Future Watch Report

Opportunities for Finnish Companies in the Bio-based Chemical and Material Markets

Contact information

Dr. Petri Vasara, Global Practice Head
Juulia Kuhlman, Senior Consultant
Henna Poikolainen, Senior Consultant

Pöyry Management Consulting Oy
Jaakonkatu 3, P.O. Box 4
FI-01621 Vantaa, Finland

Tel. +358 10 33 22611
petri.vasara@poyry.com

Pöyry Management Consulting

The leading advisor to the world's energy, forest and bio-based industries. Clients choose us for the sharpness of our insight, deep industry expertise and proven track record – because results count.

Tekes – the Finnish Funding Agency for Innovation

Tekes is the main public funding organisation for research, development and innovation in Finland. Tekes funds wide-ranging innovation activities in research communities, industry and service sectors and especially promotes cooperative and risk-intensive projects. Tekes' current strategy puts strong emphasis on growth seeking SMEs.

Team Finland Market Opportunities

Global Team Finland network seeks proactively business relevant insights to meet the needs of Finnish companies. **Future watch** is part of the service and monitors change phenomena reshaping the future demand. www.marketopportunities.fi

Executive summary

Bioeconomy has been lifted as one of the cornerstones for future economic growth in Finland. There is strong knowhow around bio-based solutions in Finland, but in order to succeed in the global market, knowhow about global business within the segment is absolutely necessary. To help Finnish companies in finding out new opportunities and to give solutions to bypassing existing hurdles, Tekes and Team Finland Market Opportunities service/ Future Watch have funded this report focusing on existing solutions to common market barriers.

The report aims to provide examples of smart, existing solutions to common problems. To this end, it describes 10 cases which provide solutions to the most common barriers that companies face such as securing cash flow, finding partners with the best fit, choosing the right technology and business model and getting familiar with your market.

The findings of this report can be summarized as a set of "rules of thumb" supported by real-world cases for avoiding common pitfalls to the Finnish companies operating in the bio-based chemicals and materials field.

- *Shield yourself from obvious cash flow risks by producing commodities, leveraging your know-how or expanding to supporting businesses.*
- *When finding partners for your business look for the best, look globally and look further in the value chain than you first thought – and think of what your value chain should look like*
- *Develop a solid strategy and business model prior to commercial production – and stick to it unless conditions change*
- *Turn market barriers into competitive advantage – if things are difficult for all, become a solution provider. Find your role and reinforce it. Make a virtue out of necessity*
- *Prepare for changes like disruptive technologies or regulation in the business environment well ahead of the mainstream*
- *Innovative marketing strategies could expand your business through your customers' support. Think what benefits your product brings for the whole value chain*
- *Dare to see the potential in combining your technology with a potentially competing one into a composite/hybrid, don't be afraid to see the larger potential in joint solutions throughout the value chain.*

It is our hope that the solutions collected here will provide practical help for deserved business growth for promising companies in promising sectors.

Abbreviations

ABS	Acrylonitrile Butadiene Styrene, plastic resin
BDO	Butanediol, intermediate chemical
ECH	Epichlorohydrin, intermediate chemical
FAME	Fatty Acid Methyl Ester, biodiesel
IP	Intellectual Property
JV	Joint Venture
MEG	Monoethylene Glycol, intermediate chemical
MPG	Monopropylene Glycol, intermediate chemical
NFC	Natural Fibre Composite
PBS	Polybutylene Succinate, plastic resin
PE	Polyethylene, plastic resin
PET	Polyethylene Terephthalate, plastic resin
PHA	Polyhydroxyalkanoate, plastic resin
PLA	Polylactic acid, plastic resin
PS	Polystyrene, plastic resin
THF	Tetrahydrofuran, intermediate chemical
WPC	Wood Plastic Composite

1. Introduction

The objective of this report is to help Finnish companies overcome market hurdles by presenting successful cases from the area of bio-based materials and chemicals

Bioeconomy has been lifted out as one of the cornerstones for future economic growth in Finland. There is strong knowhow around bio-based solutions in Finland, but in order to succeed on the global markets, knowhow about the global business environment is needed. To help Finnish companies in finding new opportunities and to give solutions to existing problems and hurdles, Tekes and TF Market opportunities service/Future Watch launched a project focusing on “Opportunities for Finnish Companies in the Bio-based Chemical and Material Markets”. Pöyry Management Consulting Oy was selected to help Tekes within the project.

The objective of this work is to recognize and find new future needs for biomaterial-based business – and ways to get in. The report gives cases from the area of Bio-based Chemical and Materials Markets analysing the problems and solutions in successful market access. This material is tailored for Finnish companies looking for answers to their market-related problems in penetrating biomarkets.

This report presents the results of the market analysis. The long list of cases studied is listed in Annex 1 and 2 and the selected cases analysed in detail are presented in chapter 4. In addition we discuss shortly the main drivers and barriers within the bio-based chemicals and materials market and the geographical hubs that were included in the report. In the end short conclusions in the form of implications for Finnish companies are presented.

2. Methodology

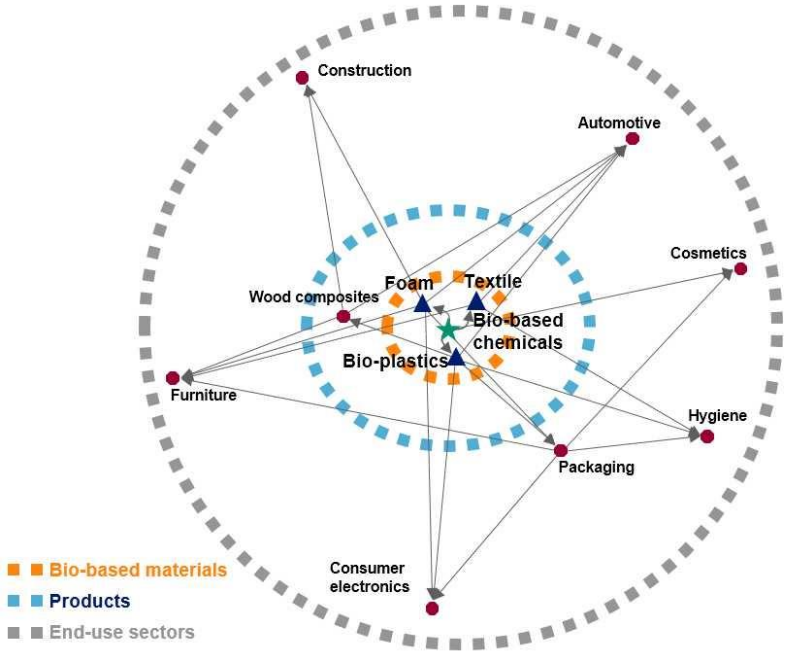
The project was divided into two phases. In the first phase Pöyry collected a selection of 30 cases from various interesting market areas. Short case descriptions were presented to the project working group which selected the most interesting cases for deeper analysis.

