THE FUTURISTIC CRADLE OF SPINNOVA

A JOURNEY FROM LAB TO MARKET

SPINNOVA®

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BCSD PORTUGAL

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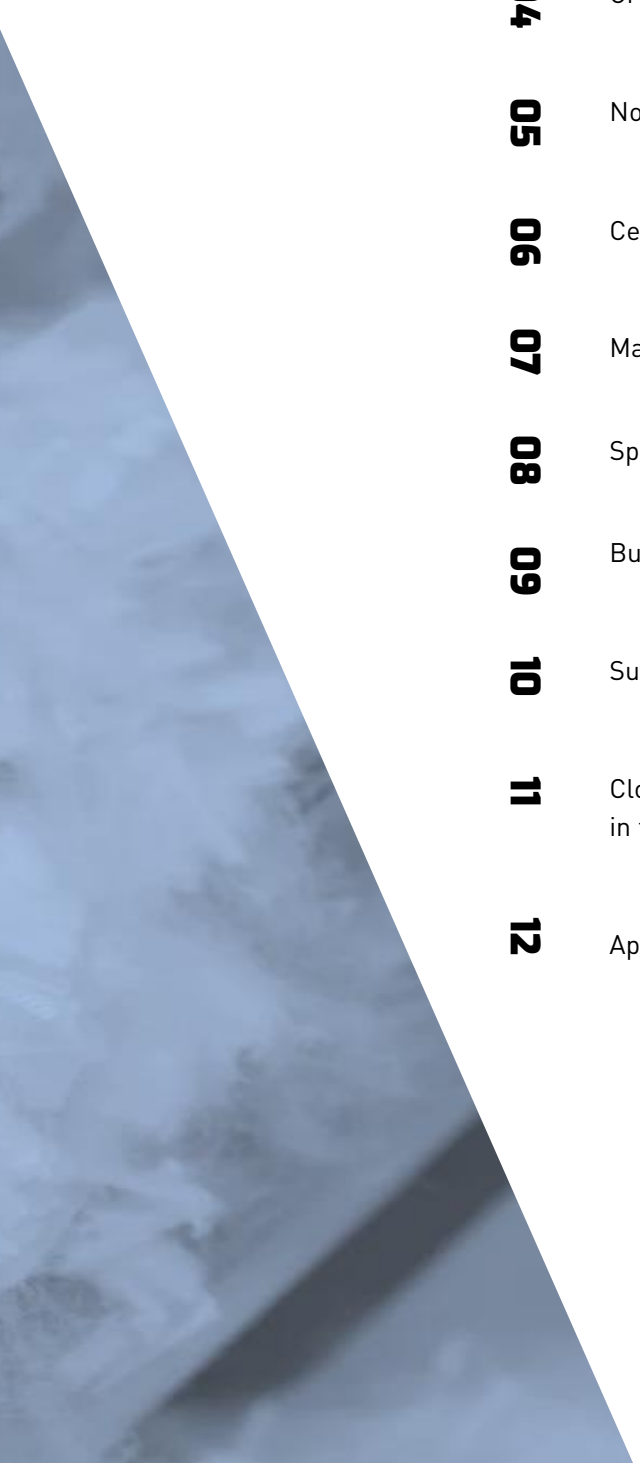

01 Executive Summary

In the constantly evolving scenario of sustainability based on advances in technology, Spinnova emerges as an inspiring example of innovation in the textile industry. This case study delves into the company's remarkable journey, providing a comprehensive understanding of the pioneering sustainable deep technology solutions it has developed.

By basing its value proposition on the deep technology model (DeepTech) to respond to the concrete challenges that plague the fashion and textile sectors, Spinnova managed to revolutionize the cotton value chain, the natural fiber most used by the sector and widely recognized for the negative environmental and social impacts associated with it.

This case study invites readers to walk the path of Spinnova's creation, exploring the complexities and triumphs of adopting sustainable practices in the textile sector and offering insights into the key drivers of the company's success. Readers can expect to gain a comprehensive understanding of the innovative technology created and the potential of the proposed disruption, which challenges traditional methods of textile production. The research presented here will also demonstrate the fundamental role of collaboration in Spinnova's success, emphasizing the importance of partnerships between technological innovators, industry stakeholders and political actors in driving concerted sustainability efforts.

By completing this case study, readers will be equipped with relevant information about Spinnova's leading role as a notable example of sustainable DeepTech in the textile sector, and will be empowered to explore the intersection between technology and textiles, envisioning what the future will hold of sustainable fashion and managing to identify the critical role that innovators like Spinnova play in transforming our world.

02 "We're creating a future that feels good"

JYVÄSKYLÄ, MARCH 2023. At Spinnova's headquarters, expectations were high with the opening of the Woodpsin factory, a partnership between the company, listed since 2021 on the Nasdaq Helsinki First North Growth Market, with Brazilian pulp giant Suzano, the culmination of Juha Salmela's vision, and for which he had worked tirelessly since 2015.

Spinnova, an innovative deep-tech company, emerged as a pioneer in the mission to revolutionize the textile industry, replacing conventional cotton and mitigating its associated environmental impact.

This case study covers Spinnova's remarkable journey from laboratory research to the establishment of the joint venture with Suzano in 2021. By presenting an overview of Spinnova 's innovative technology, the company's sustainable DNA and the meaning of these achievements, we seek to shed light on the transformative potential of sustainable fibres and the contribution of deep-tech companies in leveraging the pressing changes that the textile sector, which causes the 4th biggest environmental impact in the European Union[1], will have to implement by 2030.

Looking at Spinnova and at what it has achieved so far is looking at the new paradigm and what is necessary for the resilience of the textile sector. And at the scale of the disruption involved: a radical inspiration in natural systems and processes, based on business collaboration and symbiosis of flows, which force both a rethinking and redesign of business models that started with the Industrial Revolution and which have been to this day oblivious of the evident finitude of natural resources.

To speak of Spinnova is speaking of the perfect intersection between numerous factors: on the one hand, we have scientists who dare becoming entrepreneurs, taking the risk of setting up a company based on the principles of sustainability

[1] Textiles and the environment: the role of design in Europe's circular economy — European Environment Agency (europa.eu)o

and technological innovation, with the mission of combating the harmful effects of cotton production on the environment; on the other hand, we have the advanced solutions enabled by deep-tech, and which Spinnova took advantage of in order to develop a pioneering fibre production process that avoids traditional resource-intensive methods. Its innovative technology uses wood pulp as a primary material, cutting the need for harmful chemicals, the extensive use of water and energy-intensive processes related to cotton production. With its relentless focus on research and development, Spinnova was able to scale its laboratory prototype operations into a fully operational joint venture plant with Suzano, the undisputed global leader in renewable cellulose.

