



Bio-based products – from idea to market

“15 EU success stories”



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EUROPEAN COMMISSION

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edited by COWI, Bio-Based World News and Ecologic Institute

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OVERVIEW

BACKGROUND AND POLICY CONTEXT

The bio-based sector is among the key players in the European bio-based economy. It contributes to an innovative, resource-efficient and competitive society. The bio-based industry in Europe is, however, still a fairly small and nascent industry under development. While the financial crisis and periods of low oil prices constituted short-term setbacks towards development, the bio-based industry appears to have regained momentum in recent years. Many EU Member States have, over the last 5–6 years, developed holistic approaches to the bio-based sector, in particular in the EU-15. Sector specific policy frameworks further stimulate its development.

Demand-side developments are also positive. Investors and consumers increasingly focus on environmental and health aspects of products; however, typically not at the expense of performance. While green investments and investments supportive of the U.N. Sustainable Development Goals (SDG) are in high-demand, investors also continue to demand that these be bankable. A recent study concluded that the bio-based sector continues to *face issues accessing private capital*¹. Seen from the investors' perspective, there may be different underlying explanations for this. Some investors may thus be new to the bio-based sector and lack the institutional history, tools, and staff to evaluate the potential of these new concepts. More specifically, they may be concerned about perceived long lead times from investment to profitability. For early-stage investors more comfortable with the above considerations, bio-based barriers and risks related to feedstock, customer preferences, regulatory concerns and competition aspects vis-à-vis traditional products may exceed their risk tolerance.

AIM AND METHODOLOGY

This collection of 15 success stories on specific products aims to address likely investor concerns in the growing bio-based sector. The success stories demonstrate the broadness of the sector, and provide concrete examples of 'bio-based concepts' that have succeeded in progressing from the early ideas to a final product placed on the market. Thus, the success stories serve to illustrate the potential commercial success for bio-based products. They serve to provide illustrative, concrete examples of such successes, including: their development path, factors that enabled this success and risks companies were confronted with, and how these challenges were overcome. The sample of 15 success stories are intended as a means to provide real-life, concrete examples that can

serve as inspiration for investors, companies and project promoters. The collection of 15 success stories should not be seen as a selection of particularly remarkable successes. Rather, it provides a sample of 15 successes selected with a particular focus on demonstrating successes for a range of different products, applications and company types. The success stories are drawn from many EU Member States, and providing a good selection of new and innovative products.

A range of criteria underpins the selection of the 15 success stories presented in this report. Thus, the aim has been, among other considerations, to include different types and sizes of companies, different product types and applications and a wide geographical coverage across the EU. Moreover, the intention was to present products that are innovative and fairly new in the market. Further, individual success stories should deliver on at least one of three key criteria of success. In order of priority, these criteria are a) profitability, b) product on the market, and c) success in mobilising critical external finance. Further, the readiness of the companies in question to participate was a necessary condition.

The development of the success stories considers the history of the product development from idea to market, it provides descriptions of technology, product and feedstocks, and it considers how funding has been obtained as well as the existing and potential markets. All success stories provide a simple SWOT (identification of Strengths, Weaknesses, Opportunities and Threats) and they identify the key drivers of the observed success. The respective companies have been involved in preparing the success stories: A four page description has been prepared on each of them. They have kindly provided data, participated in interviews, and they have endorsed the final four page description. Each success story rests largely on the information provided by the company in question. In all cases, certain key information has been considered confidential by the company in question and, thus, has not been shared. This applies for example in many cases to information regarding R&D costs, production costs and sales information and forecasts. Consultations with four specific investors have supported the identification and development of success stories, for example in terms of providing feedback to intermediate lists of possible candidate success stories, in terms of explaining concerns and issues of importance to investors, and in terms of providing reflections on what elements of a success story would be of relevance to an investor, and hence relevant for inclusion in the descriptions.

¹ 'Access-to-finance' conditions for investments in bio-based industries and the blue economy, Commissioned by DG RTD and prepared by InnovFin Advisory/EIB, June 2017.

PRESENTING THE GROUP OF 15 SUCCESS STORIES

While different in many dimensions, the success stories presented in this report share one key feature: they succeeded in developing a product to a fully commercial level, or close to that. The 15 successes presented here are thus successful in the sense that they have progressed significantly in their journey, and thus they have managed to overcome risks and challenges along the way including financial challenges. All but two products are on the market today. For at least half of the products, they are profitable today or they are expected to become profitable in the near future.²

The 15 success stories presented here originate in nine different EU Member States:

SUCCESS STORIES PER COUNTRY

Number of Success Stories
1 2 3

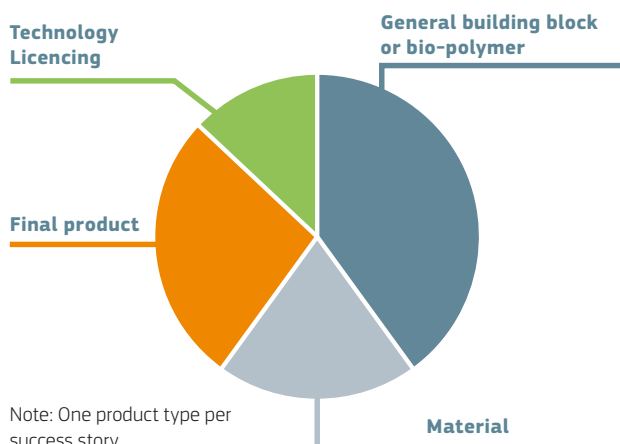


Note: One company is Israeli-based, but is partly owned by a Swedish company and has received Horizon2020 funding. The company is therefore shown once in Israel and once in Sweden.

They represent different company sizes: 20 % are micro-enterprises, 40 % are SMEs and the remaining are large companies. About two-thirds of the companies have bio-based activities at the core of their business.³

Most products described here are new in the market: Thus more than half (8 out of 15) reached the market only in 2015, or later. It is thus assessed that 13 of the products are at TRL level 9 today, or will reach that level in the near future. The two success stories that rest on a business model in licencing of their technology to third-parties are assessed to be at TRL7, or to reach that stage very soon.

SUCCESS STORIES PER PRODUCT TYPE



Note: One product type per success story.

In terms of product type, the 15 success stories provide examples of different types that can be categorised in four main categories.

Further, as detailed in the table “Overview of the fifteen success stories” at the end of this chapter, around half of the success stories (seven products) in the sample have benefitted from EU funding along their Research & Innovation and/or commercialisation path, e.g. from H2020 funds (including through the SME Instrument) or ESIF. Within these seven success stories, six have been developed by SMEs or micro-enterprises and one by a large company.

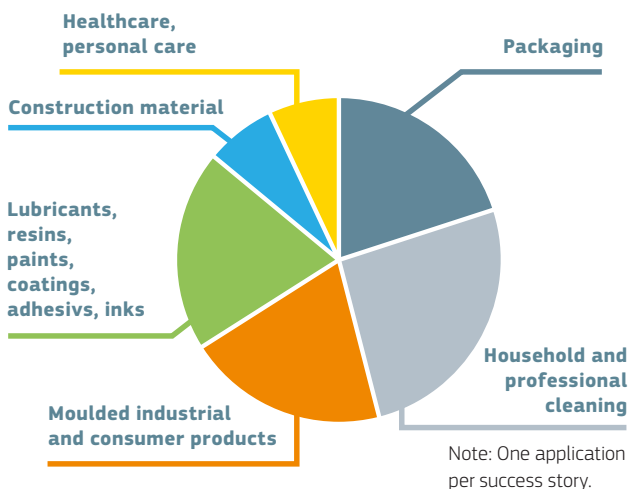
In the sample, within the success stories developed by SMEs or micro-enterprises, it is interesting to note that six (see above) out of nine have benefitted from EU funding, which served to develop and/or to commercialise them and upscale their production. EU Funding originated from ESIF in two cases, from H2020 in three cases (two of which relate to the SME Instrument), from FP7 in three cases and EIP in one case, with three of these products benefitting of EU funding from two different funds.

In the sample, within the success stories developed by large companies, only one benefitted from EU funding (from FP7) as mentioned above. However, besides this, four of the five large companies remaining in the sample received EU funding for their other R&I activities in the bio-based sector (i.e. activities relating to other bio-based products than their corresponding success stories). This funding was received from H2020 (including participation in BBI-JU projects) or from FP7.

² For the remaining ones, information on profitability has in most cases not been disclosed by the company in question

³ Here, we have applied a simple definition that defines company size solely in terms of the number of employees: micro: less than 10, SME: 250 or less. Small companies that are spin-offs of large companies have been categorised as large, as their challenges and modalities for financing resemble more those of large companies.

SUCCESS STORIES PER APPLICATION



In terms of applications, the products presented here provide examples of a wide range of existing applications. In addition to existing applications, i.e. the applications that currently constitute the core of the company's sales, the success stories often point to other possible future applications and/or products.

The success stories presented in this report rest largely on information provided by the companies in question. Companies have also approved of the wider dissemination of the success stories. While the companies' participation and readiness to allocate time and provide data is highly appreciated, it should also be noted that factual information on sensitive data was not shared by most of the companies.

GENERAL KEY INSIGHTS

Looking across the 15 success stories, a number of interesting observations emerge that can inform on shared risks and mitigation actions. These shared themes can be categorised under four specific themes each of which is of possible interest to a potential investor: a) lead time from early investment to profitability and returns from investments, b) price competitiveness as an indicator of how the product performs in competition with other products, c) attitudes and perceptions of customers and product performance providing an indicator of the market's recognition of the product and/or the willingness to pay a so-called 'green premium', and d) owners role in making it happen. The four themes relate to areas that are likely to be relevant to potential investors.

Lead time. There is often a considerable lead time from the early investment to a break-even point as a profitable business. Typically, lead times can extend to 10 years or more. Larger and consolidated companies can typically mitigate this risk through their mere size, financial robustness and capacity to mobilise finance, as well as through

their internal access to R&D, market access and through their internal vertical and horizontal supply chains. These factors can also render them less vulnerable to external risks such as financial crises and drops in oil prices. Thus, the larger and consolidated companies included in this study have been able to move forward in quite an effective and efficient manner, as they have all overcome what is likely the key challenge to them: obtaining internal endorsement and resource allocations for the project.

Smaller companies, in particular new bio-based companies, confront a slate of challenges that can prolong the lead time, making the journey towards a profitable business longer and less efficient. Challenges observed include: access to finance, lack of skills in mobilising finance, market access and knowledge and supply chain management.

Access to public national or EU level finance has often played a role in mitigating these challenges, in particular during early stages. For many of the 15 success stories, EU funding has helped to overcome an 'access-to-finance' issue, in particular, but not only, at the early stages. Further, the ability to mobilise venture capital not only provides finance, but also involves access to knowledge and skills that help the businesses enhance their management teams. Another key factor that can reduce lead time is partnering with one or several entities. Partnering can help: overcome supply chain challenges, e.g. access to feedstocks and other inputs; increase production capacity; and ease market access. Patents and IP are important conditions to attract finance, and hence to shorten lead time through mobilisation of finance.

Price competitiveness. In most cases, bio-based products were not price-competitive vis-à-vis the alternative traditional products. Drops in oil prices such as those occurring in the 2010s further accentuated this challenge. In the success stories, economies of scale are recognised by companies as a key action to improve price-competitiveness, and many, in particular products relatively new to the market, are at a stage where they focus on this need to expand production. Raising capital to increase production capacity is one way of meeting this challenge and some of the companies that face this challenge have succeeded in this already. Others find themselves at the conflicting stage where additional capacity is required to reduce costs and attract more customers, but increased customer sales are required to justify capacity expansion. Another remedial action observed was to partner up with others whereby costs can be reduced, e.g. through outsourcing elements of production.

Attitudes and perceptions of customers and product performance. Perceptions and attitudes of customers are a challenge at the later stages of the development path. Put simply, customers must be willing to pay the higher price for the bio-based product compared to the traditional product. To

some extent, the success stories demonstrate that this market barrier is diminished by end-customers and brand-owners increasingly being aware of green and sustainable product features. Still, price remains a main consideration and a decisive factor in succeeding in the market and achieving significant sales volumes. Success stories demonstrate that product performance is an important element in meeting this challenge. Companies thus work continuously to improve the performance of their product, to identify and to target market segments that recognise the performance attributes of the product.

Owner's role. Last, it comes out clearly throughout the 15 success stories that a key success criterion for many smaller, new companies is the dedication, commitment and knowledge of the founders. Ideas that later developed into a business have often been conceived by the founders e.g. in an R&D community, or in a previous employment developing similar yet fossil-based products. Their commitment and willingness to invest own resources and time, and their specific knowledge and networks, are factors that have played a crucial role during early stages. The latter may include technical knowledge, customer knowledge, market knowledge, supply chain networks and own financial means.

Along the same line, many success stories also demonstrate a development path along which hard choices are made. The ability and willingness to re-orientate and to change or narrow the scope often plays a vital role in maturing a product towards market entry. This need can arise because of, for example, external events (i.e. oil price developments), signals from the markets (which segments recognise the product and demand it) and regulatory costs (e.g. in regards to obtaining necessary approvals).

KEY INSIGHTS ON RISKS

In elaborating the 15 success stories, a particular focus has been on understanding the specific risks that the journey from idea to market was confronted with and how companies responded to these risks, and on understanding what particular factors can be seen as the key drivers of the observed success. The observed risks may be categorised under three main headings:

Technology, production and finance. The appropriate technology and a sufficient production capacity are crucial factors to achieve success in the market. The success stories concern new technologies or processes. Hence, they involve a significant uncertainty and risk. This makes it in turn difficult to attract the necessary finance. The success stories have overall mitigated this risk through several means:

— Willingness to invest own time and money. This investment is possible in larger consolidated companies, once a strategic decision is taken to pursue the opportunity. The companies then provide the finance and RDI capacity internally. In smaller companies, it is typically the owner(s) and founders that invest their own time and expertise in the development and mobilise financing from private loans or savings.

— Partnering along the value-chain. Co-development is a commonly observed way to accelerate the development, hedge or share risk and reduce the need for finance. Co-development can be with a technology provider, feedstock supplier, technology user, or traditional research institutes. The outsourcing of production combined with proper IP protection can be a way to reduce investment needs related to upscaling the production. Two of the success stories are on a business case that rest on a licencing concept. This reduces the financial needs, as the product is the licence to use the technology and not the resulting product per se.

— In SMEs and micro-enterprises, the mobilisation of a strategic external investor is often a key factor to mitigate the risks related to production capacity and finance in particular. Such investors often bring finance together with expertise and invest against a stake in the company. Examples of such investors include angel investors, venture capitalists and existing industries active somewhere along the value chain. Once mobilised, the involvement of such investors helps to attract further financing.

Feedstocks. Stable supplies of feedstock in sufficient quality and amounts are crucial to a successful development from idea to market. The 15 successes demonstrate that this theme is often an integral and important component of the phase in which the technology is developed. It is also an important theme when reaching the stage to scale up the production. In this later phase, it is not uncommon that the companies engage into agreements with specific suppliers of feedstock or raw material. The sustainability of feedstock and the costs of feedstocks are also factors that contribute to the risk picture. Compared to fossil-based products, sustainability is an important attribute that the bio-based products offer. It is therefore essential that customers are satisfied with the sustainability features of the product. To that end, most of the success stories demonstrate a continuous focus on improving and documenting the sustainability of feedstocks, e.g. through aiming to substitute existing feedstocks by more sustainable ones and through obtaining specific certifications. Furthermore, many success stories involve a shift in feedstock along the development path: with the aim to improve product performance and to reduce production costs.

Price competition and market. The higher price of bio-based products compared to the fossil-based alternative is often an important risk to achieving success in the market. Mitigation actions observed are manifold and include efforts to reduce production costs: improving technologies, processes and feedstocks, and upscaling of production. In terms of sales, the bio-based products may be confronted with a market that is conservative, skeptic and well-established. Here, the success stories demonstrate a strong benefit from owners or management with a past track record in the sector: such as experiences from teaming up with consolidated players in their go-to-market strategy, and a focus on co-development of for example show-case applications together with possible customers. The latter can also help to demonstrate superior performance features of the bio-based product compared to the fossil-based product, which can partly offset the price differential to customers. Another mitigation action is concerned with identifying and targeting market segments (applications, customer segments, product types) that are less cost-driven. The performance/price ratio of the product needs to be appreciated in the market in order to deliver results. To that end, the success stories demonstrate approaches such as general awareness, collaboration with advocates (e.g. bloggers) and investments in obtaining certifications to document the sustainability features of the product and its feedstock as well as documentation and approvals to demonstrate performance aspects.

Other risks. The demands of existing legislation for products in contact with food can be costly to comply with in particular for smaller companies. In some cases, the absence of a common regulatory framework makes it cumbersome to enter different EU markets. In general, a stronger global or regional regulatory push in support of the bio-based products could support an accelerated development of and increased market for bio-based products and reduce the possible competition from 'fake' bio-based products. Most of the products covered in the success stories are patent protected. However, obtaining patents is costly and resource demanding, and this can constitute a constraint to smaller companies: one of the success stories thus has no patent in place for its product.

KEY INSIGHTS ON DRIVERS OF SUCCESS

Across the 15 success stories, the key and most common drivers of success include:

A strong and market-oriented business case and early interaction with the market. The move from innovation to commercialisation often builds on a somewhat wide range of products and applications. Testing this in the market through

real interaction with potential buyers provides market feedback that is often used to re-orientate and sharpen the business case: towards segments where there is volume, price competitiveness, and recognition of the performance of the product. Many of the success stories concern products or technologies with wide potentials, but where the market interaction leads to a narrower or more strategic focus in terms of product, application, market and/or geography. From the investor perspective the wider potential remains however an attractive feature.

Partnering is seen across most of the success stories in many forms. Commercial partnerships may be along the supply-chain, with for example feedstock providers, technology providers, users and customers. Financial partnerships can provide finance and knowledge and such partnerships may be with an industry investor, possibly combined with a commercial partnership, or with for example venture capital investors.

Strong and dedicated management teams. The management team has a crucial role to play in successfully taking the product to the market. Management teams need to include strong skills in commercialisation and mobilisation of finance. Companies have to that end contracted additional management team members, succeeded in establishing collaboration or joint ownership with active professional investors or contracted specialist assistance from the outside. From the investor perspective, the attitude, personalities and clear visions of the management, including their commitment and willingness to make hard choices are key factors to provide an attractive investment opportunity.

Ability to mobilise the necessary finance is a determining factor in all success stories. Larger and established companies tend to succeed in mobilising the necessary finance from internal sources. SMEs and micro-enterprises on the other hand depend on the ability to mobilise external finance. Strong business plans, the mindsets, attitudes and skills of management and owners are factors that have successfully convinced other investors of the feasibility of their products. Such investors are not however passive investors such as banks, but rather for example venture capital funds and industry investors.

Patents as a crucial means of ensuring that one will capitalise on the investments made. Patents thus help to protect founders'/owners' future possible profit streams, and patents are therefore also crucial to investors.

Investing for the future. For the large companies among the 15 success stories, most have developed the bio-based

product as an addition to a wider – bio-based or not – product slate. They have thus been able to mobilise the finance internally through leveraging on profits generated elsewhere in the business. A feature shared by large companies that are not specialised in bio-based activities is that they have invested in such activities as an investment for the future.

Greening of society. Along with the SMEs and micro-enterprises they largely built their business case on the current trend of a ‘greening of society’ reflected in a growing consumer preference for green products, in CSR and purchase policies of large brands and buyers, and in a focus of investors and public funds on SDG investments.

THE 15 SUCCESS STORIES

The 15 products described in this report all deliver on one or more of the three individual success criteria described above. Further, they were selected to jointly provide a good coverage in terms of the criteria described above. Last, it was essential that the companies that produce them were ready to participate in the study. The products in the table below are presented by company size (i.e. Large, SME, Micro) and product name.



OVERVIEW OF THE FIFTEEN SUCCESS STORIES

Product name	Company name	Country	Products, applications and markets	Company size ⁴	EU funding ⁵
Bio-based 1,4-Butanediol (bio-BDO)	Novamont	IT	A bio-based chemical intermediate building block. It is used as solvent and for the production of plastics, elastic fibres and polyurethanes. Bio-based BDO is an alternative to fossil-based BDO. The production plant was developed in a strategic partnership with a US based owner of an innovative technology that is integrated in the production process. The product is mainly used internally to increase the bio-based content of Novamont's downstream bio-based plastics. <i>Type: 'building block'. Application: 'Packaging and tableware'. Other possible future application areas include: 'moulded industrial and consumer products'.</i>	Large	FP7
BioFoam®	Synbra Technology	NL	A foam for packaging and technical applications (insulation), using sugar cane as a feedstock. The product has been developed with a technology partner. The final product is sold internally within the Synbra Group and to external customers. <i>Type: 'material'. Application: 'packaging and tableware'. Other possible application areas include: 'insulation materials', and 'moulded industrial and consumer products'.</i>	Large	No
Carboxylate® CMI	Cosun Biobased Products	NL	A scale inhibitor (antiscalant) used in detergents for dishwashers, washing machines and alkaline cleaners, and in filtration processes for potable water production. CMI is produced from inulin that is not suitable for human consumption. The inulin is derived from chicory roots. <i>Type: 'general building block'. Application: 'household and professional cleaning'.</i>	Large ⁶	Not for product

⁴ Company size estimated according to number of employees only: Large (>250 employees), SME (between 10 and 250 employees), Micro (<10 employees)

⁵ The column on EU funding indicates whether the success stories (products) have benefitted from funding from the European Union along their R&I and/or commercialisation path. If this is so, the table shows the source of the EU funding received (e.g. from H2020) for the examined success story. The wording „Not for product“ indicates that the company behind a success story has received EU funding, not for the examined success story in question, but for other activities in the bio-based sector (i.e. activities not directly relating to this success story). The wording „No“ indicates that the company has not received any EU funding for its activities in the bio-based sector.

⁶ Cosun Biobased Products in itself is an SME, but as an offspring of Royal Cosun it is categorised as a Large company.

Product name	Company name	Country	Products, applications and markets	Company size ⁴	EU funding ⁵
Desmodur® eco N	Covestro AG	DE	The product is a hardener for lightfast polyurethane coatings used to protect a material's layer. Its feedstock is cornstarch and it is applied in automotive equipment, automotive coatings, plastics, wood and industrial coatings. In the long term, the product is expected to replace existing petrochemical hardeners in the company's product line. <i>Type: 'building block'. Application: 'lubricants, resins, paints, coatings, adhesives, inks'.</i>	Large	Not for product
Lipex®	Novozymes	DK	The product is a lipase-based enzyme solution. It is an alternative to traditional surfactants, which are the active compound in detergents that clean stains. Lipex® is used in detergents, to enhance the detergent capacity to remove grease stains. <i>Type: 'building block'. Application: 'household and professional cleaning'.</i>	Large	Not for product
Rilsan® HT Rilsan® Invent	Arkema	FR	A bio-based polyamide (PA-11) produced from castor oil (vegetable oil), which is used where high durability, flexibility and temperature resistance are required. Rilsan® HT is used in automotive applications and specific Rilsan® Fine Powder products have been developed for 3D printing. <i>Type: 'building block'. Application: 'moulded industrial and consumer products'.</i>	Large	Not for product
Wheat bran disposable tableware	Biotrem	PL	Disposable tableware produced from compressed wheat bran. The products are used by restaurants, event organisers, catering companies and private consumers. <i>Type: 'final product'. Application: 'packaging and tableware'.</i>	SME	ESIF; H2020 (SME Instr.)
Curran®	CelluComp Ltd	UK	The product is a cellulose non-fibre material produced from sugar beet pulp derived from waste streams from food processing. It is used as a bio-based additive to provide rheology and reinforcement in applications such as paints and coatings. Other relevant applications include concrete, drilling fluids, cosmetics and personal care products. <i>Type: 'general building block'. Application: 'lubricants, resins, paints, coatings, adhesives, inks'.</i>	SME	EIP; FP7
Ecover All Purpose Cleaner	Ecover	BE	A hard surface cleaning product, commercially available since the early 2012. It is used by household consumers and, to a lesser extent, also in professional cleaning. The product's innovative ingredient (eco-surfactant) uses rapeseeds as a feedstock. <i>Type: 'final product'. Application: 'household and professional cleaning'.</i>	SME ⁷	FP7
Lumir® Spray	Lumir Oy	FI	The product is an indoor sound absorption solution in spray, based on a wood-fibre coating produced from wood pulp. It is an alternative to glass or rock wool based indoor sound absorption. It can further be directly applied onto surfaces with minimal or none preparation and contains colour pigments eliminating the possible need for acrylic paints. The product is marketed to professionals in the construction and building sector, such as architects. <i>Type: 'material'. Application: 'construction material'.</i>	SME	No

⁷ Ecover has approximately 250 employees worldwide, and is therefore at the threshold between an SME and a large company. It was recently acquired by a large company. We have categorised the company as an SME, as their past challenges and modalities for financing have resembled more that of SMEs.

Product name	Company name	Country	Products, applications and markets	Company size ⁴	EU funding ⁵
Melodea CNC technology	Melodea Ltd.	IL/ SE	CNC is a nano-structured cellulose that can be used to enhance existing materials and produce novel products. Applications include papermaking additives, coatings, paints, packaging, building material and bio-composites. Melodea's business model aims to licence out the production process, but also develops strategic applications to create for its technology. The production process extracts CNC from wood pulp in the side streams of the pulp and paper production. <i>Type: 'technology licencing'. Application: 'lubricants, resins, paints, coatings, adhesives, inks'.</i>	SME	H2020; FP7
Paptic® bags	Paptic Oy	FI	Paptic produces a wood-fibre based bag and wrapping material that can replace bags and wrappings made from plastic, while exhibiting a higher longevity/reusability. Accordingly the applications are for any non-food wrapping and bagging, such as e-commerce packaging, banners, and dry food packing; however, Paptic currently focuses on the application as a reusable carrying bag. <i>Type: 'final product'. Application: 'packaging and tableware'.</i>	SME	H2020 (SME Instr.)
Abilar®	Repolar Pharmaceuticals Oy	FI	Abilar® is an ointment to treat wounds and burns, and particularly hard-to-heal wounds. It contains 10 % refined resin from the Norway Spruce, mixed with a salve base. The product is used in home care and by health-care professionals, and can be obtained in pharmacies. <i>Type: 'final product'. Application: 'healthcare, personal care'.</i>	Micro	No
BioLite™	Triflon AB	SE	BioLite™ are bio-composite based of natural fibres from industrial hemp and with features similar to conventional composites. BioLite™ involves the mixing of hemp-based natural fibres with polymers that come primarily from recycled plastic. It is produced in two product classes. One product class is used for automotive panelling, home and garden goods, consumer products (e.g. dust collectors, food trays) and luggage, and the other for e.g. brackets and industrial parts as well as home, garden and consumer goods. <i>Type: 'final product'. Application: 'moulded industrial and consumer products'.</i>	Micro	No
ICCP technology	BioBTX B.V.	NL	A process for the production of a drop-in replacement for conventional fossil-fuel based BTX produced as by-product in oil refineries. The technology produces aromatic compounds benzene, toluene and xylene (i.e. BTX) from biomass. BTX compounds are used as building blocks for products of the petrochemical industry and the manufacturing of polymers such as PET and other plastics. The business model rests on the licencing of the technology and the provision of the associated services. <i>Type: 'technology licencing'. Application: 'moulded industrial and consumer products'. Other application areas include: 'packaging and tableware', 'lubricants, resins, paints, coatings, adhesives, inks'.</i>	Micro	ESIF

Bio-BDO by Novamont

PRODUCT NAME

Bio-based 1,4-Butanediol (bio-BDO)

PRODUCT DESCRIPTION

Chemical used as solvent and as building block in plastics, elastic fibres and polyurethanes

FEEDSTOCK

Glucose syrup derived from the hydrolysis of starch

ORGANISATION

Novamont S.p.A. through 100 % owned Mater-Biotech S.p.A. subsidiary

EMPLOYEES

75 direct employees Mater-Biotech plant; 700 direct employees in Novamont Group (2017)

COUNTRY

Italy

R&D START

2012

MARKET ENTRY DATE

2016 (EU)

PRODUCTION CAPACITY (EU)

30,000 tonnes bio-BDO/year (EU)

PRODUCTION VOLUME

Expected to reach full annual production capacity (30,000 tonnes) in 2018

SALES (GLOBAL)

Not applicable (captive product use)

INVESTMENT

EUR 100 million investment for establishing the production plant financed from private sources

PRICE

Costs are less than double compared to published fossil-BDO prices. Product currently not sold to external customers

EARNINGS

Not disclosed (results consolidated yearly in Novamont Group's balance)

CHARACTERISTICS

- 100 % bio-based
- Biodegradable
- Drop-in replacement of fossil based substitute products
- Patent protected producing technology
- Enables an increase of bio-based content of bioplastics to circa 60 %

A bio-based building block for bioplastics



PRODUCT

1,4-Butanediol (BDO) is an industrial chemical widely used as a solvent and as a building block for the production of plastics, elastic fibres and polyurethanes. Until recently, it was only possible to obtain BDO from fossil sources. Novamont has invested in a production facility that derives BDO from renewable sources through fermentation. The resulting product, bio-BDO, is a **100 % bio-based drop-in replacement** for the fossil-based BDO on the market. The company uses the product as an input for its own downstream bioplastic products, which constitute the company's main business.