Within this work we have focused on bio-based materials and chemicals excluding biofuels and bioenergy. The bio-based solutions vary from products replacing earlier fossil based solutions or offering improved new features to existing products or totally new solutions.

The case descriptions were selected based on market areas which are relevant to Finnish companies and have significant market potential. These areas include e.g. bio-based platform chemicals, fine chemicals, pharmaceuticals, wood based biomaterials, composites, textiles and packages. In addition, some cases were brought in where the solution was not case or market area specific but can be applied to various uses. This is because the bio-based chemical and material sector crosses many industries and end uses and is an area where so-called network effects can be leveraged (i.e. chains of events quickly spreads success in a large network). This creates a possibility of a single innovation, improved process or advance in cost propagating across multiple sectors at surprising speed. The implication is very significant: an innovation or other development in e.g. bioplastics can with surprising speed spread among many different end use sectors. Find the right chemical or material, and you can win in sector after

sector. This means that a technology/cost breakthrough can cause a sudden jump in the growth projection (Figure 1).

Figure 1 The Dynamics of Bio-Based Chemicals and Materials: Success propagating from core across industries



Geographically the study focused on four hubs which determine the global dynamics of the sector (Europe, North America, Latin America and Asia). In addition, a time horizon was added to the cases to cover both existing markets and touch future opportunities. We divided the cases into three different classes, namely 1) Existing, Close to mainstream; 2) Existing, Future oriented; 3) Visionary (Figure 2).

Figure 2 Summary of case examples

Existing, Close to mainstream	Existing, Future oriented		Visionary
Novamont – Local resources	Anellotech – Credibility	TerraVia – Refined focus	Adding features to existing product
Onbone – End-user experience	MHG – Integration	M&G Chemicals – Cutting premium	Sensor filled 3D printed hair
GFBiochemicals – Levulinic acid	Gevo – Securing cash flow	Natur-Tec – Geographical expansion	Seeweed based bone
Beologic – Exploiting barriers	BioAmber – Exclusive partnerships	Solvay – Bypass sale	Formable liquid
FKuR – Adding value	Green Biologics – Retrofitting	Oszko – crowdsourcing and branding	3D printing of nanopatterns
NaturaCosmetics – success abroad	Amyris – Automatisation	Houses that absorb pollutants	Biofibre construction
SABIC – influencing standardisation	Newlight – Risk mitigation	Biomaterial tooth spray	
Food industry – ingredient branding	TerraVerdae BioWorks – Microbeads	Composite fibres	

The case descriptions are based on publicly available material, such as webpages, published interviews, articles and seminar presentations, and also Pöyry weak signals and technology analysis. In addition Pöyry has used its databases, accumulated understanding and existing material related to the markets of bio-based chemicals and materials. The analysis combines Pöyry know-how from its work in market dynamics, consumer trends, weak signals and future research.

3. Key drivers and barriers

The key drivers within the market are functionality, cost reductions, consumer trends and the changing business environment

A recent EU funded research project BIO-TIC collected extensive amounts of information related to the key drivers and barriers within the bio-based industry in Europe[1]. The stakeholders involved within the project saw that in addition to macroeconomics and population growth, the key drivers in the market of bio-based chemicals and materials are functionality, cost reductions and consumer trends in addition to a changing business environment. Within most of the cases more than one trend is present, but the most dominating trend is often obvious.

Consumer trends cover both increased environmental consciousness that has an impact on consumption within the bio-based materials and chemicals sphere, but also things such as search for increased convenience and low maintenance and the consumer need to be involved or show status.

Cost reductions cover reductions in any part of the value chain producing the product (e.g. raw material, logistics, production, distribution) and also cost reductions for the client.

Changing business environment includes changes for example in regulation and policies which have generally been a major driver within the market and for example standardisation which is often requested as proof of bio-based content or sustainability. It also covers changes in the business environment such as responding to the challenges of ageing, climate change, pollution or changed consumption patterns or consumer preferences.

Functionality is the main driver when the bio-based product can offer new improved features to existing products or aid in developing totally new products which fill an existing or emerging need.

How significant each driver is naturally differs between products. The cases selected within this study were grouped by dominant driver (**Figure 3**).

[1] BIO-TIC project web pages: http://www.industrialbiotech-europe.eu/bio-tic/about-bio-tic/ BIO-TIC market roadmap: Overcoming hurdles for innovation in industrial biotechnology. 2015. available at: http://www.industrialbiotech-europe.eu/new/wp-content/uploads/2015/10/Market-Roadmap-Final-1-OCT-2015.pdf

Figure 3 Case examples by key drivers

The key barriers for business success within the bio-based materials market were seen to be market entry, policies and regulations and research and development. The market related hurdles are three: cost competitiveness, image and functionality[1]. During the discussions with the project working group we also mapped some of the challenges that especially Finnish companies are facing. These included securing cash flow during the first years, deep knowhow of markets and competing technologies, lacking or preventing standardization and regulation, difficulties in finding partners along the value chain within Finland, difficulties in finding risk investors within Finland, the costs related to scaling up and challenges in creating early-stage demand. The selected cases demonstrate solutions to these issues.

