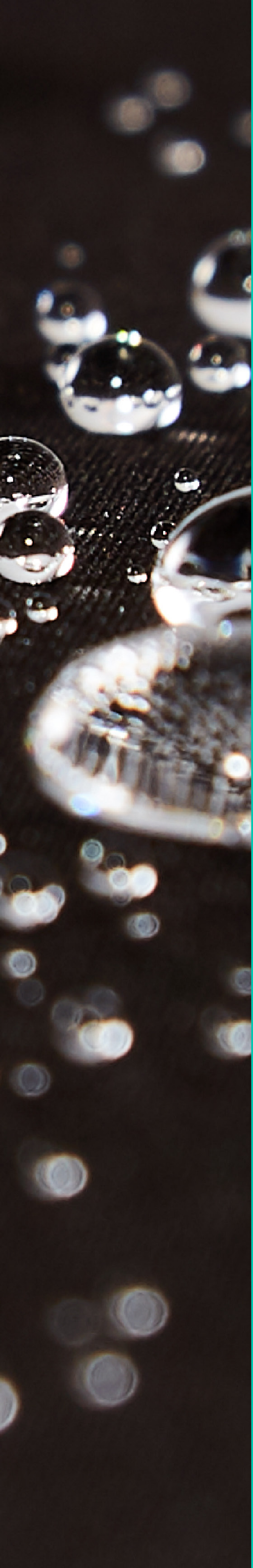

July 2023

FASHION FOR GOOD

TEXTILE PROCESSING GUIDE:

PRETREATMENT, COLOURATION & FINISHING

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Acknowledgements

LEAD AUTHORS

JANA VAN DEN BERGEN
INNOVATION ASSOCIATE
FASHION FOR GOOD

GEORGIA PARKER
INNOVATION PLATFORM DIRECTOR
FASHION FOR GOOD

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ABOUT FASHION FOR GOOD

Fashion for Good is a global platform for innovation, made possible through collaboration and community.

At the core of Fashion for Good is their innovation platform. Based in Amsterdam with a satellite programme in Asia, the global accelerator programmes gives promising start-up innovators the expertise and access to funding they need to grow. The platform also supports innovators through its scaling programme and foundational projects, driving pilots and supply chain implementation with partner organisations. The Good Fashion Fund catalyses access to finance to shift at scale to more sustainable production processes.

As a convener for change, Fashion for Good houses the world's first interactive museum dedicated to sustainable fashion and innovation, a Circular Apparel Community co-working space, and creates open-source resources and reports.

Fashion for Good's programmes are supported by founding partner Laudes Foundation, co-founder William McDonough and corporate partners adidas, BESTSELLER, Burberry, C&A, CHANEL, Inditex, Kering, Levi Strauss & Co., Otto Group, Patagonia, PVH Corp., Reformation, Target and Zalando, and affiliate and regional partners Arvind Limited, Birla Cellulose, Norrøna, Pangaia, Paradise Textiles, Shahi Exports, Teijin Frontier, Vivobarefoot, Welspun and W. L. Gore & Associates.