Cotton production is known for its major environmental footprint, including excessive water consumption, pesticide use and soil degradation. Spinnova's sustainable fibre offers an attractive solution by significantly reducing these impacts. Its manufacturing process requires 99% less water than traditional cotton, doesn't use harmful chemicals and releases fewer greenhouse gases. In addition, the fibre itself is biodegradable and can be recycled, ensuring a closed-loop production cycle that aligns with circular economy principles. Spinnova has been acknowledged for its commitment to reducing environmental damage and a key player in sustainable textile innovation.

Spinnova's remarkable journey from laboratory to commercial scale highlights the transformative potential of deep-tech companies in the transition to sustainability. By successfully establishing a joint venture factory with Suzano and offering a sustainable alternative to cotton Spinnova is not only addressing the environmental impacts of textile production but reshaping the future of this industry. Its innovative fibre technology, built on research and development driven by the observation of spiders' natural fibre production system, is a testament to the power of collaboration, creativity, and sustainable entrepreneurship.

As the world faces unavoidable environmental challenges, Spinnova's story is a source of inspiration to guide entrepreneurs and innovators seeking to create positive change through the deep-tech model.

03 From spider web to the sustainability thread

Juha Salmela studied Applied Physics at the University of Jyväskylä and continued his research at VTT (Technical Research Center of Finland). He also spent a year as visiting scientist at the Pulp and Paper Center at the University of British Columbia in Canada, where he worked on the complex fluids group, headed by Professor Mark Martínez. Janne Poranen studied Applied Physics, also at the University of Jyväskylä. After finishing his PhD related to physics of paper coating, he joined VTT. During his work at VTT he was a visiting scientist at the University of Maine working with Professor Doug Bousfield. He ventured into Management and Innovation at the IMD Business School in Switzerland and continued working at VTT in different managing positions.

They lived in the city of Jyväskylä, the largest in central Finland and the so-called lakes area, which is affectionately nicknamed the Athens of Finland. Outside the lab, Juha and Janne were always passionate about sports and outdoors, fishing and hunting together. Juha became a ski instructor and took the pilot licence from Light-Sport Aircrafts (LSA). As for Janne he was a volunteer football coach in a children's team.

Juha and Janne soon stood out as leaders and researchers at the VTT, the Technical Research Centre of Finland[2], a public institution founded in 1942 to lift post-war Finland and accelerate its technical capacity. A European leader in the search for the most visionary innovation, which makes "major global challenges into sustainable growth", in favour of "employment, well-being and exponential hope". Its motto is *Miracles Often Begin on Mondays.*

In the Research and Development field, Juha Salmela led the *rheology[3] and process flows* team between 2005 and 2014. Janne Poranen started working as

[2] Welcome to VTT | VTT (vttresearch.com)

[3] Rheology is the branch of physics that studies the deformations and outflows of matter. Viscosity is the best-known rheological property, and the only that characterizes Newtonian fluids. https://en.wikipedia.org/wiki/Rheology

VTT's group Manager, advanced as Technology Manager leading a team of 120 researchers in the field of fibres and bio-based materials.
Both founded Spinnova Ltd., in 2015 - today, Juha Salmela is the Chief Technology Officer (he was appointed European CTO of 2018 in the SME category) and Janne Poranen is the Executive Chair of the Board (he stepped down as CEO in 2022).

Between the years 2000-2010, Finnish pulp and paper related research was focusing on *"highly refined pulp fibres, their properties and industrial applications*", and on what could be done *"with these micro and nanofibrils"*, Juha Salmela explained in an interview[4].

The idea for the new Spinnova technology came up when he attended a *"very interesting"* lecture by Professor Fritz Vollrath, a specialist in Zoology in the Department of Biology and researcher in the field of Environmental Research, at the University of Oxford. Vollrath *"explained the similarities between spider silk protein and wood nanofibrils: how both flow through small channels in a similar manner"*. Salmela thought:

> ***What if wood fibre could be "spun" into a textile fibre in the same way that a spider naturally does it?"***
>
> Juha Salmela, Co-Founder and CTO at Spinnova

he recalls. That's when he realized he might be able to combine what he already knew about the flow of wood fibres with what he'd discovered about the natural ability of spiders to build their webs. And apply this knowledge to creating a way to spin textile fibres from wood micro fibrils using no harmful chemicals.

They tried to develop this idea at VTT, but did not get enough funding and, five years after that impactful lecture, Poranen, at the time Head of Fibres and Bio-based Materials at VTT, challenged Salmela to create a spin-off[5] where the technology patented by Salmela and his team could be leveraged.

[4] Interview conducted by the BCSD team on May 7th 2023.
5 A spin-off refers to an independent company that is created when a parent company disposes of a portion of its business operations or assets to form a separate entity. A spin-off company is usually established to operate independently and pursue its own strategic objectives, separately from its parent company. The purpose of a spin-off is usually to release the value of a specific business unit or asset that may not be fully recognized within the larger

Figure 1. Janne Poranen
(image credits: Spinnova)

Figure 2. Juha Salmela
(image credits: Spinnova)

Together they founded Spinnova and were joined by three VTT researchers, Pasi Selenius, Johanna Liukkonen and Sanna Haavisto, and started the first real trials. Today, Spinnova has a team of more than 80 employees.

04 Green technology that mimics the environment

The team of scientists at Spinnova then focused on the creation of a completely new 100% sustainable fibre made from cellulose by imitating nature. The researchers focused on the behaviour of cellulose pulp, used as the raw material for making paper and cardboard. Their research resulted in an unprecedented way of using microfibrillated cellulose in the textile industry.

This cellulose pulp is supplied exclusively by Brazilian company Suzano which specialises in pulp and paper and the wholesale of raw pulp, which is then refined in Finland to create micro fibrillated pulp.