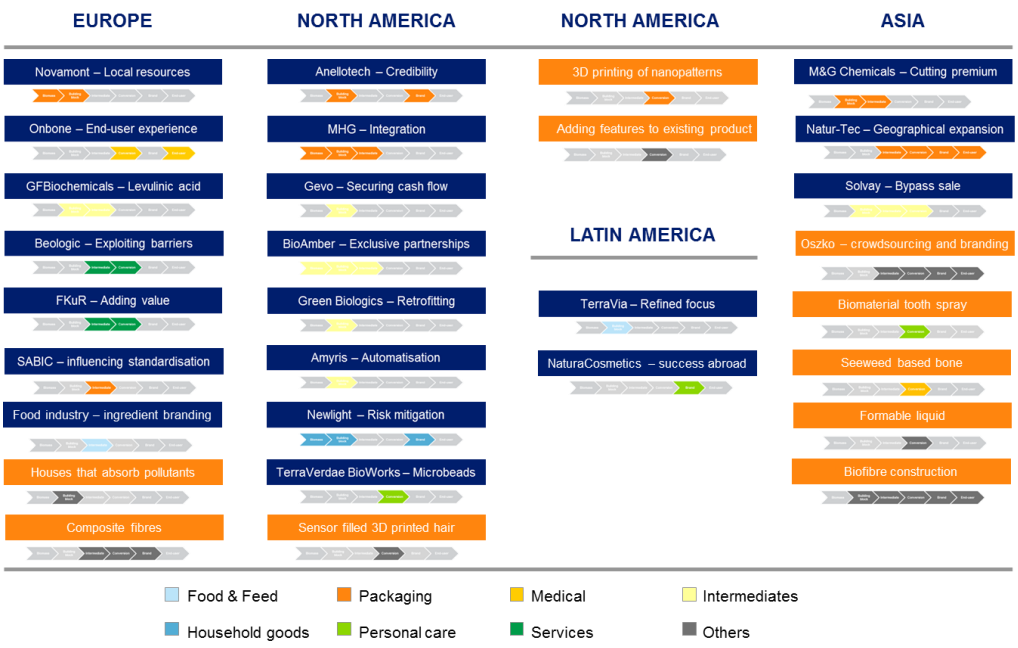
4. Geographical hubs

The bio-based market is very global. Do not forget to check emerging opportunities outside the closest markets.

Looking at the most important markets for Finnish bio-based products and materials one can easily argue that Europe is the most important. However, the situation is not always that simple. The bio-based world is working in wider networks which cover the whole world. For example, the well-known Swedish brand IKEA has invested in the US based company Newlight which develops technology in order to produce bioplastics[2]. Also the IKEA group has formed a partnership with Neste to produce bioplastics for their needs[3]. They also invite other companies to join their initiative. This case is a splendid example of how breakthroughs in bio-based plastics are emerging. Raw material producer, technology providers and end user work together globally, driven by market and consumer needs.

Within this study we have widened the perspective from Europe to other areas. Geographically the study focused on four hubs; Europe, North America, Latin America and Asia (Figure 4). While Europe is an important market for Finnish companies it has also been a driver within the development of the bio-based market. On the other hand most of the new investments within the bio-based chemicals and materials area are done in North America, Latin America and Asia. Currently both markets and investments have been smaller in Oceania and Africa and thus these areas were left out from this study.

Figure 4 Case examples by geography



Europe

The European bio-based industry is and has been very active in developing new technologies and solutions to help the move towards a world with less dependency on fossil raw materials. In addition, some of the European brands are the forerunners in

[2] http://newlight.com/newlight-signs-10-billion-pound-production-license-with-ikea-2/
[3]http://www.biobasedworldnews.com/neste-and-ikea-teaming-up-on-bio-based-plastics-and-seeking-further-partners

committing to bio-based solutions, such as IKEA and Danone. Also European governments have stepped up in supporting bio-based industries through regulation such as plastic bag regulation in Italy and in France. Europe is also one of the key markets for bio-based solutions.

North America

North America is another key hub for the bio-based market. With significant consumption power and various policies supporting the bio-based market, it is one of the largest markets for new bio-based materials and chemicals. It is also estimated to show a healthy market growth during the coming years. A major share of the new innovations in bio-based chemicals and materials are coming from North America. The European industry should watch out for disruptive technologies springing up especially here when assessing competition in the market.

Latin America

A number of countries in Latin America are implementing close-to-market measures to attract production hubs and promote faster market development around the bio-based markets. Production of bioenergy and biofuels has been the focus, but now e.g. ethanol producers are looking for options to move towards bio-based chemicals to widen their product portfolio and lessen the dependence on energy markets and bio-energy subsidies. It is also estimated that Latin America will be a future growth market for bio-based solutions, but given the current economic challenges the major economies of Latin America such as Brazil and Argentina are struggling with, it seems that there is a delay in the development.

Asia

Asia has abundance of residual biomass from e.g. palm oil industry which could transform to important low-cost feedstock for bio-based chemicals and materials. Countries such as Malaysia[4] and Thailand[5] are pushing local industries to explore new bio-based products and are fast becoming key production hubs for bioplastics. By 2020, China and Thailand will represent majority share of global production of biodegradable plastics. Asia is not only a major producer, but also an emerging consumer of bio-based solutions. Growing economies correspond to increased purchasing power and there are already domestic markets for e.g. biodegradable packaging materials although organic waste collection is still in its infancy.

5. Best practices

From the 30 cases collected in the first phase of the study 10 were selected for further analysis and to represent best practices within the bio-based chemical and material

[4] http://www.theborneopost.com/2016/02/26/pm-launches-sabah-and-sarawak-biomass-industry-devt-plan/

[5] http://www.nia.or.th/bioplastics/

markets. The selected cases are described more closely with the focus of opening up the solutions to common barriers within the market.

The cases were grouped under the following barriers:

Secure cash flow

5.1 M&G Chemicals – Cutting premium
5.2 FKUR – Adding value

Find partners with the best fit

5.3 Solvay – "Bypass sale"
5.4 BioAmber – Exclusive partnerships
5.5 GFBiochemicals – Focusing on one promising chemical, levulinic acid, from multiple directions

Choose the right technology and business model

5.6 Beologic – Exploiting barriers

Know your market

5.7 Terraverdae bioworks – Microbeads
5.8 Ingredient branding – Clever marketing
5.9 Sensor filled 3D printed hair – The amazing innovations
5.10 Economic savings from fibre composites – The practical side of the argument

5.1 M&G Chemicals – Cutting premium

Be aware of disruptive technologies, and ensure cash flow when dealing with novel processes with high technical risk

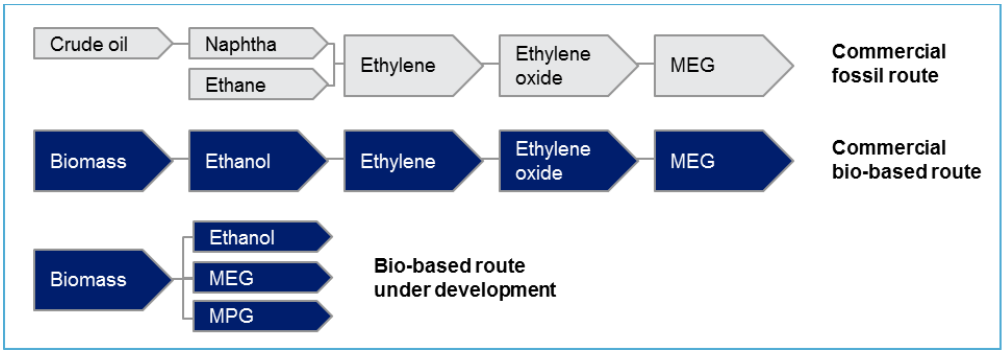
Ethylene is one of the most widely used petrochemicals in the world and a key precursor to a wide variety of derivatives such as monoethylene glycol (MEG), an intermediate in PET plastic production. Bio-based ethylene is currently produced in India, Taiwan and Brazil by catalytic dehydration of ethanol. Even with cheap Brazilian sugarcane ethanol, bio-ethylene cannot compete in price with low-cost naphtha or ethane derived ethylene. Bio-ethylene derivative monoethylene glycol is currently sold at approximately 30% premium to fossil-based MEG.

