconomy and clean solutions". The strategic priorities are being implemented by specifying key projects and providing funding for them. "Wood on the move and new products from the forest" is one of the key projects. From the point of view of timber construction, the action plan for this key project has the following goals: to support the development of an internationally competitive industrial wood-building industry and knowledge to support the development of a long-term carbon sink in the built environment and to facilitate the continuity of internationally networked research and development activity in the wood-based building sector. The Ministry of the Environment is leading this cross-ministerial project.

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Associate Professor, D.Sc. (Tech.), Architect
Tampere University of Technology

Photo: Vastavalo

Biofuels

Like other energy sectors, transport needs to be de-carbonized. The general carbon emission reduction targets for the transport sector are some 30 per cent by 2030 and 60–80 per cent by 2050. The means for reducing carbon emissions from transport includes reducing road transport (which could conflict with the needs of economic activity), improving the energy efficiency of vehicles as well as that of transport systems, and finally introducing renewable energy in transport. Some of the new energy carriers require new refuelling infrastructure and new vehicles, whereas fungible liquid drop-in fuels can also be implemented for legacy vehicles. Thus, liquid biofuels can provide a fast track to the decarbonisation of transport. For instance, the public transport authority of the Helsinki region, HSL, is planning to decarbonize the bus services in the Helsinki Metropolitan Area by 2020 by using a combination of advanced biofuels and electric buses.

The energy carriers also differ from each other regarding applicability. Electricity is best suited for light-duty vehicles and for urban vehicles, whereas heavy road freight, construction equipment, commercial aviation and international shipping will mainly depend on liquid fuels. Obviously, to reach a 30 per cent reduction in carbon emissions from transport by 2030 in a situation in which mobility as such is not restricted, a balanced mix of improvements in energy efficiency, biofuels, electricity and other low-carbon energy carriers is required.

Finland has actively and successfully promoted biofuels for transport. The actions taken to promote biofuels in transport include:

- Support for R&D activities
- Support for investments in the production of innovative biofuels (first units)
- A progressive obligation for biofuels in road transport (20 per cent by 2020, taking into account double counting)
- A fair taxation system taking into account the energy content, CO_2 intensity (well-to-wheel basis) and local emissions

The Finnish biofuels target for 2020 was already reached in 2014. The actual contribution of biofuels was some 13 per cent, and as the greater part of these biofuels were eligible for double counting according to Directive 2009/28/EC (biofuels produced from wastes, residues, non-food cellulosic material and lignocellulosic material), the calculated share of biofuels reached some 24 per cent. Raw materials at that point were mainly vegetable oils and by-products, agricultural

Finland has set the target to raise the share of biofuels to 30 per cent of oil-based fuels.

Bio-diesel can be produced from crude tall oil, a side product of pulping. (Photo: Shutterstock)

The Finnish biofuel target of 2020 was already reached in 2014.

biomass and waste-based biogas. Wood-based biofuels (UPM BioVerno) entered the Finnish market in 2015.

In 2016, there were several Finnish actors in the field of advanced biofuels, which is a fast-growing international business area. St1 is producing ethanol from industrial waste streams and household waste. North European Bio Tech (NEB), jointly owned by St1 and the S Group (a cooperative in the retail and service sectors), is building a plant to produce lignocellulosic ethanol from sawdust and considering complementing this with several new investments. UPM is producing renewable diesel from tall oil, a side product from pulping. Neste is producing hydrotreated vegetable oil (HVO) for the world market and is, in addition, testing refinery co-feeding of tall oil pitch. Metsä Group's next generation bioproduct mill in Äänekoski will, among other products, also produce biogas. Kaidi Finland plans to build a globally unique second-generation wood residue gasification plant for renewable diesel and petrol in Kemi by 2019. VTT Technical Research Centre of Finland Ltd has a long history in research and development of various innovative biofuel production value chains, and has a unique research and pilot facility called "Bioruukki".

In 2015, the current Finnish government set a very ambitious target of 40 per cent renewable energy in transport by 2030 (taking into account double counting). Most of this renewable energy will come from advanced biofuels. VTT and VATT Institute for Economic Research have made calculations of transport CO_2 abatement costs, including effects on the national economy. The conclusion is that in the case of Finland, taking into account the industrial structure and natural resources, biofuels from indigenous biomass resources would be more cost effective than a massive introduction of electric vehicles and competitive with biofuel imports. In November 2016, the Government presented its energy and climate strategy for 2030. In this strategy, the ambitions are even higher: Finland will aim to achieve a 50 per cent reduction in greenhouse gas emissions from transport by 2030 through a combination of a factual share of 30 per cent biofuels and 250,000 electric vehicles.

Nils-Olof Nylund
Research Professor
VTT Technical Research Centre of Finland Ltd

The chemical industry in the green circular bioeconomy

Chemistry is a key enabler of the circular bioeconomy. From the manufacture of fertilizers needed for biomass cultivation to the refining of biowaste, chemical companies are involved in the entire biomass cycle. Without chemical expertise and know-how, it would be impossible to grow and utilize different types of biomass smartly and sustainably.

The chemical industry is one of the most important industrial sectors in Finland, accounting for about one-fifth of the gross industrial production and one-fifth of the industrial exports of goods. A considerable share of the innovations and growth within the Finnish chemical sector is related to the bioeconomy and the circular economy. Approximately one-third of the chemical companies operating in Finland use bio-based raw materials. Boosted by novel technologies and co-operation, the use of renewable raw materials as well as various biotechnological solutions is on the increase.