Suzano claims to have a sustainable eucalyptus plantation on 1.2 million hectares of land and claims to maintain 900,000 hectares of protected forest[6]. Eucalyptus trees managed by Suzano have a growth cycle of between 6 and 7 years, reaching productivity faster than other trees which, to reach the same size, can take between 20 years and a century to grow.

organization. An academic spin-off is a type of *spin-off* company originating from an academic or research institution such as universities, research centres, or laboratories. Academic spin-offs are formed when researchers, teachers or students collaborate to commercialize their scientific discoveries, inventions or innovative technologies. These spin-off companies leverage the intellectual property, experience and knowledge generated within the academic institution to develop practical applications or products that can be brought to market. The goal of an academic spin-off is to bridge the gap between academia and industry by transforming scientific or technological advances into commercially viable real-world solutions. Spin-off Definition, Plus Why and How a Company Creates One (investopedia.com)

6 CLIMATE POSITIVE | Suzano - 2050 now

Raw pulp is acquired because *"it has more qualities and does not lose important elements such as hemicellulose*[7]*, for example,"* explains Shahriare Mahmood, Spinnova 's Chief Sustainability Officer (CSO). *"But instead of the traditional cellulose process, where wood pulp fibres are treated to dissolve in cellulose polymers, and then regenerated to form a textile fibre, using very harmful chemicals, Spinnova uses its own technology."* The pulp is refined in a mechanical process, a kind of milling and *"transformed into microfibrils, which are modified so that they can 'flow' and adapt to the rotating spinning nozzles, specially designed by Spinnova in the production flow"*, Juha Salmela points out.

This modification assumes the creation of a chemical suspension of cellulose, that is, a heterogeneous mixture composed of small particles of a solid material dispersed in a liquid medium in which these particles do not dissolve, even if they are microscopic, and remain suspended.

It produces a kind of dope which then enters Spinnova 's rotating spinnerets: *"The fibrils rotate in filament, flow through a single high-pressure nozzle and align with the flow thereby creating a natural textile fibre that is then wiped and collected, ready to spin and turn into yarn,"* concludes the scientist.

And just as spiders launch their kind of "drool" to create their webs, which already contain fibre, in this case protein, the Spinnova solution is cellulosic. *"The only difference is that we have slightly more moisture, which will then evaporate, and that is why we use a dryer, to dry it,"* says Mahmood.

7 Hemicellulose - Wikipedia

Figure 3. Micro-fibrillated celulose suspension
(image credits: Spinnova)

Figure 4. Micro-fibrillated cellulose
(image credits: Spinnova)

05 No harmful chemicals, minimal water and energy use

The disruptive Spinnova technology ensures strong filaments without resorting to harmful chemicals used extensively in common textile industry processes, mainly in dissolution (using iron cells to clean the fibres, for example), and in regeneration, which is done through the web spinning.

The large amounts of water of traditional chemical processes are also avoided, namely the water that carries the chemicals: since no harmful chemicals are used, *"the large amounts of water normally required to rinse the fibre after chemical reactions are not needed. The water we use is contained in the dope, it's a processing water,"* Mahmood explains [8]. Thus, Spinnova officially guarantees that it uses 99% less water and releases 74% less CO2 in its production than in conventional cotton production.

It also reduces the amount of energy used. The heat that needs to be generated to dry the fibres coming out of the spinning nozzles is produced in a kind of dryer, as mentioned above. Its waste, *"the so-called residual heat is recovered by feeding the district heating network"*, explains the Chief Sustainability Officer of Spinnova. *"This means that the amount of coal needed to produce urban heat, can be replaced with the extra heat from Spinnova*, [which sells it to the public grid], *thus leading to big savings. Hence our claim that this is in fact a positive process for the climate because the carbon footprint we generate, all together, is around 1.28 kgCO2 [per kilogram of fibre]. In fact, we save more carbon than we produce."*

Spinnova and its associates have also agreed on the use of renewable energy sources alone. "*We belong to this mobilization for wind energy installed in Finland, to ensure that the company only uses renewable energy*", says CTO Juha Salmela.

[8] Interview conducted by the BCSD team on March 31st 2023.

And looking back to the value chain, and to the issues related to the transport of the raw material, it is worth mentioning that Suzano has its own port in Brazil, and the pulp arrives in Europe at a high density, *"approximately 600/700 tons per square meter and we can thus ship a large amount of pulp in one container,"* says the scientist. *"We take this into account in our environmental impact calculations, which represents less than a 1% increase in emissions. We are also considering the option of shipping the fibre ourselves. This is a very complex value chain, and we must factor this in."*

The use of waste raw materials not only creates a value-added product but also helps solve some of the major environmental problems associated with them. For example, in agriculture, stubble is often burned on site, causing toxic emissions that pose health hazards. And we all produce about ten kilograms of textile waste per year, and about 30% of it is cotton.

For its part, Spinnova 's fibre also has unique characteristics so that it can be recycled in the process, once again without having to dissolve or use harmful chemicals. Thus, in the future, *"a product can be collected from the consumer by a brand Spinnova works with, delivered for processing and ground back into microfibrils. Recycled fibre is just as good, if not better quality, than original fibre. And it can be transformed into new products without having to add new fibres,"* says Juha Salmela. *"Just as this cellulose processing can be used in other cellulosic biomasses, that can be ground into microfibrils and spun into textile fibre, without requiring further technological development."*

Regarding the potential for upcycling, Spinnova has already partnered with Bergans of Norway[9], creating a simple model: when buying a Bergans of Norway jacket, made of Spinnova fibre, a part of its value is returned if it is delivered to the brand "at the end of its useful life". Or the consumer can receive a new garment made from the same Spinnova fibre.

"This was launched a couple of years ago and we already did a little test with backpacks which we took back to Spinnova. They were aligned and refined and turned into new Spinnova fibres. This is a main theme, we are still working on it and running tests as it's a very recent discovery", explains Salmela. *"And we have*

9 Bergans of Norway

been discussing this matter with other brands, but we still have no commercial scale, nor any deal. It is very difficult and requires new business models."

According to Spinnova 's Chief Sustainability Officer, there are areas in the company's sustainability strategy that are still in the development phase, namely in dyeing, which is known to be one of the most critical and polluting stages of the textile value chain: *"We are trying to figure out if it is possible to produce dope dyed fibre (suspended dyeing) If it proves viable, we will do the dyeing at Spinnova thereby generating great savings from an environmental point of view, as it won't be necessary to dye later, in the last stages. This is where we are investing our efforts in*," said Shahriare Mahmood. *"And we have also tested other raw materials, including recycled textile fibre and agricultural waste, which could bring several opportunities in the future."*

06 Cellulose as the front runners in textiles

Without rethinking the system of extraction, production and consumption of clothing, the textile industry will not be able to meet the environmental targets set out in the Paris Agreement[10] and should become accountable for 25% of greenhouse gas emissions by 2050.

In 2022, the value of the global textile market corresponded to 1.6 billion euros and a CAGR[11] of 7.6% was expected until 2030, when the market will represent 3 billion[12].

To meet growing demand, global fiber production doubled between 2000 and 2021 (from 58 million tons to 113 million tons, respectively), a trend that shows that almost everything remains to be done. Additionally, a slowdown is not expected, but rather an increase to 149 million tons of fibers produced in 2030, if the sector continues with business as usual.