Global brand owners such as Coca-Cola, Danone, Procter & Gamble and Nestlé are increasingly considering bioplastics as part of their sustainability programme but market adoption is limited by premium pricing. M&G Chemicals, one of the world's largest producers of PET resins, has developed a novel technology for MEG production from cellulosic feedstocks. As illustrated in **Figure 5**, this new process significantly shortens the production chain from feedstock to monoethylene glycol, and thus, offers opportunities for cost reduction.

M&G's first bio-MEG project is a joint venture with local feedstock supplier Guozhen in Fuyang region, China. To reduce technology and market risk, the plant is designed to produce 200 000 t/a of cellulosic ethanol, 90 000 t/a propylene glycol and 80 000 t/a MEG. The project has been delayed from initial timeline, and is now likely to start in 2018 first with just ethanol production.

RULE OF THUMB: ENSURE CASH FLOW There is an obvious risk here, and M&G is ensuring cash flow by also, in the same group of companies, producing e.g. ethanol, other chemicals and energy to ensure a healthy bank account and business supporting the risk.

Figure 5 Production route to bio-based monoethylene glycol (MEG)



5.2 FKuR – Adding value

Adding value in bio-based value chains does not always require high capital investment

Bioplastics have great potential to substitute part of fossil-based plastics in a wide variety of applications, but the majority of current bioplastic grades require changes to processing equipment and operating settings. These changes add switching costs to already premium priced polymers. In addition, the end-use applications of bioplastics are still somewhat limited due to unique polymer properties.

FKuR Kunststoff GmbH is a German company specialised in blending and compounding bio-based plastics. FKuR improves compatibility of bioplastics with existing processing equipment and creates completely new functional properties by blending different polymers and additives. All FKuR bioplastics compounds can be processed directly on existing equipment as a drop-in solution to wide variety of plastic applications.

FKuR products include BIO-FLEX® blends of co-polyester and polylactic acid (PLA), cellulose-based BIOGRADE®, wood plastic composite FIBROLON® and Terralene® compounds made from bio-based polyethylene (PE). Key benefits of each of these products are summarised in **Table 1**. To secure steady cash flow and increase revenue, FKuR is also the key distribution partner in Europe for Braskem's bio-based polyethylene known as Green PE®, Toyota's 30% bio-based polyethylene tepehthalate (PET) known as GLOBIO® and Evonik's bio-based polyamide Vestamid Terra®.

RULE OF THUMB: FIND YOUR ROLE FKuR has found a good niche in the value chain for itself – the "wizard" creating value and new properties by blending knowhow. It is leveraging its knowhow, not heavy investments.

Table 1 Bioplastic compounds by FKuR

Product	Description	Key benefits
Bio-Flex®	Biodegradable plastics for extrusion	• Certified biodegradable and compostable • Drop-in solution for existing equipment
Biograde®	Biodegradable plastics for injection moulding	• Certified biodegradable and compostable • Similar properties to standard thermoplastics (e.g. ABS, PS) • Drop-in solution for existing equipment
Fibrolon®	WPC for injection moulding and extrusion	• High strength and stiffness • Drop-in solution for existing equipment
Terralene®	Bio-PE compounds for injection moulding and extrusion	• Portfolio of extrusion, blow moulding and injection grades • Drop-in solution for existing equipment

5.3 Solvay – "Bypass-sale"

Identify and convince key decision makers in bio-based value chains, the rest will follow

Glycerol production has increased dramatically in the past two decades as the result of growing demand for FAME biodiesel. Each tonne of vegetable oil or animal fat based biodiesel produced yields 0.1 tonnes of crude glycerol as a by-product. Such an increase in glycerol supply has resulted in record low prices for crude glycerol.

The Belgian chemical company Solvay took advantage of the increased availability of glycerol and developed a novel production route to epichlorohydrin (ECH) using bio-based crude glycerol as feedstock. Epichlorohydrin is an important precursor for epoxy resins which are found for example in coating formulations. Depending on the market conditions, Solvay's production costs for bio-based ECH are either lower than or on-par with conventional fossil-based epichlorohydrin.

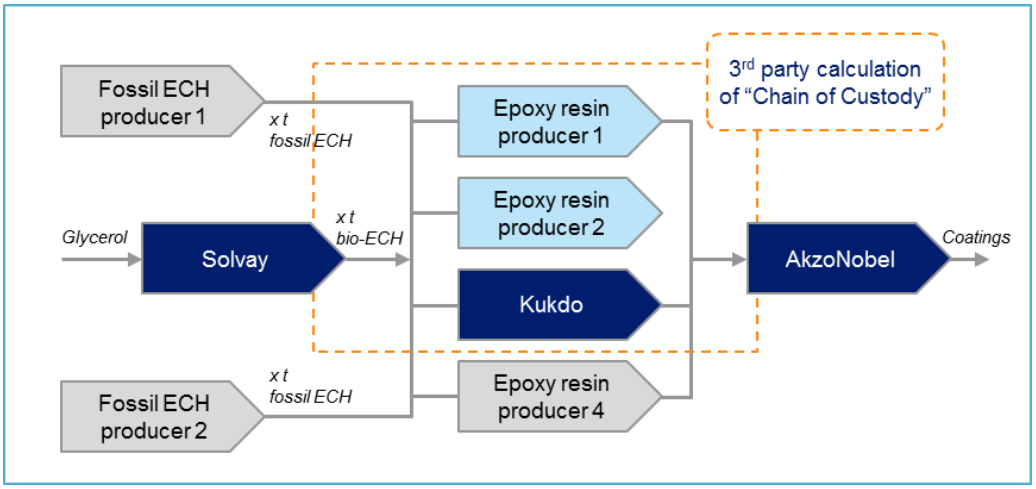
Solvay knew that one of the major coating producers further down the value chain, AkzoNobel, was interested in reducing its environmental impact and was looking to replace fossil-based chemicals with bio-based alternatives. Solvay and AkzoNobel also share a sales philosophy: they don't charge their customers a premium, but manage to increase market share and gain customer preference with bio-based components and improved environmental profile.

To complete the value chain for bio-based epichlorohydrin in coating applications, Solvay and AkzoNobel approached Korean epoxy resin producer Kukdo with ready supply and off-take agreements (Figure 6). Kukdo had very little risk in agreeing to process bio-based ECH with ready contracts and guaranteed margins.