SUCCESS

Novamont's bio-based BDO enables the production of their fourth generation bioplastics, raising the renewable content from about 35 % to more than 60 %. It is the first commercial scale dedicated plant to produce bio-based BDO through single-step fermentation, thanks to bioengineering technology that Novamont successfully licensed and integrated into the production process. While product development benefited from EU funds (FP7) at the R&D stage, the bio-BDO industrial plant is the result of over EUR 100 million investment financed entirely from private sources. Industrial production from the plant started in 2016.

PROSPECTS

The prospects for bio-based BDO are **positive**. Its integration in Novamont's biopolymers production, also dedicated to compostable carrier bags, will be a prerequisite to meet stricter standards with respect to minimum bio-based content, such as those introduced by Italian and French national laws. Bio-BDO thus reinforces the market position of current customers, namely internal Novamont Group companies that use it in their production of bioplastics. Besides legislative requirements, sustainability commitments of brand owners of products that make use of BDO (e.g. in textiles) create opportunities for the future deployment of bio-BDO by external customers. On the supply side, the price difference compared to traditional products has been reduced as a result of cost reduction measures in the production process. Medium to long-term supply-side improvements are already now being considered, including research into a shift to lignocellulosic biomass feedstock.

HISTORY

Since its foundation in 1989, Novamont's core business has been the production of biodegradable and compostable bioplastics. Over time, the focus expanded to new materials and chemicals that enable Novamont to develop bioplastics with improved characteristics - most recently its 4th generation of bioplastics with higher bio-based content. This led to the development of bio-BDO and the foundation in 2012 of a dedicated subsidiary around the investment in a bio-BDO production plant (*Mater-Biotech*).

Since the initial phases of developing bio-BDO, Novamont concluded an agreement with Genomatica, a California-based bioengineering company, for licensing the company's bio-BDO process technology. Novamont worked for the reconversion of a decommissioned industrial plant to the production of bio-BDO. The conversion was carried out between 2014 and 2016. The related investment amounted to over EUR 100 million, raised from private sources, including Novamont's internal finances, and bank loans.

The project entailed significant technology risk, related to both the reconditioning of an abandoned plant initially designed for a different fermentation process and the **scale up of an entirely innovative process**. Novamont overcame technical challenges through R&D investments, and by enhancing the research and engineering teams meanwhile leveraging on pre-existing skilled human resources. The risk was also mitigated by working closely with Genomatica throughout

Drivers of success

- » Novamont Group's reputation and established market position for bioplastics, the current application for bio-BDO. Vertical integration facilitates market access for bio-BDO
- » EU Bioeconomy Strategy, Italian and French environmental legislations that introduce minimum bio-based content criteria for lightweight plastic carrier bags; Italian corporate tax law that rewards innovation
- » Strong company focus on R&I and know-how in developing low-impact processes, team profile of high level researchers and engineers
- » Development of Novamont's biotechnology platform
- » Novamont's ability to work closely with key partners, in particular in reaching a licensing agreement with Genomatica for the integration of their innovative technology in the bio-BDO plant
- » The availability of EU and national public funding for R&D and demonstration projects that helped prepare the ground for the industrial scale investment

the plant conversion, capitalising on biotechnology expertise that was complementary to Novamont's in-house know-how in developing low-impact processes.

The production of bio-BDO does not yet benefit from economies of scale to the same extent that competing, traditional products do. This was partly addressed through measures taken during plant construction that increased the plant capacity from 18,000 to 30,000 tonnes per year. Commercial production at Novamont's bio-BDO production plant started in July 2016.

SWOT ANALYSIS FOR FOR BIO-BDO

S

STRENGTHS

- Established company position in bioplastics market
- R&D focus and know-how in low-impact processes
- Partnership with a bioengineering company and European license agreement for bio-BDO technology
- Company shareholders include venture capital and banking firms with access to finance
- Drop in replacement for a product with established supply chain

W

WEAKNESSES

- Price competitiveness vis-a-vis fossil equivalent product

O

OPPORTUNITIES

- Favourable policy agenda, including national bio-based standards for certain products
- Availability of EU funding at the R&D and demonstration phases, national support schemes for the bioeconomy and innovation

T

THREATS

- Absence of strong regulatory push for bio-based products in Europe
- "Fake" bio-based plastic products on the market with misleading claims
- Low oil prices

FUNDING

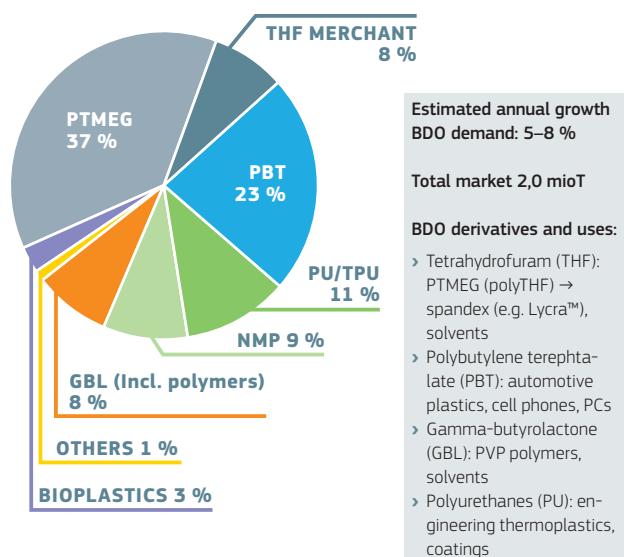
The set-up of the bio-BDO industrial production plant involved a **private investment of EUR 100 million**. This was mobilised from the company's internal finances. In particular, Novamont is controlled 75 % by Mater-Bi S.p.A. – whose shareholders are Banca Intesa, Investitori Associati, and others – and 25 % by Versalis – Eni's subsidiary and one of Italy's biggest chemical companies.

Novamont did not receive EU or national public funding for the reconditioning of the plant. In the initial phase, Novamont benefitted from EU funds available for R&D activities that prepared the ground for the investment in the industrial scale plant. The FP7 BIO-QED project included R&D activities aimed at cost reduction and sustainability improvement of bio-BDO and generated evidence on key technical and economic design parameters for the investment. Novamont has over the years been actively involved in additional R&D projects in relation to bio-based activities that have received support from EU research and innovation programmes. This has included funding under FP7 and H2020, including under the BBI-JU.

MARKET INFORMATION

As bio-based BDO has similar characteristics to the fossil-based BDO, the total potential market size for bio-based BDO corresponds to the total market size of the fossil-based BDO. The total global market for BDO (fossil- and bio-based) was estimated to be at least 2 million tonnes in 2016 and **growing over the years**. Currently, on the basis of studies and market data, Novamont estimates it to have reached about 2.5 million tonnes. The growing demand for spandex in textiles and increasing applications of BDO derivatives in industrial processes have been the key drivers of recent growth.

THE TOTAL MARKET FOR 1,4-BUTANEDIOL (FOSSIL- AND BIO-BASED) IN 2016, its derivatives and uses



Source: Company estimates

Presently, the market penetration of bio-based BDO (including that of Novamont's competitors) remains relatively low given the newness of the industry. For 2016, Eurostat data show moderate sales levels of just over 5,000 tonnes of bio-BDO produced in the EU, and imports of close to 32,000 tonnes into the EU from other countries. However, changes have started to emerge in recent years as a result of investments and it is expected that this dynamic will continue.

Bio-BDO produced at the Mater-Biotech plant is used by Novamont Group companies as a building block for the production of bioplastics. In the future, there is potential for expanding the customer base to include external customers.

REGULATORY ASPECTS

An enabling factor for the development of bio-BDO has been the Italian and French legislations on lightweight plastic carrier bags. Italian law effectively banned the sale of non-biodegradable lightweight plastic bags since 2011. This initiative, which anticipated the European legislation, also signalled to the industry that further requirements could be expected in the future in relation to minimum bio-based content. In 2017, the implementation of the EU 2015/720 Directive "Reducing the consumption of lightweight plastic carrier bags" introduced minimum standards in Italian legislation concerning the bio-based content of lightweight plastic carrier bags: 40 % as of January 2018, 50 % as of January 2020 and 60 % as of January 2021.

Another case is France, where the law on energy transition and green growth provides specific measures on plastic bags, plastic packaging and waste. Starting from January 2016, single use plastic bags are banned, and from January 2017 fruit and vegetable bags have to be compostable. A technical decree was adopted to set the percentage of bio-based content, increasing over the years for plastic bags.

With the integration of bio-BDO in its bioplastics, Novamont is able to meet these minimum requirements, which gives them a competitive advantage in the market.

However the market potential is still locked, since there is a high percentage of "fake" bio-based products that do not comply with European standards and national laws. This could be alleviated in the future by initiating actions for the enforcement of existing laws and related sanctions.



TECHNOLOGY INFORMATION

Novamont's bio-based BDO is derived directly from renewable sources through a single step fermentation process. More specifically, bio-BDO is made with a metabolically engineered strain of E. coli type bacteria using sugars. This strain was developed by Genomatica which granted Novamont the European licence to use it. Novamont has developed a biotechnological platform and the two companies also worked closely together throughout the bio-BDO plant conversion.

Bio-BDO industrial production from Novamont's plant started in July 2016. Accordingly, the **Technology Readiness Level is 9** (actual system proven in operational environment).



ENVIRONMENTAL IMPACT

Novamont's internal LCA studies show that bio-BDO results in a $\approx 60\%$ greenhouse gas reduction across the BDO life-cycle when compared to fossil-BDO ("Cradle to gate" boundaries). Bio-BDO improves the environmental profile of products in which it is used as a building block. Depending on the specific product application, bio-BDO enables an **increase of the bio-based content of downstream bioplastics** from about 35 % to about 60 %.

The production process of bio-BDO encompasses the recovery and valorisation of co- and by-products, which leads to reduced net energy consumption and waste streams as compared to conventional processes. This is done through a cogeneration system and a biodigester.

The feedstock currently used for the production of bio-BDO is sugars (glucose) derived from the hydrolysis of starch – the so-called glucose syrup, commonly used in industrial fermentation processes. The glucose syrup is supplied from a local Italian production plant that uses starch sourced in Europe. Novamont's choice of supplier has helped revitalise the business of a local glucose production plant, creating positive impacts along the value chain.

According to company estimates, the quantity of plant raw materials required for its bio-BDO production constitutes about 0.05 % of total European annual production. Therefore, the current demand for glucose syrup is assessed to not significantly influence the market for these raw materials. Looking into the future, and to address possible future concerns with respect to feedstock competition with food, Novamont has been conducting research on obtaining sugars from lignocellulosic biomass. This technology has proven to be feasible at the pilot stage.

THE WAY FORWARD

The outlook for bio-BDO is positive in terms of sales volumes owing largely to national regulatory requirements that are being phased in at the national level (Italy and France) and which will require an increasing percentage share of bio-based content for certain bioplastic products. Therefore, the bio-BDO plant can be expected to reach full capacity in the short to medium-term, as Novamont moves to its 4th generation bioplastics as its standard product offering to meet such requirements.

BDO is in **high demand for a wide range of applications** besides plastics, e.g. in sectors such as textiles, automotive and consumer goods. Sustainability commitments of brand owners in these sectors create opportunities for the future deployment of bio-BDO. In the future, there could be a **potential for expanding the customer base** to also include customers external to the Group. This would assume that Novamont succeeds in further scaling up production, and is subject to strategic decisions and priorities within the company.

At the same time, improvements in the production process and measures aimed at cost reduction will drive growth alongside demand-side factors. The quantity of plant raw materials required for bio-BDO production in Mater-Biotech plant is around 0.05 % of total European annual production (2012 data). Therefore, the current demand for sugar to produce bio-BDO does not significantly influence the market for these raw materials. However, within Novamont's logic of continuing innovation, the company is investigating the use of various renewable by-products as feedstock for the bio-BDO production process. Novamont researchers have conducted experiments aimed at obtaining sugar from lignocellulosic biomass (so-called second generation sugars). Novamont pilot-tested this technology, which has proven to be technologically feasible.

BioFoam® by Synbra Technology

PRODUCT NAME

BioFoam®

PRODUCT DESCRIPTION

Foam for technical and packaging applications

FEEDSTOCK

Sugar from cane or beets

ORGANISATION

Synbra Technology of Synbra Group, owned by Gilde Buy-Out Partners

EMPLOYEES

Circa 900 direct employees at the Group level

COUNTRY

The Netherlands

R&D START

2006

MARKET ENTRY DATE

2010 (EU)

PRODUCTION CAPACITY (EU)

BioFoam® capacity corresponding to 6,000 tonnes PLA/year (Synbra's PLA plant capacity)

PRODUCTION VOLUME

BioFoam® production volume corresponding to 30 % of Synbra's PLA plant capacity

SALES (GLOBAL)

EUR 1.6 million (current); EUR 0.5 billion (in 2025 with scaling up investment)

INVESTMENT

A PLA plant of 70,000 tonnes per annum requires an estimated EUR 200 million

PRICE

Double of conventional fossil-based substitute products

EARNINGS

Positive at company level. Product line expected to be positive in the near future

CHARACTERISTICS

- 100 % bio-based (DIN CERTCO certified)
- Biodegradable
- Carbon neutral (PAS 2060 standard) and Cradle-to-Cradle™ certified
- Patent protected
- Trademarked (2008, international; 2009, the EU)

A bio-based alternative to plastic-based foams



PRODUCT

BioFoam®, a polylactic acid (PLA⁶) based foam, is an alternative to traditional plastic-based foams. It is suitable for use in **technical** and **packaging applications** interchangeably with expanded polystyrene (EPS) and polystyrene (PS). Applications have included packaging for large domestic appliances, icebox insulation, cavity wall insulation, surfboards etc. It is both **bio-based (100 %)** and **biodegradable**; and it can be remoulded after use into other end-of-life applications.

SUCCESS

Synbra formulated a **strategic vision** in 2006: to develop PLA based materials that can substitute traditional fossil-based packaging materials in technical and packaging applications. The aspiration is to ensure the sustainability of the business in the longer term, and to drive a market evolution towards **more sustainable bio-based materials**. A major step was taken five years later: the opening of a fully operational PLA plant; the only of its kind in Europe. BioFoam® has been on the EU market since 2010, largely thanks to the capacity of Synbra to mobilise internal finance for the product development.

PROSPECTS

The prospects for BioFoam® are **positive**. The price difference compared to traditional products is continuously reduced thanks to for example continuous improvements in the production process. Global **demand for PLA products** is expected to increase over the coming years, largely stimulated by legislative actions and by CSR commitments in companies. Medium to long-term supply-side improvements are already now considered, including research into a shift to non-food crop feedstock for PLA, e.g. 'thinning wood'.

⁶PLA is a polymer that is both bio-based and biodegradable. It is derived from renewable resources such as sugar cane or beet, which is refined to sugar, then fermented to lactic acid, from which lactide is made. Lactide is then transformed into PLA through a polymerisation process.

HISTORY

BioFoam® is the result of Synbra Technology R&D activities, primarily financed internally from within the Synbra Group. This work began in 2006, in consideration of the potentials of PLA as raw material. Initial R&D was done together with Wageningen University and confirmed the suitability of PLA as raw material.

Confronted with a shortage of supply of PLA, the Synbra Group invested in 2008 in its own PLA plant, constituting the **single largest investment made by the Group**. The plant was developed in partnership with a manufacturing technology company and a feedstock supplier, Sulzer Chemtech and Corbion respectively. The plant was fully operational in 2010. However, the economic crisis reduced demand for PLA-based products considerably, due to low economic activity and low oil prices influencing their cost competitiveness vis-a-vis the conventional fossil-based foam products, i.e. expanded polystyrene (EPS). Production has thus remained at levels below full capacity.

Following a considerable write-off in 2013, the company's strategy was refocused on PLA foam applications and the BioFoam® brand. BioFoam® is considered by the Synbra Group as a **long-term investment** over making short-term profit. Synbra is active in both fossil-fuel based and bio-based plastics, and BioFoam® competes with the company's own "traditional" EPS products as well as with the 10 major players on the global EPS market. BioFoam® is the centrepiece of Synbra's long term strategy to **transition away from fossil fuels**, and a core element also to ensure the financial and environmental sustainability of the business in a future low-carbon economy.

Despite considerable investment requirements, and the unforeseen decline of oil prices and the economic crisis, BioFoam® has succeeded relatively fast: **Five years from initial R&D to BioFoam® being commercially produced**. The company has in the process overcome risks in relation to reduced demand

Drivers of success

- » Capacity of Synbra to mobilise internal finance for the product development;
- » Partnerships with Wageningen University, a manufacturing technology company (Sulzer Chemtech) and a feedstock supplier (Corbion);
- » Long term perspective and strategy, underpinning the continuous commitment of Synbra's management to the product;
- » Strong position of Synbra in the relevant industry segment, which enabled it to leverage on its existing know-how and market knowledge.

due to the economic crisis and low oil prices, mobilisation of finance, as well as access to raw material. An important explanatory factor for this rapid development is the flexibility of Synbra's decision making and the simple financial structure behind the development.

FUNDING

The development and commercialisation of the product has been mainly funded from the company's **internal finances**. The company has used the profit made through other business activities to finance the R&D and commercialisation efforts related to the BioFoam® product. External finance could not be mobilised, primarily due to the time span between the capital investment being made and the potential resulting sales and profits. Internal finance was also the main source of funding for the construction of the PLA production plant in the Netherlands.

The company's strategy for product development has been continuously endorsed by the company's owner, Gilde Buy-Out Partners, a **private equity fund** who has held the entire share capital of Synbra since 2006. The internal funding mobilised for the development of BioFoam® was subject to a robust initial **risk assessment** commissioned from a consulting firm. This exercise concluded that pursuing the product development did not expose Synbra to an unacceptable financial risk – even in a worst-case scenario.

..... SWOT ANALYSIS FOR BIOFOAM®

S

STRENGTHS

- Established production, ability to expand, patents
- Involvement in actions to improve SD performance further
- Accreditations and verifications of product

W

WEAKNESSES

- Ability to mobilise finance for possible new plants
- Ability to continuously provide the best SD features of the products

O

OPPORTUNITIES

- SD gaining momentum with businesses and positive regulatory local changes
- Expected global PLA market growth at 10 % per year until 2021
- Oil price developments

T

THREATS

- Oil price developments
- Absence of strong regulatory push for bio-based products in Europe

Besides internal finance, Synbra together with their co-operation partner Corbion received a total of EUR 800,000 in subsidies from the Dutch Government in support of the initial R&D activities relating to the product. Synbra has also benefited from various fiscal instruments in the Netherlands in **support of innovation** (e.g. lower tax percentage using the environmental investment deduction methodology MEA; wage tax subsidies).

MARKET INFORMATION

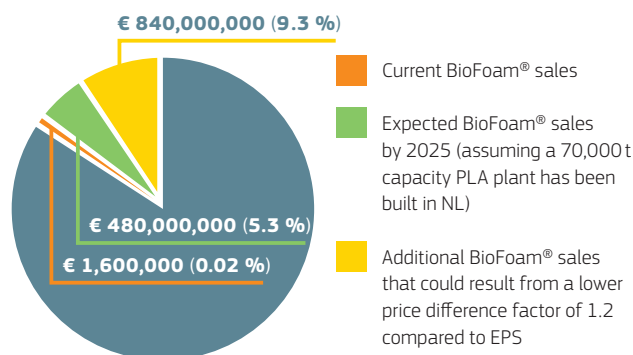
In recent years, Synbra's PLA production amounted to between 10–30 % (depending on oil price levels) of the plant's annual production capacity of 6,000 tonnes. Currently the price difference is estimated at a factor 2:1 when comparing Synbra's PLA based products to traditional EPS based products, down from a factor of 5:1 in 2011. Further measures that are in a test phase have demonstrated the capacity to reduce the price differential to a factor of 1.6, while some investment in new machinery would bring the factor down to an estimated 1.2 in the medium term. The above factors are before tax, and the actual **price differential** becomes even less pronounced when the fees that producers and importers of packaging in the Netherlands must contribute to the "Packaging Waste Fund" are taken into account (see more under Regulatory Aspects).

The Synbra Group of companies cover the entire **value chain** from raw materials to construction, packaging and recycling. Synbra Technology's direct customers include companies within the Group e.g. Synprodo (for packaging solutions with BioFoam®) and IsoBouw (for construction materials from BioFoam®). In addition, the company has built a customer base from outside the Group, with several customers based in Italy, the US, and France.

In terms of market potential, considering the **expected growth in demand for PLA-based materials** including BioFoam® (expected global PLA market growth at an average rate of 10 % per year until 2021⁷) and the limited production capacity of PLA currently available worldwide, the company expects to reach its maximum annual production volume of 6,000 tonnes in the near future. After that point, the company has the ability to double its production capacity by expanding its current PLA plant or potentially purchasing additional PLA from the market. Considering the existing price differential compared to traditional products, the market opportunities for BioFoam® in the immediate future lie in new/niche applications that are less driven by price considerations, before moving to the market segment for replacement products as the price differential narrows.

Although current sales are modest, BioFoam® has in the medium to longer term the potential to gain up to **15 % market share** from the current EUR 9 billion global EPS foam market.

CURRENT AND FUTURE GLOBAL MARKET SHARE FOR BioFoam® as a % of the global EPS foam market



Global EPS foam market (2016): EUR 9 billion

Source: Company estimates

REGULATORY ASPECTS

Producers and importers of more than 50,000 kg of packaging in the Netherlands must contribute to the "Packaging Waste Fund", with the fee per kg of conventional plastic packaging in 2017 amounting to as high as EUR 0.64/kg, while for biodegradable plastics the corresponding fee was as low as EUR 0.02/kg. This narrows the price differential between BioFoam® and EPS products and illustrates the **long-term competitiveness** of the product.

Moreover, the gradual introduction of bans on EPS use in specific packaging products in certain regions (e.g. in North America, Far East) are key drivers of demand for BioFoam®, and similarly so are end-user sustainability commitments that effectively introduce 'voluntary bans'.

TECHNOLOGY INFORMATION

BioFoam® is made by expanding PLA-based microbeads with a size of 0.7 mm–1.0 mm or 1.0 mm–1.6 mm to typically 25–40 kg/m³, and moulding these beads using custom-made moulding equipment. The **Technology Readiness Level (TRL) is 9** (actual system proven in operational environment). The BioFoam® product is protected by patents.

The polymerisation technology for the PLA plant was developed through a partnership with Corbion (which was called Purac at the time) and Sulzer Chemtech. The same technology is currently being deployed at a new PLA plant built by Corbion in Thailand and is expected to be completed in 2018. Before it acquired the license from Sulzer and Corbion, Synbra tested their PLA material in its own EPS bead-making process, using CO₂ as a blowing agent.

⁷ Global production capacities of bioplastics 2016–2021, Report, European Bioplastics. Data for 2016



ENVIRONMENTAL IMPACT

Feedstock and bio-based rating: the PLA raw material for BioFoam® originates from **100 % bio-based feedstock**, namely GMO-free sugar from cane or beets. The geographical origin is predominantly Thailand (sugar cane). Synbra's supplier (Corbion) have in place sustainable sourcing commitments and a sugar code, covering environmental practices, land rights, good agricultural practices, and biodiversity, as well as business ethics, human rights, and labour conditions. Synbra is also involved in work on the development of 2nd generation PLA from "thinning wood". BioFoam® has the highest bio-based rating (between 85–100 %) DIN-CERTCO certified.

Production and end-of-life: Synbra has received the Cradle-to-Cradle™ certification for BioFoam®, as well as the **Carbon Neutrality verification** in compliance with the PAS 2060 specification standard. After use, BioFoam® can be remoulded into a new product and has additional end of life options (it is biodegradable and can be industrially composted).

In addition, the PLA itself has been awarded the Cradle-to-Cradle™ certification. The BioFoam® manufacturing process uses CO₂ instead of pentane for the purpose of blowing the foam, and the CO₂ emitted during production is in fact captured in the material. Overall, the demonstrated environmental qualities of BioFoam® have been an important deciding factor in major end customers endorsing the product.

THE WAY FORWARD

The outlook for the BioFoam® product is positive, both in terms of sales volumes and profitability owing to the several underlying factors and trends that support its expansion to new applications and markets. Firstly, end-user sustainability commitments as well as governmental actions towards a greener, low-carbon economy will continue to be key drivers of demand for BioFoam®. A recent significant milestone that has the potential to be positive is the decision of a **major furniture retailer** to approve BioFoam® as a packaging material for their products and to stop using EPS-based packaging. At the same time, improvements in the production process of BioFoam® will drive growth alongside the demand-side factors.

Considering the limited production capacity of PLA currently available worldwide, the demand for PLA-based materials (including BioFoam®) may soon outpace the growth in production capacities and this may lead to a shortage of PLA on the market, at least until new production facilities are built. In the case of Synbra, the company is likely to reach its maximum annual BioFoam® production volume (corresponding to the annual production capacity of its PLA plant of 6,000 tonnes of PLA) in the foreseeable future, and has a debottlenecking plan in place that will increase the production capacity of its existing PLA plant.

In the medium to longer term, investments in new PLA production facilities will be indispensable to meet the expected demand growth. To give an illustration of investment needs, an estimated 2 years' time and an **investment of about EUR 200 million** would be needed for establishing **3 plants**, for lactic acid production, lactide production and PLA polymerisation respectively which would enable the production of **70,000 tonnes of PLA per year**. Any investment in second-generation feedstock would be in addition.

Medium to long-term supply-side improvements are expected to include a shift to a new generation feedstock for PLA, shifting away from the currently used sugar cane, to a feedstock that would address any concerns in terms of implications for the food production chain. Synbra is member in a consortium of companies actively working on the use of 'thinning wood' generated as a residue of harvests as the feedstock for producing lactic acid (which is transformed into PLA).

Carboxyline® CMI by Cosun Biobased Products

PRODUCT NAME

Carboxyline® CMI

PRODUCT DESCRIPTION

Scale inhibitor (antiscalant) used for detergents formulations and water purification

FEEDSTOCK

Chicory roots

ORGANISATION

Cosun Biobased Products, subsidiary of Royal Cosun

EMPLOYEES

15 direct employees and another 10–15 indirect R&D employees at Cosun Biobased Products; Around 3900 employees at Royal Cosun

COUNTRY

The Netherlands

R&D START

1995

MARKET ENTRY DATE

2010 (EU)

PRODUCTION CAPACITY

Not disclosed

PRODUCTION VOLUME

Not disclosed

SALES (GLOBAL)

Not disclosed

INVESTMENT

Multimillion EUR investment

TYPICAL PRICE

3–8 EUR/kg (detergents application),
3–5 EUR/kg (potable water application)

EARNINGS

The product reached its breakeven point in 2016, since then its net sales has steadily increased

CHARACTERISTICS

- 55–70 % bio-based
- Biodegradable
- Eco-label
- Ecocert
- Safer Choice by EPA: Safer Chemical Ingredient

A functional biopolymer that deals with hard water challenges



PRODUCT

Carboxy Methyl Inulin (CMI) is an environmentally friendly scale inhibitor (antiscalant).¹¹ It is used in detergents for automatic dishwashers, laundry machines and alkaline cleaners,¹² as an alternative to fossil and phosphorus based chemicals.¹³ It is also used in filtration processes for potable water production. A modest modification of the product could broaden its application to other markets such as personal care. It is bio-based and biodegradable. The product is derived from company produced inulin that is not suitable for human consumption.

SUCCESS

Royal Cosun invested in large inulin plant with an aim to produce inulin for food production. Some inulin however does not comply with food safety standards and hence it cannot be used for human consumption. CMI is a research result exploring possible uses of inulin in non-food markets. Upon development of CMI, Royal Cosun decided to create a dedicated company, that specialises in bio-based products. Established in 2010, Cosun Biobased Products quickly reached the market and, within 5 years, it has now reached breakeven and profitability of CMI.

PROSPECTS

The prospects for CMI are **positive**. The market uptake in the home care sector is steadily including more sustainable solutions, facilitated by stricter environmental rules for detergents since 1 January 2017 and by the company's continuous investments in research and development. Also, CMI sales in the potable drinking water market are growing. At present, CMI is used by the largest potable water producers in the Netherlands. Furthermore, the company is actively working on entering new markets.