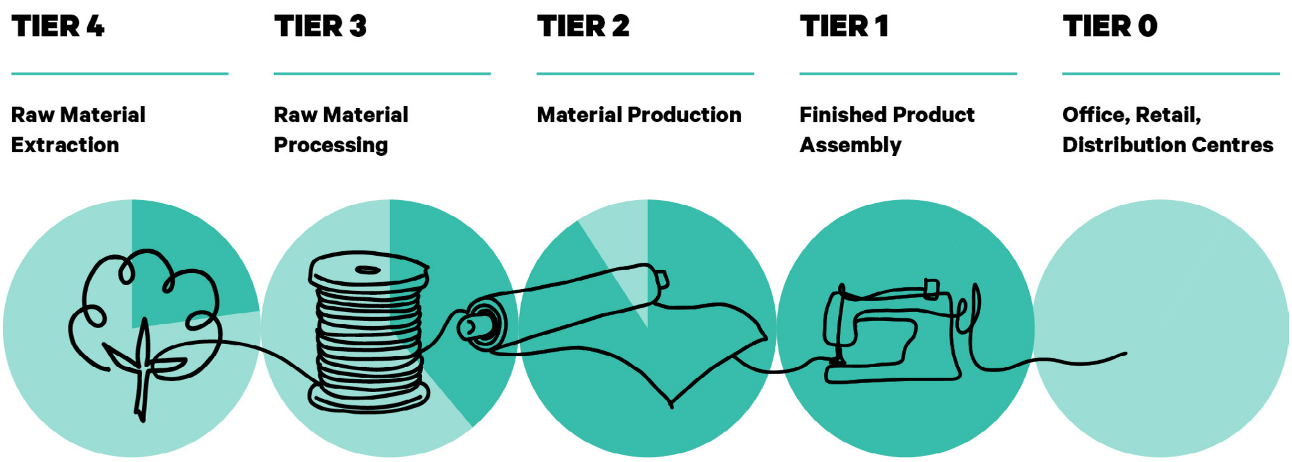
A definition of all the key terms highlighted in teal can be found on page 33.

Introduction

The impact of today's fashion industry has far reaching environmental consequences. And while raw material production and end of use may spring to mind, the processing stage of the supply chain, including pretreatment, colouration (dyeing and printing) and finishing, is often overlooked as a critical area for pivotal and positive change. This guide, based on industry and Fashion for Good research, is designed to provide an overview and deeper understanding of the processing stage, including innovative technologies that would help drastically reduce the water, energy and chemistry used, as well as replacing hazardous chemistry currently used[1]. A definition of all the key terms highlighted in teal can be found on page 32.

The textile industry's supply chain is commonly represented in four Tiers, this is used to describe the production process from raw material extraction to the finished product. Tier 4 includes the cultivation and extraction of raw materials from the earth, plants or animals. Tier 3, the processing of raw materials into yarn and other intermediate products. The processing stage, discussed in this report, falls into Tier 2, which is often referred to as material production. Tier 1 is the assembly and manufacturing of the final products[2].

Tiers 3 and 4 are often cited as the main cause of the fashion industry's high environmental impact but actually make up only 38% of all greenhouse gas (GHG) emissions in the fashion supply chain. Whilst Tier 2 equates to 53% of the GHG emissions, and requires a significant amount of chemistry and water[3].



Four Tier Supply Chain Model. Source: WRI and Aii (2021)

As a result, there is ample opportunity to reduce impact in this stage of the supply chain. Fashion for Good works with brands, manufacturers and innovators to orchestrate collaborative projects and pilots aimed at accelerating innovation and implementation. The D(R)YE Factory of the Future, consortium project for example, was launched and orchestrated by Fashion for Good together with partners adidas, Kering, PVH Corp., Arvind Limited, and Welspun India and several innovators in textile pretreatment, colouration and finishing. The project brings together several novel technologies with the aim of disrupting the current processing of textiles in the fashion supply chain.

An Overview of Processing

During the processing stage, the fibres, yarns, fabrics or garments go through multiple steps to achieve the performance and aesthetic properties desired by brands and their consumers. These steps can be broadly categorised into pretreatment, colouration and finishing treatments and make up most of the impact taking place in Tier 2.

	PRETREATMENT	COLOURATION	WASH/DRY & FUNCTIONAL FINISHING
Description	Pretreatment's main purpose is to clean the fibre/fabric and make the dyeing or finishing step more efficient. It's often followed by a dry heat stentering process to induce stability into fabrics.	Colouration is the application of dyestuff on textile materials such as fibres, yarns or fabrics with the goal of achieving colour with desired colour fastness.	Post wash/drying is required to fix chemicals to the fabric. Functional finishes are applied to a textile to give it a specific desirable quality or functionality. Additional heat setting is applied as required.
Processes* & Functions examples	Functions: (De)sizing, Scouring, Bleaching, Neutralisation, Mercerising, Optical Brightening, Bio-polishing Dominating machines: padder or heated chemical bath (e.g. pad-steam, pad-roll, J-box, Jigger)	Functions: Dyeing & Printing Dominating machines chemical bath (e.g. jigger & jetter) *Different dye types are used for different fibres*	Functions: fixing chemistry, DW(O)R, Flame Retardancy, Stain resistance, Easy Care, Softening, Antistatic, Antimicrobial, Biopolishing, Improved handle Dominating machines: padder or heated chemical bath (e.g. pad-steam, pad-roll, J-box, Jigger)
Impact	Key impact: A significant amount of water, energy and chemistry required to heat up large baths.		