10 The Paris Agreement | UNFCCC
11 Compound Annual Growth Rate (CAGR) Formula and Calculation (investopedia.com)
12 Textile Market Size, Share & Trends Analysis Report By Raw Material (Wool, Chemical, Silk), By Product (Natural Fibers, Polyester), By Application, By Region, And Segment Forecasts, 2023 - 2030 (researchandmarkets.com)

Synthetic fibres have dominated the textile market since the mid-1990s when they first exceeded cotton output volumes. In 2021, they represented 64% of global production, equivalent to about 72 million tons. Among these, polyester takes the lead, accounting for 60.5 million tons, which translates into 54% of world production. In contrast, natural plant fibres such as cotton, jute, hemp and linen represented altogether around 28% of the market.

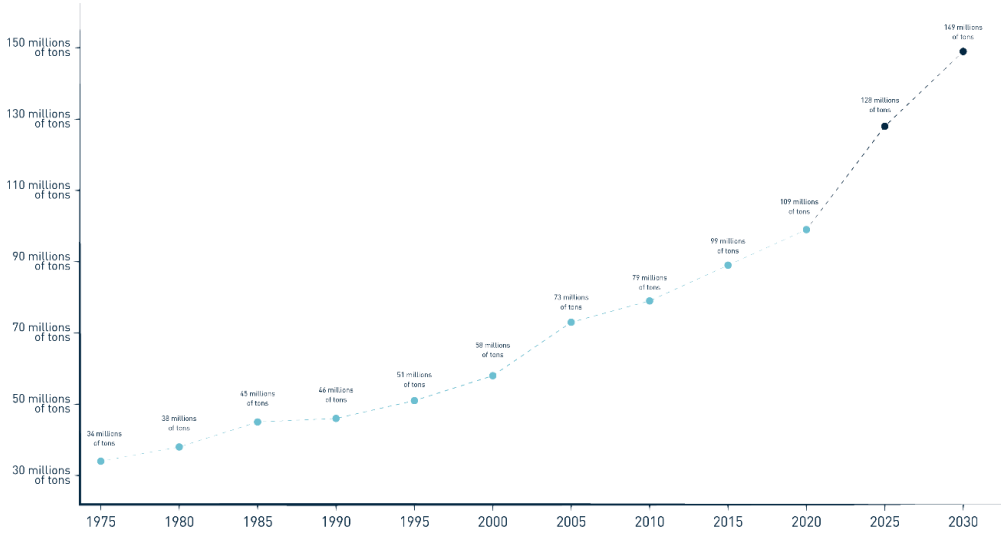

Figure 5. Global growth of textile fibre production[13]

Despite its potential mitigating role in greenhouse gas (GHG) emissions, preventing biodiversity loss, halting negative impacts on soil and reducing water consumption, in 2021, pre and post-consumer recycled materials accounted for less than 1% of the global fibre market. However, despite the increase in the market share of recycled fibres compared to virgin fibres, this does not mean that, in absolute terms, fewer virgin fibres are produced today: more and more fibres of all kinds are produced.

The total production of 1 kilogram of polyester fibre (fibre or filament) involves an energy consumption between 96 and 125 MJ, 62 litres of water and a carbon footprint between 1.7 and 4.5 kilograms of CO2 equivalent.

Polyamide, the second most produced synthetic fibre, has a carbon footprint ranging from 8.0 to 9.4 kilograms of CO2 equivalent per kilogram. The primary energy consumption for polyamide production processes ranges from 35 to 250

[13] Textile Exchange – 2022 Preferred Fiber & Materials Market Report: Biosynthetics

MJ/kg, with 35 being the value pointed to PLA, a biodegradable thermoplastic of natural origin and produced from renewable sources (such as corn starch or sugarcane) and 250 MJ/kg corresponding to the production of nylon.

Natural fibers	Artificial fibers	Synthetic fibers
Fibers extracted from elements of natural origin, which may be vegetable, animal or mineral. (example: cotton, hemp, wool, silk, ramie, jute...)	Chemically produced using precursors from petroleum. (example: polyester, polyamide, elastane...)	Obtained from the transformation of natural polymers (mainly cellulose), through the action of chemical agents. (example: viscose, modal, lyocell...)
28% of total fiber production	**64%** of total fiber production	**8%** of total fiber production

Figure 6. Types of textile fibers and their market sike (in 2021)[14]

Cotton, historically the most studied fibre, raises issues in terms of carbon footprint and water use, followed by eutrophication (excessive accumulation of organic matter, from sewage or resulting from the development of 'algae', in aquatic environments), energy use, toxicity and soil exploitation which, due to the intensity of use, loses nutrients, thus degrading. The carbon footprint of cotton fibres is estimated to be between 0.5 and 6 kgCO2 equivalent per kilogram of fibres (excluding the CO2 captured naturally by the fibre). The impact of organic cotton is slightly lower when compared to conventional cotton, which is mainly due to the lower need for artificial fertilizers.

The total water used to produce cotton fibre is very variable, from a negligible amount up to 24m3 per kilogram of fibre. Although organic cotton generally uses less blue water than conventional cotton[15], the amount of water required for its cultivation depends far more on the climate and specific conditions of each region than the variations witnessed in the cultivation of conventional cotton. As regards the use of energy, the production of cotton fibre requires between 12 and 55 MJ per kilogram of fibre produced.

[14] Textile Exchange – 2022 Preferred Fiber & Materials Market Report: Biosynthetics and https://www.fibrenamics.com/intelligence/reports/as-fibras-o-que-sao-e-que-tipos-existem

15 Blue water refers to fresh water available in rivers, lakes, aquifers and other surface and groundwater sources - essential for human consumption, agriculture, and industry.

The task of assessing the toxicity and impacts of land use thus becomes more difficult as there is little research on this issue, and the existing ones generally use different characterization methods that cannot be compared. However, it is widely agreed that the cultivation of organic cotton has advantages when it comes to reducing the environmental impacts compared to traditional cotton, as it restricts the use of harmful pesticides and imposes soil management requirements, such as crop rotation. A study analysing flax, hemp, jute and kenaf fibres states that their carbon footprint is between 0.6 and 0.8 kg CO2 equivalent per kilogram of fibre produced.

	polyester	polyamide	cotton	flax, hemp, jute and kenaf	all cellulosic fibers
energy	96 a 125MJ/kg	35 a 250MJ/kg	96 a 125MJ/kg		
equivalent CO_2 emissions	1,7 a 4,5kg	8 a 9,4kg	0,5 a 6kg	0,6 a 0,8kg	-2 a 13kg
water	≈0,062m³		0 a 24m³		

Figure 7. Resource consumption and carbon footprint of different textile fibres

Cellulose-based regenerated fibres, developed from 1846, are often regarded as the most sustainable alternative to cotton, also a cellulose-based fibre. There are many similarities between the two when it comes to comfort.