Smart refining in industrial symbiosis

The two companies specialised in crude tall oil (CTO) fractionation, Arizona Chemical, a Kraton Company in Oulu, and Forchem in Rauma, have long traditions in Finland. The refining process of CTO starts with distillation, after which the fractions obtained are further upgraded into a variety of high-value bio-based products to be used, for instance, in paints, lubricants, adhesives, road marking agents and functional food and feed. The carbon footprints of these pine chemicals are approximately 70 per cent lower than those of their fossil counterparts. One of the latest innovations is the use of CTO derivatives in animal feed (Progres®), where they act as natural anti-inflammatory agents and thus provide a way to reduce the use of antibiotics in poultry farming. Although this practice is not common in Finland, it is quite widespread in many other countries, leading to concerns over bacterial resistance.

The chemical expertise and know-how is on a high level in Finland. The sector is a key enabler of the circular bioeconomy.

As CTO, a renewable mixture of natural chemicals, is obtained from coniferous wood as a co-product of the forest industry's pulping process, this ecosystem is an example of a well-functioning industrial symbiosis between the chemical industry and the forest industry. Other examples include the upgrading of cellulose into CMC, cellulose gum, to be used, for example, in detergents, paper coatings, and as a thickening agent in dairy products, and the production of the tooth-friendly sweetener xylitol from xylose purified from the pulp and paper industries' side streams. The world's largest xylitol production plant is situated in Kotka. Envor Protech has developed EPAD biogas technology, which is globally the first technology that utilizes forest-based slurries from the pulping process as the feedstock and turns them into biogas for transportation, carbon dioxide for the pulping process, as well as fertilizers and solid biofuel for boiler plants.

The bioeconomy needs enzymes and water chemistry

Clean water is also part of the bioeconomy. The Finnish company Kemira is specialised in water chemistry and management and produces and develops solutions that contribute to the growth of the bioeconomy, e.g. by improving the efficiency of biorefining processes, which may use large quantities of water. In the field of biotechnology, companies such as Roal and Metgen operate in Finland and develop and produce industrial enzymes for biorefining. Enzymes are needed, for instance, in the production of bioethanol from starch and cellulose-based raw materials. In several plants all over Finland, ST1 Biofuels converts food industry and household bio-waste and residues, as well as saw dust, into bioethanol to be used as an advanced biofuel in traffic.

Connectivity counts

In addition to forest biomass, chemical companies also utilise other types of renewable raw materials. Neste is the world's largest producer of renewable diesel (HVO), refined from waste and residue fats and vegetable oils. Production is based on an in-house-developed NEXBTL technology. HVO can be used in high concentrations or as such in all diesel engines, as well as in aviation. Currently, various wastes and residues make up nearly 80 per cent of all the renewable raw materials used by Neste. In 2016, the global use of Neste renewable fuels reduced greenhouse gas emissions by a total of 6.7 million tons. This is equivalent to the annual emissions of around 2.4 million cars. The objective of Neste is also to revolutionise the markets of aviation fuels and bioplastics with new renewable products. Neste has partnered with the Swedish furniture and home accessories company IKEA, and the companies have invited others to join their project to utilise their resources in the growing market of bio-based products.

Connectivity is the new source of productivity. The chemical sector is connected to almost all other sectors: it is difficult to find a single value constellation from the whole manufacturing industry in which chemistry is not involved. As in the circular bioeconomy, ecosystems and refining chains will be of increasing importance in the future, the chemical sector will play a key role.

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Sustainable forestry

In Finland, 86 per cent of the land area is covered by forests (www.investinfinland.fi). In comparison with other European countries, this is by far the highest percentage. Private non-industrial forest owners own over 60 per cent of the forest land, which consists of 375,000 forest property entities. The number of individuals counted as forest owners in 2013 was about 632,000, which is about 13 per cent of the population (Koponen et al. 2015). This means that forest resources provide economic benefits to a large part of the population.

Since 1920, inventories of forest resources have been carried out in Finland. Currently, this digitalised Multi-Source National Forest Inventory (MS-NFI) utilizes several data sources: field measurements, satellite images and digital maps. With this method, forest statistics and thematic maps can be produced for any given area (www.luke.fi).

Photo: Vastavalo

Sustainable forestry and the forest carbon balance

In most European countries, forest resources have been growing rapidly during recent decades. This development has mainly resulted from improved forest management. In Finland, the growth of trees has exceeded the annual harvest since the 1970s. As a result, the growing stock (volume of standing trees) today is about 50 per cent greater than in the 1970s (2.3 bill m^3 vs 1.5 bill m^3).

Due to efficient forestry management, the forests in Finland are growing more rapidly than they are used.

Finnish forests – the raw material base for the bioeconomy and a CO_2 sink

Finnish forests provide a sustainable raw material base for biorefineries and energy production. The forest ecosystem remains healthy when forests are managed in a sustainable and balanced way. As a result, the bioeconomy has access to raw materials and carbon is captured and stored in forests.