*A description of all processes and functions can be found in Appendix A

FIGURE 1: OVERVIEW AND DEFINITIONS OF PROCESSING STEPS

Traditionally pretreatment, colouration and finishing are referred to as wet processes as they take place in large tanks or baths filled with water that is constantly kept at a high temperature[4]. Alongside the pretreatment, colouration and finishing steps, a significant amount of water and chemistry is wasted as the fabrics also have to be washed off to remove excess dyes and chemicals. Approximately 10-50% of dyes are washed out in this process, ending up in the effluent water[5].

An Overview of Processing

Fashion for Good divides the processing stage in two categories to help differentiate between the chemical applied ie: chemistry and the process by which this chemistry is applied ie: machinery. An overview is outlined below in Figure 2.

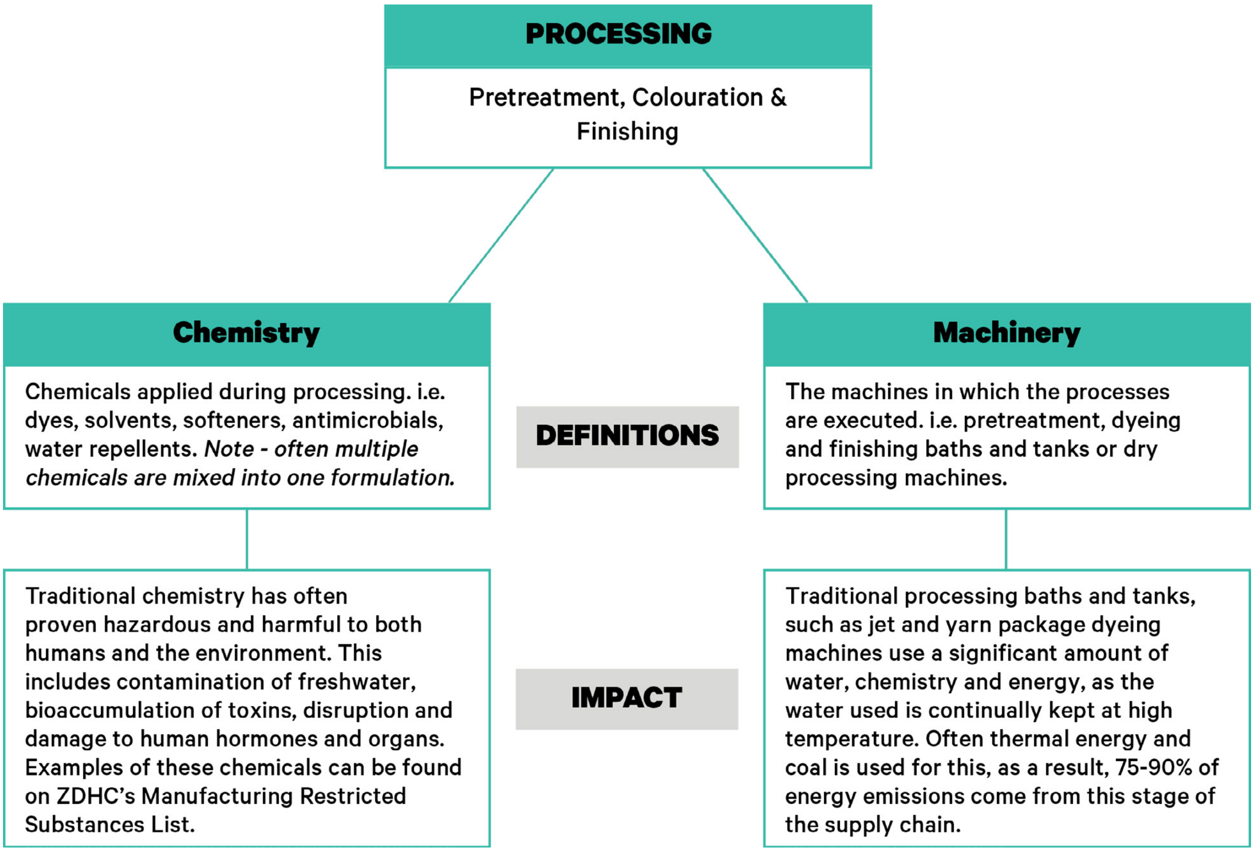


FIGURE 2: OVERVIEW OF CONVENTIONAL CHEMISTRY AND MACHINERY

An Overview of Processing

DW(O)R FINISH AND PFCs

What are Durable Water and Oil Repellency (DW(O)R) and perfluorochemicals (PFCs)?

- DW(O)R finishes ensure fabrics repel water and oil by preventing these liquids from spreading on the fabric surface and wetting the fabric.
- The performance of the repellency can be assessed through a variety of testing methods.
- Traditional DW(O)R finishes contain perfluorochemicals (PFCs) to achieve high performance.
- PFC can refer to two distinct but related chemical classes:
    - The first are chemicals which include toxic perfluorooctanesulfonic acid (PFOS) and other per- and polyfluoroalkyl substances (PFAS).
        1. PFOSs have been linked to kidney and testicular cancer, as well having a negative impact on human thyroid function
        2. PFOAs are reprotoxic; decreasing fertility and having adverse developmental effects
    - The second refers to perfluorocarbons, which share similar characteristics but only contain fluorine and carbon atoms. They are difficult if not impossible to break down and are therefore also referred to as forever chemicals.