From 1990 to 2021, the production volume of regenerated cellulosic fibres more than doubled, from three million tons of fibres produced in 1990 to 7.1 million tons in 2019. In 2021, regenerated cellulosic fibres such as viscose, acetate, lyocell, modal and cupro accounted for about 6% of the total fibre production volume, corresponding to 7.2 million tons. This value is expected to keep increasing, also supported by the emergence of new fibres in this category.

Today, regenerated cellulosic fibres are produced mainly from wood, and less than 1% are made from alternative or recycled raw materials. It is estimated that only about 0.5% of these fibres are of recycled origin, a figure that is expected to grow with the increasing research conducted in this field.

In the global regenerated cellulosic fibre market, the percentage of regenerated cellulosic fibres with FSC and/or PEFC certification increased from about 55-60% in 2020 to about 60-65% in 2021. FSC is a non-profit organization with a global presence, whose goal is to promote responsible forest management, and PEFC is a global alliance of national forest certification schemes. The global FSC and/or PEFC certified forest area increased from about 1% in 2000 to 11% in 2021.

Several factors influence the environmental impact of regenerated cellulosic fibres, such as where the wood is sourced (whether it comes from deforestation or not, for example), whether the production of fibres is integrated into the pulp mill, the source of the energy used and under which conditions chemicals are used.

The carbon footprint of traditional regenerated cellulosic fibres - such as viscose, acetate, modal and lyocell - ranges from about -2 to 13 kg CO2 equivalent per kilogram of fibres produced. According to different studies, water consumption for industrial use (excluding water required for tree growth) can range from 0.29 to 0.74m^3 per kilogram of fibres produced. This means that regenerated cellulosic fibres require less water than cotton.[16]

07 Main mission? Transforming the industry's raw material base

We can therefore talk of revolutionary sustainability in the textile industry, with this new stable and resistant fibre of completely natural and recyclable origin from Spinnova. Although natural fibres cannot compete, in terms of strength, with synthetic fibres such as polyamide and polyester, when compared to other cellulosic fibres Spinnova's, is closer to cotton.

"In terms of aesthetics, elasticity, touch, lustre/shine it's like other natural fibres like hemp. When compared with other equivalent cellulosic fibres, i.e. man-

16 Gustav Sandin, Sandra Roos e Malin Johansson, *Environmental impact of textile fibres – what we know and what we don't know - the fibre bible part 2*, 2019 ISBN:978-91-88695-91-8

made, it has the same character, in terms of moisture, and absorption to viscose and lyocell. Its application is very different, because they are brighter and silkier, and can be used to produce a party dress, for example. 'Spinnova fibre is closer to cotton, it looks more natural and therefore has the potential to replace cotton," says Chief Sustainability Officer Shahriare Mahmood.

To this end, the company wants to expand the production scale of their sustainable fibre and reduce cotton in the composition of fashion garments and accessories where Spinnova fibres are employed. Spinnova 's vision is that its fibre is so resistant and efficient that it replaces the intensive use of cotton in the making of fashion garments and accessories while becoming, in the long run, an example for the textile industry.

Spinnova 's motto is: "We produce the most sustainable textile materials in the world for the benefit of the Environment and Humanity. By doing so, we will transform the raw material base of the entire global textile industry for the better."

08 Spinnova is a DeepTech

According to the MIT, the *term* DeepTech has been used in recent years to distinguish a specific category of innovative solutions, namely those that are at the forefront of technology and are based on science and engineering. A DeepTech company is therefore [17] a start-up based on the development of disruptive scientific technologies and with a few characteristics, as regards time, capital intensity and level of uncertainty.

The deep technological innovations made available by DeepTech tend to be radical and enhance the creation of new markets, or even the extinction of existing ones. However, they have a long journey ahead when it comes to bringing the solutions they propose to the market. The time and investment required for the development of these technologies, and their application and validation, is

17 What is "Deep Tech" and what are Deep Tech Ventures? (mit.edu)

Figure 8. Spinnova fibre® (image credits: Spinnova)

much longer than the development time of startups based on already available technologies. In the creation of profound technological innovations, it is often

necessary to develop specific machinery adapted to the creation and development of new solutions, as there are no similar solutions on the market.

There are five criteria defined by the MIT to identify DeepTech:

1) positioning at the scientific frontier, with long and uncertain R&D cycles: dependent on intense research, access to funding and with a high risk of failure;

2) development of tangible products and processes: not aiming at the production of abstract knowledge, the products it creates are based on the combination of intellectual property and intangible assets (knowledge) and this implies considerations of scale, engineering skills, development of industrial processes and configuration of complex supply chains which require a large amount of capital;

3) association with the ecosystem, namely higher education institutions: born from the intersection of scientific knowledge, engineering fundamentals and access to specialized human capital and infrastructures, most often found in interconnected ecosystems such as higher education institutions or research centres. *"It is impossible for two people in a garage to come up with a meaningful deep-tech innovation"* but, as they evolve towards commercialization, they need to connect with a broader ecosystem to meet their funding needs and sources of demand which, due to barriers in collaboration between different stakeholders, often lead to their failure;

4) problem or mission orientation: seeks to make a difference and solve important societal challenges, usually related to health and environmental sustainability[18] that serve the purpose that punctuates a long and complex journey all the way to the much desired impact;

5) development through a dynamic risk cycle that acknowledges the options space available for both founders and investors.

In the traditional path of a DeepTech, after the idea for an innovative technology comes the research phase to validate its viability and design conceptual formulation for the research. It follows the development phase, which culminates in a laboratory prototype, its testing in a real environment and demonstrations in the field, until it is fine-tuned and finalized. Finally, we enter the production phase, which is expected to scale, to enter the market.

18 What is "Deep Tech" and what are Deep Tech Ventures? (mit.edu)

There are several challenges faced by a DeepTech, starting with the need to create the right machinery for the proposed technology. It may also be strategic for these companies that the machinery developed from scratch adapt to other purposes to suit other markets or raw materials. Spinnova was able to do this as its technology can also produce Spinnova® fibre from materials other than wood and leather waste-based, such as agricultural and textile waste. *"We are more of a process technology,"* as Juha Salmela described it.

