Population growth plus increasing pressure on raw materials and resources will inevitably alter how we manufacture clothes. Companies investing in the bio sector are hoping to spur the supply chain into re-evaluating the raw materials of the future.

Back to nature

A world where all textiles are grown not sewn, are based on annually renewable feedstocks or are developed from the living world around us is not as far away as most people would imagine. As the population increases – some estimates suggest by 2050 the planet will be home to 30% more people, 9 billion – pressure on resources will intensify. If we are going to continue to clothe and feed people, the move away from finite resources is inevitable, and a number of companies are banking on that with recent investments in this forward-thinking sector.

Biosynthetics is nothing new – scientists began looking at ways to reduce dependence on non-renewable resources for textiles in the early part of the last century. Pioneers including DuPont and Arkema launched products such as Sorona and Rilsan that are still in use today, but a renewed focus over the past few years have seen spurts of growth in the field.

Researchers are looking for solutions to future pressures: pressure on oil as a raw material for synthetic fibres, pressure on land as textile crops compete with food crops which will take precedence as population grows, and pressure on water as availability declines. Cotton uses such vast amounts of water and land that seeking alternatives will be a priority. "We've got the basis of early biopolymers from the 1940s that we can build on and we can really push the dial when it comes to innovation," says Sophie Mather, founder of consultancy biov8tion. "Although there are solutions out there today, it's a relatively untapped area – we're at the beginning of this journey and I am excited to see where we can go to make a real difference."

Brands, organisations and governments are



Calvin Klein golf jacket featuring DuPont's Sorona polymer.

DuPont

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preparing for this journey. The European Union's Horizon 2020 project has earmarked €79 billion of funding available from this year to 2020, aimed at taking ideas from the lab to the market across various sectors. One focus is to reduce the EU's dependency on fossil fuels to help it meet energy and climate-change targets for 2020. It estimates a shift to biological raw materials and biological processing methods could save up to 2.5 billion tonnes of CO_2 equivalent per year by 2030. Similarly, the US is taking a more proactive line: its National Bioeconomy Blueprint published in 2012 mapped out a new focus on bio which also includes investing in research. "Industries such as textiles and paper have moved towards biobased products for both manufacturing and clean-up, and they now use microorganisms or biologically derived industrial enzymes that are more environmentally friendly and cost effective," it says.

DuPont's new target

There are, of course, a number of 'bio' textiles on the market. Manufactured cellulose fibres, such as those made from wood pulp such as Lenzing's Tencel, already have a large market presence (see the next issue of *WSA* for a look at the cellulose market).

DuPont offers a partially bio-based PTT (polytrimethylene perephthalate) marketed as Sorona and Advansa Biophyl. Sorona contains 37% annually renewable plant-based ingredients (from corn sugar), and its manufacture uses 30% less energy and releases 63% fewer greenhouse gas emissions than nylon 6, according to DuPont. The group created Sorona in the 1940s but did not commercialise it at the time due to the high cost of the key ingredient propanediol (PDO). In 2004, a joint venture between DuPont and Tate & Lyle was formed to build, manufacture and sell the new monomer, and the first Bio-PDO plant began commercial production in 2006.

At the end of last year, the company's vice-president for technology, Lewis Manring, said that within 15 years, DuPont wants half of the polymers it makes to be bio-based. The aim is to offer resins that have high levels of renewable content as a drop-in replacement for existing petrochemical-based content.

Manufacturing challenges

There are a number of companies offering fabric made with corn-based Ingeo including Swiss manufacturer Radici, Germany's Trevira and Chinese textile group Wuxi Fecund. Ingeo manufacturer NatureWorks, at its Nebraska, US-based factory, uses a process of fermentation, separation and polymerisation to transform the carbon and other elements in the natural sugars into Ingeo.

Over the past few years, NatureWorks has seen 25% to 30% increases in annual demand and has doubled its Ingeo production in the past two years. It is currently building a second plant in Thailand, after a $150 million investment from olefins maker PTT Chemical, which is expected to come on stream in 2015.