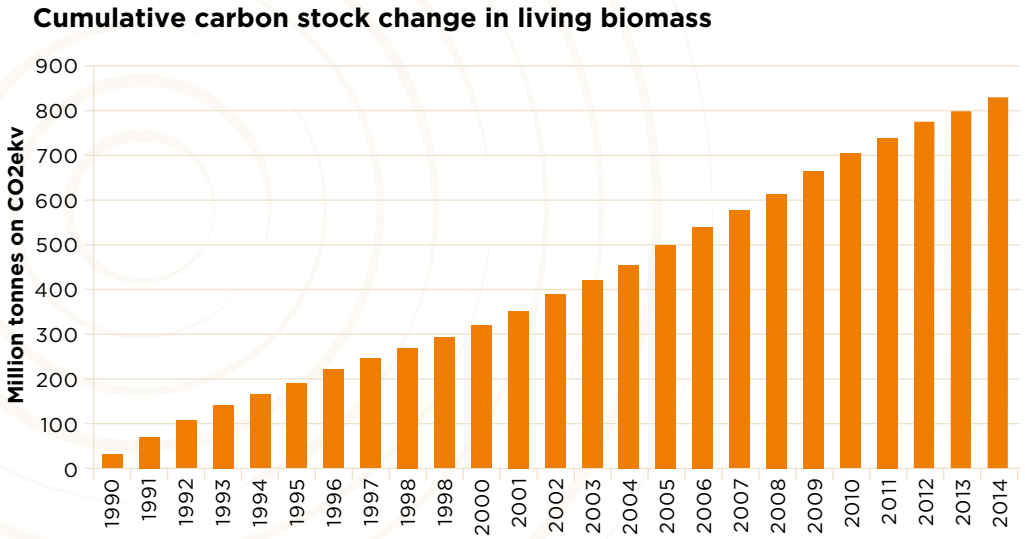
Roughly half of the carbon emissions generated annually in Finland through fossil fuel-based energy production are sequestered by forests, soil and wood products. Forests and soil are currently the only ways to capture and store carbon emissions. Since the CO2 inventory started in 1990, the carbon stock in living trees has increased by over 800 million tonnes of CO2 equivalent. In the future, the role of forest products as carbon sinks will increase, and it is important to promote long life-cycle uses of wood also having a long-lasting carbon storage capacity.

Wood-based bioenergy is the most important source of energy for Finland, representing more than a quarter of energy production. Bioenergy is based on the utilisation of residues released in the production of wood-based products and on low value biomass from silvicultural and harvesting operations. Thus, the Finnish way of utilising biomass is very resource efficient.

Despite the foreseen increase in the future use of wood, the carbon storage of forests in Finland continues to accumulate. This is due to the accelerating growth of the growing stock resulting from implemented forest management measures and from climate change. However, the increasing use of wood calls for investments in forest regeneration, tree breeding and silviculture to maintain forest growth.

Forest management and longer life cycles of wood-based products enhance carbon capture

The sustainable use of forest resources is the core of a successful forest-based bioeconomy. A significant part of Finnish forests are privately owned. The more income forests yield for the owners, the better they manage their forest assets. This improves the growth and carbon sequestration of forests.



Since the CO_2 inventory started in 1990, the carbon stock in living trees has increased by over 800 million tonnes of CO_2 equivalent. The role of forest products as carbon sinks will further increase in the future. (Diagram: The Natural Resources Institute Finland)

Eighty-six per cent of the land area in Finland is covered by forests.

Forests constitute a carbon sink in Finland, since their annual growth is greater than the volume of trees that are annually harvested. (Photo: The Natural Resources Institute Finland)

Multi-storey wooden residential house in Jyväskylä. (Source: Puuinfo Ltd)

Forest certification has had positive effects on the preservation of biodiversity in forests. (Photo: The Natural Resources Institute Finland)

The changing climate is anticipated to stimulate forest growth in Finland. At the same time, the risks, such as wind damage, drought, pests and other natural disasters, may increase. This emphasizes the importance of monitoring the health of forests and rapid reaction to counteract possible threats. Complementary measures include forest tree breeding for resistance, the selection of suitable tree species for different growing sites, timely forest management actions, and activities to improve the resilience of forests.

Finland will attain the targets set by the Paris climate conference if the forest-based bioeconomy evolves and attention is paid to the material cycles of wood-based materials. The key is to further develop forest management and utilisation methods that enable the use of forest-based raw materials and at the same time preserve forest biodiversity and carbon sequestration.

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Certification of forests and wood-based products

In addition to national and EU-level forest and nature legislation, wood suppliers and producers of wood-based products can demonstrate a commitment to responsible and sustainable forest management by participating in global voluntary forest certifications schemes. Certification schemes are market-based mechanisms that cover the whole forest supply chain from forests to final wood-based products.

Sustainable forest management considers three different pillars of sustainability: ecological, economic and social. All three pillars are also included in forest certification standards. Sustainable forest management is an evolving process, and the parameters and requirements of standards are therefore regularly revised based on new scientific data and the development of society. Revisions are always a multi-stakeholder processes.

- Forest certification covers the whole forest supply chain from forests to final wood-based products. It is a guarantee of responsible and sustainable forest management that also promotes the preservation of biodiversity.
- The Chain of Custody (CoC) certification is an essential part of the certification system and ensures that claims about products originating in sustainably managed forests are credible and verifiable throughout the supply chain. It is used to certify entities all along the value chain of forest-based products.
- In Finland, more than 85 per cent of the forests available for wood production are certified.
- Most consumers want products with forest certification labels, as they are a guarantee of responsible and sustainable forest management.

Photo: Shutterstock

At present, only circa 11 per cent of the world's forests are certified under international forest management standards, of which the FSC standard, operated by the Forest Stewardship Council, and the PEFC, operated by the Programme for the Endorsement of Forest Certification, are most commonly in use. In Finland, more than 85 per cent (17.6 million hectares) of the forests available for wood production are PEFC certified. Most of the privately-owned forests and all state and forest company owned forests are PEFC certified. The agreement on the first FSC forest management standard was reached in 2011, and the FSC-certified area has now exceeded 1.5 million hectares. Almost all FSC-certified forests are owned by forest companies.