¹¹ In detergents sector, CMI is used to prevent the formation of inorganic scale, which is often formed due to the presence of hard water. An example of inorganic scale is a lime scale. It is the calcium carbonate residue that forms on cookers, water kettles, or dishwashers.

¹² In detergents application it prevents inorganic scale formation. In water purification purposes, it prevents scale formation in membrane installations.

¹³ Performance efficiency is comparable to phosphorus-based products.

HISTORY

Cosun Biobased Products is a subsidiary of Royal Cosun, an agro-industrial group that processes arable crops and other vegetable raw materials. 120 years ago, Dutch sugar beet growers formed a cooperative and thus, established Royal Cosun. Today, the cooperative has 8,856 members/shareholders and it has grown into a business with 3,900 employees and 35 production facilities in 10 countries, altogether processing over 9 million tonnes of vegetable raw materials. The annual turnover was EUR 2.1 billion in 2017.

In the late 1980s, the company invested in a large factory to produce inulin for food consumption. At around the same time, it embarked on various **research projects** to consider other possible inulin uses. The goal was waste reduction as, due to food safety standards, part of the inulin is deemed not suitable for human consumption. Their most promising findings emerged in the 1990s when the first molecule of CMI was being developed.

Commercial production of CMI then started in 1997. Given Royal Cosun's lack of experience in the non-food market, they entered into an exclusive partnership with an external company, responsible for product marketing and sales.

By 2009, and due to the recognised market potential of CMI, Royal Cosun changed its strategy and, in 2010, founded Cosun Biobased Products as a **dedicated bio-based products company**.

CMI targeted different market segments in 2010. These include home care, industrial water treatment, potable water production, and the pulp and paper industry. By 2013, due

Drivers of success

- » Vertical integration, strategic partnerships, and co-development throughout the whole value chain
- » Royal Cosun's drive to innovate
- » Building a homecare product portfolio helped compete with larger competitors
- » Working directly with customers to find new solutions and applications of the product
- » CMI's higher price compared to fossil fuel and phosphorus-based products are offset by customer demands for quality and value product

to the recognised market potential Cosun Biobased Products narrowed their focus to only two of these markets: home care and potable water production. This decision has been supported by additional investment in R&D and marketing exposure, financed by Royal Cosun.

Considering the capital investments to launch the new bio-based products, CMI reached its **breakeven point by 2016 and since then, they have been profitable**. The profitability is partly due to increased sales but profitability has also been enhanced by streamlined production costs and ending of depreciation (costs) of early investments.

FUNDING

CMI's growth has primarily been financed through **internal finances**. Nevertheless, securing this funding required Cosun Biobased Products to present their business case to Royal Cosun, similarly as it would have been done in the case of external funding. Furthermore, between 1997 and 2009, the company received approximately EUR 3.3 million from the **Eureka funds** to support research and development phases.

SWOT ANALYSIS FOR CMI

S

STRENGTHS

- Strong R&D focus
- Ability to adapt and change market focus
- Awareness of other possible applications
- Ability to tailor-make product for specific customers
- Size of umbrella company
- Vertical integration throughout the whole value chain

W

WEAKNESSES

- Costly and lengthy testing required in order to demonstrate performance of the product compared to conventional alternatives (home care sector)
- Cost of feedstock

O

OPPORTUNITIES

- EU Regulation (No 529/2012) limiting the use of phosphorus content in the standard dosage in consumer automatic dishwasher detergents (home care sector)
- Expanding to different markets (both geographically and application wise)
- In line with circular economy

T

THREATS

- Competing with large chemical companies
- Costly and expensive registrations and not EU harmonised requirements (potable water application)
- Environmental aspects of the product alone are not sufficient to attract consumers
- Price of competing products is lower

MARKET INFORMATION

Home and fabric care market: CMI is used in automatic dishwashing detergents (tablets, gel, and powder), laundry detergents (powder and liquid), and cleaners (hard surface and carpet cleaners). Most of CMI's home and fabric care sales are in Western Europe and North America.

Today, the home and fabric care market is CMI's strongest market. This is seen as a direct result of their investment in R&D and product testing. These efforts have demonstrated CMI's better performance against competing fossil fuel and phosphorus based products.

Furthermore, recent EU regulation limiting the use of phosphorus in detergents helped to strengthen their market position. Competitors, whose chemicals contained banned amounts of phosphorus no longer met market standards and found themselves investing in new solutions. These investments are consequently reflected in higher prices within this market. Additionally, product performance standards of some competitors' new formulations resulted in lower performance than their original, phosphorus-based products.

CMI is 3 to 4 times more expensive than similar, fossil based products, because CMI's feedstock is more expensive. The higher price can, to some extent be justified by better cost performance of consumer products for which the product is used.

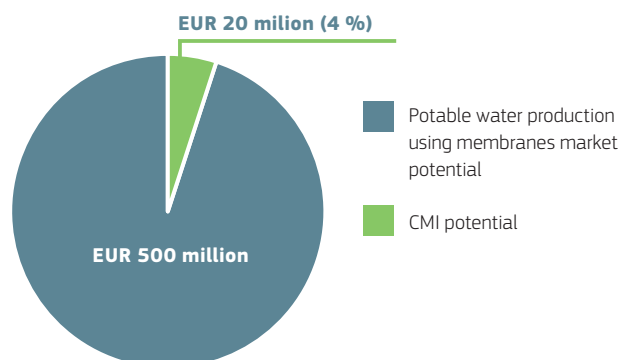
Cosun Biobased Products states that the overall potential for all bio-based products in the home care market is about EUR 50–170 million and growing steadily. Cosun estimates that the potential market share for CMI could be about 5 %.

Water treatment: CMI is also in water treatment, e.g. it is used for potable water production. It is used during the filtration and water purification stages. CMI sales in the potable water production is limited to the Netherlands and the United States.

Unlike home care, the CMI prices in this market are comparable to prices for competing products. Additionally, Cosun Biobased Products estimates that CMI used for potable drinking production is more cost-effective than fossil and phosphorus based chemicals.

According to Cosun Biobased Products, the worldwide market for antiscalants for potable water production using membranes amounts to over EUR 500 million and is growing rapidly. The market **potential** for CMI in this market is max. EUR 20 million.

MARKET POTENTIAL POTABLE WATER PRODUCTION



Source: Company estimates

REGULATORY ASPECTS

Since 1 January 2017, phosphate is no longer allowed in household dishwashing products (EU Regulation No 648/2004). This led to a significant shift in the market and stimulated an increased demand for CMI.

In potable water applications, CMI is facing significant regulatory burdens in accessing new markets. Certification is a costly and lengthy process and individual permits are obtained in each EU Member State separately.

TECHNOLOGY INFORMATION

Carboxy Methyl Inulin (CMI) is a functionalised biopolymer produced by carboxymethylation of inulin, which is a plant reserve polysaccharide extracted from chicory roots. It is a renewable raw material.

In brief, CMI performs well as a threshold scale inhibitor for various types of inorganic scaling due to its three main functionalities: complexing of metal ions, crystal growth inhibition and dispersancy.

As a result of these basic functionalities, CMI offers benefits such as spotting-filming prevention in automatic dishwasher detergent and anti-redeposition of dirt particles in laundry detergent. Moreover, it prevents membranes used for the production of potable or process water from scaling.



ENVIRONMENTAL IMPACT

CMI is inherently and ultimately biodegradable, which means that it slowly degrades in the natural environment and is not persistent.

Its safety profile, renewable origin, inherent biodegradability (OECD 302A) and the fact that CMI is free from phosphorus and nitrogen are characteristics that add positively to its sustainability.

The inherent biodegradability gives the product a certain amount of microbiological stability. As a result, less or no preservatives are required and this results in a reduced environmental impact.

The very low eco-toxicity of CMI has been confirmed by several chronic toxicity tests. These tests indicate that CMI does not have adverse effect on the environment during its resident time prior to mineralization.

THE WAY FORWARD

CMI is well established on two market segments (home care and water purification). Sales are steadily growing and the recent EU regulation limiting the use of phosphorus in detergents has further spurred demand. Since it reached its breakeven point in 2016, CMI has ensured its profitability. The future growth projections are underpinned by both the company's commitment to the bio-based industry as well as by the market's shift toward more sustainable and environmentally friendly solutions. A trend that is also to some extent supported by legislation.

At the end of 2017, Cosun Biobased Products moved their headquarters and manufacturing facilities to the Cosun Innovation Centre in Dinteloord, the Netherlands. The centre will eventually also house the IRS (the Netherlands' sugar beet knowledge and research institution). This joint R&D centre will continue to further improve uses of agricultural raw materials, innovation in process technologies, energy management optimisation, and development of new products.

While home care and water treatment markets will remain a significant part of the company's focus, Cosun Biobased Products is also looking to expand to new applications of the product and new markets. Currently, a new modification of CMI is being developed that will target the personal care market.

At the same time, Royal Cosun is working on a second generation feedstock. More specifically, they are looking into improvement the chicory yield in sustainable way.

From a geographical perspective, the company is mainly marketing CMI in the US and Western Europe. Their strategy is to continue expanding to other countries. The largest potential market is expected to be Asia, more specifically China, South Korea and Japan as these regions shift to higher environmental standards.

Desmodur® eco N by Covestro AG

PRODUCT NAME

Desmodur® eco N, part of the Desmodur® line

PRODUCT DESCRIPTION

Hardener component for coating systems

FEEDSTOCK

Cornstarch

ORGANISATION

Covestro AG

EMPLOYEES

Over 15,000

COUNTRY

Germany

R&D START

2007

MARKET ENTRY DATE

2015

PRODUCTION CAPACITY

20,000 tonnes PDI/year

PRODUCTION VOLUME

A few tonnes; Less than 1 % of capacity

SALES (GLOBAL)

Less than 1 % of the entire Desmodur® line; Expected double-digit growth of Desmodur® eco through 2020/2021

INVESTMENT

Not disclosed

PRICE

Higher than its petro-chemical Desmodur® equivalent

EARNINGS

Break-even on investment is expected by 2020–2025

CHARACTERISTICS

- 70 % bio-based (ASTM D6866 standard)
- 30 % lower carbon footprint, to comparable products (i.e. aliphatic isocyanates)
- Near drop-in character
- Patent protected
- Trademarked

A bio-based hardener for coatings



PRODUCT

Desmodur® eco N is the world's first bio-based hardener for lightfast polyurethane coatings which are typically used to protect a material's layer. Commercial applications include coatings for automotive, plastics, wood and industrial applications. The product is expected to replace the existing petrochemical aliphatic hardeners in the long term. Due to a high sensitivity in the coatings industry to product changes, Desmodur® eco N is a “near drop-in” solution. This means that it behaves similarly to and has a similar quality as its petro-chemical equivalents. This **minimises adoption costs down the supply chain**. It is **bio-based (70 %)** and it **reduces the carbon footprint** compared to the average footprint of comparable fossil-based products by 30 %.

SUCCESS

Covestro started its research into Desmodur® eco N in 2007. Eight years later, the product entered the market. The underlying aspiration of this development was to maintain a competitive position on the market, as Covestro's downstream customers seek using sustainability to differentiate themselves on the consumer market. Along the way, Covestro secured critical financing to the product's development and production entirely through internal funds. One critical driver of success is that Covestro implements a joint pilot case with Audi and BASF to demonstrate that the product performs similar to established polyurethane-based clear coats and can be applied in existing assets.

PROSPECTS

Covestro continues to expand the product range with a variety of properties and extra features like the recently introduced water-mixable version, the Bayhydur® eco, which fits perfectly to the requirements in high performance waterborne wood coatings. In parallel Covestro is further engaged with the development of the next feedstock generation of cellulosic- and waste biomass. The success of Desmodur® eco N may depend on the reputation of bio-based materials in the coatings industry. If current trends continue, sales of Desmodur® eco N are expected to grow by double-digits for the upcoming years.

HISTORY

Desmodur® is used as a hardener for paints, coatings, adhesives, such as automotive (including Original Equipment Manufacturers (OEM), sports (e.g. footwear adhesives)), wood and furniture coatings as well as for plastic coatings. Essentially, Desmodur® eco N was developed as a bio-based alternative to Covestro's existing fossil-based products and traded under the Desmodur® label, which are hexamethylene-diisocyanate (HDI) based.

Covestro initiated research to develop a bio-based aliphatic isocyanate hardener in 2007. At that time, there was a belief in the industry that such a hardener could not be developed. The project was funded exclusively by internal R&D funds. It was internally categorized as a low risk investment, as the know-how for the technology and a rough idea of the desired feedstock already existed within the organisation. The primary risk was to identify a feedstock supplier with a sufficient quality. The result was a Pentamethylene-diisocyanate (PDI), produced from fermented industrial cornstarch.

Covestro reports that the coatings industry is strongly sensitive to changes in product formulations, as small changes, impurities, or by-products can lead to high adoption costs further down the supply chain. The industry is therefore reluctant to adopt new products. A bio-based alternative needed to behave as close to its fossil-based counterpart as possible. From the outset, Covestro pursued a vision to develop a bio-based product with at least the same performance as established polyisocyanates. To ensure this, Covestro involved external partners of the value chain already at an early stage of the project.

Drivers of success

- » Covestro had the market knowledge to understand the evolving needs of its direct customers for bio-based and sustainable products already at an early stage. Covestro still enjoys a first-mover advantage.
- » Covestro succeeded to formulate a "near drop-in" solution that behaves and reacts almost exactly as its fossil-based version. This minimised the adoption costs for customers down the supply chain.
- » Knowing its client portfolio, Covestro knew where to exactly plug in with the marketing of its product.
- » The application of successful pilot cases such as with Audi & BASF helped convince potential but reluctant clients.
- » Covestro had the financial strength to dedicate all funds internally, without putting the company at risk.

Following the successful identification of the exact feedstock, Covestro was confronted with the challenge to identify a supplier. Many candidate suppliers had promising concepts, but lacked the experience to produce a consistent quality in the desired scale. This challenge was addressed by selecting potential suppliers on the basis of their practical experience at the desired production scale and in the proper quality as well as their environmentally sound production methods.

The scepticism that the development of a bio-based aliphatic diisocyanate was not possible posed a **financial risk**, as potential clients could have been reluctant to adopt to the new product. The initial success of Desmodur® eco N's development relied therefore strongly on the ability to **prove to stakeholders** the "near drop-in" performance. To mitigate the scepticism of potential clients, Covestro convinced Audi and BASF to conduct a **joint pilot case** on the application of

SWOT ANALYSIS FOR DESMODUR® ECO N

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STRENGTHS

- "Drop-in" design to minimise adoption costs
- Go-to-market strategy addressing end consumers instead of clients
- High financial strength, limiting the risk exposure
- High recognisability of the brand, being attractive for external partners
- Product is available in industrial scale at constant quality

W

WEAKNESSES

- Slow adoption of new products in the coatings and adhesives industry
- Competes against well established and optimized petrochemical processes

O

OPPORTUNITIES

- Marketing collaboration with large brands down the value chain (e.g. Audi & BASF) to create momentum
- Reduced carbon footprint contributes to the global sustainable development (e.g. the UN's SDGs)
- Market preferences for sustainability are becoming more mainstream

T

THREATS

- Global reputation that bio-based products struggle to deliver a sufficiently high and consistent quality can impact the demand for the product
- Industry is characterised by a slow adoption rate of new technologies
- Future low oil prices would make Desmodur® eco N a less price-competitive alternative

the fully developed product for an automotive paint coating. This served to demonstrate the “near drop-in” characteristic of Desmodur® eco N and the fact that customers are able to work with the new product.

Desmodur® eco N delivers a quality comparable to its petroleum-based counterpart, with the added value of being more **sustainable**. Accordingly, the product is sold at a higher price. Thus, direct customers must be willing to pay a premium for the sustainability feature of the product. To ensure this, Covestro uses an **innovative push and pull marketing strategy**. The strategy pushes marketing, by approaching contact points in companies down the supply chain, who are likely to share a common long-term vision about sustainability. Typical candidates are executive managers or marketing departments. The strategy establishes market pull by marketing Desmodur® eco N to manufacturers of consumer products, which are customers of Covestro’s direct customers. Covestro thus markets the product throughout the whole value chain of the coatings industry.

FUNDING

Being a large company, Covestro had the financial strength to develop and commercialise the product exclusively with **internal financing**, without putting the company at risk. The company states that it invests a significantly higher share of its profits into R&D than other players in the industry.

In support of its bio-based activities, Covestro participates in a Bio-based Industries Joint Undertaking (BBI JU) project under Horizon 2020, and receives funding for a different bio-based technology under Horizon 2020.

Covestro processes an intermediary input into its final product and has contracted an external supplier that prepares the raw material (industrial cornstarch). Covestro was thus not required to invest into a production facility for the raw material, and could continue derive the final product in their existing facilities for Desmodur®. The capital investment costs for the product were thus relatively low.

The “near drop-in” character of Desmodur® eco N implies that producers along the supply chain incur minimal costs to transition away from the fossil based Desmodur® version. Covestro managed to mitigate the financial risk, as the required capital investment was limited for Covestro as well as its customers.

MARKET INFORMATION

Desmodur® eco N is destined for markets with a high demand for sustainable products, like coatings for wood and automobiles, in which consumers are willing to pay a price premium for sustainability. Sectors that are strongly cost-driven or in which the bio-based property has no added value to the user, such as corrosion protection, are in turn not in focus.

Product development was driven by customers down the supply chain who seek to differentiate themselves on the consumer market. A particular driver of this change was the automobile OEM industry. This development put in effect pressure on Covestro’s direct customers, which led Covestro to develop Desmodur® eco N to maintain a competitive position on the coatings market. Currently, typical clients are those with a corporate sustainability mission.

Covestro did not establish a new market in the long term, but is in the process of **transitioning** its Desmodur® line **away from fossil fuels** in an effort to maintain and enhance Covestro’s long-term competitiveness on the market and to support its sustainability goals.

In 2013 Covestro was the largest producer of HDI, capturing about half of the total (bio- and non-bio-based) market. Current market research expects that the global isocyanate market, of which HDI and PDI are only one segment, will grow from a value of EUR 26.74 billion in 2016 to EUR 42.71 billion in 2022, at a compound annual growth rate of 8.02 %.

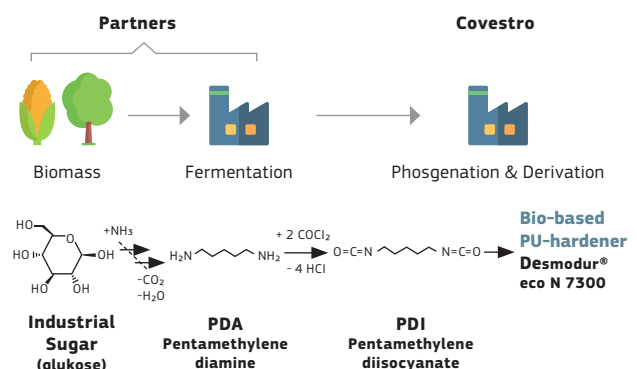
The industry reportedly invests heavily into R&D activities to develop new bio-based raw materials, due to the anticipation of good market opportunities from those. Covestro’s development of Desmodur® eco N can thus be understood as a necessity to stay competitive.

The specific market of Desmodur® and similar products is a market with 5 major competitors: Covestro (DE), Evonik (DE), Vencorex (FR), Wanhua (CN) and Tosoh (JP), who together count for 89 % of the total aliphatic isocyanate derivatives market.

REGULATORY ASPECTS

Desmodur® eco N requires mandatory REACH registration, as any other chemical in the EU. The fact that the product is bio-based has essentially neither facilitated nor complicated regulatory approval.

ILLUSTRATION OF THE PRODUCTION STAGES OF DESMODUR® ECO N



Source: Covestro



TECHNOLOGY INFORMATION

Covestro produces Desmodur® eco N from Pentamethylene-diamine (PDA). The PDA is produced in a fermentation process of industrial cornstarch, supplied to Covestro by an external supplier.

Covestro's PDA suppliers are engaged in the development of a second generation feedstock, for which cellulosic- and waste biomass are potential sources. The development is currently at an early stage, with no anticipated release date at this point.

Desmodur® eco N production is fully operational. All production infrastructure is in place to produce a volume of up to 20,000 tonnes per year. The current production is small, and there is thus scope for economies of scale. Desmodur® eco N is offered at a higher price than the product it replaces in the long term, but according to Covestro at a competitive level. The **Technology Readiness Level (TRL) is 9** (actual system proven in operational environment).

Desmodur® eco N is protected by patents.



ENVIRONMENTAL IMPACT

Desmodur® eco N is **70 % bio-based**, and is made from a non-edible corn (maize) variety. Non-validated estimations show that the production of one tonne of Desmodur® eco N corresponds to a land use of 0.44 ha corn. For the existing production capacity of 20,000 tonnes, the equivalent is 8,833 ha. The production of sufficient Desmodur® eco N for the paint of 90 million cars would constitute a land use of 31,800 ha.

Desmodur® eco N shows, according to Covestro's internal cradle-to-gate comparison with the industrial-average conventional aliphatic petroleum-based alternatives, **a reduction of the carbon footprint by 30 %**. Furthermore, the synthesis process has been reduced from four to two stages, improving production efficiency.

As already mentioned, Covestro chose its supplier, among others, based on how reliable and environmentally sound the production method was. In order to ensure sustainability in the long term, Covestro conducts regular LCA audits of its supplier.

THE WAY FORWARD

Covestro will expand its product range with a variety of properties and extra features (e.g. Bayhydur® eco). The feedback from customers is an important aspect, as changes in the formulations or unexpected behaviours of the material can result in its customers turning to other providers. The development of extra features will be a particular focal point to create a stronger value proposition.

On a broader dimension, Covestro believes the reputation of the quality of bio-based products an important component of the future because bio-based versions tend to have a reputation of having variations in quality, which needs to be consistent in the coating industry. If other players fail to deliver a promising product, the general reputation of bio-based products may affect the reputation of Desmodur® eco N.

Market preferences of consumers for sustainability are becoming more mainstream. If this trend continues, it is likely that other competitors will follow soon. Covestro expects double digit growth for Desmodur® eco N through 2020/2021 and still has a large scope for economies of scale. Desmodur® eco N is therefore able to compete with other bio-based products.

Lipex® by Novozymes

PRODUCT NAME

Lipex®

PRODUCT DESCRIPTION

An enzyme preparation, containing a lipase used in detergents to clean fat stains

FEEDSTOCK

Sugar, *Aspergillus oryzae* microorganism

ORGANISATION

Novozymes

EMPLOYEES

6,245 employees

COUNTRY

Denmark

R&D START

Approximately 1990s

MARKET ENTRY DATE

2002

PRODUCTION CAPACITY

Not disclosed

PRODUCTION VOLUME

Not disclosed

SALES (GLOBAL)

EUR 633 million (Household Care division), 2017

INVESTMENT

Product level: Not disclosed; R&D spending at company level: 13.2 % of revenue

PRICE

Not disclosed

EARNINGS

27.9 % (company level EBIT margin)

CHARACTERISTICS

- Classified as Readily biodegradable (OECD 301)
- Patent protected
- Trademarked

A bio-based alternative to remove fat stains



PRODUCT

Lipex® is an enzyme preparation containing a lipase. It is used as an ingredient in detergents. As a component in the detergent, Lipex® degrades edible fats and oils. It is effective across a temperature range 30–60 °C. The product replaces a part of surfactants (cleaning agents) or other ingredients in the detergent composition. These can be produced from vegetable or mineral oils. Lipex® is produced using a microorganism *Aspergillus oryzae*. Sugar is used to feed the microorganism, which ferments producing the required enzyme. Lipex® is **100 % bio-based** and is **biodegradable**.

SUCCESS

Lipex® has been **on the market** since 2002. It was the first enzyme in its class to achieve stain removal at the first-wash. According to Novozymes, it is currently the only lipase enzyme used in detergents. As such, it has no competitors among enzymes. Compared to the surfactants it replaces, Lipex® is considered performance competitive: it achieves comparable results at lower temperatures. Replacing detergent ingredients with enzymes can also lead to economic gains to detergent producers. The company has succeeded in achieving economies of scale, rendering it a profitable product. Currently, Lipex® is used by many major detergent brands.

PROSPECTS

The prospects for Lipex® are **positive**. The company is continuously working on improving the product to satisfy the requirements and needs of the market. The potential for lipase class enzymes is not yet saturated in the detergent market. Between 25 % and 60 % of detergents do not use enzymes, depending on the region. The main future growth is expected to be seen in emerging markets, in Asia and Africa, where the proportion of detergents that contain enzymes is lowest. Future GDP and population growth in these markets is expected to drive growth. This is combined with customer demand for high-performance detergents that are effective at low temperatures.

HISTORY

Novozymes is a biotechnology company, specialised in enzymes and microbes, including the Lipex® product. The history of the company started in 1925, when Novo Terapeutisk Laboratorium was founded. Novozymes in its current structure was formed in 2000 when Novo split into three different companies: Novo Holdings A/S, Novo Nordisk A/S, and Novozymes A/S. At the time, the company already had a portfolio of enzymes for both food and beverages and household care markets.

Lipex® has been developed as a result of the company's high focus on research and development. It is the result of more than 10 year's of research effort.

Novo initiated research into lipases for use in detergents in the late 1980s. They collaborated with a Japanese detergent producer, Lion, to develop the first fat-stain removing enzyme. A microorganism, *Thermomyces Lanuginosus*, was identified as a good source of suitable lipase. The customer required high volumes of the product to provide to the Japanese market. The amounts required could not be generated using the *T. Lanuginosus*. Hence, further research was conducted to find a combination that allowed high yields that the customer required. In this solution, another microorganism, *Aspergillus oryzae*, was modified using the *T. Lanuginosus* genetic code. Thus the predecessor of Lipex® entered the market.

However, customer feedback indicated that detergents with this enzyme removed fat stains only after multiple washes.

Drivers of success

- » Specific product formulations developed together with customers, to fit their needs
- » Company strategy focused on innovation, with a high dedicated R&D budget
- » Attitudes and preferences of direct customers (detergent producers): SDGs, triple bottom line important in their strategies
- » Financial strength of the company enabling it to finance continued research by internal means

Hence in the 1990s, Novo scientists conducted further research to improve the lipase so it can clean at first wash. The product based on this new lipase was Lipex®. It entered the market in 2002.

When introducing Lipex® to the market, Novozymes needed to convince customers that the product is efficient when washing at lower temperatures, by hand and in different machines. Consequently, additional resources have been devoted for testing its performance for different laundering methods, different machine types, and different temperatures.

At the time of market entry, Lipex® was the first product on the market which enabled removal of fat stains at the first wash. Lipex® benefited from this first-mover advantage, gaining acknowledgement from major detergent producers. According to the company, it is currently the only lipase enzyme on the detergent market.

SWOT ANALYSIS FOR LIPEX®

S

STRENGTHS

- Documented improved performance of detergents when using Lipex® as ingredient
- First-mover advantage
- Documented lower impact on the environment
- Detergent producers can save costs by replacing other ingredients with enzymes

W

WEAKNESSES

- Detergent formulation with enzymes requires know-how and attention to raw material storage and transportation

O

OPPORTUNITIES

- Improving living standards in emerging markets creating demand for better-performing products
- Drive towards innovation among detergent producers with the purpose to improve wash performance at low temperatures and improve sustainability profile of their products

T

THREATS

- Traditional consumer habits, e.g. washing at high temperatures
- Regulations favouring surfactants over enzymes in emerging markets
- Sustained low costs of competing products, reducing the adoption rate of high-performance enzymes
- Pressure on detergent prices in regions where the market is more saturated, e.g. the US

FUNDING

The research and development of lipase enzymes, including Lipex® has been funded **internally**. The company did not receive EU or any other public funding for this specific product. The company has taken part in various R&D projects and received EU funding for other activities. This includes four projects under Bio-based Industries Joint Undertaking (BBI JU) scheme on development of new bio-based products. Novozymes has taken part in a number of other H2020 and in FP7 projects related to development of industrial enzymes and novel applications of enzymes in various industries: food, medical, and biorefinery.

R&D is at the centre of the company activities, with around 23 % of its employees working with R&D. At company level, R&D spending constitutes around 13 % of revenue.

Each of the company's divisions has an application development unit, with the purpose of keeping the R&D and commercial sides close together. A Portfolio Board manages the overall pipeline. They evaluate potential projects according to their strategic and financial impact, their risk, contribution to CSR goals, and the involved resource utilisation and resource needs. The overall goal is to achieve a balanced portfolio across areas. As such, to acquire resources and approval for a specific project, the Portfolio Board must be convinced of its potential and endorse its initiation.

MARKET INFORMATION

Lipex® is used as an ingredient in laundry detergents. The customers are thus detergent producers. Detergent patents by Procter & Gamble, Unilever, and Henkel AG include Lipex® as one of their preferred ingredients.