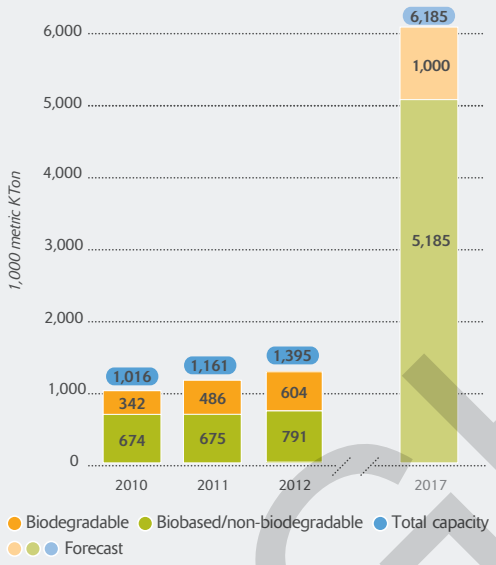
Italian textile manufacturer E.Boselli admits working with Ingeo has been a challenge. "To produce a fabric from this biopolymer featuring high-tech characteristics from a natural origin is something not just innovative but also completely aligned with contemporary market needs, which include responsibility in the product features," says company owner Marco Boselli. However, there is a "learning process" in terms of how to handle Ingeo. "We need to be aware that this is a brand new fibre, and so all the related processes need to be aligned with this."

However, once these processes are in place, he says there is a compelling argument for brands, which also need to be convinced from an aesthetic, performance and quality perspective. "Innovative, high-quality products are always a good argument for contemporary market players, even if, of course, this is a process that needs proper time, elaboration and development in order to be appropriately positioned and activated," he adds.

PEF and plant-based PET

NatureWorks in 2010 teamed up with Netherlands-based bio technology company Avantium to test a new generation of bio-based polymers, complementary to the Ingeo portfolio.

Global production capacities of bioplastics



Source: European Bioplastics / Institute for Bioplastics and Biocomposites

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Fashion of the future

There are a number of programmes under way which are taking a more radical look at 'future' textiles. "The more exciting ones for me are bacteria, algae and fungi, because plants obviously require a huge amount of land and water, and in some cases chemicals and pesticides, but we can produce bacteria, fungi and algae in vast quantities in a renewable way without conflicting with food-generating crops," says Sophie Mather. "The textiles of 2050 will be completely different from anything we are wearing today, mainly because of the resource crunches that we are going to be facing."

During the recent recession, companies scaled back on research and development to cut costs, but are now starting to reinvest, adds Ms Mather, who previously worked in Nike's innovations team where her fascination with biopolymers first started. "A lot of the things I'm hearing from the industry at the moment indicate a desire to go down this route but, with other things going on in terms of sustainability, people are fighting for resources, and so resources aren't going into this level of future thinking. I want to encourage the industry to look into the more advanced areas." This means looking at processes that are so new that machinery doesn't yet exist, she adds. "Companies will need to stick their necks out and invest."

Established in 2011, German company QMilch makes textiles from casein, a fibre derived from milk protein, and is



A seamless, stitchless dress made from Acetobacter bacteria from red wine.

Gary Cass, Micro'be'

Avantium has also been working with Coca-Cola, Danone and ALPLA on PEF (polyethylene furanoate) since 2011 when it inaugurated a furanics-based polyester pilot plant in Geleen, the Netherlands. Furanics are made using sugars from a range of biomass sources.

Last November, Avantium demonstrated that bottles made from PEF (polyethylene furanoate) can be recycled into fibres. The PEF fibre spinning and fabric weaving and dyeing was performed by the Institute of Textile Technology at RWTH Aachen University, Germany, using conventional polyester processing technology and equipment to create 100% bio-based T-shirts. "The production of the first bio-based PEF adds apparel and sportswear to the many potential outlets of PEF," says Avantium's CEO, Tom van Aken.