Certification has improved the quality of forest management, with significant positive effects on the preservation of biodiversity in forests. The single most effective measure promoting biodiversity is retention trees required to be left at the final harvesting site. As a result of certification, more than 500,000 cubic metres of retention trees are left in Finnish forests every year. This equates to 8 million cubic metres since the beginning of forest certification in Finland. Other contributions worth mentioning are environmental guidelines for harvesting energy wood, the requirement for controlled burning and buffer zones alongside water bodies.

After harvesting, wood-based raw materials undergo many processing, transformation and manufacturing processes before reaching the final consumer. The Chain of Custody (CoC) certification outlines the requirements for the tracking of timber from forests to the final product. For a product to qualify for certification, all entities along the supply chain taking legal ownership of the product must hold a valid CoC certificate. Only then are certified products eligible for a forest certification label.

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Photo: Vastavalo

Sustainable bioenergy

Wood-based bioenergy is the most important source of energy in Finland, representing more than a quarter of energy production. In Finland, bioenergy production is largely integrated into the forestry and forest industry. Eighty per cent of Finnish wood-based energy is produced using by-products and residues from forest industry, silvicultural and harvest operations. Black liquor, bark, sawdust and other industrial wood residues represent a major share of the raw materials from which wood-based fuels are made. However, in recent years, the use of logging residues, stumps and small-diameter trees has rapidly increased. The small-scale use of wood for heating in residential houses, summer cottages and farms, mainly consisting of chopped firewood, pellets and residues, is also a significant part of the bioenergy mix. The share of waste or demolition wood from the construction sector and wood from municipal solid waste is rather small in Finland.

Bioenergy enhances social sustainability

In Finland, the role of traditional firewood in the wood flow is considerable, amounting to 6 million m^3 annually. It is used for the heating of houses, summer cottages and saunas. In the winter, firewood plays an important role as a source of energy in electrically heated houses by cutting the peak in the use of electricity. Finnish technology for the production of firewood is well known, from axes to modern splitting machines. On farms, bioenergy – based on wood and agricultural residues – improves the economy and energy security of agriculture.

Eighty per cent of wood-based bioenergy is produced using by-products and residues from harvesting and production operations of the forest industry.

Photo: Vastavalo

Most Finnish municipal centres outside the capital region use district heating plants, where wood is the main source of energy, accompanied with peat, especially in the larger CHP plants. These plants acquire their fuels from the surrounding countryside, providing an income and livelihood to the forest owners and the entrepreneurs operating the biomass harvesting and transport fleet. The annual income from the forest energy biomass corresponds to the costs of seeding and planting in private forests.

Bioenergy is an integral part of the Finnish bioeconomy

Managing water quality and biodiversity

Nutrient losses from leaching and the harvesting of forests can be reduced by good harvesting practices: a sufficient residue drying period on site for logging residues and delimbing of small-diameter trees for energy helps to return the nutrients to the soil. For example, the Finnish silvicultural guidelines require that at least 30 per cent of tops and branches are left at the harvest site. A reduced amount of dead wood in forests can affect the diversity of species dependent on it. Therefore, it is important to recognize and protect biodiversity hotspots and ensure that enough dead wood is also left in forests managed for biomass supply.

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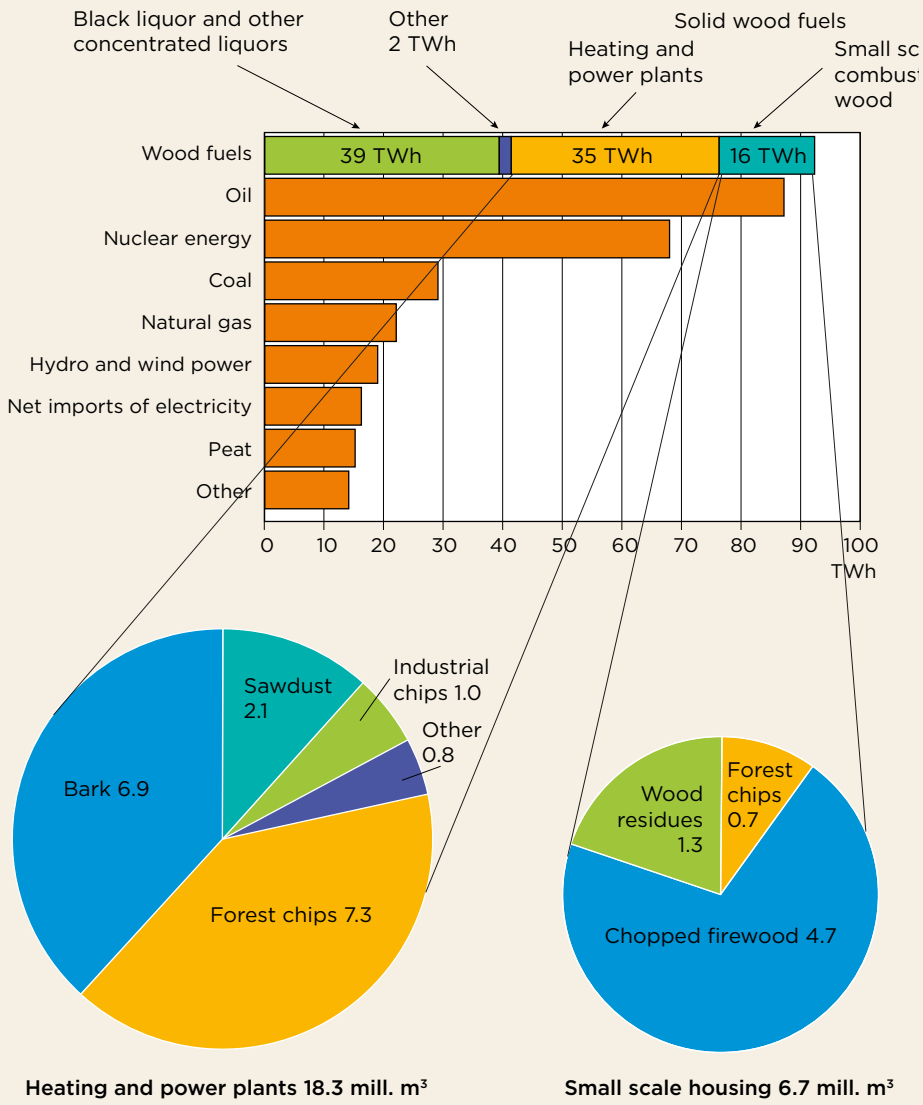
Most Finnish municipal centres outside the capital region use district heating plants, where pellets and wood residues are the main energy source.