According to the International Association for Soaps, Detergents and Maintenance products, the European laundry care market was worth EUR 13.5 Billion in 2016, a small growth of 0.8 % from 2015. Over the last decade the growth has been more substantial, at almost 30 % (about 2–3 %/year), according to a Novozymes presentation.

The global export market for enzymes and enzyme preparations was around EUR 4.5 Billion in 2016, according to International Trade Centre Statistics. The value has steadily increased over the last decade. In the enzyme market, Novozymes is the largest global producer. It competes with other biotechnology firms, such as DuPont (USA), DSM (Netherlands), and Amano Enzyme (Japan). In addition, it competes with surfactant producers, such as BASF.

The future market potential is highest in emerging markets: in Asia-Pacific and Africa. In the EU and the US, the majority of detergents already use enzymes, including Lipex®. Meanwhile, in emerging markets, less than half of the detergents

do so, according to a Novozymes presentation. Many such markets are experiencing an increase in income per capita, where customers are also increasingly demanding improved performance.

When Lipex® is used in an enzyme solution designed to replace a portion of surfactants, it can be done in a cost-beneficial or cost-neutral way. Weight-wise, a small amount of enzymes can replace a significant proportion of surfactants, according to a research report by Novozymes.

In addition, its price does not fluctuate when oil prices change. Hence, it offers a high stability in detergent production cost and the price to final consumers. Overall, replacing other ingredients with enzymes can lead to economic gains for the detergent producer.

REGULATORY ASPECTS

Lipex® performs well under low temperatures, while it reduces CO₂ emissions and lowers energy consumption. Therefore, a key market segment for Lipex® is detergents that seek to obtain CO₂ emissions or green labelling. Examples of labelling schemes for laundry products include the EU Ecolabel and Nordic Ecolabel.

In general, the regulatory status of enzymes in most countries is set according to product control procedures for chemicals. Enzymes are typically listed in chemical inventories. Examples of such inventories are EINECS in the EU and TSCA in the US. Laws and regulations regarding the use of chemical and biochemical products are different across countries, and this diversity can be a challenge. According to Novozymes, product standards in emerging markets often favour surfactants over enzymes, providing a barrier to growth.

TECHNOLOGY INFORMATION

Lipex® is an enzyme preparation containing a lipase. Lipases are enzymes that catalyse the hydrolysis of fats. The main industrial application of this product is as an ingredient in detergents. It replaces a portion of surfactants⁸ in the detergent composition. The function of Lipex® is to target specifically fat and oil stains in the laundry.

Lipex® is produced using the microorganism *Aspergillus oryzae*. A genetic code for extracting lipase is derived from another microorganism *Thermomyces Lanuginosus*.

Thermomyces Lanuginosus is a compost fungus that is found in spoil tips, senescent grass, leaves, sewage, and peat and bog soils. It produces a number of enzymes, some of which have broad industrial uses. *A. Oryzae* is a domesticated fungus species, used in fermentation required to produce traditional Japanese foods, e.g. soy sauce, sake, miso (fermented bean paste).

⁸ Surfactants are the active compounds in detergents that remove stains.

While *T. Lanuginosus* produces a good lipase enzyme suited for industrial production, it does not ferment well. On the other hand, *A. Oryzae* has excellent fermentation properties. Hence the properties of both are combined in producing Lipex®. In addition to genetic changes to *Aspergillus oryzae* to improve the effectiveness of the enzyme, modifications to the enzyme protein itself have been introduced.

The process of Lipex® production using modified *Aspergillus oryzae* involves two main steps:

- › **Fermentation.** At this step, *A. oryzae* is fermented under laboratory conditions. During fermentation, it produces the required enzyme, triacylglycerol lipase. The enzyme is separated from the *A. oryzae* and purified.
- › **Formulation.** This is the stage where the final product is made, tailored to the specific application and customer requirements (e.g. granulated or liquid form and specific colour).



ENVIRONMENTAL IMPACT

Lipex® is an alternative to petroleum and vegetable oil based surfactants. A small amount of enzymes is used in a detergent, compared to the amount of surfactants it replaces. While production of enzymes requires sugar to feed the microorganisms, the amount of sugar necessary is small compared to raw materials required to produce surfactants.

Compared to surfactants produced from vegetable oil, the use of enzymes is thus likely to result in a lower net land use. In addition, surfactant manufacturing uses chemical processing, while Lipex® production involves a bioprocess. Compared to a chemical process, it reduces the need for toxic catalysts in the production process. It also generates lower amounts of waste and by-products.

Positive environmental impacts are seen at the stage of the use of final product (detergent). Adding enzymes to detergents *improves* washing performance at the same water temperature. Hence, to achieve the same result, a lower temperature suffices. Thus, less energy is needed, resulting in CO₂ savings. Novozymes studies indicate that 150–450 g of CO₂ per wash can be saved for temperature reductions of 10–30 degrees Celsius. However, achieving these results relies on consumers actually using the lower temperature settings.

After the wash, some of the water goes directly to the environment. The detergents entering the water bodies can contribute to water toxicity. Lipex® has been tested for its effects on aquatic organisms. Based on the results, Lipex® is not classified as toxic to the environment. Moreover, enzymes require less water to be “neutralised” compared to surfactants. Hence, replacing a proportion of surfactants with enzymes in a detergent reduces the overall environmental impact of the detergent. Lipex® is classified as readily biodegradable.

THE WAY FORWARD

The company is continuously working on improving the product and keeping up with market demand. The potential for lipase class enzymes is not yet saturated in the detergent market. The main future growth is expected in the emerging markets, where the proportion of detergents that contain enzymes is lowest. Future GDP and population growth in these markets is expected to drive growth. This drives demand for higher-performance detergents that are effective at low temperatures. Increasingly, environmental awareness also plays a role.

To be successful in these new markets, Novozymes will need to overcome some challenges. Washing habits vary in different parts of the world. What works in Europe cannot be directly adapted to other markets. Hence testing the product with different washing methods (e.g. washing by hand) is essential. The product will be tailored as needed to fit these conditions.

Novozymes is confident they will continue to be the market leader of lipases, thanks to their extensive knowledge and many years of experience.

Rilsan® HT and Rilsan® Invent by Arkema

PRODUCT NAME

Rilsan® HT and Rilsan® Invent

PRODUCT DESCRIPTION

Bio-based, high performance polymer

FEEDSTOCK

Castor oil

ORGANISATION

Arkema's High Performance Materials segment, Specialty Polyamides

EMPLOYEES

Circa 19,800 at company level, 1,000 under Specialty Bio-Based Polyamides

COUNTRY

France

R&D START

Early 2000s – Rilsan® HT
Late 2000s – Rilsan® Invent

MARKET ENTRY DATE

2009 (Rilsan® HT); 2011 (Rilsan® Invent)

PRODUCTION CAPACITY

In the range of 10s of thousands t/year of amino acid monomer

PRODUCTION VOLUME

Close to full capacity

SALES (GLOBAL)

EUR 2 billion in 2017 – Advanced Materials (N/A at product level)

INVESTMENT

Planned EUR 300 million for a new production plant

PRICE

~ 50 % higher than metal (Rilsan® HT) but offering a full cost solution up to 50 % cheaper than metal

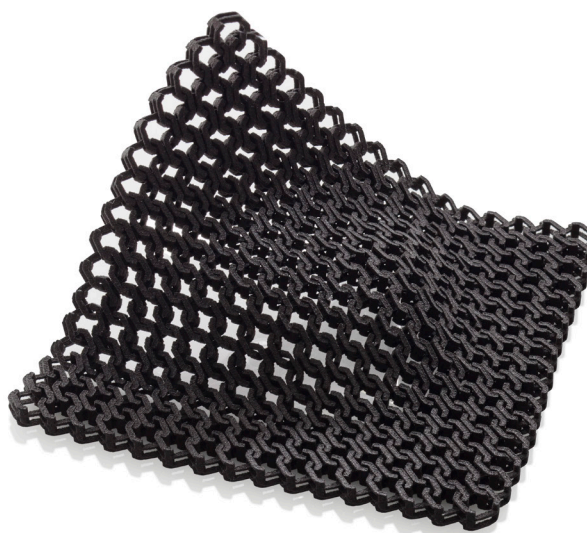
EARNINGS

Break-even expected in 2018

CHARACTERISTICS

- Rilsan® – 100 % bio-based; Rilsan® HT – 70 % bio-based; Rilsan® Invent – 95–98 % bio-based
- Net CO₂ emissions of Rilsan® production 41 % lower than fossil-based polymer
- Patent protected
- Trademarked

Continued innovation to achieve long-term success



PRODUCT

Rilsan® is a 100 % bio-based polyamide (PA-11) produced from castor oil (vegetable oil). It is a high-performance polymer in the family of nylons, used in e.g. the automotive industry, sports equipment, and electrical applications. Specific PA-11 based products have been developed to fit specific applications. This factsheet focuses on two of the most recent sub-products, Rilsan® HT and Rilsan® Invent. The former is a highly flexible and temperature resistant polymer used in automotive applications and the latter has been developed for use in 3D printing.

SUCCESS

Rilsan® products have stayed on the market for many years, due to continuous investments in R&D and continuous development of new variants and applications. In the early 2000s, Arkema realized they could modify Rilsan® to compete with rubber and steel parts in the automotive industry. Rilsan® HT was launched in 2009, initially targeting high-end brands. A major achievement came in 2012–2013, when large vehicle manufacturers started to use Rilsan® HT. Continuing their R&D focus, and seeing growth potential, Arkema developed a product line for 3D printing, Rilsan® Invent. Initial uses of PA-11 fine powders in 3D printing began in the 1990s. To achieve properties more suited to the market, the powders were dramatically improved in the 2000s. Rilsan® Invent was launched in 2011. The new product is an improved Rilsan® Fine Powder fully dedicated to 3D printing. A milestone was achieved in 2017, when Rilsan® Invent was included in the HP Open Platform. This is a collaborative platform where customers, 3D printer manufacturer HP and raw material providers work together to address specific industry needs.

PROSPECTS

The prospects for Rilsan® products are **positive**. The higher price when compared to metal is offset by lower costs when Rilsan® HT is formed into car parts. This represents an overall cost reduction to customers, and is illustrated in its increasing uptake by smaller manufacturers. In this respect, Arkema expects an annual 30 % increase in demand for Rilsan® HT in the coming years. The 3D printing market is expected to increase by 20 %/year until 2020. Rilsan® Invent is expected to grow faster due to its bio-sourced nature and documented high performance. To meet these demands, investments of EUR 300 million have been earmarked for building a new production plant to increase the capacity by 50 %.

HISTORY

The original PA-11 polymer based on castor oil was first patented in 1947. The industrial plant started production in France in 1949, the same year the product gained the brand name Rilsan®. The Marseille monomer plant was built in 1955. Originally competing with nylon in textile applications, it was eventually outcompeted by polyesters and other polyamides which could be produced on a larger scale. However, the development of bio-plastics applications started early, mitigating the effect of this downturn.

The subsequent history was marked by innovation and expansion to different markets and applications. For example, Rilsan® brand products are found in the automotive industry, sporting equipment, healthcare, and electronics. In practice, the various Rilsan® brand products are based on the bio-based polymer PA-11, but modified to obtain desired properties for different applications.

The ownership of the brand changed numerous times over the years, but Rilsan® division, which gradually became a wider specialty polyamides line, maintained its autonomy. It has been under the current structure in Arkema since 2004.

Rilsan® HT and Rilsan® Invent result from Arkema's continual R&D. To remain competitive, Arkema maintains its R&D spending at 2 %–8 % of sales. This is used to develop novel products and applications. In the early 2000s, they realised Rilsan® could be modified to withstand high temperatures. This would allow it to compete with metal as a raw material for car parts near the engine. The result of this research was Rilsan® HT (High Temperature). Rilsan® HT was launched in 2009. As it was **50 % more expensive** per kilogram than the metal alternative, this presented a potential initial barrier. Initially,

Drivers of success

- » Working with customers to develop products to meet desired specifications
- » Able to reduce overall costs to customer in using the product despite higher product sales price than competition
- » Hedging risk through multiple products and sales markets
- » Creating partnerships with suppliers and customers
- » A strong focus on R&D
- » Vehicle emission regulations create preference for lighter vehicle parts thus increasing demand
- » As a large company with long track record, it relies on internal finance, product development experience, network, supply chain management, and market access

it was marketed to and used by high-end vehicle manufacturers. To broaden the market reach, the company focused on improving and illustrating Rilsan® HT's performance. They also demonstrated that the overall costs of using this material are lower than using metal. Since 2012–2013, a number of large European vehicle manufacturers have started using the product. Currently, US and Asian markets are starting to follow this example.

Seeing potential in the 3D Printing market, in the late 2000s, the company accelerated the development of a version of Rilsan® Fine Powders specifically for 3D Printing. The product resulting from this research, Rilsan® Invent, was launched in 2011. Making the product market-relevant and to enhance the reach potential, Arkema formed a partnership with HP in 2017.

In terms of sales of both Rilsan® HT and Rilsan® Invent, the company targets markets globally: Europe, North America, and Asia. This global strategy is used by the company more generally. The company finds that this helps mitigate the risks posed by **fluctuations in oil prices** and changes in demand that occur due to **changing regulations**.

SWOT ANALYSIS FOR RILSAN® HT

S

STRENGTHS

- Long R&D tradition
- Documented higher performance than competing products
- Global presence, hedging risks in different markets
- Lower cost of processing material into parts

W

WEAKNESSES

- Higher costs compared to fossil fuel alternatives
- Sustainability is not the main customer priority

O

OPPORTUNITIES

- Favourable policy agenda (e.g. emissions reduction, LCA requirements)
- Interest from large customers

T

THREATS

- Strong competitor pricing
- Oil or feedstock price fluctuations
- Changes in national regulations

 **FUNDING**

The development and commercialisation of the products has been funded internally. The company has applied profits from existing sales to finance further R&D and commercialisation efforts related to the new Rilsan® based product applications.

Bio-based materials are a strategic area for the Arkema Group. Arkema dedicates around 75 % of the overall R&D budget to sustainable development, including bio-plastics. This budget is used to continue investing in the development of new bio-based and hybrid applications. Rilsan® HT as well as the new Rilsan® Invent are examples of forward-looking investments.

In general, Arkema is involved in many European and national collaborative R&D projects with bio-based contents. This includes projects under H2020 and FP7 funding mechanisms. This covers different projects in three main areas: 1) development of biotechnology for reusing CO₂ in chemicals and plastics 2) development of crops suitable for industrial processes, and 3) conversion of waste into chemicals and biorefinery.

 **MARKET INFORMATION**

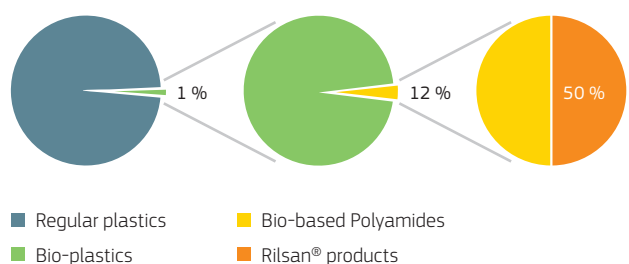
The price of Rilsan® HT is higher than competing products by about 50 %. For customers to produce tubing from metal or alternative materials, the process involves two additional main cost elements: processing and assembly. Assembly costs are roughly the same regardless of the material. However, processing Rilsan® HT incurs significantly lower costs than processing metal. As a whole, according to the company, the total costs to the customer of producing parts using Rilsan® HT are therefore reduced by about 50 % compared to traditional inputs.

No special equipment is required to process Rilsan®HT – regular equipment used for other types of PA materials can be employed. Hence, while the actual **price differential** is not reduced, overall costs to clients of using Rilsan®HT are lower.

In general, bioplastic production constitutes around 1 % of overall plastic production, of which polyamides (PA) constitute nearly 12 %. Rilsan® family constitutes more than 50 % of the bio-based PA.



INDICATIVE MARKET SIZE OF RILSAN® PRODUCTS



Source: European Bioplastics Association and company estimates



The global market for bio-based polyamides is experiencing a growth rate of about 15 % per year. Arkema itself is planning to increase PA-11 production by 50 %, supported by new investment in capacity. This will involve building a new production facility in Asia, for which EUR 300 million have been allocated.

In the automotive market, Arkema expects to increase Rilsan® HT production by 30 %/year, since the market is still growing and not saturated. This trend will be supported by a number of OEM manufacturers following the example of the large vehicle manufacturers, who have started using the product. Regulation in terms of vehicle emission standards is an important driver for Rilsan® HT.

3D printing is an innovative area, which is likely to grow as the technology becomes more mainstream. Growth factors include a variety of possible applications: attractiveness due to reduced development time and costs; design freedom allowing complex and custom parts to be produced; and decentralised manufacturing.

The 3D printing market has grown by 30 % annually for the past 4 years and is expected to grow further by 20 % per year until 2020.

 **REGULATORY ASPECTS**

Regulations that stimulate the demand for Rilsan® HT include those related to transport emissions and requirements related to LCA.

In terms of **transport emissions**, regulations influence demand positively by requiring car manufacturers to reduce their CO₂ footprint. They seek alternative materials and other ways to decrease overall fuel consumption of vehicles. Since Rilsan® HT is lighter than alternatives, it can help fulfill these aims. Such regulations are well developed in the EU, namely: emission reduction targets for new vehicles (EU Regulation (EC) 443/2009) and complemented with CO₂ labelling of cars (“Car labelling” Directive 1999/94/EC). A new proposal for post-2020 targets for emission reductions was presented in November 2017. Emission standards exist in some US states and are expected in China.

Possible requirements for performing **life-cycle assessments** (LCA), such as green or eco-labelling, have the potential to improve the market position of Rilsan® family products. In the presence of such requirements, the industry is inclined to purchase products that enhance their final product’s LCA. In this respect, Rilsan® HT and Rilsan® Invent offer added-value to the automotive and spare parts (3D printing) industry. EU regulations that have such elements include: End of Life of Vehicles Directive (2000/53/EC), Waste Framework Directive (WFD, 2008/98/EC), and EU Ecolabel (Regulation no 66/2010).



TECHNOLOGY INFORMATION

Rilsan® is a 100 % bio-based polyamide (PA) produced from castor oil. It is a bio-plastic in the family of nylons⁹, dubbed PA-11.

It is derived from castor oil, via a multi-step chemical transformation process. Two types of plants are required to produce PA-11. The first type is a monomer plant, which transforms castor oil into an amino acid.¹⁰ The process also results in several co-products that are used in cosmetics and lubricants industries. The second type plant is a polymerisation plant, which converts the amino acid monomer into the polymer (a long chain of repeated molecules). The result is Rilsan®. Manufacturing of the specific products (e.g. Rilsan® HT and Rilsan® Invent) involves combining the bio-based amino acid with other monomers. This brings new properties like high temperature resistance, as is the case for Rilsan® HT. For Rilsan® Invent, the bio-based amino acid monomer is polymerised using a process specifically designed for 3D printing requirements. Both Rilsan® HT and Rilsan® Invent are at **Technology Readiness Level (TRL) 9** (actual system proven in operational environment).

Arkema is the only producer of this type of polymer (PA-11) in the world.



ENVIRONMENTAL IMPACT

Rilsan® originates from **100 % bio-based feedstock**, castor oil. The geographical origin is predominantly India. Feedstock for producing PA-11 and its associated products is derived from the castor oil plant, which is grown in tropical areas. To secure a steady and reliable supply, in 2013, Arkema partnered with a castor oil producer in India. This supplier delivers most of the feedstock required. The castor oil plants can grow on marginal lands, in water scarce conditions.

Arkema has a CSR strategy in place, which includes expectations towards suppliers. The code of conduct for suppliers includes items regarding human rights and labour standards, environment, business ethics and transparency, and suppliers may be audited to assess compliance.

An eco-profile assessment of Rilsan® conducted by Arkema shows that the total gross energy required to produce 1 kg of PA-11 is 162 MJ/kg. This is 22 % lower than comparable petroleum-based plastic PA-12. Net CO₂ emissions of production are 41 % lower than PA-12. This improvement is lower for Rilsan® based products that contain less than 100 % bio-based polymer. Rilsan® HT contains 70 % PA-11 and Rilsan® Invent powders contain 95–98 % PA-11.

Further impacts across the life-cycle depend on the application. For example, Rilsan® HT, which is used to manufacture automotive parts, is lighter than substitute materials, hence reducing fuel consumption and emissions. Overall, it is estimated that 30–40 % less CO₂ is generated over the life-cycle of (pure) PA-11 compared to PA-12.

THE WAY FORWARD

The outlook for the Rilsan® product line is positive as sales volumes are expected to continue to increase. The main drivers behind this development are sustainability commitments among customers and emission regulations. More vehicle manufacturers are expected to switch to Rilsan® HT, as it contributes to fuel efficiency by reducing overall vehicle weight. Arkema expects growth rates of 30 %/year in the automotive sector, as more manufacturers are expected to follow the example of large ones already using Rilsan® HT.

The 3D printing market is experiencing rapid growth, and regulations that support bio-based materials may help spur demand for bio-plastics. Rilsan® Invent has demonstrated better impact resistance than competitors, which is one of the main characteristics motivating customers, e.g. in aeronautics. Due to this and its bio-based nature, Rilsan® Invent is expected to grow faster than the market average of 20 %/year.

Overall demand for PA-11 is already becoming higher than the production capacities currently available. To keep up with the trend, Arkema is planning to build new monomer and polymer production facilities. To this end, Arkema has earmarked **funds in the range of EUR 300 Million**.

⁹ Its chemical formula contains 11 carbon atoms, hence dubbed PA-11, or nylon 11. Rilsan® is the brand name of PA-11

¹⁰ 11-Aminoundecanoic acid is obtained from castor oil via: transesterification, pyrolysis, hydrolysis, hydrobromination, and amination

Wheat bran disposable tableware by Biotrem

PRODUCT NAME

Wheat bran disposable tableware

PRODUCT DESCRIPTION

Tableware such as plates and bowls made from wheat bran

FEEDSTOCK

Wheat bran, i.e. the hard outer layer of the grain

ORGANISATION

Biotrem

EMPLOYEES

15 full time direct employees (2017)

COUNTRY

Poland

R&D START

1990s in relation to the production process

MARKET ENTRY DATE

2015 (EU)

PRODUCTION CAPACITY

15 million pieces /year (EU)

PRODUCTION VOLUME

10 million pieces /year (EU)

SALES (GLOBAL)

Not disclosed

INVESTMENT

EUR 3.25 million for the project to establish the production plant; EUR 1.75 million for R&D

PRICE

Circa EUR 0.25/piece (wholesale packaging); EUR 0.4/ piece (retail packaging), or about 5 times the price of plastic plates

EARNINGS

Not disclosed

CHARACTERISTICS

- 100 % bio-based
- Biodegradable in 30 days (certified by DIN Certo)
- Production process certified at food production safety level by BRC
- Patent protected technology
- Trademarked (global)

An alternative to disposable plastic and paper tableware



PRODUCT

Biotrem offers a range of fully bio-based and biodegradable disposable tableware, including plates, bowls, and cups, produced from compressed wheat bran. Bran is the hard outer layer of the grain and is a by-product in the production of refined grains. Biotrem products are used by restaurants, event organisers, catering companies and private consumers for serving hot and cold meals and offer an alternative to disposable tableware made from paper or plastic.

SUCCESS

The manufacturer was founded in 2012 and has successfully attracted sufficient private and public (EU and national) funds for R&D, testing, and establishing a commercial production facility of wheat bran tableware in a rural area of north east Poland. The products have been **commercially available since 2016** and are currently sold in 40 countries. Biotrem's business model incorporates the core principles of circular economy: It supports an agri-food system designed to prevent losses and waste and to recover raw materials.

PROSPECTS

The prospects for Biotrem tableware are positive. Global demand for disposable tableware products has grown in recent years. At the same time, many consumers have become more focused on sustainability aspects. The company has been expanding their network of distributors and engaging in efforts to support their expansion on promising international markets. The price difference compared to traditional products is expected to decrease via improvements in the production process and economies of scale. The patented production technology allows for feedstock flexibility. The company is investigating the possibility of using alternative feedstocks, e.g. algae, cassava and other agri-food industry by-products.

HISTORY

The wheat bran tableware production process was invented in the 1990s by a professional miller. He saw the potential in the higher value utilisation of wheat bran. Biotrem was founded in 2012 to capitalise on this invention. Research through to prototype development (TRL 1–6) was performed by the inventor prior to the founding of Biotrem. Further product and process development leading up to the establishment of the commercial production plant in 2015 (TRL 7–9) was carried out under the new company, Biotrem.

With the founding of the company, the inventor formally took up the responsibility for R&D and technology development. Additional critical roles were assigned to a newly hired senior management. These include a CEO responsible for management, strategy and investment processes, and a Commercial Director responsible for sales and for building the network of company representatives worldwide.

To launch the commercial-scale production, investments in R&D and in a production plant were required. The company actively sought public and private financing. Public funds have been used for the establishment of the production plant and for R&D and branding. Biotrem also worked in other ways to improve their financial resources. For example, they have devised cooperation agreements with business partners, in which cost-sharing schemes are set-up. Currently, Biotrem is looking into new ways to approach funding. They are planning to launch a crowd funding campaign and are considering to become a publicly traded company.

Biotrem tableware has been commercially available since 2016. Until now, demand has been lower than expected. One reason for this is the different properties of the products compared to “traditional” disposable tableware made from paper or plastic.

Drivers of success

- » Commitment of the inventor and his knowledge of feedstock and his network in the milling industry
- » Ability to establish a good management team to move the product from research to commercialisation
- » Availability of and capacity to attract public funds
- » Hedging risk through multiple sales lines in terms of geographical outreach, as well as branding efforts
- » Customer trends towards sustainable practices
- » Availability of feedstock and proximity of the production plant to flour mills supplying wheat bran

To address this, the company has dedicated resources to influencing consumer perceptions and has engaged in certification efforts. The consumer perceptions are targeted by involving video bloggers who act as ambassadors, and by engaging people at events and schools. Safety concerns have been addressed by conducting tests and consequently obtaining certifications. The company also takes part in various competitions. It is expected that such participation increases visibility and if awards are won, this will positively influence customer perceptions.

Price competitiveness has also been a challenge: Biotrem is more expensive than “traditional” products. Further efforts are required to reduce costs through economies of scale. To that end, the company is extending its sales channels and distribution networks. In particular, they focus on expanding their presence in the most promising international markets, where sustainability concerns play a significant role in consumer choices. These efforts are expected to be accompanied by increased production capacities and volumes, through building local production facilities in other parts of the world.

The company is aware that using wheat bran as feedstock could be a limiting factor today in some markets and possibly even more of a challenge in the future, largely due to consumer

SWOT ANALYSIS FOR BIOTREM TABLEWARE

S

STRENGTHS

- Founder’s readiness to provide in-kind contribution in the early phases
- Patents and technology flexibility regarding feedstock
- Access to low-cost feedstock (wheat bran, corn bran, cassava by-products, seaweeds)
- Wide spectrum of management skills in company

W

WEAKNESSES

- Product is very different from the “traditional” products it competes with
- No certification that demonstrates better environmental performance than “traditional” products
- High production cost and price

O

OPPORTUNITIES

- Market preferences – mainstreaming of sustainability demands (SDG)
- Favourable policy agenda in relation to waste and food loss reduction

T

THREATS

- A market with an increasing number of ‘sustainable’ and/or bio-based choices for consumers
- Sustainability/acceptability of feedstock may be questioned in the future

trends towards gluten-free products. Therefore the company has started R&D on alternative feedstocks. Biotrem technology is flexible, and can be adapted to use other types of feedstock. Examples being tested include algae and cassava by-products.

FUNDING

In the period prior to the founding of Biotrem, R&D activities were sustained by the inventor's in-kind contribution and his family's milling company.

When the company was founded, the current CEO and her business partners brought in some capital for R&D and the machinery. They also brought in the expertise and capability to successfully attract available public funds. Along the different stages of commercialisation, the company has relied on EU and national public funding. This includes using Horizon 2020, and European Structural and Investment Funds (ESIF) to reach the current level of business and technology advancement. An ESIF-funded project under the Polish Operational Programme for Innovative Economy has been instrumental in providing finance for the building of Biotrem's production plant. The project value was EUR 3.25 million with EUR 1.35 million in EU contribution from the European Regional Development Fund (ERDF). Other sources of funding have included private funds, bank loans, EU and national funds specifically earmarked for SMEs. This includes EU support for a feasibility study on how to successfully commercialise the technology (through the Horizon 2020 SME instrument), and branding support to assist in taking the product to relevant markets (through the Go To Brand Project co-financed by the ERDF).