In addition to Solvay's bio-based ECH, Kukdo converts also fossil-based ECH to epoxy resins. Similarly, AkzoNobel also purchased epoxy resins from other suppliers than just Kukdo. The bio-based content of AkzoNobel's coatings is thus calculated based on "Chain of Custody" principle by an independent third party.

RULE OF THUMB: FIND THE RIGHT PARTNER FOR THE RIGHT MOVE If Solvay had gone the usual route, to the next step in the chain, i.e. e.g. Kukdo, it would have had a very difficult sales job. It would have had to convince Kukdo of the existence of markets, offtakers, and profit to be made. Instead, it bypassed the next step (hence "bypass-sale"), went to AkzoNobel, made an agreement, and together the new allies could offer both supply (Solvay) and demand (AkzoNobel) to the middle player.

Figure 6 Bypass sale by Solvay



5.4 BioAmber – Exclusive partnerships

Develop a solid strategy and business model prior to commercial production – and stick to it unless conditions change

Succinic acid is a building block chemical of which global production from fossil resources is around 40 000 tonnes per annum. The applications of succinic acid have traditionally been limited by high production costs and high market price.

Succinic acid was selected as one of the 'Top Value Added Chemicals from Biomass' by the US Department of Energy (DoE) because of its versatility, wide variety of potential applications and interesting economics. The production costs of bio-based succinic acid are claimed to be lower than the conventional production costs using fossil resources. This has led to a number of new bio-based succinic acid projects which have started commercial production in the past few years.

In 2016, bio-based succinic acid capacity already exceeds current demand. Succinic acid producers and developers thus need to partner with downstream players to invent new end-uses and applications for succinic acid.

BioAmber is the world's leading producer and developer of bio-based succinic acid. To secure a leading position in what was forecast to be an oversupplied market, BioAmber devised a clear and decisive strategy: sign strong partnerships with chemical distributors and intermediate producers while having only minimal production. So, it chose to be almost the opposite of a many extremely technology oriented companies, which first assure themselves of having 100 % secure high-quality production and then look for partners. With 3 000 tonnes per annum of toll-manufacturing, BioAmber created an impressive partnering network. Table 2 summarises examples of BioAmber's partnerships and collaborations from the past six years. Most of these partnerships are on exclusive terms.

RULE OF THUMB: FIND A DIFFERENTIATING STRATEGY AND STICK TO IT

BioAmber's business model is based on collaborations and shared profits. BioAmber pays royalties per net sales e.g. to Cargill on all succinic acid sales, to Celexion on possible adipic acid sales and to DuPont on 1,4-butanediol (BDO) and possible tetrahydrofuran (THF) sales.

Table 2 Examples of BioAmber's partnerships and collaborations

2010	• BioAmber signs exclusive license agreements with Cargill and Celexion, and non-exclusive license agreement with DuPont • Agreement on exclusive use of ARD demo facility, and start of 3 kt/a toll manufacturing • Exclusive Asian distribution rights to Mitsui
2011	• 70/30 JV with Mitsui to build a 30kt plant in Canada • Exclusive supply agreement with Mitsubishi Chemical and PTTMCC • Joint Development Agreement with LANXESS for succinic acid based plasticizers
2012	• Exclusive supply agreement to the Faurecia-Mitsubishi partnership for automotive plastics
2013	• 50/50 JV with NatureWorks to commercialise PBS/PLA blends • Distribution agreements with Brenntag and IMCD
2014	• 15 year take-or-pay agreement with Vinmar for 100kt bio-BDO planned to start in 2018
2015	• Start of 30 kt/a succinic acid plant in Sarnia, Canada
2016	• Cellulosic sugars off-take agreement with Comet Biorefining, including some exclusive rights in the fields of succinic acid, BDO and THF

Hence, BioAmber saw a market getting crowded. It found what it saw as a good solution: hurry to the top by securing deals and partners, using a very small production capacity as basis. The strategy succeeded: now, it is hard to break BioAmber's network, and it can expand production on secure terms.

5.5 GFBiochemicals – Focusing on one promising chemical, levulinic acid, from multiple directions

Reach for the best resources – be it people, assets or IP

Levulinic acid is another bio-based building block chemical which was similarly selected by the US Department of Energy (DoE) on its list of 'Top Value Added Chemicals from Biomass'. Similarly to succinic acid, applications for levulinic acid are limited by high price.

GFBiochemicals has developed new technology for levulinic acid production from second generation non-edible biomass which is likely to reduce production costs and open new application and opportunities for levulinic acid. The first commercial levulinic acid facility by GFBiochemicals was started in 2015 in Caserta, Italy. GFBiochemicals roadmap from foundation to commercial production is presented below in Figure 7.

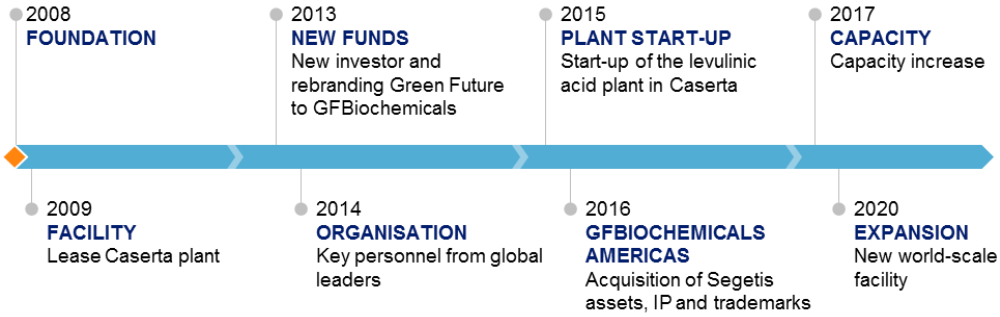
BioAmber went the commercial network route for its bio-based chemical and wanted to be the best networker; GFBiochemicals chose to be the collect the best resources under one roof. To succeed in the challenging task of market development, GFBiochemicals hired three key experts from DSM for Chief Commercial Officer, Director Technology & Applications Development, and Director Technology &

Engineering positions[6]. DSM, Dutch multinational focused on health, nutrition and materials, had their own levulinic acid project but decided not to move forward to commercialisation.

In February 2016, GFBiochemicals acquired all assets, intellectual property (IP) and trademarks of Segetis, the main levulinic acid derivatives producer in the US market. Segetis acquisition included over 250 patents worldwide, which contain rights for several proprietary applications for levulinic acid – including fragrances, plasticizers for PVC & biopolymers, personal care, household & industrial cleaners, agrochemicals formulations and coating / adhesive strippers industries.