Energy consumption in Finland by energy source in 2015. Wood-based fuels constitute the largest source. (Source: The Natural Resources Institute Finland)

Photo: Sami Helenius

Intelligent machinery for sustainable forestry

The harvesting and transportation of wood-based biomass from forests to processing for a variety of end uses calls for efficient logistic and information systems in order to ensure that the operations are sustainable both from the economic and ecological points of view. In Finland, Ponsse Plc produces innovative forestry machines and wireless automated data-intensive solutions that can optimise the needs of the entire biomass value chain. Wireless remote applications are also used in transporting machines between logging sites and in maintenance and diagnostic services for machines worldwide. Since the 1970s, Ponsse has manufactured over 12,000 forestry machines, and today its export and service network covers 40 countries. Ponsse, John Deere and Komatsu together share more than 90 per cent of the global market for forest machines – each accounting for roughly a third.

A technologically highly advanced harvester with the brand name "Scorpion" was launched in 2013, with new solutions that improve productivity and ergonomics. For example, the new crane solution offers the driver visibility in all directions. Cabin levelling keeps the driver stable, even in difficult terrains. The frame of the machine consists of three parts and the cabin is located in the middle frame, enabling comfort for the driver at work. The stability of the machine is based on eight wheels and an active smart stabilisation system. Wireless solutions enable the management of logistics and transportation of biomass procurement over the entire value chain. Ponsse also uses wireless

Wireless solutions serve the biomass value chain from the forest owner to the mill site.

New forest machinery enables the cutting of only selected trees from the forest. This promotes the regeneration of forests and speeds up their role as carbon sinks. (Source: Ponsse Plc)

applications in its worldwide preventive remote operations, in maintenance services, and in spare part deliveries for forestry machines, as well as for informing drivers who operate the transportation carriages of machines. Ponsse's partners both upstream and downstream in the value chain play important roles in the next steps of product development.

Intelligent forest machinery and wireless services ensure sustainable operations from both economic and ecological points of view.

In effective forestry management, the key issue is how information is acquired and exchanged across the whole value chain, from the procurement of wood in the forests to transport and logistical operations and industrial processing. Through wireless intelligence, traditional logging has been transformed into wirelessly managed automated and data-intensive solutions for the whole value chain. Real-time data are visualised for easy monitoring and decision-making, from the logger to the fleet manager and the services. Machines are equipped with monitoring operations informing where the machine is moving, whether it needs a transportation carriage to change place, and what is the engine output and fuel consumption. As data are transferred to the cloud, entrepreneurs can keep track of their machines.

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The role of consumers

Consumer awareness of bioproduct options is essential, because consumers ultimately choose which of the alternatives available are most suitable for them. As the scope of products, services and environments – in which wood as a raw material plays an important role – is widening at an accelerated pace, the role of consumers has to be taken into account in new ways.

Suominen's nonwoven materials are made of 100 per cent cellulosic fibres and designed for flushable wipes that are both biodegradable and dispersible in an aquatic environment. (Photo: Suominen Plc)

How do innovative wood-based solutions relate to the changing consumer reality?

The consumption trends of today are an interesting mixture of somewhat clashing currents that give rise to new lifestyles, born out of the controversy between convenient consumerism and the strive towards active engaged citizenship, both facilitated by widespread digitalisation. To remain competitive, new products and services must meet the demand for convenience, but at the same time rise to the challenge of addressing existing social and environmental issues. Although a renewable resource, the use of wood has been regarded with caution in terms of sustainability. However, the priorities set out by the new consumer reality, such as innovativeness, well-being and functionality, reveal the new uses and pertinence of wood-based solutions in such essential consumption domains as housing, food, mobility and clothing.

Global instability, financial struggles and corporate greenwashing in response to environmental problems have led to the phenomenon of more concerned and questioning consumers. They are not easily convinced and are less trusting towards simplistic promotional messages. Fast access to information and the multitude of information sources have led to the situation where the debate about what is sustainable and ethical is explicit and vibrant. Being doubtful and in search of personal meaning is socially accepted, because the new reality is complex and rapidly changing. It requires adjustments to what had once been established truths. New ways of communication significantly accelerate the pace of discussion and the rhythm of life. To make sense of the information-intensive reality, virtual communities are being formed and the meaning of "experts" in society has transformed. Increasingly, consumers use digital tools to articulate and fulfil their needs, trusting and relying on advice obtained through virtual communities.