- As a result, a significant effort is going into finding high performing PFC-free DW(O)R treatments, Fashion for Good is supporting innovators, such as OSM Shield ZERO and Dryfiber, focusing on this.

Source: *EPA (2019), Sepa (2019), Nicole (2013), O'Rourke & Strand (2017)*

ANTIMICROBIAL FINISH AND HEAVY METALS

What are antimicrobial finishes and heavy metals?

- Antimicrobial finishes are applied to inhibit the growth of bacteria, mould and fungi on fabrics. This keeps the fabrics hygienic and prevents odours. Antibacterial finishes are a kind of antimicrobial finish that can kill or inhibit the growth of bacteria such as E.coli. These finishes will not be effective against viruses (e.g. coronavirus)[6].
- Antiviral finishes claim to kill or inhibit viruses, typically in addition to being antimicrobial[7].
- Many antimicrobial and viral finishes have been proven to contain heavy metals such as silver, copper and zinc[8]. These can leach into water and impact aquatic life. Besides this, studies have shown they can be harmful to humans when ingested or exposed to skin. In fact, the extent of the effects of heavy metals on humans is still unknown[9].
- Bio-based and/or heavy metal free antimicrobial finishes are being developed. Fashion for Good is supporting multiple innovators, such as Nordshield and OSM V-Shield, who focus on this.

A number of solutions exist that would help reduce the use of water, energy and harmful chemistry in this stage of the supply chain. Some of these are incremental solutions whilst others are disruptive innovations. The next section briefly touches on some of these incremental solutions, you can learn more about these solutions in Fashion for Good x Apparel Impact Institute (Aii)'s report '*Unlocking the Trillion - Dollar Fashion Decarbonisation Industry'.* The report charts a trajectory for the industry to meet its net-zero ambition, breaking down the funding needed and mapping the integral levers across existing and innovative solutions.