RULE OF THUMB: GO FOR THE BEST TALENT AND ASSETS GFBiochemicals boldly went for being number one in knowledge and skills around levulinic acid, and took steps needed for that, risking recruitments and acquisition with high ambition. So far, the strategy seems succesful.

Figure 7 Roadmap to market by GFBiochemicals[7]



[6] www.gfbiochemicals.com/company/#our-team, 4 August 2016
[7] Adapted from GFBiochemicals presentation at 5th Biobased World conference, May 2016

5.6 Beologic – Exploiting barriers

Turn market barriers into key differentiators and competitive advantage – if things are difficult for all, become a service provider

Compared to just pure wood or plastics, natural fibre and wood plastic composites (NFC, WPC) can bring new functionalities to products such as stiffness, weatherproof and natural touch, in addition to the bio-based content. NFC and WPC are widely used in construction, automotive and furniture industry, but increasingly also in consumer goods.

Wood plastic composites typically contain 25-85% of wood fibres, which can make material processing in conventional extrusion machines very difficult. One of the major hurdles for wider market adoption of natural fibre and wood plastic composites is the limited compatibility with existing processing equipment

Beologic is a Belgian supplier of NFC and WPC compounds but sees itself primarily as a technology leader and a support focused company. To overcome market barriers, Beologic offers extensive customer support including R&D services, tooling, processing, product development and tool refurbishment – also for clients using compounds from other WPC compounders than Beologic. All wood plastic composite granules from Beologic are specifically designed to be processed in standard extruders with special focus on tool design. Beologic has succeeded in turning a market barrier to key differentiator and competitive advantage.

Examples of support services offered by Beologic include[8]:

- Start-up with WPC
- Technical support
- Product design
- Engineering network
- Rheology
- Process auditing
- Initial trials
- Demonstrations
- Training / Know-how transfer
- Sample production / Market evaluation
- Rent a tool

RULE OF THUMB: TURN BARRIERS INTO ENTRY DOORS – MAKE A VIRTUE OUT OF NECESSITY Beologic made a virtue out of a necessity. For most technology providers, support and services are a necessary evil standing in the way of wonderful technical innovations. Beologic saw the opportunity of being both a technology provider and the one providing the services and support. This is a “judo” move: use the market barrier’s strength (technical difficulties) against it.

[8] www.beologic.com, 15 July 2016

Prepare for changes in the business environment well ahead of the mainstream

5.7 TerraVerdae BioWorks – Microbeads

Microbeads are small solid plastic particles (less than 5mm in size) that are used in products such as toothpastes, facial scrubs and shampoo for exfoliating and cleansing purposes. The microscopic beads flow down drains, pass through wastewater treatment plants and end up in rivers, lakes and oceans where they harm aquatic life and can enter human food chain. According to a recent estimate, at least 8 million tonnes of plastics leak into the ocean each year[9] (Figure 8).

New York and California initiated laws to ban beauty products containing non-biodegradable plastic microbeads in 2014 and 2015, which resulted in leading brands such as L'Oréal, Unilever, Johnson&Johnson and P&G deciding to phase microbeads out of their products by 2017. In December 2015, President Obama signed a federal law H.R. 1321 also known as "Microbead-Free Waters Act of 2015" which bans the production of personal care products and cosmetics containing plastic microbeads from July 2017.

TerraVerdae BioWorks is an industrial biotechnology company with operations in the UK, the US and Canada. It is focused on developing bioplastics and biomaterials and was one of the first companies to offer direct biodegradable replacement for plastic microbeads. TerraVerdae's microspheres are made from bio-based and biodegradable polyhydroxyalkanoate (PHA) material, which to date is the only bioplastic grade proven to degrade in marine environment.

RULE OF THUMB: PREPARE FOR CHANGE AND TURN THEM INTO ADVANTAGES TerraVerdae BioWorks could have waited, swimming in the mainstream of microbeads. Instead, it closely followed and anticipated regulatory initiatives and technology developments – and took the decision to build its operations on what it saw coming. The brave decision gained it a first-mover advantage in biodegradable microbead production.

Figure 8 Plastic waste on a beach

[9] J. R. Jambeck et al., Plastic waste inputs from land into the ocean (Science, 13 February 2015)

5.8 Ingredient branding – Clever marketing

Marketing doesn't always require large advertising budgets

There is a growing interest in ingredient branding e.g. among the food industry adopted from other industries with success stories such as "Gore-Tex ®" in clothing and "Intel Inside ®" in consumer electronics. This could be implemented in any area of bio-based products.

The key to success in any ingredient branding case is to ensure that the ingredient brand can create value to the host brand. There are basically three ways to do that, namely: improve the quality of the host product, create a point of differentiation and provide an alternative and, finally, cost efficient marketing strategy. Each of the points are opened up more in the figure below.

RULE OF THUMB: USE THE POWER OF MARKETING AND THE POWER OF CLIENTS' MARKETING CHANNELS Using ingredient branding a small innovative company could save significantly on marketing costs while expanding markets through the sales channels of another company. The point is not huge budgets, it is being smart enough to realise what value an "Intel Inside" type of brand for a Finnish biostartup could give it – and most of all the larger brand benefiting from it and promoting it.

Figure 9 How to create value for the host brand in ingredient branding

5.9 Sensor filled 3D printed hair – The amazing innovations

Look out for disruptive technologies that could change whole industries creating vast amounts of opportunities

The Tangible Media Group at MIT's Media Lab has in 2016 created 3D printers that are able to print hair-like strands of material with micron density. This was not possible with the standard 3D printers available in the market. Further, the group was able to produce hair that can respond to and interact with the environment around it. The materials could also be used as motors. The motors work without any gears or moving parts simply by applying specific vibrational frequencies to the materials. The hair covered materials can also move objects along pre-determined paths or be used to sort objects e.g. by weight and move them along.

The application areas for the technology are almost limitless: it could be used to produce e.g. customized paint brushes, gearless motors, movable surfaces, adhesive surfaces and even next generation tactile surfaces. This technology could change many industries with the numerous applications.

Currently the hairs are build up from synthetic materials, but what kind of opportunities could be raised from bio-based materials such as composites, cellulose or similar?

RULE OF THUMB: SPOT THE POTENTIAL DISRUPTOR AND ACT FAST This case is just one example of a potential disruptor, but which Finnish small or large company grasps the right application for these "active printed surfaces", makes them bio-based, applies them to a promising end use and reaches the markets ahead of competitors?

5.10 Economic savings from fibre composites – the practical side of the argument

Combining new technologies to reach costs savings opens up significant markets

Researchers at the Hong Kong University of Science and Technology have developed carbon fibre reinforced aluminium which has better strength properties than aluminium and is cheaper and lighter than steel. To be able to mix carbon fibre with aluminium, the researchers have used nanotechnology to modify the composition of the carbon fibre.