Biotrem is also taking part in an ongoing ESIF project to improve the production process. The goal of the project is to achieve a more aesthetically appealing product, and reduce energy consumption. This is a EUR 3.3 million project under Poland's Smart Growth Operational Programme. EU contribution constitutes EUR 1.8 million.

Overall, the company estimates to have spent over EUR 5 Million on R&D to date, including EUR 3.25 million that were put into building the production plant.

MARKET INFORMATION

The main types of disposable tableware traded globally are plastic and paper tableware products. The global export market of such products has grown in the last few years to about EUR 22 billion in 2016. At the same time, growing environmental awareness among businesses and consumers as well as legislation creates a market niche for alternatives. To take advantage of this development, more companies offer products made from alternative materials such as sugar cane, bio-based polymers, bamboo, or banana leaves.

Currently, Biotrem products compete directly with other bio-based disposable tableware, at a comparable price level. Competing with plastic or paper products in terms of price is

not yet possible. A pack of 10 Biotrem plates (24 cm) can be purchased online for around EUR 4. While being comparable to the price of other bio-based disposable products, up to 50 regular white plastic plates can be purchased at the same price. Considering this price differential, the market opportunities for Biotrem tableware in the immediate future lie with 'green' consumers that are less driven by price considerations, i.e. are willing to pay a 'green premium'.

To capture 'green' consumers from across the world, the company is pursuing growth by expanding their presence internationally. Currently Biotrem sells its products in 40 countries. Its clients are restaurants, caterers, bars, organisers of large events (e.g festivals), and wholesalers. With a future expansion of distribution channels and sales networks, supported by intense marketing efforts, the company expects that the business-to-business customers will be supplemented by an increasing number of end consumers.

Biotrem production capacity is currently at **15 million pieces** of disposable plates or bowls a year. Currently, production is based on orders received and sales have been modest so far. However, Biotrem tableware has the potential to reach its maximum annual production volume in the medium to long-term. The company expects to achieve this by 2018–19, due to positive changes in demand driven by attitude shift and regulation and supported by their targeted marketing efforts. Therefore, the company is currently discussing with a number of potential partners regarding further large-scale commercialisation, including building new production facilities. Achieving this would provide for economies of scale thus improving its competitiveness on the market.

REGULATORY ASPECTS

Legislation that provides favourable conditions for Biotrem includes waste-related legislation and initiatives aimed at reducing food losses along production chains. Initiatives in terms of waste legislation play a role in influencing demand. For example, a possible ban of disposable products made from plastic at a national or municipal level could mean that customers need to seek alternative types of tableware. Specific initiatives on the table include EU Strategy for Plastics, the proposed EU Directive on Packaging Waste, and programmes on plastics in national and regional waste management plans in specific countries. According to Biotrem, the French ban on plastic disposables (from 2020) and a ban on plastic in New Delhi have generated large interest in Biotrem products in these markets.

Initiatives to reduce food losses could play a role in encouraging investment in Biotrem technology. Relevant initiatives in this area stem from UN Sustainable Development Goal (SDG) 12.3 'to [...] reduce food losses along the food production and supply chains'. Initiatives in this area promote the valorisation of agricultural raw materials and emphasise the need for reduction of food losses from the food processing sector. Wheat bran is one such by-product, where development of high-added value applications can contribute to this goal.



TECHNOLOGY INFORMATION

Biotrem tableware has been commercially available since 2016 and is sold in 40 countries. The **Technology Readiness Level (TRL) is considered to be TRL 9** (actual system proven in operational environment), although actual sales volumes are still assessed to be modest. Biotrem tableware is made solely from wheat bran and water. The bran is pressed and baked in a single production cycle. The shaping is achieved through the application of heat and high pressure. A small amount of water is added, depending on the moisture content of the raw bran.

The products are designed and certified for short-term contact with warm or cold, processed, or unprocessed food. They can be safely used in ovens or microwave ovens. In addition, the manufacturing process is fully automated and designed to comply with food safety standards, minimising human contact with the product. The process has been certified at a food production safety level, and thus complies with strict standards that typically apply to food production.

Biotrem is protected by a number of international patents with respect to both the production method and materials. This allows for the possibility to include licencing to third parties as a business model in the future.



ENVIRONMENTAL IMPACT

Biotrem tableware products are derived from **100 % bio-based feedstock**, namely wheat bran. The tableware production plant is supplied by wheat bran from local mills in the North-Eastern Polish region of Podlasie.

Wheat bran is the hard outer layer of the grain. It is part of the whole grain, and a by-product of milling in the production of refined grains. The majority of bran is used as animal feed and a smaller fraction as a source of dietary fiber by the food industry. According to Biotrem, the bran that is used would otherwise be unutilised or under-utilised. As such, the use of bran to produce tableware represents a value added component of this raw material.

The production process requires only bran and water. No further ingredients are used. The process of shaping Biotrem tableware involves using high temperature and high pressure.

Biotrem products are an alternative to most disposable tableware, such as that made from plastic or paper. After being used, the products can be composted. The products are **fully biodegradable**: it takes 30 days for them to decompose through composting. Biotrem is certified by DIN Certco, under a certification scheme for products made of compostable materials.

According to company estimates, 1 kilogram of wheat bran plates or bowls generates around 1.3 kg of CO₂e, considering the whole wheat cultivation process, transportation, processing, and utilisation. This compares to about 8.5 kg of CO₂ generated for the production of 1 kg of polystyrene disposable plates or cups. While a single polystyrene plate is much lighter than a wheat bran plate, 11 polystyrene plates are needed to provide the same rigidity and heat insulation properties as a single wheat bran plate.

THE WAY FORWARD

Overall, it took only three years after the company was founded to achieve commercial production, thanks to the availability of public funds and the company's in-depth knowledge of the feedstock supplying industry as well as the preceding R&D that it built on. Continuing with this trend of rapid development, the outlook for Biotrem tableware is positive, both in terms of sales volumes and profitability. However, the product is challenged by its marked difference compared to traditional disposable tableware, and by its higher price. The company is taking efforts to overcome these challenges: improving the production process and promoting active customer engagement. Trends that present opportunities for Biotrem's growth include consumer and business sustainability commitments and policy initiatives to establish a circular, low-waste economy. These are likely to continue to be key drivers influencing future sales of Biotrem.

Optimisation of the production process and investment in additional production facilities are expected to provide the necessary economies of scale and narrow the price differential compared to traditional products. Nevertheless, price competitiveness with paper or plastic is not expected within the short-to-medium term. However, economies of scale will improve its standing among competing bio-based products. On the demand side, rising environmental consciousness among consumers and businesses is increasingly spurring Biotrem's customer base such as event organisers and caterers to choose sustainable tableware. The company is likely to reach the maximum annual production capacity of the current facility in the next two years.

The company is currently investigating into alternative types of feedstocks, e.g. algae, cassava or other agri-food industry by-products. The feedstock choice will depend on the availability at the market where investments in new production facilities will be realised (e.g. cassava by-products in South America). At the same time, feedstock flexibility will allow addressing consumer trends towards gluten-free products.

PRODUCT NAME

Curran®

PRODUCT DESCRIPTION

Microfibrilated Cellulose

FEEDSTOCK

Beet pulp (by-product of sugar processing)

ORGANISATION

CelluComp Ltd.

EMPLOYEES

17 employees (2018)

COUNTRY

The United Kingdom (Scotland)

R&D START

2005

MARKET ENTRY DATE

2014

PRODUCTION CAPACITY

Small-scale plant (current):

400–500 tonnes/year (EU)

Future commercial plant (2021):

10.000 tonnes/year (EU)

PRODUCTION VOLUME

Varies depending on commercial demand

SALES (GLOBAL)

Expected to increase after completion of the commercial plant

INVESTMENT

EUR 22.6 million CAPEX for commercial scale plant plus working capital

PRICE

Currently sold in units of 15 kg,
3–4 EUR/kg

EARNINGS

Break-even expected once the commercial plant is built and operating to scale

CHARACTERISTICS

- 100 % bio-based
- Low carbon footprint due to efficient process
- Non-toxic
- Low dust
- Zero volatile organic compounds (VOC)
- Patent protected

A sustainable alternative for water-based formulations and composites



PRODUCT

Curran® is a microfibrilated cellulose material (sometimes referred to as nanocellulose) produced from sugar beet pulp derived from waste streams of the food processing industry. Curran® fibres have both **mechanical and rheological¹⁴ properties** and have **numerous applications** as additive to for example paints and coatings, concrete, cosmetics, drilling fluids, home care products, food. Curran® fibres' high-performance allows the production of composites with performance characteristics comparable to those based on conventional fibre technology. Curran® is **100 % bio-based**, and is commercialised in two forms: as a paste/slurry or as a powder.

SUCCESS

CelluComp has developed a **price-competitive green alternative to carbon composites**. The product entered the EU market in 2014, approximately 9 years after initial research. The company has so far successfully managed to overcome the innovation 'valley of death' and bridge the gap from research to the market, by securing **consecutive rounds of private capital investments** from business angels and venture capital, as well as national public funding. CelluComp also benefited from EU funding under the Entrepreneurship and Innovation Programme and under FP7. Currently, the Curran® plant in Scotland (UK) is the **first plant of its kind** in Europe and the company is expected to turn profitable once the commercial size plant will be built (expected in 2021).

PROSPECTS

The prospects for Curran® are positive. The commercial potential of the product is high as a result of its properties, as well as the price difference compared to competing incumbent alternatives. The selling price of Curran® compared to competing alternatives would be within a ratio between 0.5 and 1 once the commercial scale plant is functional, meaning a lower price for Curran®. Given the various applications of Curran®, the product has strong potential for expansion and growth on new market segments, other than the paints and coatings additives market segment, as well as in other geographical markets (e.g. North America, Asia). In driving the expansion to new markets, CelluComp is focussing on signing new agreements with large companies that produce cosmetics, food, composite materials and paper with a strong position in their respective sectors of activity.

¹⁴ Rheological properties: related to the flow of the material.

HISTORY

CelluComp was founded in 2004 with the aim of producing **green alternatives to carbon composites**, initially targeting the sports goods market. Today, the company focusses on producing a bio-based additive - Curran® - that can be used as an economically viable solution to rheology and reinforcement in many different industries, such as paints, coatings, concrete, personal care products and food.

Curran® was developed in 2005 by two material scientists (Dr. Hepworth and Dr. Whale), founders of CelluComp, and was first introduced through two composite products: (a) a fishing rod (The Reactor™), which blended the unique properties of Curran® and carbon fibre and won the 'best rod in show' award in Las Vegas, and (b) a high end skateboard, which used Curran® in sheet form. CelluComp sold the fishing rod business in 2008, due to the financial crisis, and developed a new business strategy focussed primarily on the development of Curran®. The business strategy was further developed in subsequent years by the new CEO who concentrated on strategic business development through the set-up of partnerships and focus on scaling-up production and sales.

The development and commercialisation of Curran® was financed primarily from the internal resources of the founders of CelluComp as well as through several rounds of private investor's funds, in particular angel investors. The efforts of the founders of CelluComp, as well as the CEO, in attracting private financing have been instrumental in the development of the product. CelluComp has also benefitted from substantial public sector funding (EU and national). Overall, as of 2005, CelluComp raised in excess of EUR 9 million to finance its activities.

SWOT ANALYSIS FOR CURRAN®

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STRENGTHS

- Ability to attract private financing for R&D and commercialisation
- CelluComp CEO capability and engagement and ability to attract private finance
- Patents
- High market potential and strong potential in multiple industries
- Access to and flexibility of low-cost feedstock

W

WEAKNESSES

- Target markets are conservative and adoption is long and time-consuming
- Challenges in scaling up due to high initial investments
- Piloting and testing a novel product is time-consuming and costly
- Steady supply of seasonal feedstock required, which may increase storage costs

O

OPPORTUNITIES

- Market preferences – mainstreaming of sustainability demands (SDG)
- EU funding opportunities in order to raise finance
- In line with circular economy developments

T

THREATS

- High regulatory costs for testing and licensing
- Investors demand a track record and solid projections
- The bio-based feature may not be sufficient to justify the 'high price' but once scaled up the costs will be reduced
- Potential other competitors will emerge

Drivers of success

- » CelluComp's capacity to effectively mobilise internal and external funding gradually and to utilise the financial support for R&D and commercialisation
- » High commercial potential owing to the properties of the material
- » Price competitiveness in comparison to traditional competing materials and other bio-based products
- » Sustainable and price-competitive feedstock and feedstock flexibility
- » Low capital investments required at the outset compared to other bio-based products (estimated around EUR 22.6 million)
- » Capacity and engagement of the CelluComp team and investors

Currently, CelluComp has a total of 17 employees. Curran® is produced at the CelluComp demonstration plant in the United Kingdom (Glenrothes, Scotland), which has a maximum production capacity between 400–500 tonnes/year. This is **the first plant of its kind in Europe**. As of 2017, the product was being sold at a loss due to the small scale of the production and associated high unit costs. The company plans to build a commercial size factory which will enable CelluComp to produce 10,000 tonnes/year of Curran® and, as a result of economies of scale, also increase its profit.

The company successfully overcame initial risks and barriers, including risks related to the novelty of the technology, competitive barriers to the market, the initial choice of composite materials as target market, high investment requirements and (so far) low profitability. The company is **expected to turn profitable once the commercial size factory is constructed and in operation** (expected in 2021).

FUNDING

The R&D and commercialisation of Curran® was financed primarily by **leveraging private capital**, mostly from **angel investors** and **venture capital**, as well as by securing public grants from national investors.

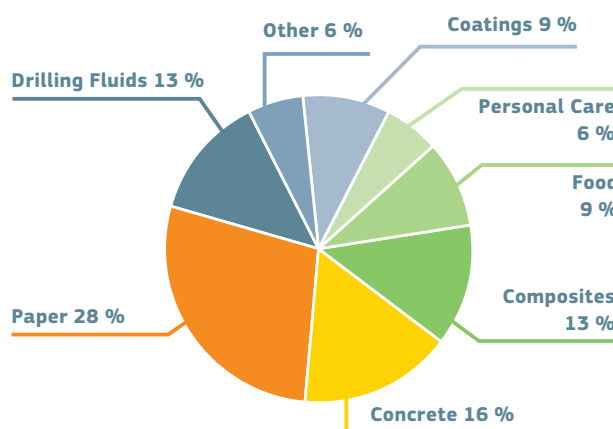
Through a targeted business strategy that included focus on piloting and prospecting new markets, CelluComp addressed the risks in a way that raised investor's confidence. CelluComp's CEO business strategy to attract new investors was also instrumental to the company's success in securing financing. As such, CelluComp managed to secure multiple rounds of financing (once every two years) including from the Scottish Seed Fund (2006), Discovery Investment Fund, Abundant Venture Partners, Claridge (2012, EUR 1.1 million), Soffinova Partners – Green Seed Fund (2013, EUR 2.7 million), FPCI CapAgro Innovation (2016, EUR 4.1 million).

Apart from this, CelluComp received substantial **public national and EU funding** in particular from the Scottish Enterprise Group that promotes start-ups active in Scotland. CelluComp also benefitted from an **EU grant**, of EUR 1 million starting in 2013 and covering a period of 3 years. The grant was financed under the EU's Entrepreneurship and Innovation Programme and supported both the manufacturing and the commercialisation of the Curran® product. Further, CelluComp secured EU funding under FP7. The grant was used for a project (NanoCelluComp) that focussed on the development of a technology to utilise the high mechanical performance of cellulose nanofibres, which relied on the technological know-how from the production of Curran®. The value of all received public sector grants amounts to approximately EUR 2 million. CelluComp secured only **limited bank financing** due to bank risk aversion.

MARKET INFORMATION

In recent years, the production of Curran® amounted to a good percentage of the annual production of nanocellulose fibres. Although Curran® has virtually no existing share of the large total additive market for coatings (both fossil fuel and bio-based), its potential is significant. Estimates indicate that the production of Curran® on a commercial scale would be price-competitive against other producers of micro-fibrillated cellulose. The selling price of Curran® compared to competing alternatives would be within a ratio between 0.5 and 1 once commercial scale plant is functional, meaning a lower or similar price for Curran® compared to current competing alternatives. Curran® can be used for various applications as a result of its mechanical and rheological properties, which means that it has access to a wide range of relevant product markets. Currently, the main market targeted by Curran® is the **paint and coating additives** market. This is estimated to amount to EUR 2.2 billion globally.

..... CURRAN® MARKET POTENTIAL



Source: Estimates CelluComp
.....

According to estimates provided by CelluComp, the **future potential market** for Curran® worldwide is high. It is estimated to amount to **EUR 32 billion**, covering the markets for paints and coatings, paper, food, cosmetics, home care, composite materials.

REGULATORY ASPECTS

The evolution of European and national **regulatory framework indirectly supports the development and commercialisation of Curran®** as a result of more rigorous requirements for products concerning sustainability and health protection. Curran® is mainly affected by the general regulatory framework on health and safety aspects and there are no sector-specific regulations that have an impact on the product development (e.g. the product is not noxious for health or the environment).

TECHNOLOGY INFORMATION

Curran® is currently **produced from renewable feedstock, sugar beet pulp and carrot fibres**. The feedstock used for Curran® originates from different locations in Europe. For the production of 1 kg of Curran®, approximately 1 kg of dry sugar beet pulp is required. Other possible feedstocks for the product in the future include starch (from potato waste).

Curran® is produced through green chemistry processes including water-based reactions at low temperatures and pressures, which maximise the energy efficiency of the manufacturing process.

The primary state of Curran® is in **granules form** with approximately 20 % solid matter and 80 % water. Dilution to approximately 2 % solid matter generated a pumpable **Curran® slurry**. The granules and the slurry can be readily mixed into water based coating formulations, resins, cosmetics

and other aqueous liquids. The granules are used in paints and coatings as they are convenient to transport, store and disperse into aqueous systems using conventional industry mixing equipment.

The **Technological Readiness Level (TRL) is 8–9** (i.e. 8 – system completed and qualified, 9 – actual system proven in operational environment). Curran® is protected by **10 patents** covering the product, the process and some of the applications. Some of the patents held by CelluComp for Curran® are co-owned. The company also has **one license agreement** in place.



ENVIRONMENTAL IMPACT

Feedstock sustainability: Curran® is produced 100 % from renewable feedstock. Currently, the main feedstock is sugar beet pulp from waste streams, a by-product of sugar processing commonly used for animal feeds. The business model to produce Curran® extracts value from a relatively under-used

biological resource, increasing its economic value by an estimated factor of 50. The production of Curran® involves the extraction of nano-fibres and leaves behind the carbohydrates and proteins. As such, the residues from the extraction of Curran® can be further used in the production of high-value materials, such as energy or as animal feed.

Energy efficient and green chemistry production process:

The production process of Curran® has a low carbon footprint as it involves water-based reactions at low temperatures and pressures. As a result, the production of Curran® has lower unit energy consumption than other paint thickeners which reduces its environmental impact. Additionally, when substituting other cellulose ethers, Curran® has environmental advantages as it uses up to 5 less chemicals during manufacturing compared to cellulose ethers and has improved performance characteristics.

In addition, Curran® is non-toxic and has no emissions of VOC.

THE WAY FORWARD

The overall outlook for Curran® is **positive**. Given the multiple applications of Curran®, the product has good potential for expansion and growth on new market segments, other than the paints and coatings additives market segment, as well as in other geographical markets (e.g. North America, Asia). In driving expansion to new markets, CelluComp focusses on signing new agreements with large companies that produce cosmetics, food, composite materials and paper and which hold a strong position in their respective areas of activity. Moreover, CelluComp sees customer outreach as a key strategic goal underpinning future growth. As such, the focus is set on building a customer pipeline in applications beyond the present ones. Given the high costs (time and financial resources) associated with the development and testing of new applications, CelluComp's focus is on enabling customers to move swiftly from the product testing phase to the commercial phase.

In terms of financial outlook, CelluComp is challenged in increasing the profitability of Curran® due to difficulties in scaling up production. In the medium term, the main barrier for CelluComp is addressing the issue related to production capacity, and in this respect, securing a new round of funding for the construction of a commercial size plant that will enable CelluComp to produce larger volumes of the product and deliver lower unit costs through economies of scale. Although the market prospects are generally assessed to be positive due to the wide range of applications of the product, there are certain market risks associated with the up-scaling and commercialisation of the product. They relate to uncertainty in relation to the future demand and the level of competition from other cellulose nano-fibre materials, for example from wood and cotton.

All Purpose Cleaner by Ecover

PRODUCT NAME

Ecover All Purpose Cleaner (APC)

PRODUCT DESCRIPTION

Hard-surface household cleaning product

FEEDSTOCK

All ingredients derived from plant-based sugars and oils; Eco-surfactant ingredient fermented from glucose and rapeseed oil

ORGANISATION

Ecover

EMPLOYEES

250 employees (globally)

COUNTRY

Belgium

R&D START

2001

MARKET ENTRY DATE

2009

PRODUCTION CAPACITY

Not disclosed

PRODUCTION VOLUME

Not disclosed

SALES (GLOBAL)

Estimated around EUR 200 million

INVESTMENT

EUR 2 million for R&D

PRICE

10–20 % higher than conventional products, depending on geographical location

EARNINGS

Product line has been generating 25 to 40 % profits since 2015

CHARACTERISTICS

- 99 % bio-based
- Biodegradable
- Includes patent-protected eco-surfactant ingredient
- pH-neutral (skin friendly)

A bio-based all-purpose cleaning product



PRODUCT

Ecover's All Purpose Cleaner (APC) is a **99.4 % bio-based**, hard surface cleaning product. It is suitable for cleaning hard surfaces, such as floors, countertops, tiles, and similar. Core clients are household consumers and to a lesser extent professional cleaning companies.

SUCCESS

Ecover's APC has been **commercially available** on the market since 2009. Ecover has been among first-movers to offer an ecological, bio-based cleaning product with cleaning performance on par with that of conventional cleaning products. This was possible largely thanks to successful R&D for the development of the product's key innovative ingredient: the 'eco-surfactant'. This is a surfactant derived solely from renewable raw materials. R&D was carried out in cooperation with Ghent University, and relied largely on EU (FP7) and national public funding. The establishment of APC's commercial production was funded through the company's internal finances. Today, Ecover's APC can be commonly found in supermarkets across Western Europe and has seen growing sales over the years, reaching up to 5 % of the total market (fossil- and bio-based) in key European markets in 2017. As a product line, it has been **generating 25 to 40 % profits** since 2015.

PROSPECTS

Since its market entry in 2009, the product has experienced an increase in sales of up to 15 % per year. This indicates the product responds well to market drivers such as environmental and health impacts and cleaning performance. The company thus expects its APC market share to continue to grow and its sales to expand beyond green consumers. Branding and awareness actions to improve consumers' "perceived" performance of bio-based cleaning products are also starting to pay off in the same direction. Planned supply-side changes include the switch to feedstocks from waste streams, a topic Ecover is currently researching. Prospects for the APC product are positive, with the recent acquisition of Ecover by a large market player, internationally and in the European market. Ecover now has the opportunity to tap into additional resources that will allow it to reach new markets.

HISTORY

Ecover was founded in 1979. During its first 20 years, the company's strategy focused on providing alternatives to conventional cleaning and washing products, such as products free from certain environmentally harmful ingredients (e.g. phosphate). Their products, including the all purpose cleaner (APC) product, were originally targeted towards niche green consumers. However, the company ran into financial difficulties in the early 1990s, and realised that the cleaning performance of their products needed to be at least on par with that of fossil fuel-based products. This was seen as necessary in order to expand beyond the niche customer segment they originally targeted.

In 1992, private investment company Skagen took over Ecover. The company was relaunched with a focus on innovations in plant-based, renewable ingredients for its products, and ecological production processes. Their strategy was re-orientated to a stronger emphasis on cleaning performance, while still retaining the focus on green innovation.

The development of the Ecover APC product is an example of this strategic shift. The company set out to develop a bio-based key ingredient for its APC product that would ensure good cleaning performance: an 'eco-surfactant'. This is a surfactant derived solely from renewable raw materials instead of fossil fuels. The basis for this R&D project was a theoretical concept found in a 1960's scientific article. Ecover's R&D manager succeeded in building support within the company's management as well as externally about the concept's practical applicability. The company then partnered up with the University of Ghent and pursued a 7–8 year R&D

Drivers of success

- » Recognition of the need to improve product performance to reach a larger market and management willingness to invest
- » The ability to convince the company's management to pursue the R&D to prove the practical feasibility of the eco-surfactant theoretical concept
- » Establishing a partnership with the University of Ghent for the development of the eco-surfactant
- » The availability of public EU and local funding for R&D
- » Advice from Ecover's owner (Skagen) and external experts on IP valorisation, and subsequent licensing agreement with a supplier that took on the large-scale production of the eco-surfactant
- » Branding and awareness actions to improve consumers "perceived" performance of bio-based cleaning products

proof of concept effort. The R&D phase benefitted from EU FP7 and national public funding. In 2008, Ecover was awarded a patent for the use of eco-surfactants in cleaning products.

Despite this breakthrough, the next phase proved more challenging. This phase aimed to scale up the production of the eco-surfactant ingredient to a commercial level, which would allow Ecover to produce the APC in volumes sufficient to enter the market. Typically, Ecover co-develops ingredients in partnership with ingredient suppliers. This is seen as a good way of ensuring the basis for the subsequent scale-up. However, the path towards the development of the eco-surfactant had not involved such a cooperation. Thus, Ecover was faced with a risk that they would not be able to enter the market and hence to harvest from investments made in R&D. The challenge was overcome by a concerted effort to identify and reach a licensing agreement with an ingredients' supplier, who could take on the production of the eco-surfactant at a large scale. Ecover entered into discussions with several potential

..... SWOT ANALYSIS FOR ECOVER ALL PURPOSE CLEANER

S

STRENGTHS

- IP for eco-surfactant and EU-Ecolabel
- Ability of R&D manager to build support for pursuing R&D in the eco-surfactant, resulting in fruitful R&D partnership with Ghent University
- Company owner support from the outset
- New company owner is a large cleaning products manufacturer with substantial resources that Ecover can capitalise on

W

WEAKNESSES

- No involvement of ingredients' supplier at the beginning of the process
- Higher price compared to fossil-based cleaning products

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OPPORTUNITIES

- Growing consumer interest in green cleaning products

T

THREATS

- Influx of competing ecological products on the market
- Feedstock sustainability could be questioned in the future

suppliers. In parallel, the company sought advice from their owner at the time, Skagen, and from external experts on how to commercialise and license the generated eco-surfactant intellectual property. This process helped in eventually reaching an agreement with their current eco-surfactant supplier, specialty chemicals company Evonik.

The eco-surfactant together with other plant-based ingredients are combined in the company's ecological production facility in Malle, Belgium to produce Ecover's APC product. Today, the product can be commonly found in supermarkets across Europe and has seen its market share increasing at a rate of up to x1.15 per year in key markets. The segment of bio-based green cleaning products has attracted financial interest, and Ecover was acquired at the end of 2017 by privately held SC Johnson, a global manufacturer of household cleaning products.

FUNDING

The investment for setting up the commercial production line for the APC was funded through Ecover's internal finances. The R&D phase was funded through a combination of internal financing and external financing through EU and local funding (grants).

Ecover together with partners has received national and European support for various research projects on the topic. These funds allowed deepening of knowledge and expertise on the new eco-surfactant and its applications. Ecover has received an estimated EUR 1 million in grants for the APC product specifically, of which the large majority were in EU support from the EU FP7 research and innovation programme.

MARKET INFORMATION

Ecover is positioned as an environmental brand. Their products, including the APC product, are marketed to green consumers. The company is undergoing what they consider a successful shift from the niche green consumer segment to mainstream green consumers. The core markets for Ecover's APC are in the (western) EU, and the US, while there is also a small market share in Asia.

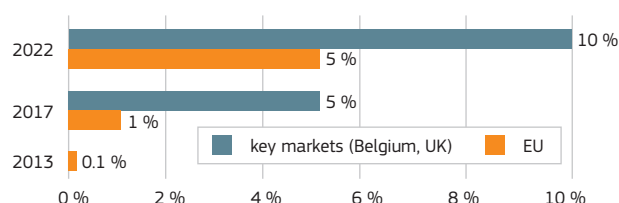
The APC product is sold directly to end consumers, either online or via supermarkets. Its price is about 10–20 % higher than conventional products. This price premium stems from more expensive, bio-based bulk ingredients that are currently not produced at a large scale and are therefore more costly when compared to traditional fossil-based ingredients.