Toray's ecodear brand, launched last April, is an umbrella for its biomass-based polymers including bio-based polyethylene terephthalate (PET), bio-based nylon and PLA. The Japanese company currently offers a partially plant-based PET, using plant-based ethylene glycol (EG) from waste from sugar refining, produced by India Glycols, and Teraphlatic acid (TPA). By 2020, working with US-based chemical company Gevo, it hopes to offer the world's first fully plant-based PET using plant-based raw materials. Coca-Cola and Indian polyester manufacturer JBF are currently building a bio-based EG plant in Brazil, with a 500,000-tonne-per-year capacity, due to be completed this year and which Toray will tap into.

"Toray has a plan to off-take Gevo's bioPX (renewable paraxylene), and will carry out test production for fully renewable PET," explains Hiroshi Kagao, IP group manager for sportswear and clothing materials at Toray. "We will evaluate if bioPX would be the same level of specification as petro-based PX and if fully renewable PET fibre and film, including processing and application, can achieve the same as a petro-based PET."

The company will also validate an economic evaluation to Gevo's bioPX process, he adds.

Forging ahead

A number of other companies have announced they are forging ahead in the field in the past six months. Yarn producer Invista and computational biology company SilicoLife are developing new technologies to boost bio-derived processes, with the initial focus on butadiene – a starting material for nylon 6.6. "We anticipate this will help us accelerate our timeline to develop new bio-derived processes for a range of industrial chemicals, helping us improve our cost and sustainability position in this area," says Warren Primeaux, president of Invista Intermediates.

Last November, Danish biotech company Novozymes announced it will supply enzyme technology to a biomass-to-glycols bio-refinery,

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in the process of setting up a factory with a capacity of 1,000 tonnes per year. "Approximately 20% of milk produced in Europe doesn't satisfy strict food standards and is considered waste," says managing director Anke Domaske, who formed the company after reading about the fibre's perceived skin compatibility.

Casein protein appears once the milk turns sour, water is added and the mixture ground into a paste. The pulp is pushed through a spinneret to form the fibre. Compared with standard casein production, the new process is quicker, requires very little water and fewer chemicals, adds Ms Domaske, with the resulting textile biodegradable, and Global Organic Textile Standard certified. Some of the negatives include cost and a yellowish tint, but more than 600 companies have expressed an interest in collaborating and the new plant is set to be operational in April.

Researchers at Central St Martins College of Arts and Design in London are studying bio textiles as part of its Masters course in Textile Futures. They are looking into how designers will be integral to the movement by choosing new materials, and studying the crossover between biology and design. Suzanne Lee, formerly a lecturer on the course, launched the BioCouture project using bacteria grown in bathtubs of sweet green tea. She now runs a design consultancy focused on promoting living and bio-based materials to fashion, sportswear and luxury brands.

Researcher Gary Cass of Micro'be' created a dress from red wine while working with the University of Western Australia. Bacteria ferments the alcohol into fibres that can be extracted and fashioned into clothing. "The material has the potential to compete against other textiles by offering a low production cost material for fashion that is adaptable and has the potential to replace synthetic materials in manufacture," says Mr Cass. "As the fabric is naturally grown it minimises the use of machinery and offers a green alternative to traditional, carbon-producing textile manufacture."

Current downsides include a fairly long process (a dress takes a couple of days to dry) and the smell remains (although chemicals can be added to remove it). However, the project is continuing and Mr Cass is now adapting it for use in healthcare. "We are still researching the material for the fashion industry, concentrating on improving flexibility," he says. "Over the last couple of years we have also successfully researched the material for medical use, including scaffolding for tissue engineering."

Some of the other more futuristic projects being looked at include hagfish slime and seaweed. Last October, researchers from the Ocean University of China and Sun Yat-sen University completed genome sequencing of saccharina japonica, a type of kelp, which they say could be used by the textile industry and whose yield can now be improved, while Chinese textile maker Xiyingmen Group built a factory in Shandong to extract alginate fibre to produce fabrics. There are exciting times ahead.

which is being built by Chinese manufacturers M&G Chemicals and the Guozhen Group. The new facility in Anhui province will begin production in 2015 and will have the capacity to process one million tonnes of biomass per year, producing mono-ethylene glycol (MEG). One of MEG's main application areas is in the production of polyester fibre and as one of two main components in PET production.