The material could be used to produce envelope systems that are safer, cheaper, more energy-efficient and easier to use. The material enables significant savings also on labour costs. The system exceeds the thermal resistance requirements of building materials e.g. in Hong Kong, Shanghai, Beijing and Moscow. Other application areas for the composite material include automotive, electronics and airplanes. The innovation could expand the application areas of aluminium significantly.

Innventia in Sweden has on the other hand developed bio-based carbon fibre. Joint efforts could lead to bio-based composite high tech construction materials able to halve construction time and labour costs.

RULE OF THUMB: DON'T BE AFRAID TO JOIN YOUR MATERIAL WITH A COMPETING ONE Daring to see the potential of combining one's technology with a potentially competing one into a composite; seeing the larger potential for a joint solution; likewise daring to approach the identified partners with an unorthodox proposal – difficult tasks for most companies, but potential keys to huge success

6. Implications for Finnish companies

Finnish companies are well respected within the bio-based market and have excellent chances for wider success.

Finnish companies are well respected within the bio-based chemicals and materials market. They are seen as trustworthy companions producing products with good and steady qualities and with all the necessary certificates. Finnish products are seen as environmentally friendly, safe and following the principles of sustainable development. All these arguments are significant in the marketing of bio-based chemicals and materials. These are the things that we are good at. In some other areas we might need some further improvement.

Know your market: Each of the bio-based products has unique markets, applications and business environments. Some markets have overcapacity, others strong demand without product. There are also markets where large players or close partnerships have left little room for competitors. Markets can open up or close by developing legislation and regulation. And, what should be obvious: disruptive technologies can change the whole business upside-down. A thorough market and technology analysis is essential to turn your case into feasible business.

Secure cash flow: Companies need a solid plan for surviving the valley of death -and projects inside larger companies likewise. Some producers have short-term focus on specialties to enable long-term success in commodity products. Others produce commodities to enable further investments to new bio-based products. Funds and partnerships can help to bridge the gap between groundbreaking and full operation. However, one has to have a plan to survive the next years before making a 10-year strategy.

Find partners with the best fit: Partners can share development costs, bring added knowhow or other resources, speed up market entry or secure off-take, but they can also be a major constraint, limiting business opportunities and eat off revenue base. Be wise in selecting your partners. Think of the whole value chain – do not be afraid of going several steps up or down. Think of what your value chain should look like that, and what you can do to influence it.

Choose the right technology and business model: There is in-house process development, technology licensing, open innovation and contract manufacture. Different degrees of horizontal and vertical integration are available as well as value chain involvement. Some producers are focused on the supply while others have strong brands and work closely with consumer brands. It is crucial to benchmark not only the technology but also the selected business model to be able to succeed. Sometimes boldly facing the existing barriers can be the best business model there is.

Define added value: Some products are already cost competitive drop-in solutions to fossil based counterparts; others are unlikely to ever reach price parity. It is important to define what adds value to end-users when using your products. Is it new functionalities or environmental benefits? And what is the best way to market your products? Is it direct contact to clients, social media or ingredient branding? All marketing and communication should be in line and supported with quantified claims.

The findings of this report can be summarized as a set of “rules of thumbs” for avoiding common pitfalls to the Finnish companies operating in the bio-based chemicals and materials field.

- *Shield yourself from obvious cash flow risks by producing commodities, leveraging your know-how or expanding to supporting businesses.*
- *When finding partners for your business look for the best, look globally and look further in the value chain than you first thought – and think of what your value chain should look like*
- *Develop a solid strategy and business model prior to commercial production – and stick to it unless conditions change*
- *Turn market barriers into competitive advantage – if things are difficult for all, become a solution provider. Find your role and reinforce it. Make a virtue out of necessity*
- *Prepare for changes like disruptive technologies or regulation in the business environment well ahead of the mainstream*
- *Innovative marketing strategies could expand your business through your customers’ support. Think what benefits your product brings for the whole value chain*
- *Dare to see the potential in combining your technology with a potentially competing one into a composite/hybrid, don’t be afraid to see the larger potential in joint solutions throughout the value chain.*

.

Annex I – Description of existing cases from the first phase

Novamont – Local resources
Europe, Packaging

Novamont has found new uses for thistle which grows on marginal land and is considered primarily as a weed. They have also managed to utilise existing infrastructure on a closed down chemicals site, and have benefitted from local skilled labour, which has been unemployed since the site closure.

Onbone – End-user experience
Europe, Medical

Collaboration between catalyst researchers and a senior orthopaedic surgeon led to innovative portfolio of bio-based casting materials.

GFBiochemicals – Levulinic acid (See p. 14)
Europe, Intermediates

GFBiochemicals secured a leading position in a developing market by hiring key experts from DSM's abandoned levulinic acid project team, and by acquiring downstream developer Segetis to improve access to market.

Beologic – Exploiting barriers (See p. 15)
Europe, Services

The major hurdle in natural fibre composited is the poor compatibility with existing equipment. Beologic turned this market barrier to competitive advantage by offering extensive customer support including R&D, tooling, processing, product development and tool refurbishment.

FKuR – Adding value (See p. 11)
Europe, Services

FKuR adds value to bioplastic granules by compounding. The company improves compatibility with existing processing equipment and creates completely new functional properties by blending different polymers. In addition, FKuR secures steady cash flow by distributing "original" bioplastic granules.

SABIC – Influencing standardisation
Europe, Packaging

CEN/TC411 is in the process of developing standards for determining bio-based content. Original approach included only C14 radiocarbon analysis. SABIC has launched a portfolio of renewable plastics based on ISCC+ cerfitication, which works on a "mass balance system". Doing this they have forced TC411 to consider mass balance approach in their work.

Food industry – Ingredient branding (See p. 17)
Europe, Food & Feed

There is a growing trend of co-branding or ingredient branding in the food industry. Ingredient branding helps to differentiate, address core business challenges and strengthen sales. Successful cases include e.g. Microban providing antimicrobial surfaces for various consumer products

Anellotech – Credibility
North America, Packaging

Anellotech has managed to secure funding in the midst of low oil prices by building credibility in technology development. They outsource 50% of the "brain-power" in technology development to top-tier partners Axens, Ifpen and Johnson Matthey. Anellotech also signed partnership with a major downstream off-taker Suntory prior to a demo facility.

MHG – Integration
North America, Packaging

AgroCrush (canola producer), Meredian (bioplastic producer) and Danimer Scientific (compounder) merged into the MHG group offering more sustainable and cost

competitive PHA bioplastic resins. Canola offers local farmers new opportunities for double-cropping, and their long-term commitment is secured by joint ownerhsip.