In 2013, Ecover's APC was estimated to have a modest share of the total (fossil- and bio-based) market of 0.1 % in Europe. However, it was recognised to be amongst the most prominent 'green cleaning' brand. The European hard surface cleaning market was heavily dominated by a few well-known and globally recognised manufacturers: the top six organisations in the European market for surface care had about 59 % of the

market share in 2013 while there were also more than 100 other players with less than 1 % of the market. SC Johnson, the new owner of Ecover, ranked 6th with a market share of 7.2 %. The total retail value of APCs in seven EU countries (France, UK, Italy, Germany, Netherlands, Denmark and Poland) was EUR 1.954 million in 2013. The total retail value of all hard surface care cleaning products in the EU was estimated at EUR 4.232 million in 2013.¹⁵

Since 2013, there has been an upward trend, and the company currently estimates the Ecover APC sales to represent about 1 % of the European market, a tenfold increase compared to 2013 estimates. For key European markets (UK, Belgium) Ecover estimates its market share to be close to 5 %. In the future, it expects its market share to continue to grow, reaching by 2022 an estimated 5 % in Europe, and 10 % in key markets.

ECOVER TOTAL APC MARKET SHARE IN EUROPE, 2013–2022



Source: Based on company estimates and JRC (2014)

Note: No available estimate for key markets in 2013

REGULATORY ASPECTS

Ecover APC is a consumer product. Thus, initiatives and regulations pertaining to labelling have an impact on sales. The Ecover APC product has been awarded the EU Ecolabel. This helps European consumers distinguish it as an environmentally friendly product when making purchase decisions. On the other hand, the company considers the Regulation on the classification, labelling and packaging of chemical substances and mixtures (CE 1272/2008) to constitute a challenge: the symbols that should be used on labels according to this Regulation leave an immediate impression with consumers of a product that one should be cautious about, and consumers may pay little attention to the actual meaning of the different labels.

TECHNOLOGY INFORMATION

Ecover's APC product has been produced commercially since 2009. The **Technology Readiness Level (TRL) is thus TRL 9** (actual system proven in operational environment).

The APC core innovative ingredient is a yeast-based eco-surfactant, developed in a cooperation between Ecover and Ghent University. They invented an innovative new process using a special 'bioreactor', which provides the breeding ground for yeast cells. This in turn provides for harnessing the yeast's unique ability to combine water-soluble sugars and non water-soluble oils to produce what Ecover has termed an 'eco-surfactant'. The collaboration proved

¹⁵ JRC (2014), *Revision of European Ecolabel Criteria for All-Purpose Cleaners and Sanitary Cleaners*.

successful and Ecover and Ghent University were jointly awarded a patent for the use of eco-surfactants in cleaning and washing products. The eco-surfactant together with other plant-based ingredients are combined in the company's production facility in Malle, Belgium to produce Ecover's APC product.

ENVIRONMENTAL IMPACT

The eco-surfactant production process is a low-energy biochemical process based on natural fermentation. Conventional methods for the production of surfactants – be it bio- or fossil-based – typically require a chemical process involving high pressures and temperatures. In contrast, Ecover's process operates at a low temperature of 30 °C and only requires ambient atmospheric pressure, thereby saving significant amounts of energy. The eco-surfactant allows for a cleaning performance of the bio-based APC on par with that of petrochemical-based products, and at the same time allows for the complete biodegradability and low toxicity of the product.

In addition, Ecover's bio-based products use Northern-European-sourced feedstocks. The eco-surfactant – the APC key ingredient – uses local rapeseed oil as feedstock, having switched away from the palm oil previously used. In the medium- to long-term, the aim is to switch to feedstocks from waste streams to address possible future concerns

in relation to competition with food supply. The company is already carrying out R&D in this direction: for example, under an ongoing project they are exploring the use of waste alcohol produced as a by-product of zero-alcohol beer production.

The company is paying particular attention to packaging, which accounts for a significant part of the product's total footprint. The currently used APC bottles are a mix of 75 % bio-based plastic and 25 % postconsumer recycled plastic. By purchasing and using recycled plastic, Ecover provides demand for recycled materials that helps drive the recycling economy. Ecover is also looking at fibre-based structures for packaging such as grass, potato peel or paper.

Supply chain decisions such as the sourcing of ingredients and packaging are guided by a company internal tool that measures the environmental and health impacts of products. Based on this tool, Ecover has set itself minimum standards, for example that all surfactants be biodegradable and that all products be at least 80 % bio-based.

Besides producing an ecological product, Ecover operates from sustainable manufacturing facilities located in Belgium, France and since 2015 in the US (Chicago). Finally, Ecover's APC has been awarded the EU-Ecolabel, recognising that it is in the top 10–20 % of products on the EU market in terms of its environmental performance.

THE WAY FORWARD

The Ecover APC product responds well to key market drivers that beyond price include cleaning performance, health considerations and environmental sustainability. Moreover the price differential compared to conventional cleaning products, which currently results from the use of more expensive bulk ingredients, is expected to get narrower as some ingredient suppliers scale up production of bio-based ingredients with low ecotoxicity.

While the actual performance of Ecover's APC is on par with that of conventional products, consumers often judge performance based on "perceived" performance (e.g. this is where characteristics such as fragrance come into play). Ecover will continue carrying out branding and awareness efforts to inform consumers about the value, performance and quality aspects of bio-based cleaning products thereby improving their "perceived" performance. Through such efforts and through tapping additional resources of its new owner, Ecover's expects to reach new markets and expand sales beyond green consumers. The company expects its APC market share to continue to grow, reaching by 2022 an estimated 10 % in key markets (UK, Belgium), and an estimated 5 % in the EU.

On the supply side, planned changes in the medium term include a switch to waste biomass feedstocks, the use of which Ecover has started to investigate through dedicated research projects. The company anticipates that the use of a particular such ingredient to be technically proven in 2020, and that it could make the complete transition in a further 8 years thereafter, by when waste-biomass feedstock supply can be expected to become more established and commercially viable.

The company employs a culture of continuous innovation and for the longer-term development of its cleaning products they are paying increased attention at the concept of biomimicry. This could mean a transition to probiotic cleaners encompassing living micro-organisms as the active ingredient, which are active in the presence of dirt but benign otherwise.

Lumir® Spray by Lumir Oy

PRODUCT NAME

Lumir® Spray

PRODUCT DESCRIPTION

Sound proofing spray for interior walls

FEEDSTOCK

Wood pulp from FSC-certified forests in Finland

ORGANISATION

Lumir Oy

EMPLOYEES

14

COUNTRY

Finland

R&D START

2009

MARKET ENTRY DATE

2013 for its first cotton-based coating.
Gradual transition to wood fibres as a feedstock between 2015 and 2017

PRODUCTION CAPACITY

600 m² of Lumir® Spray per day;
Investment into material for larger capacity on-going

PRODUCTION VOLUME

100 m² of Lumir® Spray per day per site.
Total capacity is utilised by 17 %

SALES (GLOBAL)

EUR 1.1 million

INVESTMENT

Not disclosed

PRICE

Ca. EUR 60 per m²

EARNINGS

EUR -864,000

CHARACTERISTICS

- 100 % bio-based
- FSC certified feedstock
- Patent protected
- Low VOC emissions (M1 – RTS Standard)
- Highest possible European class for fire retardant wood products (BS1D0 according to EN 13501-1)

Acoustics isolation in spray



PRODUCT

Lumir® Spray is an indoor sound absorption solution. It improves indoor acoustics through reduced reverberation. The product is a **100 % bio-based** wood-fibre coating that is produced from wood pulp. It further serves as an alternative to glass-wool based indoor sound absorption. Lumir® Spray contains colour pigments. It therefore eliminates the need for potentially fossil-based acrylic paints and the production of plastic packaging waste. It can be applied directly to any surface that is not sensitive to water with minimal preparative work. This saves the use of other building material required for indoor walls and ceilings, such as fillings, wall plaster or the like.

SUCCESS

Lumir has succeeded in introducing its product on the market. As of 2018, it has been applied in more than 100 construction projects. Accordingly, Lumir demonstrates a growing turnover. The product is produced on a commercial scale, utilising Lumir's current production capacity by 17 %. Lumir is not yet profitable, but anticipates to break even during 2018. The company succeeded in securing private financing early in its foundation phase. Lumir has further managed to secure national funding to shift its feedstock away from cotton fibres.

PROSPECTS

Lumir is engaged in developing the next feedstock generation, of which waste fibres from the paper production are under consideration. Lumir seeks to enter its first market outside Finland, and considers Denmark, Sweden and the Netherlands as possible candidates. The company continues to develop the value proposition of its products with new product variations, moving away from offering only sound alteration solutions towards making building and construction processes more efficient.

HISTORY

Lumir was founded in 2009 with the aim of providing an alternative to glass-wool sound insulation solutions, with which Lumir's founder worked in the past. The aim was to improve existing solutions' visual quality, potential health impact and ease of installation.

Convinced of the market potential of Lumir, Takoa Invest, a venture-capital firm, invested in the company. Accompanying this early investment, the investor took an active role in the company by filling several positions on the company's board as well as the initial Managing Director position. This enabled the founders of Lumir to focus on product development and utilise their technical and market insights and expertise.

The first versions of Lumir® Spray used cotton as a feedstock. This was imported from China and Kazakhstan. Lumir conducted small-sized trials with this version from 2011 and onwards and entered the market with this version in 2013. Challenges with cotton fibres as feedstock, such as variable fibre quality and unsustainability, however led Lumir to change to wood fibres as a feedstock in 2015.

This resulted in the contracting of Lumir's current product director in 2015, who brought in experience with cellulose and nanocellulose chemistry, among others from working at VTT Technical Research Centre of Finland Ltd (VTT). The wood fibre development took place in collaboration with Lumir's feedstock provider Stora Enso, one of the world's largest paper and pulp producers. The wood fibre content of Lumir® Spray has increased gradually over time reaching 50 % in 2016 and 100 % in 2017.

Drivers of success

- » Involvement of a dedicated investor already in the company's founding phase. This secured the financial means and ability of company founders to fully focus on the development of the product.
- » Lumir adapted its management competences as needed along the development path by contracting additional experience in developing a new feedstock and to focus on establishing Lumir more solidly on the market.
- » The co-development of a product version together with a well-known player in the construction and sound insulation industry. This contributed positively to consumers' confidence in the product.
- » National funding (Tekes) enabled the necessary research to change the feedstock from cotton- to wood fibers.

Lumir® Spray is exposed to the risk that it needs to generate a credible reputation with users as a **quality and/or price competitive** product. Improper installation can involve higher costs and/or reduced quality. Purchasing the product includes installation by a Lumir team, to remain in full control of the quality of the installation. In order to cover the growing demand, Lumir has also contracted a partner firm for the installation, and is negotiating contracts with additional firms. As of 2018, Lumir® Spray has been installed in more than 100 buildings in Finland, including notable public buildings such as the National Library of Finland.

Lumir's primary customers are in the building and construction sector, primarily architects. The company operates in the business-to-business domain. Lumir states that there is some reluctance in the building and construction sector to apply new products offered by small suppliers on the market. Accordingly, it requires sustained effort to convince architects and construction companies to use Lumir.

SWOT ANALYSIS FOR LUMIR® SPRAY

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STRENGTHS

- Ability to adapt (management level) and re-orientate where necessary
- Flexible feedstock allows production in wood pulp-scarce areas
- Strong internal R&D skills in wood chemistry
- Patent protected

W

WEAKNESSES

- Difficult to demonstrate that the product has a better environmental performance than glass- and mineral wool

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OPPORTUNITIES

- National support schemes helped to finance the change of the feedstock
- Paper and pulp industry in search for new business models to hedge against declining demand for traditional paper products
- Possibility to use paper production by-products as feedstock, could help the paper industry to be more 'circular'

T

THREATS

- Conservative and established market and relations between suppliers and buyers, which is hard to enter for a small company with a novel product
- Bigger companies could try to out-compete the company
- Sustainability of feedstock (wood pulp) may be questioned in the future

A key break-through in this regard was that Lumir managed to co-develop a product with a major German building material supplier, Knauf. Lumir sells Lumir® Board, in which the spray is combined with a sound absorbing gypsum board by Knauf. While this cooperation did not enable Lumir to enter foreign markets, cooperation with this large player in the market contributed positively to the credibility in the market about Lumir® Spray's qualities.

In order to promote and focus more on growth, a new Managing Director was recruited in 2017. This brought in experience from the buildings and construction sector. Further, a Sales Manager was brought in with previous experience as a technical product manager for acoustic ceilings at Knauf.

FUNDING

Lumir has been mainly privately financed by the investment firm, Takoa Invest. Takoa Invest invested in Lumir when the company was founded. Next to the large market potential of the product, Takoa Invest's motivation was that the founder of Lumir had a strong track record with working on different start-ups in the past. Takoa Invest maintains a significant share in the company and holds four out of six board seats and retains the board's chairmanship. Prior to the hiring of the current Managing Director, Takoa Invest filled this position as well.

Lumir has obtained national funding and a loan from Tekes, a public Finnish business development fund, for the development of the wood fibre feedstock, and has further initiated a second application process for research on wood fibres. Lumir has otherwise financed the rest of its research expenses internally.

To date, Lumir has not received EU funding. Lumir is currently however preparing an application for Horizon 2020 funding for its first application outside of Finland.

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TURNOVER AND PROFITS OF LUMIR ON THE COMPANY LEVEL

	2013	2014	2015	2016	2017
Turnover (EUR 1,000)	145	95	631	752	1,082
Profit (EUR 1,000)	- 757	- 549	- 415	- 571	- 846

Source: Asiakastieto.fi & Lumir

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Lumir has a growing turnover (see above), which indicates that the demand for Lumir is growing. Particularly since the change in feedstock was initiated in 2015, turnover has increased, though no profits have been generated. In

part, this is because Lumir gradually developed its product further (e.g. the mentioned change of the feedstock) while already selling the product on the market. Lumir expects to break even in 2018.

MARKET INFORMATION

The company states that the price of a Lumir® Spray acoustics installation matches that of competing products, such as glass and mineral wool panels. While the price of Lumir® Spray is EUR 60 per m², compared to some EUR 15–65 per m² of competing, non-bio-based, products (depending on the sound absorption capability),¹⁶ Lumir states that the higher material price is off-set by less installation time and lower material consumption.

The company's overall value proposition is that its products make building processes more efficient: necessary building components like paint are already included in the coating.

The bio-based feature is not a driving factor of the product demand. Rather it is the product's quality, durability and customisability (e.g. in terms of colour) that are determining demand factors. Overall, the company states that product quality and price are the main decisive factors in the building and construction industry.

REGULATORY ASPECTS

Lumir reports that the fire classification of the material according to the European classification standard (EN 13501-1) was a regulatory challenge. A low classification would have led to limitations on the amount of material allowed to be used in a construction. This would in effect expose Lumir® Spray to the risk of not being competitive to the competing glass- and rock wool based products which generally have the highest fire classification possible (class A1). To ensure a sufficiently high classification, Lumir was required to add fire retardants. Although the company had sufficient knowledge to develop those retardants internally, the development took several attempts. Still, the effort resulted in the highest possible European class for fire retardant wood products (class B). As a result, Lumir® can be used in any building space, with the exception of fire exits.

TECHNOLOGY INFORMATION

Lumir emerged from the pilot stage and entered the market with its first cotton-based version in 2013. Over time the product has gradually changed to a 100 % wood fibre based version in 2017. With +100 applications and a growing turnover, Lumir® has achieved **Technology Readiness Level (TRL) 9** (actual system proven in operational environment).

¹⁶ An example is Rockfon®, which provides ready-made rock wool panels that can be installed on walls on ceilings.

Lumir is available with varying features, but the basis of the product, Lumir® Spray, consists of wood fibres. While Lumir does not reveal the exact type of wood fibres, it reports that it is more novel than the recent developments of nanocellulose fibres. The technology uses a patented 3D sound absorbing structure and contains colouring pigments. This effectively substitutes the need for paint, which is typically made of acrylic (i.e. plastic).

Lumir produces the spray mainly on-site and has a production capacity for 600 m² of Lumir® Spray per day. Currently, the proportion of work required for preparatory work limits however the actual production volume to 100 m² per day. Overall, the company's production capacity is utilised by 17 %, and Lumir is in the process of expanding its on-site production capacity. The company works continuously on possibilities to improve the production efficiency and hence production volume.



ENVIRONMENTAL IMPACT

The wood pulp for Lumir® Spray originates from domestic and FSC-certified forests in Finland, provided by Stora Enso.

The production of wood pulp is generally a material and energy intensive industry. The Finnish forest industry has shown strong improvements in their environmental impact over the past two decades, for example in reducing its CO₂ emissions by 60 % between 1990 and 2012. Lumir's feedstock supplier fits in this general development, and has reduced its energy-related carbon footprint by 24 % between 2013 and 2017. The energy consumption for the production, however, accounts only for one tenth of the company's carbon footprint, whereas nearly two-thirds of the carbon footprint is indirectly along the value chain (e.g. harvest and transport).

Lumir® Spray can be applied on the bare cinder rocks of buildings, which saves the use of material resources, as fillers, paint, wall plaster, or other elements to walls and ceilings are no longer required. As Lumir® Spray contains colouring pigments, fossil-resource consumption in the form of paint and the production of plastic packaging waste (e.g. paint containers) is reduced. Lumir's products can thus eliminate certain building processes and reduce resource consumption and waste production.

THE WAY FORWARD

Lumir considers to use waste fibres that result from the paper manufacturing processes for the next feedstock generation, which would otherwise be incinerated as unusable waste. This next generation will most likely enter the market by 2019. The company has also tested the use of recycled wood fibres, though these exhibited colouring issues of the material.

Lumir was founded with the idea of providing an alternative to glass- and mineral wool panels for the inside acoustics of buildings. The company states that this underlying vision has evolved into generally improving the efficiency of construction and building processes. Accordingly, Lumir has developed variations of Lumir® Spray, such as sterilising hygiene wall coatings (Lumir® Hygiene) and coatings for cooling and warming systems (Lumir® Coolia and Lumir® Comfort), which enables more customised applications, and therefrom deriving new market opportunities.

The company continues its efforts to have its first application outside of Finland. The Netherlands are a favourable candidate country, due to its proximity to the EU's largest market (Germany).

Lumir continues research on the acoustic properties of natural fibres. The results shall feed into Lumir's own knowledge, and serve to improve the academic and public knowledge on the subject matter.

Melodea CNC technology by Melodea Ltd.

PRODUCT NAME

Melodea CNC production technology

PRODUCT DESCRIPTION

A process for producing Cellulose Nano Crystals (CNC), used to reinforce existing materials or produce novel materials

FEEDSTOCK

Wood pulp or waste products of the pulp and paper production process

ORGANISATION

Melodea Ltd. with partners Holmen and Klabin

EMPLOYEES

15 (Melodea Ltd.)

COUNTRY

Israel (Melodea Ltd.)
Sweden (partner Holmen)

R&D START

2006

MARKET ENTRY DATE (OF RESULTING CNC PRODUCT)

2017

PRODUCTION CAPACITY

100 kg/day

PRODUCTION VOLUME

Swedish facility to reach full capacity utilisation (100 kg/day) by end 2018

SALES (GLOBAL)

Significant revenues foreseen in the coming two years

INVESTMENT

Above EUR 3 million

PRICE (OF RESULTING CNC PRODUCT)

Estimated future price < EUR 20/kg CNC, depending on quality, quantities and applications

EARNINGS

Expected to be positive by 2020

CHARACTERISTICS

- 100 % bio-based resulting CNC product
- Biodegradable, natural, non-toxic resulting CNC product
- Patent protected production technology and applications

A process for extracting nano-structured cellulose



PRODUCT

Melodea Ltd. has developed a production process that can extract Cellulose Nano Crystals (CNC) from wood pulp and side streams of the pulp and paper making process. The business model focuses on revenues via the **licensing of the technology** for CNC production. The resulting product – CNC – is nano-structured cellulose that is a **100 % bio-based material** and is non-toxic. It can be used to enhance existing materials and produce novel ones. Examples of applications are papermaking additives, coatings, paints, packaging, building materials, and bio-composites. In addition, the company develops technologies for CNC downstream product applications, with a strategic focus on additives for paints and high-end coatings.

SUCCESS

Melodea has **secured significant levels of investment** from private sources at critical development stages, adding to received EU funding for research and innovation. Since 2012, a Swedish-based strategic partner from the pulp and paper industry has provided part of the funds for technology development. In 2017, it provided financing for the commissioning of an industrial proof of concept CNC production facility that employs Melodea's technology. It is **the first CNC production facility of its kind in Europe**, from which significant Melodea CNC quantities will become available on the market. The company successfully attracted additional private funds from a second pulp and paper producer in early 2018.

PROSPECTS

The outlook for Melodea's CNC technology is positive. With **backing from two leading pulp and paper producers**, the company expects to rapidly diffuse the technology in this industry and be profitable by 2020. The CNC extraction process can be deployed on-site pulp mills, where the feedstock, needed infrastructure, and utilities are already in place. The resulting product, CNC, can be used in the paper making process itself or procured to other industries, opening up **new business opportunities for the pulp and paper industry** that enable it to adapt to changing market conditions. What is more, the CNC technology **can use any cellulose-containing feedstock** including agricultural and food industry waste streams, making it in the future a potentially attractive investment for such industries.

HISTORY

Israel-based Melodea Ltd. was founded in 2010 with the idea of introducing a commercially viable production method of CNC, which was previously invented at the Hebrew University of Jerusalem. Melodea's founders obtained the exclusive rights for the production method and continued to develop and optimise the CNC production process to make it viable for industrial scale production. Understanding CNC's market potential, Swedish-based pulp and paper producer Holmen AB became a partner in Melodea in 2012, with almost a 40 % stake.

This **strategic partnership with Holmen** has been a key milestone in attracting private finance. Before reaching the agreement with Holmen, Melodea approached several potential financial, strategic and private investors. The proposition concerned an investment in a new material which would require a long time horizon to mature and generate positive returns on the investment. With this long time horizon, positive interest was demonstrated only by few investors. Public research funds have also played a key role, especially in the first years of the company. These continue to do so today, albeit to a lower extent, as private financing financing (e.g. from Holmen and Klabin) has been entering the scene in terms of both ownership interest in Melodea, and investment for setting up a CNC pilot production plant.

Melodea commissioned a pilot production facility in Sweden with its investing partner Holmen in 2017. This enabled CNC

Drivers of success

- » In-depth understanding of the pulp and paper industry that has direct access to large volumes of feedstock; offering of an attractive value proposition entailing additional business opportunities for this industry with minimal investment requirements
- » Active involvement in the development of downstream CNC product applications to drive CNC material demand. Ability to adapt strategies and focus first on applications with niche characteristics.
- » A robust business plan on how to transform the CNC production process from laboratory to industrial scale in an economically viable way, supported by external market experts
- » Availability of public research funds and capacity to successfully attract these; capitalising on networking opportunities created by publicly funded projects
- » Strategic investment partnership with a large player in the pulp and paper industry with market importance, providing Melodea with funds and credibility on the market

produced with Melodea technology to enter the European market. Albeit being the size of a pilot facility, it is **Europe's first CNC production plant**, putting Europe on the map together with North America as the world's hubs of CNC manufacturing.

In order to drive demand for CNC as an input material, Melodea also engages in the development of CNC downstream product applications. A strategic focus was put in the first years on the development of CNC-based foams. The foam industry proved however to be highly cost-driven. This exposed Melodea to the risk of depleting financial funds for an application in which CNC would not be sufficiently price competitive. Melodea was quick

SWOT ANALYSIS FOR MELODEA CNC

S

STRENGTHS

- A process designed to utilise existing streams of paper production to minimise adoption costs
- Two strategic partnerships in the paper industry
- Involvement in the development of specific applications
- Feedstock flexibility allows valorisation of waste streams
- Ability to adapt (management level) and freedom of action, re-orientate where necessary
- Strong R&D skills incl. of board members and management

W

WEAKNESSES

- Environmental performance of the production process is not certified
- As production is licenced out, the environmental performance depends on the individual producer (e.g. their sustainable sourcing policies)

O

OPPORTUNITIES

- Funding and networking opportunities from EU research programmes and national support schemes
- Paper and pulp industry in search for new business models to hedge against declining demand for traditional paper products
- Possibility to use paper production by-products or recycled paper as feedstock, could help the paper industry to be more 'circular'

T

THREATS

- Competition from larger CNC players or from low grade cheap nanocellulose
- Conservative and established market and relations between suppliers and buyers
- Sustainability of feedstock (wood pulp) may be questioned in the future
- Concern/unfamiliarity with the term „nano“ and ambiguous social acceptance of nanotechnology

to realise the short-term limitations of this application and mitigated accordingly. This resulted in 2015 in a change of the strategic focus towards CNC-based additives for **paints and high-end coatings**, an application for which CNC has reportedly favourable properties and niche market characteristics.

FUNDING

The development and commercialisation of Melodea's CNC production technology and the development of applications has been financed by a combination of private investments and public grants.

A key milestone has been the investment of **Swedish paper producer** Holmen in Melodea. Holmen initially provided about EUR 1 million in 2012, as well as additional funds in the years thereafter upon the achievement by Melodea of agreed technical milestones.¹⁷ This paved the way towards an increasing importance of private funds. In addition, Holmen has financed together with other funders the commissioning of the above-mentioned CNC pilot production facility.

A second financing round was successfully completed in early 2018, with Klabin – **one of Brazil's biggest paper producers** – providing an investment of about EUR 2 million for a 12.5 % ownership share in Melodea.

Before Holmen's involvement, the company has relied on **EU research and innovation funding programmes**, in particular FP7 thematic calls on nanotechnology (FP7-NMP) and biotechnology (FP7-KBBE) that have been accessible for Israeli applicants, as well as grants from Israeli agencies. EU programmes have been a vital support in the development of the CNC technology. The company continues to pursue grants today. Through already agreed grants from the EU (e.g. M-Era-Net and Horizon 2020 thematic calls) and Israeli programmes, the company expects public funding of about EUR 2 million until 2020.

MARKET INFORMATION

The CNC pilot plant in Sweden that employs Melodea's technology has the **third highest CNC production capacity in the world, and the highest capacity in Europe** (100 kg/day). Based on public literature, CNC of a comparable high grade by the current market leader CelluForce is positioned at about EUR 20/kg. Melodea expects its own technology to result in comparable or lower CNC cost, assuming it would be produced in a facility with an economically optimal output of 3 tonnes per day.

Market research studies have estimated the total CNC market at about EUR 27.5 million globally in 2014, and project it to grow to EUR 94.5 million in 2019 at a compound annual growth rate of 28 %. Overall, the US and European countries are projected to be manufacturing hubs as well as major consumers of nanocellulose (including CNC and other forms).

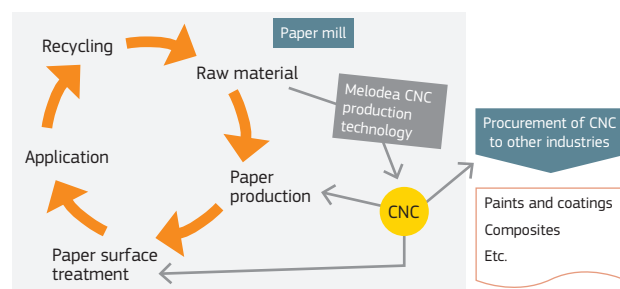
¹⁷ Holmen Annual Report 2012, p.78

¹⁸ Miller, J., (2016), *Nanocellulose: Technology, Applications and Markets*, presentation at 2016 International Conference on Nanotechnology for Renewable Materials, Grenoble, France

Based on a 2014 assessment,¹⁸ the three highest potential applications for nanocellulose in terms of volume is paper and paperboard (20,000 thousand tonnes), manufactured textiles (1,126 thousand tonnes), and paints and coatings (800 thousand tonnes). The latter is Melodea's strategic focus in terms of CNC application development.

The immediate potential for the deployment of Melodea's CNC extraction process lies with the paper industry. The CNC produced on site a paper mill can be used in the paper making process itself (e.g. to improve mechanical or surface properties of paper sheet) and in the production of downstream paper-based products (CNC can be used as a barrier material to make paperboard impermeable without using plastic film or aluminium foil), or procured to other industries such as the paints and coatings industry (see figure below).

..... PRODUCTION AND USE OF CNC DURING PAPER MAKING PROCESS OR ITS PROCUREMENT TO OTHER INDUSTRIES



Source: Illustration by the authors

.....
Melodea's business model focuses on revenues via the licensing of the manufacturing technology, targeting in particular its deployment by the pulp and paper industry which has direct access to large volumes of feedstock and established pulp mill infrastructures. This entails low technology adoption costs for paper producers, with the resulting CNC production costs estimated at only half as high as when setting up a production facility outside a mill. Melodea has already successfully licenced its technology for the CNC production plant in Sweden that paper producer Holmen has invested in. The recent acquisition of part of the shares in the company by a Brazilian paper producer could signify a possible upcoming investment in a facility with Melodea's CNC technology in South America.