The underlying consideration is that these companies often require significant financial resources to support their research, development, and marketing efforts. However, securing this funding can be challenging due not only to the high-risk nature of the ventures but also the long lead times involved in bringing DeepTech innovations to the market. Investors may prove reluctant to invest in technologies with uncertain results and an extended time-to-market.

Figure 9. Diagram representing the phases DeepTech companies experience

On the other hand, building a skilled and dedicated team is crucial for DeepTech companies. But attracting and retaining the best talent can be difficult due to the specialized knowledge and experience required in fields such as artificial

intelligence, biotechnology, or advanced materials. DeepTech companies often compete with established technology giants and academic institutions for the best scientists, engineers, and researchers with deep knowledge of the technology and its applications, a vital resource for the success of a DeepTech company.

In addition to these factors, DeepTech innovations often face challenges in market adoption for a variety of reasons. The technology can be complex and require significant integration or customization to meet industry-specific needs. In addition, market acceptance may be hampered by regulatory barriers or resistance to change in existing industries. DeepTech companies need to invest in market research, understand consumer needs, and actively engage with potential customers and industry partners to align their technology with market demands.

Adding to these challenges: the complexity of navigating the landscape of intellectual property laws that guarantee them the protection of the technology developed, through patents, copyrights, or trade secrets; obtaining the necessary approvals or certifications prior to marketing, which, depending on the sector, can raise unique regulatory and ethical issues; and the need for education and market awareness in the face of the disruption that is presented.

All these adversities highlight the importance of a complete strategy that encompasses financing, building a strong team and focus on market development for DeepTech companies to thrive and succeed, something that Spinnova is an archetypal canon of.

09 Business profile: the fibre technology of the future

Spinnova is an SME with more than 80 employees.

At the core of Spinnova's philosophy, there are five essential values: trust to be trusted, courage to change the world, sustainability and love for the planet, passion for innovation, success and teamwork.

After the laboratory testing phase, the company moved to a continuous pilot of greenfield (from scratch) technology. Several world-renowned brands showed their interest and supported the research.[19]

In 2020, they prepared to enter the market and the technology was scaled up to an industrial pilot scale. With their partners, who share the same passion for sustainability, they launched the first products made from the new fibre, whose properties and production processes keep being analysed, as new prototypes are developed.

Between 2021 and 2023, Spinnova took more concrete steps towards a zero-emission commercial scale. In 2022, they production with partner Suzano, in a joint venture and began construction of reinforced the first factory in Jyväskylä[20] – Woodspin, which started operating in May 2023. Suzano ensures the supply of micro-fibrillated cellulose of sustainable origin, obtained in the eucalyptus plantations it has in Brazil, Spinnova has the technology exclusivity, and chose Valmet[21], a global leader in pulp and paper technology, as a partner to provide drying technology for the first investments in the production line. The fibre produced is branded Spinnova®.

This "fibre factory of the future", as they call it, is a space of 'innovability', the intersection between innovation and sustainability, and its beautiful architecture mirrors just that, as described by Wallpaper magazine[22], in one of its recent editions. It is made up of structures designed to be climbed by vines, thus protecting the wooden outer surfaces from rain and temperature swings, and pillars at the entrance that bend in a continuum all the way to the hall, full of light, where small eucalyptus trees grow, in a meditative and almost religious atmosphere, and which involved an investment of about EUR 50 million.

In 2021, Spinnova carries out an IPO[10] becoming a public company, listed on the Nasdaq Helsinki First North Growth Market, which funds its growth. In 2022 the company had EUR 24 million in revenues and an EBIT[23] of EUR -12 million.

Between 2025-2027 the plan is to have partnerships with 20 textile companies that regularly use Spinnova fibre in their product line, and thus achieve a production capacity of 150,000 tons of fibres. These numbers are expected to

19 Check Appendix 1- Partners
20 Home | Woodspin
21 Valmet: technologies, services and automation to pulp, energy and paper industries
22 Is Spinnova the world's most sustainable fibre? | Wallpaper

23 *Earnings Before Interest* EBITDA: what it is and how it is calculated - Savings

Figure 10. The entrance hall of Woodspin's first factory in Jyväskylä, Finland (image credits: Woodspin)

Figure 11. Woodspin's first factory in Jyväskylä, Finland (image credits: Woodspin)

Figure 12. Architectural detail of Woodspin's first factory in Jyväskylä, Finland (image credits: Woodspin)

scale up to 80 client companies and the production of one million tons of fibres, between 2031 and 2033 reaching 200 million in EBIT.

> ***"We have created a modular and flexible technology that is easy to assemble anywhere in the world. That's why we were able to scale, according to demand."***
>
> Janne Poranen, Co-Founder and CEO of SPINNOVA

The company's partner Suzano is also prepared to increase the delivery volume of its raw material, MFC (certified micro-fibrillated cellulose[24]), one of its long-term business visions, since investing in Spinnova.

At market level, Spinnova's solution responds to the EUR 200 billion that the global textile fibre market currently represents. It has scalable technology and strong partners to scale up to over one metric ton per year between 2031-2033.

10 Sustainability as a strategy

Sustainability isn't regarded as a strategy at Spinnova 's, but the very foundation of the business, its DNA, its purpose.

Although, in some areas, the integration of sustainability is still at an early stage, the company is very attentive: *"We need to understand, from a business perspective, what sustainability benefits and advantages we have been able to achieve with this innovative product. We have done it mainly at product and process level so that we can share it with our customers and other partners"*, says CTO Juha Salmela.

24 Microfibrillated cellulose – Its barrier properties and applications in cellulosic materials: A review - ScienceDirect

The Chief Sustainability Officer of Spinnova, Shahriare Mahmood, describes the overview of ESG practices, namely, environmental, social and corporate governance: *"The company is still at a very early stage, and we need to establish formal competencies, but we have been addressing the larger and broader issues, such as reporting*."

The release of the first Sustainability report took place in 2020 and, from 2021 onwards, it gained a more formal character *"by analysing materiality, stakeholders, getting to know our target, what substances are important for our operations, we cover all these issues. In some cases, we also receive external inputs, i.e. advice and consulting, as young companies like ours do not have enough resources. When you have a large and versatile team, you have may different opinions, but when you have a small team, you have fewer opinions. Sustainability is a broad issue, involving numerous aspects, it's impossible to do everything. But we focus on what's most relevant for us, which are the materials, the certifications that we need for processing and as regards the product itself, its safety. We must understand the actual needs of our stakeholders and customers."*

On the environmental front, "*we don't need to do that much, or go into detail, because Spinnova's product does not use chemical processing, there is no waste of water, we do not produce solid waste, nor gas emissions and so our factory does not need to have chimneys. But we must ensure the traceability of our raw material, which is mostly wood pulp provided by our partner Suzano. Through collaboration we make sure that they follow good practices, and that all the raw materials we use are certified and respect biodiversity"*, explains Mahmood.