Gevo – Securing cash flow
North America, Intermediates

Gevo continues to co-produce fuel grade ethanol to fund isobutanol technology and market development. By-products from isobutanol production (distillers grains) are blended with by-products of ethanol production and sold at existing markets.

BioAmber – Exclusive partnerships (See p. 13)
North America, Intermediates

BioAmber outsourced a major part of market and technology development by building exclusive partnerships with feedstock providers, intermediate producers and chemical distributors. Development costs are compensated by e.g. direct investments and royalties per net sales.

Green Biologics – Retrofitting
North America, Intermediates

Green Biologics is reducing investment costs by retrofitting small-scale uncompetitive ethanol facilities to n-butanol production.

Amyris – Automatisation
North America, Intermediates

Amyris has managed to shorten time-to-market and reduce development costs per strain by 95% in 4 years by Automated Strain Engineering (ASE). This enabled reallocating time of PhD scientists from pipetting to research. They have recently received a grant from US government to screen new efficient production organisms.

Newlight – Risk mitigation
North America, Household goods

Newlight secured off-take of future production facilities prior to an investment decision by collaborating with a major brand owner (IKEA) and by signing 20-year take-or-pay agreement with a global distributor (Vinmar). Newlight also secured low-cost feedstock by collaborating with palm oil producer (Felda) to use palm oil mill effluents for bioplastic production.

TerraVerdae BioWorks – Microbeads (See p. 16)
North America, Personal Care

Gained first-mover advantage by following regulatory (ban of non-biodegradable microbeads in cosmetics) and technology development (PHA bioplastics is the only marine biodegradable plastics in the market).

TerraVia – Refined focus
Latin America, Food & Feed

After years of development and commercial production, TerraVia (former Solazyme) switched focus from biofuels to food, feed and nutrition. Refocusing operations brought in additional 28 MUSD funding from new investors.

NaturaCosmetics – Success abroad
Latin America, Personal care

After many trials and errors trying different strategies to widen their geographical scope, NaturaCosmetics succeeded in growing their business abroad staying loyal to its core values and business logic.

M&G Chemicals – Cutting premium (See p. 10)
Asia, Packaging

M&G plans to cut production costs of bio-based PET plastic by developing direct catalytic conversion to bioMEG (from 4 process steps to 2). They also seek to secure cash flow and minimise risks by integrating MEG to cellulosic ethanol production.

Natur-Tec – Geographical expansion
Asia, Packaging

Natur-Tec produces biodegradable packaging for e.g. Levi's clothing. They have succeeded in entering Indian markets by leveraging strong local industry (textiles), anticipating government regulations (ban of single-use plastic packaging), and offering solutions for Levi's to meet their sustainability targets.

Solvay – Bypass sale (See p. 11)
Asia, Intermediates

Solvay is a producer of bio-based epichlorohydrin while AkzoNobel was looking for bio-based components for its coating products. The two companies were missing a key part of the value chain, the intermediate producer. Solvay and AkzoNobel teamed up to approach Kukdo (epoxy resin producer) with ready supply and off-take agreements.

Annex II – Description of visionary cases from the first phase

Houses that absorb pollutants
Europe, Others

Elegant Embellishments is a research and design-manufacturing studio that has developed façade panels that absorb pollutants or CO2 from the air. Currently the panels are non biobased, but could they be made from biocomposites, http://www.elegantembellishments.net/

Composite fibres (See p. 19)
Europe, Others

Researchers at the Hong Kong University of Science and Technology have developed fibre reinforced aluminium for the construction industry. Innventia on the other hand has has developed bio-based carbon fibre. Joint effort could lead to bio-based high tech construction material able to halve construction time and labor costs. http://www.rusal.ru/en

Sensor filled 3D printed hair (See p. 18)
North America, Others

MIT's Media Lab has produced 3D printed hair that can respond to and interact with the environment around it. In one application, they printed a micro-pillar mat of cilia that could detect the touch of a finger and respond to different swiping patterns. http://www.digitaltrends.com/cool-tech/3d-printed-cilllia/#ixzz49rDJowhd

3D printing of nanopatterns
North America, Packaging

The wings of some cicada species are covered in nanoscale pillars that provide resistance to bacterial infection. Recreating such nanopatterns by 3D printing could help the design of safe antibacterial products. http://www.the-scientist.com/?articles.view/articleNo/45892/title/Nanoscale-Defenses/

Adding features to the existing product
North America, Others

Researchers from UC Berkeley in California have developed yarn that changes colour in response to electrical charges. http://futurism.com/new-thread-can-change-clothes-color

Oszko – crowdsourcing and branding
Asia, Others

Oszko has developed a functional underwear using recycled coffee grounds and recycled polyester to create sustainable high performance underwear designed for climbers. They are looking for further funding through crowdsourcing. https://www.kickstarter.com/projects/502023966/oszko-functional-underwear-made-using-recycled-cof

Biomaterial tooth spray
Asia, Personal care

Taiwanese company Toothfilm Biofilm Innovation has developed a breath freshener from chitosan, which kills bacteria and removes plague build-up. It also helps to re-mineralize tooth enamel. http://www.toothfilm.com/

Seaweed based bone
Asia, Medical

Group in the University of Wollongong (AU) have developed a 3D printing pen that can draw new bone using a seaweed-based ink. In addition they have developed cartilage that can be grown in animals. Would the technology allow us to develop e.g. revolutionary cartilage type material for the industry substituting lubricants?

Formable liquid
Asia, Others

Researchers from the Tongji University of Shanghai have developed liquid material that can be formed. It is based on 20 nm thick layer of silica with water droplets on top. The application areas range from novel lenses or containers for chemical reactions. https://www.newscientist.com Journal reference: Soft Matter, DOI: 10.1039/C5SM02765A

Biofibre construction

Asia, Others

A natural composite fibre pavillion made by robots which adopts to the people´s reactions might be the future of temporary construcion areas e.g. for exhibitions or pop-up stores (http://www.achimmenges.net) The Finnish research field is developing new bio-based composite fibres and applications for them (e.g. DWoC project) combined with architecture, zen robotics, design etc.

Annex III – Simple summary of cases from biomass, technology and products

Case	Feedstock	Technology	Main product
M&G Chemicals	Cellulosics	Proprietary	Fuels and chemicals
FKUR	Plastic granulates	Proprietary processes	Plastics
Solvay	Bioglycerol	Proprietary	Coating from epichlorohydrin
Bioamber	Many	Many	Succinic acid
GFBiochemicals	Many	Many	Levulinic acid
Beologic	Wood, mostly	Proprietary	Composites
Terraverdae	BioPHA	Proprietary	Microbeads