REGULATORY ASPECTS

CNC is covered by the provisions of general EU chemical legislation (REACH or CLP).

There are currently no explicit requirements for nanomaterials, including bio-based ones; nonetheless, the European Chemicals Agency provides guidance on the implementation of REACH for nanomaterials with respect to information requirements and chemical safety assessments. There are also specific provisions for nanomaterials in sector-specific legislation such as food,

biocides, pharmaceuticals and cosmetics legislation. **Current regulations do not constitute a barrier to the introduction of the technology.** The potential for dedicated chemical legislation pertaining to nanomaterials could, however, become a barrier in the future.

Despite the absence of dedicated regulations for nanomaterials, several studies have been carried out to evaluate the potential environmental and health hazards of nanocellulose. Melodea has carried out eco-toxicity tests for CNC, showing zero toxicity; which is in line with the findings of other independent toxicity tests of CNC.

Being “nano” however, CNC could suffer from the somewhat ambiguous social acceptance of nano-technology. At large, this is because it is a relatively new area that is little understood and has remaining uncertainties about potential (long term) risks.

TECHNOLOGY INFORMATION

CNC is extracted from wood pulp (or waste products of the pulp and paper production process), via a chemical process that breaks down cellulose fibres. Melodea’s CNC production process encompasses a recovery method of the chemicals that renders the process both cost effective and environmentally sound. The **Technology Readiness Level (TRL) is 7** (system prototype demonstration in operational environment).

The advantage of the underlying technology stems from the resulting product’s properties, including: high transparency, homogenous dispersion, no forming of aggregates, self-assembly to homogenous films, smooth surface, and

excellent dispersant of other materials (such as pigments, metal oxides, or graphene).

As Melodea’s business model focuses on making revenues via licensing, patents are indispensable. Melodea has been granted two patents (patent families) and has several additional applications in the process.

ENVIRONMENTAL IMPACT

The CNC itself is **100 % bio-based** and only consists of biodegradable, natural, non-toxic cellulose. The bio-based rating of the final product depends on the product’s final composition.

The current feedstock is **wood pulp**. The feedstock for Melodea’s production facility in Sweden originates from nearby forest plantations. In the optimal case, a CNC plant is located at a pulp or paper mill where the collection and handling of wood pulp already occurs, eliminating the need for transporting feedstock. Given that Melodea’s business model relies on licensing, the sustainability of the feedstock depends on the sourcing policy of the specific mill in question.

Melodea’s existing partners from the paper industry both have sustainable forestry practices in place. As an alternative to wood pulp, the **waste from the pulp and paper production processes** can be utilised as feedstock. However, depending on the waste type, the price of wood pulp, as well as the production scale and geography, the sludge-based production process may be less competitive and less environmentally sustainable compared to pulp-based production. This is due to higher chemical input needs for the pre-treatment of sludge before it can be used as feedstock, for which the cost can be substantial.

THE WAY FORWARD

The recent investment in Melodea by Klabin in addition to Holmen, signifies that Melodea’s technology faces a positive outlook. With backing from two leading forestry conglomerates, Melodea expects to **diffuse the technology in the pulp and paper industry** and be profitable by 2020.

The forestry and paper industry faces a continued decrease in paper consumption because of digitalisation. The growth in packaging (boosted by e-commerce) provides further opportunities. However, this segment is not without challenges as plastics are currently more competitive compared to paperboard due to, for example, low oil and gas prices. In response, the European forestry and paper industry has set itself the goal to deliver about EUR 3.5 billion added value in Europe by 2050 from the development of bio-based products. Melodea’s CNC production technology enables the pulp and paper industry to adapt to changing market conditions by developing new products and technologies and **exploiting new business opportunities and models**. The investment by two players in the pulp and paperboard industry is indicative of this.

The immediate potential for the deployment of Melodea’s CNC technology lies with the pulp and paper industry, but the technology can make use of any cellulose-containing feedstock including **agricultural and food waste streams**. This **feedstock flexibility** makes the technology in the long term also a potentially attractive investment in agriculture and food industries.

Paptic® Bags by Paptic Oy

PRODUCT NAME

Paptic®

PRODUCT DESCRIPTION

Flexible bag and wrapping material for e.g. carrying bags applications

FEEDSTOCK

Primarily wood pulp; Depending on application: PLA, Viscose and others

ORGANISATION

Paptic Oy

EMPLOYEES

12 (2017)

COUNTRY

Finland

R&D START

2015; Background technology available since mid-2000s

MARKET ENTRY DATE

2016

PRODUCTION CAPACITY

25 tonnes Paptic® material/year;
5,000 tonnes projected in 2018

PRODUCTION VOLUME

20 tonnes Paptic® material/year

SALES (GLOBAL)

EUR 50,000

INVESTMENT

EUR 1.9 million

PRICE

Depends on application; EUR 0.20 to 0.40 as carrying bag; Three-fold sales price compared to standard paper

EARNINGS

EUR -874,000

CHARACTERISTICS

- 80–95 % Bio-based, depending on application (OK Biobased certified)
- FSC/PEFC certified wood pulp
- 80 % Recyclable
- Biodegradable
- Can be recycled with paperboard
- 4 Patents
- Trademarked

Making paper bags more reusable



PRODUCT

Paptic® is a wood-fibre-based flexible bag and wrapping material that aims to replace plastic bags and wrappings made from fossil resources. Typical commercial applications are as carrying bags, pouches, sacks, banners, or shipping bags. The company is focused on the strategic niche application as a carrying bag. Paptic® is highly suitable for reuse, which strengthens the visibility of customers' brands in the public domain. Paptic® is **80–95 % bio-based**, depending on the specific application, and it is **recyclable in existing paper collection systems**.

SUCCESS

Paptic secured seed investments from multiple private investors during its formation in 2015, when Paptic was spun off from a public R&D company in Finland. One year later, the company entered the market with the Paptic® carrying bag in 2016. It is available on a small scale, and it is currently not offered at a competitive price compared to other carrying bags due to a small production capacity. However, Paptic has secured product-specific funding from the SME Instrument under Horizon 2020 to scale up the production to a commercial level. Consequently, Paptic projects an increase in the production capacity from 25 tonnes in 2017 to 5,000 tonnes in 2018, thereby providing for economies of scale.

PROSPECTS

Paptic plans to get first commercial deliveries operational by the third quarter of 2018. The resulting economies of scale will render the product more price competitive. As a result of this development, Paptic anticipates to grow to 30 employees by 2018 and break even by 2020. Following several negotiation rounds with large companies, Paptic continues its efforts to identify new equity financing opportunities. Paptic is further engaged with the development of the next generation of feedstock, of which recycled fibers are a potential source.

HISTORY

In the mid-2000s, researchers at a public government-owned R&D company in Finland, VTT Technical Research Centre (VTT), developed several technologies that build the foundations of the product Paptic®. Recognising the market potential, Paptic's founders spun-off the company from VTT in 2015 and secured seed investments in that process.

In that same year, Paptic developed the first prototypes and applications, and started a prototype production line in early 2016. By mid-2016, Paptic entered the market with carrying bags. These were sold to a Finnish fashion retailer (Seppällä, which went bankrupt in 2017) and are currently sold at most of the Finnish pharmacies and Fazer stores (bakery and leading chocolate brand) in Finland.

Paptic® carrying bags are not yet price-competitive to established materials for carrying bags, such as plastic and paper, but at same price point compared to other reusable bags. This is mainly due to the current small production capacity of only 25 tonnes annually which provides for no economies of scale in production. The Paptic® material as such competes with flexible plastic and non-reinforced paper wrapping and bagging materials in a market that is largely cost driven. This market feature entailed a risk that Paptic® would not be sufficiently price competitive and that it could be difficult to succeed in identifying the first client to enter the market with.

The characteristics of the Paptic® material helped the company to mitigate this risk. Paptic® has a higher impact resistance and longevity than plastic or paper bags. This makes Paptic® suitable as a reusable carrying bag. Focusing on these properties, **Paptic managed to identify a niche application, in which customers are willing to pay a higher price for**

Drivers of success

- » Focus on niche market application. Paptic utilized the material's characteristic of longevity to enter the market with an application, in which the reusability of a carrying bag has a marketing effect.
- » Seed investment enabled Paptic to instantly focus on the development of the production technology.
- » Paptic® material can be processed to carrying bags with existing machinery for paper and plastic bags, which reduces the adoption and production costs in its niche application.

the material's reusability. In the case of a carrying bag, a higher re-usability results in strengthened visibility in the public domain of a given print on the bag.

Paptic entered initially into a strategic partnership with a large Finnish paper manufacturer, with whom their respective products were co-developed, as their technologies had some alignments. This partner invested into a large-scale production facility in 2016, which Paptic could have used to further develop and produce the Paptic® material. This partner withdrew however and shut the production plant down when it was not successful with its own applications.

This exit of a partner with the financial capacity to incur the capital expense of establishing a production facility put Paptic in a vulnerable position, as Paptic itself could not mobilise the required financial capacity. The company then decided to out-source the small-scale production to an external manufacturer thereby avoiding the high capital expenditure involved in establishing the production facility.

Paptic reports that it has been negotiating with multiple potential partners since the exit of its previous partner. These negotiations most often fail due to a lack of strategic alignment between Paptic and the larger companies in question.

SWOT ANALYSIS FOR PAPTIC® BAGS

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STRENGTHS

- Flexible feedstock allows valorization of waste streams
- Production of carrying bags from the material can occur on existing paper and plastic bags production machinery
- Properties of bags allow for a niche application
- Patent protected

W

WEAKNESSES

- Lack of skills to find a financial equity partner
- Launch of new packaging materials to existing recycling systems is challenging
- Still in need for further key partner (brand) to go to market with
- Price competitiveness is challenge for scale-up

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OPPORTUNITIES

- Attention from large brands (e.g. H&M & Lego), and collaboration with large brands (e.g. The Body Shop)
- EU funding enables the construction of a commercial-level production facility
- Environmental impacts from plastics is an increasing and global concern

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THREATS

- Market with many old players, as well as many new players that also offer novel materials and features
- High regulatory cost to enter food-packaging certification

FUNDING

Paptic accumulated EUR 1.9 million worth of seed investment during the spin-off from VTT in 2015 and 2016. Finance was also brought in by two venture capitalist firms (public VTT Ventures from Finland and private Proxy Ventures from the United Kingdom), as well as private investors (Besodos Investors and seven other individuals). In return, these investors have gained an ownership stake in the company. Major investors further obtained a seat on Paptic's board. As Paptic states, the board takes an active role in developing the company further through their existing business networks. This enables Paptic to continue the development of the production technology.

Paptic has further secured EUR 2.2 million product-specific funding from the SME Instrument under Horizon 2020 to build its commercial scale production facility. It will become operational in 2018. As a result, the annual production capacity will increase 200-fold to 5,000 tonnes per year via the interim model and finally by end of 2019 to 40,000 tonnes per year.

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TURNOVER AND PROFIT OF PAPTIC OY

	2015	2016	2017
Turnover (EUR 1,000)	0	13	50
Profit (EUR 1,000)	-306	-840	-874

Source: Asiakastieto.fi & Paptic Oy

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The table above shows Paptic's turnover and profits. Paptic has not been profitable as of 2017 and wrote a loss of EUR 874,000 in 2017, owing to extensive product development. The company has however increased the turnover from EUR 13,000 in 2016 to EUR 50,000 in 2017, indicating that Paptic's sales are growing, yet still on a small scale.

MARKET INFORMATION

The total, bio-based and non-bio-based, global flexible packing market is projected to grow from 27.4 million tonnes in 2017 to 33.5 million tonnes in 2022, attaining a global market value of EUR 230 billion. Regarding Paptic's current niche application as a carrying bag, the European bags and sacks production capacity is expected to grow to 8.77 million tonnes until 2024.

Paptic reports that as of spring 2017, several major brands were testing Paptic's® feasibility as a possible new packing material. These tests relate to different possible applications: carrier bags, non-food flex packing, and medical packaging. The potential customers include primarily clothing retail and manufacturing companies, in which shopping bags are widely used. While most companies are anonymous, possible additional customers could be companies such as C&A, H&M, and Lego.

As a producer of bio-based wrapping options Paptic states to face competition from bio-plastics (like PLA, with Natureworks and Corbion as main competitors) and starch-based wrapping (with Novamont as the main competitor). On the domain of carrying bags, Paptic considers Billerud Korsnäs as a potential competitor who produces paper materials with partially similar properties of Paptic®.

REGULATORY ASPECTS

The most recent amendment of the packaging and packaging waste directive, Directive (EU) 2015/720 as regards a reduction of the consumption of lightweight plastic carrier bags, pursues the objective to reduce the consumption of lightweight plastic bags. While it does not promote bio-based carrying bags as such, it requires Member States to curb the use of lightweight plastic carrier bags, which can make Paptic® bags a more favourable alternative.

Paptic® can also be used for food wrapping, but it is currently only approved for contact with dry foods. Paptic® material does not yet have a sufficient water vapour barrier to be feasible for general food packaging applications. Paptic purposely de-selected food wrapping at this stage as it entails a more strictly approval process. This in turn requires more intensive product development to ensure regulatory compliance.

TECHNOLOGY INFORMATION

Paptic® is available on the market, but is so far only on a small scale. The **Technology Readiness Level (TRL) is 9** (actual system proven in operational environment).

The main feedstock is the cellulose obtained from wood pulp. This accounts for 80 %–95 % of the raw material inputs, depending on the desired properties (e.g. is the material converted by paper or plastic machines). The remaining secondary raw materials are cellulosic fibres, viscose, or polylactic acid (PLA), depending again on the desired properties.

While the product aims to replace plastic bags, and has similar properties as conventional plastic wrapping, it can also take on the properties of paper. According to Paptic®, the material stretches up to 20 %, compared to 5–7 % in typical packaging papers. Combined with a higher durability against water and tear than paper, Paptic® has a 4–6 times higher tear resistance than typical paper used in packing applications.

In the application as a carrying bag, the conversion of the Paptic® material to bags can occur with existing paper and plastic bag converters. From the production angle, the transition to Paptic® only demands an investment into the Paptic® material and not into new bag converter lines. This significantly reduces the adoption costs.



ENVIRONMENTAL IMPACT

Paptic's feedstock is bleached softwood pulp from PEFC and/or FSC certified, primarily from Finnish, forests. **Paptic® can be recycled with mixed paper streams, and where available with cardboard.** This means that consumers can recycle Paptic® bags as cardboard, even if it has the properties of a plastic bag.

Paptic conducts internal LCA assessments and has compared the global warming potential (GWP) with Kraft Paper (i.e. paper made from chemical pulp) and Low Density Polyethylene bags (LDPE), also known as 'bags-for-life' (see below). Paptic® has a GWP interval that is partially higher than Kraft Paper, and may thus be less climate friendly today, depending on the product recipe and production scale. By 2020, however, this interval is expected to completely undercut Kraft Paper, as a result of the expected gains in production efficiency (e.g. lower grammage of the material) and growth in production scale. The comparison excludes lightweight plastic bags made of High Density Polyethylene (HDPE), which tend to exhibit the lowest GWP of carrying bags. Yet, they are not as suitable for reuse as Paptic® carrying bags.

GWP OF DIFFERENT MATERIALS (PAPTIC ANALYSIS)

Material	Kraft Paper	LDPE, 10 % recycled	Paptic 2017	Paptic 2020
GWP (CO ₂ eq/kg)	1.54	2.56	1.18–1.72	1.09–1.41

Source: Paptic Oy

THE WAY FORWARD

Paptic plans to put its first commercial production facility into operation by the third quarter of 2018. This will increase the capacity by a factor of nearly 200 to 5,000 tonnes per year. This is in turn projected to generate significant economies of scale for Paptic®, making the product in effect more price competitive. As a result of this development, Paptic anticipates to grow to 30 employees by 2018 and break even by 2020. Paptic has further announced that it will increase its production to 40,000 tonnes per year by the end of 2019, paving the way for a future large-scale production.

Paptic continues its efforts to find a new partner and obtain additional equity funds. Paptic has hired an external financial investment advisor (MCF) to improve its financing opportunities and raise more equity funds. The equity is intended to be used to maximise the potential financial leverage to use debt financing from e.g. the EIB. As of March 2018, Paptic was in negotiations with three EU based specialty paper manufacturers for potential strategic partnerships, which indicates that Paptic can be a new player on the paper market that offers an interesting business opportunity for companies in the paper and cardboard market.

Paptic continues to develop the next generation of the feedstock, with recycled textile fibers as a possible feedstock. In addition, Paptic pursues the target to increase the bio-based content from 80–95 % to 100 %.

Abilar® by Repolar Pharmaceuticals Oy

PRODUCT NAME

Abilar®

PRODUCT DESCRIPTION

Wound care product

FEEDSTOCK

Resin from Norway spruce (picea abies)

ORGANISATION

Repolar Pharmaceuticals Oy
(limited company)

EMPLOYEES

6 + 3 owners contributing to the R&D

COUNTRY

Finland

R&D START

2000

MARKET ENTRY DATE

2008

PRODUCTION CAPACITY

20,000 tubes/month

PRODUCTION VOLUME

5,000 tubes/month

SALES (GLOBAL)

EUR 0.5 million (2016)

INVESTMENT

Not disclosed

PRICE

Comparable to conventional wound ointments: ~ EUR 1.20 per day of treatment

EARNINGS

Positive at product and company level in most years

CHARACTERISTICS

- Effective (scientifically proven) wound treatment
- Bio-based active ingredient
- Patent protected
- Trademarked (2010, the EU)
- ISO13485:2003 certified

Wound ointment based on spruce resin solution



PRODUCT

Abilar® 10 % Resin Salve is an ointment for treating wounds and burns, in particular hard-to-heal wounds. The active ingredient is a refined resin obtained from the Norway spruce, collected in the Finnish Lapland. The refined spruce resin is mixed with a salve base to produce the Abilar® ointment. The share of the active ingredient is 10 %, which has been found to be sufficient for the antimicrobial and anti-inflammatory effect required. The product is used in home care, as well as by health-care professionals.

SUCCESS

The concept was developed in the 2000s, and supporting research conducted by a small team of scientists and doctors. They founded Repolar in 2006, using own funds and in-kind contributions to develop an ointment based on the resin solution. The commercial production of Abilar® started in 2008, and has reached a stable level of sales over the following years. The product has been profitable over the last four years, and the profits are reinvested into market expansion.

PROSPECTS

Abilar® has reached a stable level of sales in Finland. The company aims to grow Abilar® in other markets. This is expected to lower relative production costs, due to economies of scale. An important step in this strategy is the inclusion of Abilar® into the UK National Health Service (NHS) list of reimbursable medical appliances. The demand is expected to be driven primarily by proven performance, encouraging use by health-care professionals. In addition, growing consumer consciousness about health and environmental effects of competing products plays a role.

HISTORY

Research behind the development of Abilar® ointment started in 2000, when one of the founders of the company started to work as a medical doctor in Lapland. He became interested in the local practice of using the Norway spruce resin for wound healing. Together with family and colleagues at the Helsinki University Central Hospital, he formed an R&D team to study the pharmaceutical properties of the resin. This research provided the clinical proof necessary to show that a solution made from the Norway spruce resin has antimicrobial and anti-inflammatory properties and is safe to use.

Repolar was founded in 2006 to produce and market resin-based products. The first two products were launched in 2008, one of which was Abilar®. During the course of 2007 to 2015, the founders published various research studies in medical journals to illustrate the science behind the resin. They conducted clinical trials and studies to show the practical effectiveness.

Consumer skepticism was seen as a potential risk. To counteract this, Repolar aimed to demonstrate good clinical performance and document it in a number of formats (cases, journal articles). In addition, Repolar was able to gain media attention at the time of publishing the final R&D study, spurring demand in Finland. The link of the product with local Finnish practice has also contributed to initial consumer and media attention.

The production costs of Abilar®, in particular fixed costs, are relatively high, limiting potential margins. Upscaling production would generate economies of scale, and hence render the product more competitive. However, the Finnish market is small leaving little room for this. Thus, the company started activities to expand into other markets and thereby increase its market.

Drivers of success

- » Abilar® has a unique market niche in which it exhibits positive results on difficult to heal wounds, at the same time being natural and safe
- » Proven performance and applicability to a wide range of ailments which leads health care professionals to use it regularly
- » A dedicated owner group composed of specialists willing to provide in-kind contributions and reinvest profits into the development of the company
- » Cultural factors: the product is based on a local Finnish practice. In particular at initial stages, this helped gain attention in the Finnish media and market

Staff specialised in marketing, sales and quality control were hired to lead these activities, complementing the skills of the owners who are scientists and doctors.

Abilar® entered its first market abroad in 2013 and is now available in five EU Member States (Austria, Belgium, Greece, Sweden, and the UK). The product accounts for about half of Repolar's total annual turnover.

FUNDING

Repolar has been profitable since 2013. On its way to profitability, the company did not bring in external investors. The original network of owners wanted to retain full ownership of the company. The company obtained funds primarily from its sales and in-kind contributions by the owners. The re-investment has been particularly high in 2014 and 2015. This was used to expand office space, purchase IT equipment, and invest in marketing and quality control.

The move from the development to the production stage required little investment. Repolar collects and refines the resin in-house, and has outsourced the mixing of the active

SWOT ANALYSIS FOR ABILAR®

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STRENGTHS

- Willingness to provide in-kind contribution which drove the initial phase
- Well-documented high performance
- Patent protected
- Wide application potential
- Minimal/no side effects

W

WEAKNESSES

- Capacity/capability to expand market
- No investor on board that could provide additional equity in case of unforeseen challenges (e.g. regulatory reclassification)
- Limited internal capacity to develop novel applications

O

OPPORTUNITIES

- "Natural" health features are demanded by consumers
- National support schemes facilitates research for future applications
- Network of possible partners to build future applications

T

THREATS

- Competition with large pharmaceutical companies
- Requirement for regulatory reclassification to higher risk category (leading to costs)
- Likely to remain a niche product

TURNOVER AND PROFITS OF REPOLAR, AND APPROXIMATE SHARE OF ABILAR®

	2013	2014	2015	2016
Turnover (EUR 1,000)	1,024	928	853	956
Approx. Abilar® share	512	464	427	478
Net profit (EUR 1,000)	355	0	-1	88
Approx. Abilar® share	178	0	-0.5	44

Source: asiakastieto.fi and company estimates

ingredient with the salve base, as well as the packaging. Repolar did not incur high capital expenses for the production machinery or the production of the salve base. In terms of conformity with regulations, Abilar® is registered as a medical device and only the proof of safe use is required to market it.

The company has taken part in several projects funded by Tekes, the Finnish Funding Agency for Innovation. Most recently, it has participated in a study of the anti-inflammatory properties of resin (2015–18) and XBoost market study and expansion project (2016–18).

MARKET INFORMATION

Abilar® competes primarily with silver-based and honey ointments and dressings used for wound healing. It is particularly suited for hard-to-heal wounds (e.g. diabetic ulcers, burns). It is sold in most Finnish pharmacies, and has reached consistent sales levels in its home market. The company has launched the product into foreign markets.

One important milestone in this respect is that the UK National Health Service (NHS) has included Abilar® into the approved appliances list for reimbursement.

In addition, an independent comparison of wound healing products by the NHS has concluded that Abilar® 10 % resin salve is effective in wound treatment, compared to alternatives.¹⁹

Based on these successes, the company expects to grow sales in the existing foreign markets, as well as enter new ones. It continues to conduct clinical studies to continue building international trust.

In terms of pricing, treatment with Abilar® was shown to take an average of 43 days, with a mean cost of EUR 1.2 per day. No comparative study has been conducted to show the costs of treatment with Abilar® compared to competing products. Direct comparison of unit costs is not appropriate, since length of treatment and amounts used differ.

REGULATORY ASPECTS

Abilar® is subject to the European Medical Device Directive (93/42/EEC), which classifies medical products in the European Union, ranging from class I (low risk) to class III (high risk). The categorisation depends on length of contact, the level of invasiveness and body part affected. The classification is made according to the claim of purpose stated by the manufacturer. Abilar® is categorised as class IIb, since it aims to actively heal wounds. For this category, the proof required to maintain the licence to sell is the documentation of safe use. Registering the same product as a pharmaceutical would have led to significantly higher cost, as the burden of proof and required dimension of clinical trials is higher.

Similarly, if the classification of Abilar® 10 % resin salve was changed to class III, this would require a significant financial investment. In that case, the marketing of Abilar® would require explicit authorisation rather than inspection. The company has met some pressure from authorities to change the classification to class III, based on the interpretation of the intended purpose of the product. This change would however be very financially demanding. Therefore, the company aims to maintain the description of the product purpose modest, in order to keep Abilar® at class IIb.

TECHNOLOGY INFORMATION

The product is manufactured on a commercial scale and is available in multiple EU Member States. It has been on the Finnish market since 2008. The product is therefore at the **Technology Readiness Level (TRL) 9** (actual system proven in operational environment).

The product is used in home care or by medical professionals to speed up wound healing and limit the growth of bacteria and fungi in the wound area. It is effective in a variety of external applications where anti-bacterial and wound healing properties are needed, such as traumatic wounds, surgical wounds, ulcers, burn injuries, and bacterial, or fungal infections.

The active ingredient of Abilar®, Norway spruce resin, is bio-based. This constitutes 10 % of the product. This level has been found to be sufficient for the antimicrobial and anti-inflammatory effect required. Ten freelance collectors are contracted by Repolar. They collect the resin in Finnish Lapland forests. The resin is then refined and a solution prepared by Repolar. This occurs in a small production facility in Kolari, Lapland. Two external partners are contracted to mix the solution with the salve base to prepare the ointment. For this step, the active ingredient is shipped to southern Finland and Greece for mixing and packing. The salve base used as carrying agent is largely non-bio-based.

¹⁹ Whitehead, Dawn, 2017, Case Study: Abilar® 10 % Resin Salve in Unresponsive Diabetic Foot Wound

According to World Intellectual Property Organisation database, Repolar has eight patents related to applications of the Norway Spruce resin.



ENVIRONMENTAL IMPACT

Repolar has not conducted an LCA on the production of Abilar®. According to the company, the collection of the active ingredient has almost no negative environmental impact. The resin is collected from naturally damaged trees in Finnish forests and does not involve harvesting nor harming the trees. The collection only marginally impacts the trees and keeps all ecosystem services intact.

This resin collection method is sufficient for Repolar's current production level. According to the company, production could be increased by a factor of 10 using the same method. This would be done by expanding collection in Finnish forests into neighbouring countries, such as Sweden and Russia. Repolar has nevertheless invested in a forest patch, in which the company researches the feasibility of resin production on a larger scale.

The competing products are ointments and dressings based on silver, medical honey, iodine or protease inhibitor dressings. Direct comparison of environmental impacts with competing products is challenging. While for dressings the production process is different, ointments may contain a multitude of different ingredients aside from the active agent.

THE WAY FORWARD

R&D is at the centre of the company's activities, and predates the company itself. Repolar is continuously working on increasing the clinical trial base of existing products, including Abilar®.

Abilar® has achieved consistent sales in the Finnish market. To benefit from economies of scale and reduce the currently high relative fixed costs, the company is expanding its markets elsewhere. This includes aiming to scale up sales in existing EU markets, as well as enter new ones, both inside and outside the EU.

The company expects to increase its production. Looking forward, it is exploring new ways to obtain the required active ingredient.

The anti-microbial properties of spruce resin allow a wide application potential. Thus, there is potential to develop more products and applications. Examples include resin solutions in animal feed to reduce the need for antibiotics, as ingredient in surface cleaning products due to antiseptic properties, and in cosmetics, to replace toxic substances. These applications require expertise outside of the core area of the company (e.g. animal feed, cleaning products, cosmetics). Thus, the Repolar team is working with different partners to develop these applications. For example, in partnership with Suominen Oy, Repolar is studying the possibilities to produce nonwoven fabrics (e.g. wipes) with antimicrobial properties.

By 2020, the company aims to reach the levels of earnings where they can start paying dividends to investors and/or salaries to the owners who currently provide their work in-kind.