Incremental Innovation

MACHINERY

There are opportunities to reduce GHG emissions by switching to renewable energy as well as implementing process efficiency improvements, including better insulation, heat recovery and metering. The Apparel Impact Institute focuses on implementing these improvements through their Clean by Design Programme. A recent case study from a facility who had implemented the Clean by Design Programme showed up to 10% CO_2 reduction (10% includes 4% reduction in natural gas, 5.8% in electricity, 5% in coal and 8% in steam use) can be achieved[10]. An advantage of this approach is that the projects are low risk, meaning the workflows of the textile mills are not disrupted and the performance of these technologies has already been proven.

CHEMISTRY

A significant amount of effort from all supply chain stakeholders has been put into phasing out harmful chemistry. Many brands have implemented restricted substances lists (RSLs) defined by organisations like ZDHC and AFIRM and chemical manufacturers have developed chemistries that are non-hazardous and less harmful.

Certifications from organisations such as Bluesign and OEKO-TEX help verify the content of these products and are often a requirement of brands. Alongside this compliance with REACH (Registration, Evaluation, Authorization and Restriction of Chemicals) legislation (European Union's legislation on chemicals) is required in order to be able to sell products in Europe.

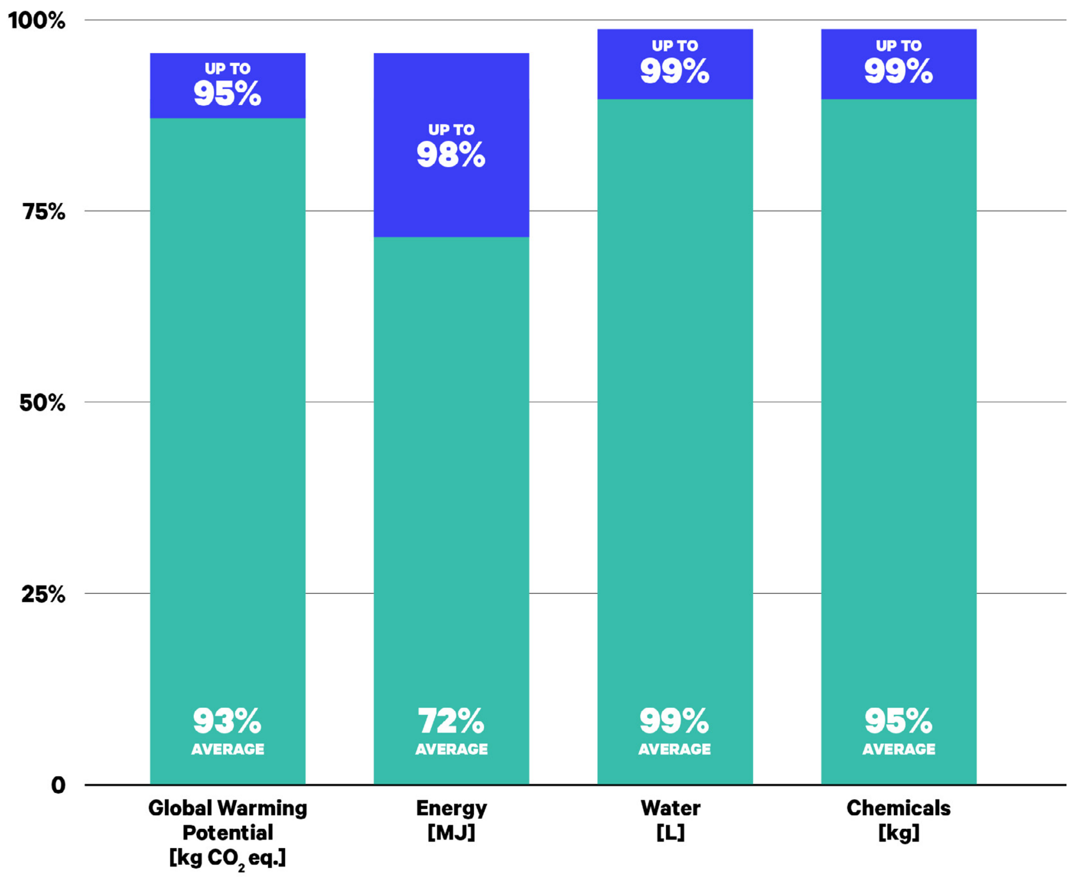
However, there is still a long way to go to phase out all harmful chemicals as innovations need to also meet the necessary performance requirements. In order to achieve a real step change, the industry needs the disruptive innovations discussed later in this report.