The yarn for the textile is made from ionic liquid-based cellulosic fibres. (Photos: Sara Riikonen)

Urgent and evident challenges, such as climate change and the refugee crisis, are a wake-up call. Consumers tend to look beyond brands for a meaningful value because of the desire to be part of the solution

Sustainable choices are becoming mainstream.

The bow tie and a pocket handkerchief have been woven from Ioncell F yarn manufactured from birch pulp. (Photo: Eeva Suorlahti)

to contemporary world challenges. Younger generations, in particular, are keen on embracing environmental and social causes to build their identity and to look for more meaningful jobs, so that the boundary between everyday life and activism is becoming blurred. Web 2.0 technologies are empowering consumers to support the causes they care about in any part of the world. There is increased interest towards solutions invented by passionate entrepreneurs – fellow citizens who dare to innovate, and may rely solely on crowdfunding to turn their ideas into reality. Consumers are becoming more open and flexible towards alternative consumption patterns, they are more willing to let go of private ownership, and instead focus on higher functionality through innovative service solutions.

Wood-based solutions offer promising possibilities not only for sustainability-conscious, but also for quality-oriented consumers.

However, due to continuing economic paroxysms, consumers are cautious in their spending, and price continues to play an important role in decision-making. As a consequence, the popularity of cost-effective services enabled by the sharing economy has made a breakthrough, as demonstrated by car pools and accommodation services. Sustainable choices are also becoming mainstream thanks to increased concerns with leading healthier lifestyles. For example, the demand for a wider range of organic food in conventional supermarkets is rising. The time-poor urban population is convenience oriented, which means that emerging sustainability-oriented products and services must be accessible, competitively priced and functional. Making smart choices today is about a combination encompassing sustainability, style and affordability.

The United Nations Environmental Programme's report on the environmental impacts of consumption and production identifies housing (including domestic energy use), food and mobility as "priority clusters" for action because of their significant environmental impacts. Thus, the provision of more sustainable options in these domains is of utmost importance. Wood-based solutions respond to the challenge and offer promising possibilities. For instance, in the construction of multi-storey wooden houses, the use of ready-made modules accelerates the construction time at the building site and drastically reduces waste. The resulting cost savings enable construction companies to offer affordable high-quality housing to lower income consumer segments. The design and use of wooden interior elements is not only about decoration, but serves acoustic and sound-proofing purposes. The use of wood in interior solutions has proved to be a healthier choice and more pleasing to the eye.

In fact, wood-based products have surprising applications in encouraging healthier habits. Derived from hemicellulose, xylitol has been demonstrated to prevent tooth decay when used after meals.

Hectic lifestyles in urban environments predispose to quick convenient on-the-go solutions for food. The

Policy-makers can facilitate the growing use of sustainable products and services with regulation and thus increase their market penetration.

range of on-the-go food is no longer limited to what is traditionally considered "fast food", as the strive for healthier lifestyles has extended the offer to salads, smoothies and liquid "super meals". All of these, however, require safe and convenient packaging. Reducing the amount of plastic while increasing the wood fibre content in food packaging significantly improves recyclability and promotes circular economy-oriented ways of operation.

The share of cotton fibres in world production has drastically decreased from 88 per cent in 1940 to 33 per cent in 2010 (WorldWatch Institute). The cultivation of cotton is very intensive in terms of water, fertilizer and pesticide use, causing adverse environmental impacts. Conversely, the use of synthetic fibres grew to 60 per cent by 2010, although its health effects and the "feel" next to the skin are not comparable to natural fibres. In this sense, textiles with wood-based fibres offer a natural alternative to the growing share of consumers concerned with the sustainability, healthiness and functionality of clothing.

As envisioned by the WorldWatch Institute, sustainable cities of the future will be participatory organisms, where citizens will find roles for governing through individual voting or as members of stakeholder groups. Already now, many are asking themselves the question "how will the world be different because I lived in it?" At this point, the task of policy-makers and businesses is to facilitate the growing use of sustainable products and services with regulation, and by so doing increase their market penetration.