BioLite™ by Triflon AB

PRODUCT NAME

BioLite™

PRODUCT DESCRIPTION

Natural fibre reinforced polypropylene

FEEDSTOCK

Industrial hemp fibres

ORGANISATION

Triflon AB

EMPLOYEES

8 employees (2018)

COUNTRY

Sweden

R&D START

2015

MARKET ENTRY DATE

2017

PRODUCTION CAPACITY

Pilot-scale plant (current): 400 tonnes/year (EU)

Commercial plant (planned): 4,000 tonnes/year (EU) (2018); 20,000 tonnes/year (EU) (2022)

PRODUCTION VOLUME

100 % of the current plant capacity

SALES (GLOBAL)

EUR < 0.5 million

INVESTMENT

EUR 1.5 million

PRICE

EUR 1.6–2.5/kg

EARNINGS

Break-even is expected in 1 year i.e. 2019

CHARACTERISTICS

- 30 % or 10 % bio-based
- Low carbon footprint
- Non-toxic
- Recyclable
- 10–25 % lighter than competing compounds
- 30 % stiffer than other mineral filled copolymers

A path toward lightweight sustainable plastics



PRODUCT

BioLite™ is a hemp fibre reinforced heterophasic copolymer designed for injection moulding. BioLite™ combines natural fibres from industrial hemp with polymers to create sustainable bio-composites. BioLite™ combines **lightweight** and good **mechanical properties** such as high stiffness, good impact resistance and low abrasion that meet the requirements for many products. BioLite™ is used in a **variety of applications** such as automotive components, home and garden goods, consumer products and luggage. BioLite™ is currently available in two forms AP21 (**10 % bio-based** – natural fibres – and 90 % polymers) and AP23 (**30 % bio-based** – natural fibres – and 70 % polymers). Currently, Triflon AB is testing new grades of BioLite™ that will be launched by end of May 2018.

SUCCESS

Triflon AB has developed a **lightweight, price-competitive green alternative** to mineral filled and glass fiber reinforced composites with good **mechanical properties** and **very low moisture absorption** that allows it to be used in demanding environments. Triflon AB successfully managed to overcome initial risks and challenges related to the novelty of the technology and **leverage private and public national capital investments** for the initial R&D and for the establishment of a pilot plant in Sweden. Currently, Triflon AB has succeeded in attracting **44 shareholders**. Triflon AB expects to turn profitable by mid-2019 as a result of an increasing pipeline of customers and anticipated increased production capacity.

PROSPECTS

The commercial potential of the product is high. The market regards the product positively as a result of its properties and bio-content. The price of BioLite™ is higher than conventional competing composites, produced from oil based plastics and glass fibre / mineral reinforcement, but lower than bio-based polymers. The product offers high-performance mechanical properties and is **10–25 % lighter** than conventional composites. Given the various applications of BioLite™, the product has good **potential on various end-markets** (including automotive, industrial and consumer goods and home furnishings) **as well as geographical markets** (e.g. China). In expanding to new markets, Triflon AB focuses on **completing performance trials for new applications** that are estimated to have a time-to-market of 1–3 years and on **signing agreements with large customers**.

HISTORY

Trifilon AB was founded in 2012 as a spin-off from research conducted by the founders of Trifilon AB with Linköping University. The focus of Trifilon AB was to develop **natural fibre reinforced composites** as an alternative to carbon composites for the aerospace industry. Today, the company produces a range of bio-composites.

BioLite™ is a natural fibre reinforced polypropylene that was developed in 2015 through a strategic collaboration with Plastal (one of Scandinavia's largest manufacturers of plastics parts for the automotive sector). The aim of this collaboration was to develop a lightweight, robust material that could be used in serial, high volume components for the automotive industry.

In 2016, BioLite™ passed all the tests of its collaboration partner Plastal, which resulted in BioLite™ being presented to key Plastal clients as a new lightweight material for serial production. In 2016, Trifilon AB was ranked by Cleantech Scandinavia Nordic among the ten most promising Nordic energy and green-tech start-ups.

A major break-through in terms of market access was the signature of a five-year exclusivity deal with EPIC Travelgear, a luggage manufacturer for the production of the luggage EPIC PhantomBIO.

Drivers of success

- » Joint venture with Plastal Sverige AB to develop a new light-weight bio-composite for use in exterior auto applications;
- » Trifilon AB's capacity to leverage effectively internal and external funding and to utilize the financial support for R&D and commercialisation;
- » High commercial potential owing to the lightweight and mechanical properties of BioLite™;
- » Price competitiveness in comparison to traditional competing materials and bio-based plastics;
- » Proximity and availability of feedstock.

Currently, BioLite™ can be used for a variety of applications and is commercialised in two classes: BioLite™ AP21 and BioLite™ AP23. **BioLite™ AP21** is suited to high impact applications like automotive panelling, home and garden goods, consumer products and luggage. **BioLite™ AP23** was designed for applications where stiffness was critical like brackets, vacuum components and industrial parts.

Trifilon AB has **8 full-time employees**, the majority of which are directly involved in the manufacturing process of the product. In addition to in-house staff, the company relies on the support of 10 additional consultants that provide ad-hoc support, including accounting, PR marketing and other business-related services. BioLite™ is currently produced at Trifilon AB's **pilot plant** in Nyköping, Sweden, which has a production capacity of 400 tonnes/year.

SWOT ANALYSIS FOR BIOLITE™

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STRENGTHS

- Ability to attract private financing for R&D and commercialisation
- Joint venture with Plastal
- Feedstock flexibility
- Access to low-cost feedstock
- Low switching costs (no special equipment needed)
- Lightweight plus good mechanical properties
- High level of technical knowledge
- Based in Sweden (culture of cooperation between companies, large OEM's with global reach, sustainability in focus)

W

WEAKNESSES

- Challenges in scaling up due to high initial investments
- Piloting and testing processes are time-consuming and costly
- Relatively small organization in comparison to other plastic manufacturers
- No patents

O

OPPORTUNITIES

- Market preferences – mainstreaming of sustainability demands (SDG)
- Market pull, especially from automotive segment, for lightweight materials
- Push to scale up electric vehicles, means more focus on lightweight materials
- Local flax fibres offer improved costs and sustainability
- Modularization of production for foreign production cells

T

THREATS

- High regulatory costs for testing and licensing
- The bio-based feature may not be sufficient to justify the 'high price' but once scaled up the costs will be reduced
- Low cost carbon fiber solution becomes commercially available
- Nano-carbon and nanocellulose become economically viable

In 2017, the turnover of the company was approximately EUR 68,000 but Trifilon AB expects a 10 fold increase in turnover in 2018 (i.e. EUR 680,000). Trifilon AB envisages an **increase in production capacity** to +4,000 tonnes/year by end of 2018, respectively 20,000 tonnes/year by 2022. As a result of increased capacity and economies of scale, the company expects to break-even in 2019.

Trifilon AB successfully overcame so far the initial risks related to the novelty of the technology and the difficulties in securing investments for the up-scaling of production. Some challenges remain as the profitability of the company remains low. However, the prospects are positive as Trifilon AB has low debt and has plans to increase capacity in Scandinavia (for the time being) and expects to turn profitable in 2019. According to the company, the increase in capacity is a key factor in providing for economies of scale and, hence, for an improved price competitiveness.

The business vision of Trifilon AB for the development of BioLite™ focuses on replacing customers' conventional plastics with a lighter, stronger, greener alternative.

FUNDING

The seed financing for R&D and commercialisation of BioLite™ came primarily from **private capital** (equity, loans) complemented with **internal resources**.

The initial investments in Trifilon AB came from its founders, as well as support from the local development bank Almi amounting to EUR 50,000. In 2015, Trifilon AB welcomed **new joint owners**, with the major investor being Ericsson Capital from Åland Islands.

At the end of 2017, Trifilon AB estimated that the upscaling and commercialisation of BioLite™ would require additional investments of EUR 1 million. In the last round of investments at the end of 2017, 30 additional investors joined (consisting of a mix of venture capital and angel investors), raising the number of shareholders to 44. The last investment round brought in EUR 1 million in external share capital. Overall, as of 2018, Trifilon raised a total of EUR 1.5 million to finance its activities.

The company estimates that with an additional EUR 4 million, it would be able to construct a full scale commercial plant.

MARKET INFORMATION

BioLite™ is currently focusing on three key market sectors, i.e. the automotive and transportation sector, industrial and consumer goods, and home furnishings. BioLite™ is providing a **substitute material for common plastics** used in these markets, e.g. polypropylene (PP).

In 2016, 335 million tonnes of plastic have been produced worldwide and around 60 million tonnes of plastic has been produced in the EU. Currently, bioplastics represent approximately 1 % of the total annual plastic production.

Polypropylene plastic accounted for 19.3 % of the EU plastics' demand, in 2016. The PP market has grown by almost 10 % in the past 5 years. Forecasts show that in the following 5 years the demand for PP is expected to remain high. In the past few years, the share of PP in the automotive sector has increased as a result of reduced costs associated with the material. In the automotive sector, PP is used to produce lightweight components but BioLite™ offers an alternative to this.

BioLite™ has a higher price than conventional competing composites but lower than bio-based polymers produced by a major competitor. The company is aiming at lowering the costs of the product by upscaling production and benefitting from economies of scale.

REGULATORY ASPECTS

The evolution of the European and national **regulatory framework indirectly supports the development and commercialisation of BioLite™**. At both EU and national level, the push for more rigorous requirements for products concerning their sustainability has provided a stimulus for demand for BioLite™.

However, the commercialization of BioLite™ on new markets (e.g. food market) is **challenged** by the existing **regulatory framework on materials that come into contact with food products**. The EU list for approved materials for food packaging at EU level (Regulation EU No 10/2011) currently contains only one natural fibre material that is approved, i.e. cellulose. According to the company, new materials such as BioLite™ have to pass through costly and complex procedures and testing to be approved for use in contact with food.

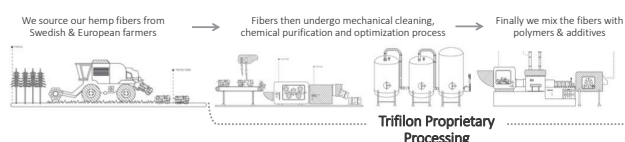
TECHNOLOGY INFORMATION

BioLite™ combines **natural fibres from industrial hemp with polypropylene** to create a bio-composite that has properties similar to conventional composites. The feedstock used for BioLite™ comes from several locations in Europe (Romania, Netherlands, Latvia). For the production of 1 kg of BioLite™, approximately 0.3 kg of hemp fibre is required. Other possible future feedstocks for the product include flax fibres.

To manufacture BioLite™, Trifilon AB processes raw hemp fibres both mechanically and chemically to ensure that an optimal bond between the polymer and the natural fibres.



ILLUSTRATION OF THE PRODUCTION STAGES OF BIOLITE™



The primary state of BioLite™ is in **granulate form**. BioLite™ AP21 contains 10 % natural fibres and 90 % polypropylene and BioLite™ AP23 contains 30 % natural fibres and 70 % polypropylene. The difference between the two is in terms of bio-content and stiffness. Still, both products can be used in injection moulding using conventional equipment.

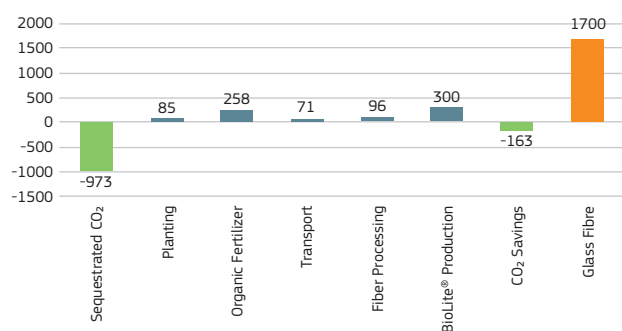
The **Technological Readiness Level (TRL) is 8–9** (i.e. although the product is on the market it is not yet at a fully commercial level). BioLite™ is not protected by patents due to the costly and time-consuming processes associated with patenting.

ENVIRONMENTAL IMPACT

Feedstock sustainability: BioLite™ is produced with different contents of renewable feedstock (10 % or 30 % of the content). The feedstock currently used for BioLite™ is derived from natural fibres from industrial hemp. However, Triflon AB is also looking into local flax fibre from the production of flax oil which is currently not utilised in any production processes. Hemp is a rapidly growing plant that **sequesters more than its weight in carbon dioxide**. Additionally, as a very fast growing plant, industrial hemp does not require pesticides or herbicides, meaning it has a very low environmental impact during its production. According to the company, as the feedstock is grown as a rotational crop, the European industrial hemp that Triflon AB utilises **does not compete with food crops**.

Low carbon footprint: Overall, the production of BioLite™ has a net CO₂ saving of 163 kg CO₂/tonne compared the production of glass fibre which results in a CO₂ burden of 1,700 kg CO₂/tonne. The low carbon footprint is primarily the result of the use of a feedstock that has a high carbon capture potential.

CO₂ FOOTPRINT OF 1 TONNE HEMP FIBRE VS 1 TONNE GLASS FIBRE



Source: Internal LCA Triflon AB

THE WAY FORWARD

The overall outlook for BioLite™ is **positive**. BioLite™ can be used a substitute to common plastic, e.g. PP. Thus, BioLite™ has a wide range of applications across a number of markets (e.g. automotive market, consumer goods etc.) being a building block material in automotive parts, caps and closures and consumer goods such as luggage and sporting goods. Given the global nature of plastic, BioLite™ has potential in geographical markets outside of Europe (e.g. in China, USA, etc.). In driving its expansion to new markets, Triflon AB is focused on supplying existing Scandinavian customers that have operations in foreign markets and closing new partnerships with producers.

In terms of financial outlook, Triflon AB is currently trying to increase the profitability of BioLite™ by scaling up production. In the medium term, the main barrier is the issue related to increasing production capacity. Triflon AB estimates that the cost of scaling up production and the construction of a commercial size plant that would enable the company to deliver lower unit costs would be of approximately EUR 4 million. Triflon AB envisages an increase in production capacity to +4,000 tonnes/year by end of 2018, respectively 20,000 tonnes/year by 2022. As a result of increased capacity and economies of scale, the company expects to break-even in 2019. The demand for BioLite™ is also expected to increase gradually, in particular in the automotive industry, as a result of the increasing demand for materials that have high resistance, lightweight and have an increased bio-content.

ICCP technology by BioBTX B.V.

PRODUCT NAME

Integrated Cascading Catalytic Pyrolysis (ICCP) technology

PRODUCT DESCRIPTION

Technology for the production of aromatic compounds BTX from biomass

FEEDSTOCK

Variety of solid and liquid biomass feedstocks, e.g. wood pulp lignin residues, used cooking oil

ORGANISATION

BioBTX B.V.

EMPLOYEES

4 direct employees and 5 researchers at University institutes

COUNTRY

The Netherlands

R&D START

2009 (fundamental research); 2012 (proof of concept)

MARKET ENTRY DATE

ICCP patent filed in 2014, published in 2017; Bio-BTX produced with ICCP to enter the market in June 2018

PRODUCTION CAPACITY

ICCP-based pilot plant of 40 tonnes bio-BTX /year underway (EU)

PRODUCTION VOLUME

60 kg of bio-BTX produced in laboratory; ICCP-based pilot plant production to start in June 2018

SALES (GLOBAL)

Expected future company sales from licenses and services in the order of several million EUR per year

INVESTMENT

Total EUR 3.5 million committed from private and public investors; Small scale demonstration plant (next phase) investment EUR 20–40 million

PRICE

Resulting bio-based BTX competitive with fossil-based BTX at approximately EUR 670 per tonne

EARNINGS

Expects to break-even in 2025

CHARACTERISTICS

- Process results in 100 % bio-based product
- Patent protected process
- High degree of feedstock flexibility

Technology for the production of BTX aromatics from biomass



PRODUCT

The Integrated Cascading Catalytic Pyrolysis (ICCP) technology has been developed by BioBTX B.V. for the production of aromatic compounds benzene, toluene and xylene (BTX) from biomass. The resulting product is a **100 % bio-based, 'drop-in' alternative** to conventional fossil fuel-based BTX produced as a by-product in oil refineries. BTX compounds are used as building blocks for downstream products of the petrochemical industry, and in particular the manufacturing of polymers such as PET and other plastics. BioBTX B.V. is a technology provider, and their business model is based on licensing the technology and providing associated services to companies seeking to produce bio-based BTX.

SUCCESS

BioBTX is among the first-movers to offer a viable technology to produce BTX from biomass. The value proposition of the ICCP technology is the **decoupling of these widely used chemicals from fossil sources**. In accomplishing this, it will contribute to a more sustainable chemicals and plastics industry. A key milestone was achieved in 2017, when BioBTX B.V. succeeded in attracting private finance from an investment fund to support the scaling up the technology and enhance the professional structure of the company. A pilot plant employing ICCP – co-financed by the European Regional Development Fund – is set to be operational in June 2018.

PROSPECTS

The prospects for bio-BTX and the ICCP technology are positive. There is high and growing demand for BTX-based plastics, and at the same time consumers and brand owners increasingly demand lower-carbon substitutes for the manufacture of their products. The availability of fossil-BTX in Europe is becoming increasingly scarce, owing to a gradual decline in demand for the primary products produced in oil refineries, where fossil-BTX is produced as a by-product. Trends toward transport electrification and higher fuel efficiency standards will likely drive petrochemical companies to search for alternative sources for BTX and associated ways of production.

HISTORY

In 2013, BioBTX B.V. was founded as a joint venture between KNN Groep and Syncom B.V. Building upon past R&D, they successfully developed and patented the Integrated Cascading Catalytic Pyrolysis (ICCP) technology by 2014. The technology produces mixtures of aromatic compounds – benzene, toluene and xylene (BTX) – from a **wide range of biomass feedstocks** (for example, crude glycerine, black liquor, wood pulp lignin residues, crude vegetable oils and fats, agricultural waste streams), as well as from end-of-life materials. Initial R&D was conducted, and continues, in partnership with the University of Groningen.

The ICCP technology is based on a two-step pyrolysis process. It protects catalysts from minerals abundant in biomass, a technical advantage over single-stage pyrolysis. BTX's main applications are in **high performance**, and **high volume polymers** such as PET, PBAT, other polyesters, aramid, PUR, ABS, epoxy resins, polycarbonate and nylon.

BioBTX's business model is licensing the ICCP technology to chemical and other companies. This model reduces capital requirements and is intended for rapid-scale up. However, without an operating plant and concrete examples of applications, it has been difficult to onboard customers and investors. As a solution, in 2016, BioBTX collaborated with **partners across the value chain** to demonstrate the technology. They converted crude glycerine, a by-product of the production of biodiesel, into bio-BTX to construct a 100 % bio-based PET cosmetics container. This tangible, high quality end-product facilitated a better understanding of their technology by investors, partners and potential customers.

Drivers of success

- » Patents on core and downstream technologies; an iterative technology development approach; catalyst and engineering expertise
- » Capitalising on diverse funding sources and early phase generation of revenues from research consultancy services
- » Light and flexible company structure allowing for fast decision-making processes, and encompassing a small, highly-skilled in-house team, encircled by strong local partners from the University of Groningen and companies along the value chain
- » Ongoing and upcoming regulatory changes and megatrends, such as the electrification of transport that changes the availability of petrochemicals especially in the EU, a political focus on circular economy in the EU, and the re-use and valorisation of waste streams

An important milestone was reached in early 2017, when Carduso Capital, among others, invested in BioBTX to enable expansion. By June 2018, BioBTX plans to complete construction of a 10 kg feed/hour (=~40 tonnes/year) pilot plant in the Netherlands as a further demonstration. Future plans include construction of a larger demonstration factory, producing 30–70 kilotonnes of bio-BTX per year.

In the long-term, the company strategy builds on the assumption that oil refining activities – through which fossil-based BTX is produced as by-product – will decline. This would make it a priority for the European and global petrochemical industry to find alternative ways to produce BTX. In the shorter-term, many petrochemical processes are moving out of Europe and closer to extraction operations. Bio-based BTX produced in the EU would reduce the EU's dependence on oil refining.

SWOT ANALYSIS FOR BIOBTX ICCP TECHNOLOGY

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STRENGTHS

- Patented, more efficient technology
- Licensing business model is very flexible
- Bio-based BTX applicable in over 99 % of all fossil-based BTX applications
- Vast feedstock potential
- Price competitive with fossil-based BTX under normal conditions

W

WEAKNESSES

- Onboarding investors more difficult without production facility
- Early stage of development
- Reliance on side consulting may delay BioBTX progress
- External certification of environmental benefits can be a costly and lengthy procedure

O

OPPORTUNITIES

- Lower-carbon footprint enables production of „greener“ final products in many sectors
- Reduced petroleum production automatically reduces supply of feedstock for fossil-based products (result: increasing prices)
- Provide EU-based oil and gas petrochemical producers with bio-based alternatives

T

THREATS

- Competition with established companies who do R&D on the topic
- Low oil and gas prices
- Lagging EU (and worldwide) regulations on lower product carbon footprints

FUNDING

KNN Groep, Syncom B.V. and the University of Groningen provided initial funding for the R&D cooperation in ICCP, which started in 2012. Resources provided included direct funds, staff, and facility resources. The founding of BioBTX B.V. in 2013 was funded by KNN and Syncom, and at later stage by Flohr Beheer B.V., a private investor.

By 2014–2015, BioBTX B.V. required new funding to continue R&D, technology promotion, and outreach to potential partners and investors. As a solution, in-house staff carried out side-research for various clients. This included research for a US-based chemical company Huntsman, also resulting in an ICCP-based patent for the conversion of black liquor. This **side-research bridged the financial gap** while the company built trust and gained visibility with potential customers and partners, thus preparing the ground for eventual investors.

In February 2017, the company **onboarded the investment fund** Carduso Capital who provided an initial investment of EUR 0.8 million against a 35 % ownership share. These funds allowed the continued technology scale up and recruitment of a new CEO and a Chemical Engineer.

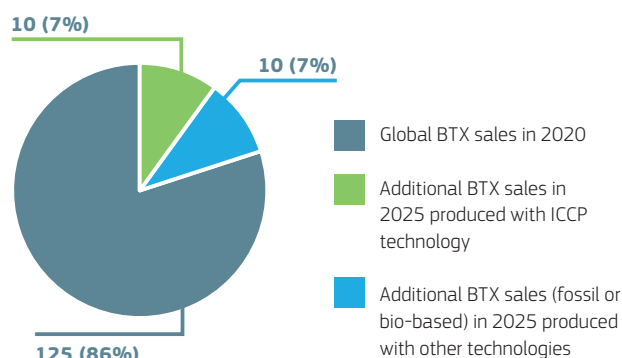
BioBTX B.V. has also **benefited from EU funds**. In particular, the establishment of the EUR 0.6 million pilot plant was partly financed by the European Regional Development Fund: the total EU support amounted to EUR 0.4 million, of which about EUR 0.2 million benefit BioBTX directly.

At present, BioBTX has achieved a total of EUR 3.5 million finance committed from private and public shareholders and investors.

MARKET INFORMATION

The company's rather early stage and small scale production is not significant compared to the fossil-based BTX aromatics market. The company sees this changing with the completion of the pilot plant and the subsequent **sales of technology**

ESTIMATED GLOBAL BTX SALES IN 2020 AND 2025 (MILLION TONNES)



Source: Company estimates

licenses. As prices vary regionally and by aromatic, prices for ICCP-based BTX can compete with fossil-based BTX when average prices for the latter hover around EUR 670 per tonne.

Worldwide, the production of BTX is over 100 million tonnes per year. This market is expected to grow by 4 million tonnes each year. Some studies estimate that the total market (fossil- and bio-based) may reach **125 million tonnes per year by 2020**. This increasing demand provides good prospects for bio-based BTX, and BioBTX B.V. expects their technology to fulfil about half the expected demand growth in the medium-term.

BioBTX's potential customer base ranges widely. They focus on licenses and on providing companies with feed- and product-specific contract research. They adapt their technology to current processes. As such, they will adapt their technology on-site to convert various feedstock types and produce the desired BTX to be used for making high performance/volume polymers that will later be used in final products. These final products range from food packaging and insulation to solvents, wire, foam, hoses, and pharmaceutical intermediaries.

REGULATORY ASPECTS

The bio-based BTX market in the EU, and beyond, is both limited and enabled by regulatory aspects related to energy, greenhouse gas emissions, and agriculture.

On the one hand, regulations aiming to decrease fossil fuel combustion provide an enabling environment for bio-based BTX. For example, EU support and infrastructure scaling-up electric vehicle use reduces EU fossil fuel consumption and demand for refined oil products.

On the other hand, some regulations may result in barriers to bio-based BTX. These, while modest, are mostly related to increases in feedstock prices or decreases in feedstock availability. The EU Renewable Energy Directive resulted in a large increase in prices of feedstocks suitable for the ICCP process. Similarly, national subsidies for energy and heat production from biomass sources, such as the SDE+ in the Netherlands reduced feedstock availability.

TECHNOLOGY INFORMATION

The ICCP technology encompasses an integrated **two-step pyrolysis which protects the catalyst from minerals** often abundant in biomass. This allows the conversion of low grade biomass and end-of-life materials into BTX in a commercially viable manner. The technology patent was filed in 2014 and published in 2017.

Feedstock flexibility is high as the technology can use any feedstock with a water content below 30 %. The technology provides bio-based BTX aromatics that are drop-in replacements for fossil-based equivalent products and can therefore be directly incorporated into existing product streams and processes.

BioBTX's technology has already proved itself at the laboratory scale and in test line-ups, which puts the **Technology Readiness Levels (TRL) conservatively at TRL 5** (Technology validated in relevant environment). The stand-alone pilot plant that is to be operational in June 2018 will likely raise this to **TRL 7** (System prototype demonstration in operational environment).



ENVIRONMENTAL IMPACT

BioBTX's ICCP process entails environmental benefits found across the BTX value chain, from feedstock to end-of-life implications. The company has carried out an in-house Life Cycle Assessment.

According to this assessment, an **estimated 3–4 tCO₂e are saved** for every tonne of bio-based BTX produced through the ICCP process, when compared to fossil-based BTX. Future plans include certification of this study by a third party. Adding to the CO₂ savings are the avoided landfilling or incineration emissions. Finally, the overall process generates heat which

can be used for energy, reducing emissions further.

The ICCP technology can process many types of bio-based and end-of-life materials as feedstocks. These range from crops grown for energy purposes to solid and liquid biomass waste streams (e.g. used cooking oil) without a need for energy-intensive pre-treatment. The technology's high feedstock flexibility allows for both availability and sustainability to be taken into account when producers choose potential feedstocks. This freedom in feedstock selection reduces chances of competition with food production.

Finally, as a complementary benefit, the ICCP technology is also able to recycle plastic waste. For example, BTX-based plastic components from decommissioned machinery can be decomposed back into their original, BTX building blocks. This further widens feedstock options.

THE WAY FORWARD

The outlook for the ICCP technology and the resulting bio-based BTX products is **positive**. The recent on-boarding of private investors and the pilot plant under construction will provide further proof of concept. BioBTX is set to significantly scale up once their pilot plant is operational in June 2018, and already plans for a larger demonstration plant in anticipation of growing demand. On the investor side, the successful on-boarding of an investment fund is expected to act as a catalyst for other investors to follow. The produced bio-based BTX is price competitive with fossil-based BTX at about EUR 670 per tonne, and when oil prices rebound the company stands to benefit.

The demand for BTX is strongly linked to consumer demand for plastics, their primary end-use. Worldwide, the current production of BTX is over 100 million tonnes/year, and estimated to increase by over 4 million tonnes each year. This expected demand growth will require investments in new production facilities, and diversification of sources beyond fossil fuel ones. Compounding demand are **megatrends such as the electrification of transport** in the EU, which will result in reduced oil refining activities over time.

In the mid-term future, the company expects to license its **ICCP technology to cover about half of the current BTX demand growth** by deploying its technology in 2 new full-scale plants each year. In the longer-term, their aim is to replace or adapt fossil-based BTX production processes to ICCP in existing facilities. BioBTX's choice of technology licensing and engineering services as a business model will allow for a fast growth in market presence, while continuing to operate as a lean organisation. It also allows for a diversification of potential customer types, ranging from chemical companies to feedstock suppliers, brand owners and engineering companies building chemical plants.

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ABSTRACT

The bio-based sector is amongst the most thriving sectors in the European bioeconomy. Industry players in this sector use biological resources (including residues and waste) to make innovative greener value added products. This nascent sector is somehow still small compared to more traditional ones but it is undergoing rapid developments. Developing and commercialising innovative bio-based products – would they be new product types or aim to replace fossil-based equivalents – demand pursued Research & Innovation efforts and is influenced by a certain number of critical factors such as access to finance, market developments (including oil prices), feedstock availability or the regulatory framework (including climate action). To progress from the initial concept to a commercial product is thus a journey with many steps and challenges. The aim of this study report is to analyse this journey – which was successful – for 15 EU innovative bio-based products. These 15 success stories deliver on at least one of three following success criteria: profitability, market entry or mobilisation of critical external finance. The 15 success stories span over nine EU Member States, and cover a wide range of products and technologies, most of which have been on the market for only a few years. Two-fifths of these products were developed by large companies, an equal amount by SMEs, and one fifth by micro-enterprises. In two-thirds of the companies, bio-based activities are at the core of their business. Each success story is presented within the report in a factsheet, which provides detailed information about it as well as insights on its drivers of success and on how it responded to risks it faced.

Studies and reports