Disruptive Innovation - Machinery

To effectively minimise the environmental impact associated with the processing stage of the fashion supply chain, a pivotal solution lies in the adoption of innovative processes that prioritise lower energy, water, and chemical requirements compared to conventional methods. This approach is exemplified by the graphs below, which highlights the average and maximal potential impact savings, in terms of Global Warming Potential (GWP)[11], Energy, Water and Chemicals usages, attainable through the shift from conventional wet processing technologies to mostly dry pretreatment and colouration innovations.

POTENTIAL IMPACT SAVINGS

PRETREATMENT



Disruptive Innovation - Machinery

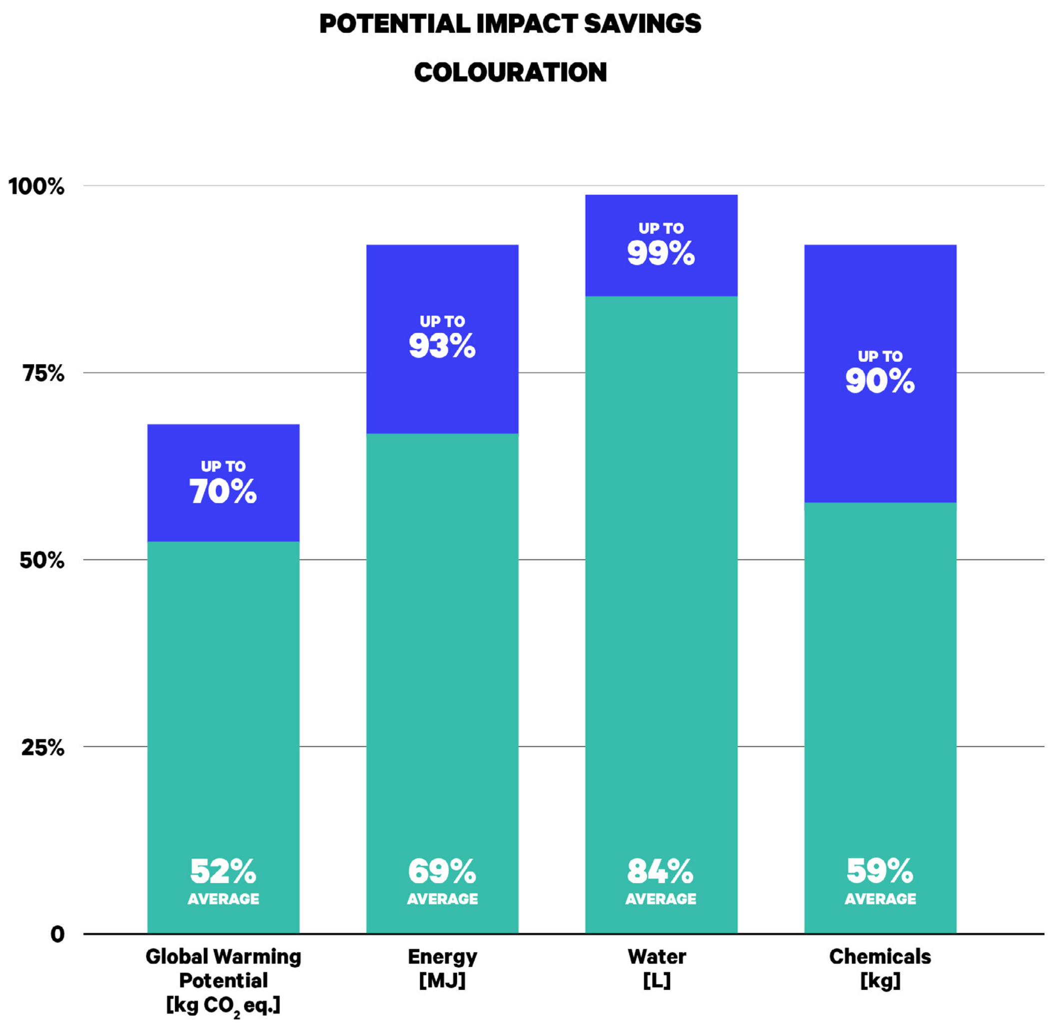


FIGURE 1. IMPACT POTENTIAL SAVINGS RESULTING FROM MOVING FROM WET TO MOSTLY DRY TEXTILE PROCESSING TECHNOLOGIES. SOURCE: FFG ANALYSIS (2023).

The results are obtained from an internal analysis that gathered savings data on the impact of different Fashion for Good innovators compared to conventional pretreatment and colouration methods for various fabric types (such as cotton, polyester, and polycotton). The calculations include wash off (removal of excess dyes, chemicals, or other impurities from the fabric through washing) and drying data whenever available. However, it's important to note that the figures reported do not include the finishing step.

In addition, the above figures show that pretreatment innovations have a higher impact reduction potential than colouration innovations. This is because pretreatment innovations are able to reduce subsequent washing steps that traditionally need to be performed after pretreatment almost entirely while colouration innovations can only partly reduce the washing activities originally required after the colouration process.

Disruptive Innovation - Machinery

Figure 5 below illustrates some of these disruptive machinery innovations, including some of the innovative companies working in this space.

PROCESSING STEP	DISRUPTIVE TECHNOLOGY	INNOVATORS
PRETREATMENT	**Plasma / Plasma & Laser**	MTiX, GRINP lights your plasma
DYEING	**Digital Spray**	imogo, Alchemie
	Supercritical CO_2	DEVEN Supercriticals, eCO2Dye, DyeCoo