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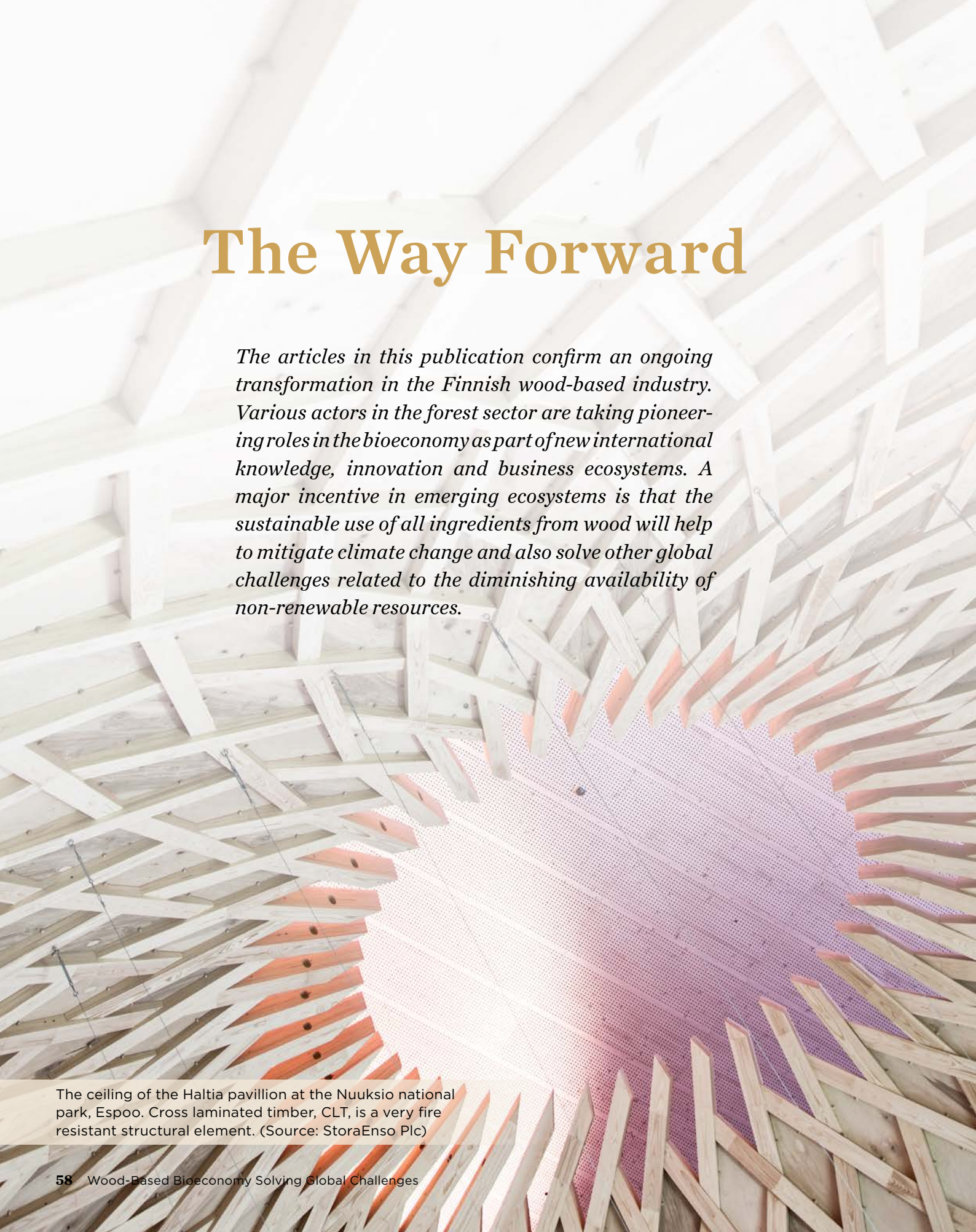
Marimekko's dresses made of birch pulp. The yarn was knitted at the Aalto University in Finland. (Source: CLIC Innovation Ltd)

The Way Forward

The articles in this publication confirm an ongoing transformation in the Finnish wood-based industry. Various actors in the forest sector are taking pioneering roles in the bioeconomy as part of new international knowledge, innovation and business ecosystems. A major incentive in emerging ecosystems is that the sustainable use of all ingredients from wood will help to mitigate climate change and also solve other global challenges related to the diminishing availability of non-renewable resources.



The ceiling of the Haltia pavillion at the Nuuksio national park, Espoo. Cross laminated timber, CLT, is a very fire resistant structural element. (Source: StoraEnso Plc)

From research and piloting to commercialisation

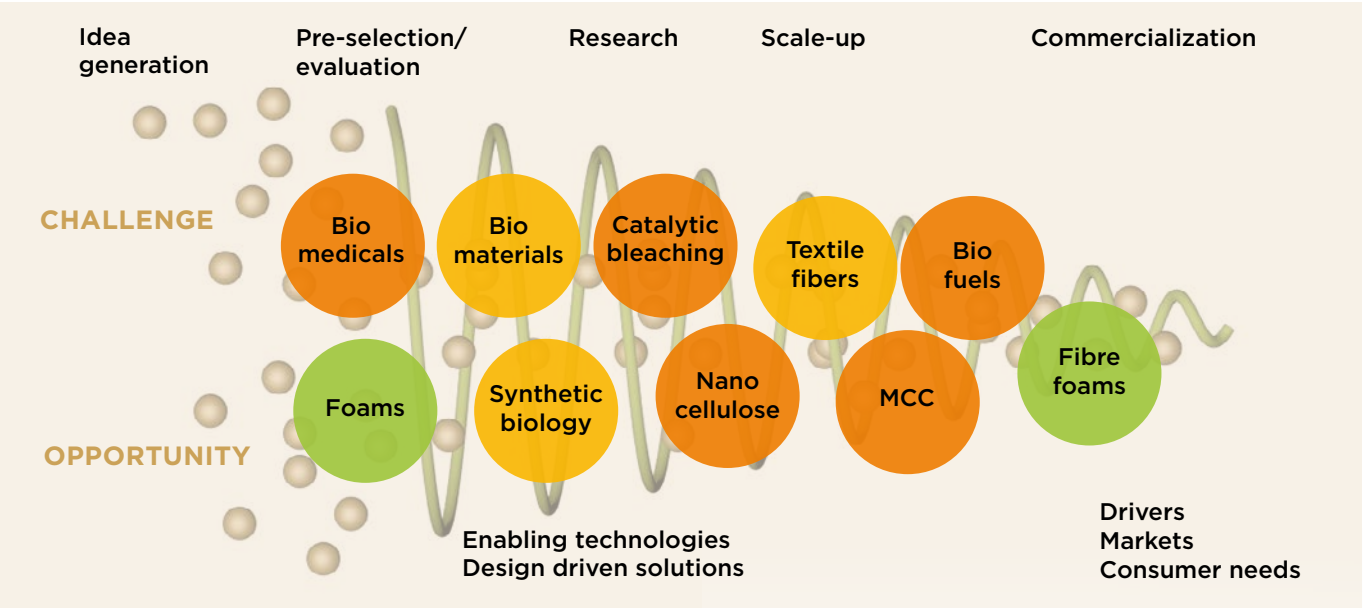
Breakthroughs in research have revealed that wood contains ingredients that have the potential for multiple end uses. To overcome the hurdles in innovation processes, multidisciplinary competences are needed. To address this challenge, the universities in Finland have undergone a restructuring process. Helsinki University of Technology, Helsinki School of Economics and the University of Arts and Design joined together to form Aalto University in 2010. Multidisciplinary research programmes as well as Master's Programmes have been launched. The organisation of the Aalto University School of Chemical Engineering (http://chem.aalto.fi/en/) has been remodelled, bringing together previously somewhat distant academic disciplines. In addition, universities and research institutes have deepened their co-operation: Aalto University and VTT Technical Research Centre of Finland Ltd have a strategic partnership with joint research consortia, joint research infrastructures, and the co-location of key research units. These moves, in combination with parallel ones elsewhere in Finland, have created or strengthened knowledge centres forming the backbone to the bioeconomy.