From a social perspective, *"we do not have external coverage, because our team is not big, but our top priority is the well-being of our workers. Health and safety are obviously very important, and we are fortunate to have very good figures in these two areas. On the social side, we designed policies and practices almost automatically, especially after we became a public company."*

They claim to follow all the practices, the basic criteria to operate in Finland. *"We mind workers well-being, how they feel, areas to improve, etc. And I, as a team manager, can say that we have been discussing it a lot, even at management team level. We've recently recruited a Chief HR Officer."*

There is also a code of conduct for suppliers in Woodspin's production: *"We wanted to make sure that all ESG criteria are covered, and we are studying the issues we have to work on."*

Hence, they communicate very intensely with their *stakeholders*: *"We are always in dialogue with our customers because sustainability is a key selling point for us - the quality of the product, its characteristics, its criteria - and they are always inquiring about our footprint. We share these issues with our brand partners, and we are also pressured by our investors on these matters, and that is why we discuss these issues with them. We also communicate through our Sustainability report, and I personally represent Spinnova in different industry forums and events to talk about its sustainability benefits. I'd say we're in good shape," Mahmood* concludes.

> ***"We have a formal way of doing sustainability analysis and discussing sustainability-related issues. We even have a sustainability committee that includes members of our management team, and we conduct interviews with our stakeholders based on our internal analysis system, which we also apply to our brand partners, investors, and our employees. Honestly, more than doing this specific analysis in environmental, social and governance terms, we have been trying to find out from all of them what they expect from us so that we can correct it later."***
>
> Shariare Mahmood, Spinnova's CSO

Thus, the challenges that Spinnova has faced in terms of sustainability *"have not been many, only those to be expected by companies at the beginning. Maybe a little less, which is pretty good. I believe that initially, and not only in Spinnova, but in all young companies, we had to deal with, and we were very focused on, the costs. But if one can do a lot of studies, one can prove a lot of things. And we have been preparing for the future, we are looking at regulation and how we can respond to growing demands because our company is due to scale up. These are*

not challenges, but we must do many things with the brands we have been partnering with."

Advice for other companies? *"From my personal experience working in research, the main thing is looking at the product as another layer of sustainability. We talk about the environment, social or financial sustainability, but we must look at the product as the fourth pillar, as part of all sustainability. Because when you design, you're already setting your sustainability priorities. For example, when you dye in black colour, do you decide from the outset the level of fibre, the process, design, and are you designing for its recyclability? The focus should be on seeing sustainability as a whole and, from my point of view, all these considerations arise at the product level, so they must be considered, from the R&D and development phase."*

In general, and for now, Spinnova has an extensive IP portfolio with international patents granted. And despite being a young company, Spinnova has already been awarded at the ISPO Awards 2019, 2020 and 2022, from Fast Company, Scandinavian Outdoor Award, from Monocle, Andam Fashion Innovation Award and Marie Claire Sustainability Awards 2021.

11 Closing the loop: conclusions and recommendations for companies in the portuguese textile ecosystem

Spinnova's remarkable journey as a deep technology company in the pursuit of sustainable fibre production has shown the transformative power of innovation and collaboration. With its unwavering commitment to addressing the environmental impacts of cotton production, Spinnova has successfully transitioned from laboratory to commercial scale, positioning itself at the forefront of the textile industry.

Throughout this case study, we explored Spinnova 's innovative technology, which draws inspiration from the intricate spinning process of the spider web. Leveraging a deep understanding of natural systems, Spinnova has developed a sustainable fibre manufacturing process that not only reduces environmental damage but also offers a viable alternative to conventional cotton.

Figure 13. Spinnova® fibre (image credits: Spinnova)

Figure 14. Spinnova® fibre (image credits: Spinnova)

One of the main achievements highlighted in this case study is the establishment of a joint venture plant by Spinnova and Suzano, a milestone that signifies successful commercialization. This strategic partnership has enabled Spinnova to leverage Suzano's expertise on pulp and MFC production and capacity to scale its operations, ensuring a constant supply of sustainable fibres to meet market demand. The factory's state-of-the-art infrastructure and large-scale production capabilities have positioned Spinnova as an innovative supplier in the textile industry.

Spinnova 's commitment to sustainability goes beyond its innovative production process. Its fibre not only requires 99% less water than traditional cotton, but also doesn't use harmful chemicals and reduces greenhouse gas emissions. In addition, the biodegradability and recyclability of Spinnova 's fibre aligns with the principles of circular economy, contributing to a more sustainable and closed-loop production cycle.

Spinnova 's success as a deep technology company is a source of inspiration for other companies in the industry. Their journey underscores the catalytic potential of technological innovation, based on research and development, to address pressing environmental challenges. By combining scientific knowledge, entrepreneurial spirit and a deep sense of purpose, Spinnova paved the way for a more sustainable future for the textile and apparel industry.

As we reflect on the achievements of Spinnova, it is evident that the transition to the primacy of sustainable fibres is not only essential but also economically viable. Spinnova has shown that deep tech companies have the potential to drive substantial change, disrupt traditional industries and contribute to an environmentally conscious world.

In short, Spinnova 's journey from laboratory to commercial scale is a testament of its vision, perseverance, and unwavering commitment to sustainability. As the textile industry grapples with the need for green and regenerative alternatives, Spinnova is a shining example of how deep-tech innovation can revolutionize traditional practices and pave the way for a greener and brighter future.

RECOMMENDATIONS:

Embrace Research and Development (R&D): invest in dedicated R&D teams and facilities focused on exploring innovative technologies and sustainable solutions for textile production. Collaborate with academic institutions, research centres and technology partners to stay at the forefront of deep technological advancements.

Foster collaboration: Look for partnerships and collaborations with deep-tech startups, research institutions, and industry experts. By joining forces, Portuguese textile companies can leverage collective knowledge, resources, and networks to accelerate their deep technology journey and drive meaningful change.

Prioritize sustainability: view sustainability as a core value and integrate it into all aspects of the business. Explore deep-tech solutions that offer alternatives to traditional textile production methods such as waterless dyeing, waste reduction, and energy-efficient processes.

Invest in automation and digitisation: Embrace industry 4.0 technologies such as artificial intelligence, Internet of Things (IoT), and data analytics to optimise manufacturing processes, improve supply chain efficiency, and reduce resource consumption. Automation can also improve product quality, customisation capabilities, and overall productivity.