German chemical company BASF also completed the global launch of its Ultramid S Balance in a version for monofilament applications. The high-performance polyamide 6.10 is available in various viscosities, and the bio-based sebacic acid used to produce it originates from the castor oil plant. "The demand for bio-based raw materials is increasing worldwide," says Hermann Althoff, senior vice-president of the firm's global polyamide and intermediates business unit. Nylon 6.10 is said to offer unique mechanical properties, such as higher dimensional stability and softness, compared with nylon 6 or nylon 6.6. These benefits arise from the fact that it absorbs less moisture and has a higher carbon content.

On a smaller scale, outdoor brand Patagonia teamed up with crop science specialist Yulex to develop material for a wetsuit made from the guayule plant (see *WSA* November-December 2013). "When we started to build wetsuits we knew that neoprene, by nature of its production, was the most environmentally



Ingeo biopolymer pellets.
NatureWorks

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harmful part the product," says Jason McCaffrey, Patagonia's surf director. The companies have developed a suit made of 40% neoprene and 60% guayule that they say betters the characteristics of the 100% neoprene and offers sustainability benefits as well as being skin friendly (some wearers can be allergic to neoprene). The companies hope to roll out a 100% guayule suit some time this year. "The sky is the limit," adds Mr McCaffrey. "The more attention given to it and the further development of non-food crops that thrive in arid regions using little to no water and no pesticides makes it a no brainer."

Limitations

If there are bio-alternative textiles on the market, what is preventing their wider scale adoption? Cost is one of the main factors, with many inevitably having a higher price tag for reasons including greater research and development input. "A lot of the brands and retailers are more price-driven and interested in how they can get a fabric in at $1 a yard rather than pushing the boundaries, looking at where bio is going to take us," says Sophie Mather.

Companies such as Avantium and NatureWorks claim their products are comparable, pricewise, to traditional production methods, while government grants might be available to subsidise research. Performance might be another limiter: lower dyeing temperatures might be touted as a plus point but they could need different manufacturing systems in place to deal with them.

There are also social 'barriers' that are being raised. Some companies' policies might prevent them using material that is considered a food source (for instance corn), although biopolymer makers tend to claim the sugars are from waste or that the amount of land used compared with the area needed for cotton, for instance, is inconsequential. "The certifications and systems are not sophisticated enough currently to make the distinction, however, this is being worked on," says Ms Mather.

The Textile Exchange, which commissioned a report on biosynthetics (available via *textileexchange.org/bio-synthetics-phase-1*), says at this point there are no truly sustainable fibres. "There is immense potential in the world of biosynthetics to reduce the dependence on non-renewable resources, decrease energy consumption and even influence the impacts of fibres at the consumer level," it says. "But there are other impacts to consider such as land use and GMOs (genetically modified organisms)."

Open-source access

The Textile Exchange's report, sponsored by H&M and Nike, concluded that having open-source access to lifecycle analysis, transparency and collaboration was key to increasing the adoption of biosynthetics. With issues of intellectual property and competition at stake, this might have to be encouraged at a policy level. The US government has said it will support the development of public-private partnerships and "precompetitive collaborations – where competitors pool resources, knowledge and expertise to learn from successes and failures" as part of a Bioeconomy Blueprint. It also intends to remove regulatory barriers to accelerate the advancement of bioinventions from laboratories to marketplaces.

EU Environment Commissioner Janez Potonik said recently: "Bioplastics made from bio-feedstock and reintegrated into the biosphere as a nutrient, or recycled with conventional plastic, clearly have a potential for being a truly sustainable material." However, he stressed that it is vital to keep the public informed.

Communication with consumers does seem key, but perhaps when the industry is ready to present a cohesive message. With potential additional benefits including better end-of-life or recycling options, a rebalancing of CO_2 as plants sequester it from the atmosphere, and using waste as biofuel, the green message is strong. "In terms of moving the agenda forward, we need to collaborate externally and internally," says Ms Mather. "We need to stay ahead of what consumers think they want."



German outdoor equipment and clothes company Yeti produced its water-resistant down jacket 'North' using biobased nylon by Toray for the outer shell.

Yeti

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