However, the movement in the innovation pipeline from laboratories and piloting facilities towards full-scale production for new value chains would not have been possible without the reorientation in large globally operating forest industry companies. They have for decades built and developed vertically integrated capital-intensive production systems that facilitate the use of different ingredients available in the wood raw material. Fortunately, after a decade of restructuring operations, due to the decline in demand for printing paper, the large forest industry companies are all making profits from their established core products. This gives them leverage to turn established mill sites into biorefineries. Now, biorefineries are platforms for using, step by step, all the ingredients in wood and for valorising them in the most valuable end uses for the markets. Such experimental processes are being implemented in knowledge-intensive epistemic communities across the globe. No wonder that foreign companies have established their operations at some biorefinery sites in Finland by purchasing established business operations, taking ownership stakes in local business operations or in start-ups.

The need for start-ups is related to the wide scope of opportunities available in the use of different types of wood ingredients. The business potential of many of these has not been significant enough for large companies. For this reason, they are actively supporting the emergence of start-ups as they enrich local knowledge ecosystems and build new value constellations across industrial divides. The same also concerns VTT Technical Research Centre of Finland. It encourages its researchers to set up spin-offs based

Multidisciplinary centres of knowledge form the backbone of the bioeconomy.

The strong bioeconomy innovation ecosystem in Finland: Industry – Research institutes – Universities



Source: Professor Janne Laine, Aalto University, School of Chemical Engineering

Start-ups enrich local knowledge ecosystems and build new value constellations across industrial divides.

on their research, piloting operations and collaborative development work with customers. VTT has established a company, VTT Ventures Ltd, which has the capacity to make investments in spin-offs and switch VTT's intellectual property rights to equity stakes in spin-offs and start-ups. Such deals increase the credibility of start-ups seeking equity funding from the markets.

The investments made in piloting facilities have also helped the start-up boom, as the credibility of inventions has to be demonstrated to potential customers via "boundary objects" that can be put to the test, and by so doing point the way to the next steps in the piloting process.

For the formation of knowledge-intensive ecosystems, a major structural change was made in the Finnish innovation system a decade ago. Innovation-oriented research programme development was decentralised by forming companies as legal entities with universities, research institutes and private companies as owners. One of the established companies was Finnish Bioeconomy Cluster Ltd. Another one, CLEEN Ltd, focused on clean tech innovations. Due to their

Forest management, harvesting and logistics provide employment all over the country.

overlapping research needs and innovation potentials, as well as the needs for multidisciplinary mobilisations and to expand the scope of cross-industrial engagement, the two research programme development companies were merged in 2015 to form CLIC Innovation Ltd (www.clicinnovation.fi). Due to the new operating context created by the merger, new collective working practices have also been developed and implemented to better establish an open innovation environment for the research programme development phase and for the actual research project phase. This has especially helped start-ups to become involved and included in projects, which helps them to move on in their product development process and contribute with their know-how to the multi-actor projects in which they are included.

This positive mood for the development of the bioeconomy in Finland has been based on the wide coverage of forests and the accumulated growth of wood in them. Digitalised data on forest resources are available for the owners, and the data can also be utilised in forestry management. Many owners make this data publicly available. Forest areas are certified in Finland, and companies comply with the practices required by the Chain of Custody certification. Access to forests is facilitated by roads. Private companies for forest management and harvesting, as well as for logistics, provide employment across the country. If companies are interested in making investments in production operations, the environmental impact assessment (EIA) of projects has been streamlined to speed up the assessment process, without relaxing the evaluation criteria. In general, Finland has for decades been rated among the top countries in the world in terms of the transparency of public decision-making.

Finally, we invite you to use the contact points and Internet links provided in the following pages. The bioeconomy will provide solutions to global challenges, and as an economic field it is growing rapidly. Join in!

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The challenge for policy-makers is to facilitate with regulation the use of sustainable products and services.

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Wood raw materials contain ingredients that have only recently been detected and developed for new uses. In Finland, traditional forest industry mill sites are in the process of becoming biorefineries. The bioeconomy will provide solutions to global challenges and as an economic field it is growing rapidly. Join in!

More information: Ministry of Economic Affairs and Employment of Finland, Enterprise and Innovation Department, e-mail: eio@tem.fi.

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