Educate and empower the workforce: ensure employees are equipped with the knowledge and tools needed to work with deep technology innovations. Offer training programs and workshops to familiarise the workforce with emerging technologies and promote a culture of continuous learning and innovation.

Embed circular economy practices: implement circular economy principles by adopting closed-loop production systems, recycling initiatives, and product lifecycle management. Encourage the design of durable, recyclable, and easily disassembled products, contributing to a more sustainable and circular textile ecosystem.

Collaborate with the industry: join collaborative projects and industry associations focused on textile sustainability and deep technological advancements. Participation in these initiatives allows Portuguese textile companies to share knowledge and best practices, collectively leading to the transformation of the entire industry.

Seek funding and government support: Explore funding opportunities and grants specifically designed for deep technology and sustainability initiatives. Collaborate with government entities, industry associations and clusters to advocate for supportive policies, incentives and funding schemes that promote the adoption of deep technology in the textile sector.

By following these recommendations, Portuguese textile companies can embark on a DeepTech journey that not only boosts their own growth and competitiveness but also contributes to the global sustainability agenda and positions Portugal as a leader in sustainable textile innovation.

Figure 15. The Adidas TERREX HS1 hoodie (image credits: Adidas)

12 Appendixes

1. SPINNOVA PARTNERS

Suzano (*www.suzano.com.br*)

Ecco (*www.ecco.com*)

Valmet (*www.valmet.com*)

Bergans of Norway (*Bergans of Norway*)

Bestseller (*https://bestseller.com/*)

Ecco (*www.pt.ecco.com/pt*)

H&M Group (*www.2.hm.com/en*)

Arket (www.*arket.com*)

Adidas (www.*adidas.pt*)

North Face (*www.thenorthface.pt*)

Marimekko (*www.marimekko.com*)

Icebreaker (*www.icebreaker.com/en-us*)

VF Corporation (*www.vfc.com*)

Halti (*www.halti.com*)

Pusu (*www.pusu.ski/en*)

2. CRITERIA FOR IDENTIFYING A DEEPTECH COMPANY *(According to the MIT)*

Criteria			Answer if Deep-tech
1. Positioned at the knowledge frontier with long and uncertain R&D cycles	**R&D at the core**	Is the developed technology at the knowledge frontier? Is there a quest for fundamental understanding?	**Yes**
		Is technology at the core of the company's activity?	**Yes**
		Is the technology internally developed?	**Yes**
	Information asymmetry	Is there sufficient available knowledge about the future trajectory of the innovation/technology?	**No**
		Is there a high regulatory risk?	**Yes**
		Is there a certain market demand?	**No**
		Is it easy to evaluate future returns of investment?	**No**
2. Importantly related to tangible products and industrialization processes	**High capital intensity**	Are there high fixed launch and development costs?	**Yes**
		Is there a need for industrialization processes?	**Yes**
	Hard scalability and tangibility	Is the product easily scalable? Is the product mainly intangible?	**No**
3. Linkages to the ecosystem and especially Higher Education Institutions	**Needs of being close to the innovation ecosystem**	Does the venture require close links to other stakeholders of the ecosystem? (in particular HEI, risk capital, government, and industry)?	**Yes**
4. Problem orientation or Mission-driven ventures	**Problem orientation**	Is there a "consideration of use"? Is interest in utility and problem orientation at the core of the company? Is the definition of the problem the core element or the "essential vector to navigate complexity"?	**Yes**
5. Creation of an "option space" and a dynamic de-risking cycle	**Optionality**	Is there a convergence of different approaches (advanced science, engineering, design) and technologies in the company? Is the focus on creating an "option space" addressing the widest possible set of problems?	**Yes**
		Is the company obsessed with a specific product or solution?	**No**
	De-risking dynamic cycle	Does the company create dynamic learning cycles to de-risk development and commercialization?	**Yes**

3. SPINNOVA'S CHRONOLOGICAL EVOLUTION

2009 – EMERGENCE OF THE IDEA

Juha Salmela, a cellulose expert investigating nanocellulose, attended a conference at the University of Oxford and heard a presentation on the similarities between spider web protein and nanocellulose.
Hence the question arises, "what if wood fiber could be transformed into textile fiber in a similar way to this natural process?"

2014 – FOUNDING OF SPINNOVA

As part of an EU project, Juha and VTT started working on this innovation and applied for a patent for the idea. Upon realizing that this was a prominent innovation in the field of nano and microcellulose, the decision was made to make a spin-off, starting the story of Spinnova.

2015 – CONSTITUTION OF THE CORE TEAM

Three key people from Juha's research team, Pasi Selenius, Johanna Liukkonen and Sanna Haavisto, also joined Spinnova, which was instrumental in the company's successful start and development. Still on a laboratory scale, the technology and fiber were on their way to the first real tests and the right concept was starting to take shape.

2019 – PILOT PHASE

After laboratory-scale research and development, the technology was scaled up to a pilot scale, but the complexities of such technology and a completely new fiber take a while to optimize. At this time, several brands had already become interested in fiber and some came together to work on joint R&D.

2020 – PREPARATION FOR THE COMMERCIAL PHASE

The technology has been scaled up from a small pilot scale to an industrial pilot scale. With partner brands, the first prototypes were presented. At this time, they are finalizing product properties and production processes, while working on new prototypes with partners.

2021 – ANNOUNCEMENT OF THE NEW FACTORY IN PARTNERSHIP WITH SUZANO

Plans to expand production were announced in a partnership with Suzano, a joint venture that built the first commercial factory in Finland, with operations expected to start at the end of 2022.
Spinnova becomes a listed company on the Nasdaq Helsinki First North Growth Market, in order to finance growth and expansion.

2021 – PUBLICATION OF THE FIRST SUSTAINABILITY REPORT

In September 2021, Spinnova's first unaudited report was published, covering the financial and sustainability area, covering the first six months of the year. Subsequently, the annual report for 2021 is published.

2022 – START OF APPLICATION OF GRI STANDARDS

Spinnova's sustainability report for the 2022 financial year was created using GRI standards.

2023 – FACTORY OPENING AND COMMERCIAL SCALE

Spinnova and Suzano officially open their first commercial-scale factory producing wood-based SPINNOVA® fiber. Operated by Woodspin – a joint venture between Spinnova and Suzano – the factory will produce 1,000 tonnes of this sustainable, recyclable and fully biodegradable textile fiber annually from responsibly grown wood.

2023 – PARTNERSHIP WITH RENEWCELL

Spinnova partners with Swedish textile recycling company, Renewcell, to develop and commercialize fibers based on textile waste, without the use of harmful chemicals. It is estimated that the first products from this new textile fiber will be available by the end of 2024.