	Ultrasonic	IndiDye
	Foam	Indigo Mill Designs
	Dope	We aRe SpinDye
PRINTING	**Gravure Printing**	NTX Next Technologies & Xvantages
	Digital Printing	Kornit Digital
FINISHING	**Plasma / Plasma & Laser**	MTiX
	Digital Spray	imogo, Alchemie
	Ultrasonic	sonovia
	Ozone	Jeanologia, Tonello THE INSPIRING COMPANY
	Laser	Jeanologia, Tonello THE INSPIRING COMPANY

FIGURE 5: OVERVIEW OF INNOVATIVE MACHINERY SOLUTIONS

Disruptive Innovation - Machinery

TECHNOLOGIES AND INNOVATIONS

Plasma / Laser

Plasma, the fourth state of matter, is formed when gas is ionised and becomes more reactive. When this ionised form of gas is applied to a substrate aka surface or fabric, it is able to alter its properties i.e. activating its surface, removing impurities, depositing a coating. It is a waterless technology, has low energy consumption and is effluent free.

MTIX*

MTIX has developed a multiplexed laser surface enhancement (MLSE®) system for textiles. The MLSE® system creates a unique quantum mechanical energy milieu with laser plasma that enables durable technical functionalities, finishes and pretreatments on all fabric types in a high volume and continuous process.

GRINP*

GRINP develops and produces machines using their proprietary atmospheric plasma technology. Their industrial machines can replace traditional pretreatments such as bleaching. The technology is fibre agnostic.

Image courtesy of MTIX

* Fashion for Good Alumni - Fashion for Good have supported over 135 innovators through our projects and programmes. They continue to be a part of our alumni network with Fashion for Good providing continued ongoing support

Disruptive Innovation - Machinery

Digital Spray Dyeing and Finishing

Nozzles spray the exact amount of dyestuff and finishing chemistry required directly onto the fabric. The process is digitally controlled and therefore highly efficient. As a result, it uses very little water and much less dyestuff and chemistry than traditional processes. This process is not the same as digital printing (explained below), digital printing focuses on creating artworks on the surface of a fabric while spray dyeing mostly focuses on dyeing fabrics in solid colours with deep penetration. As a result, the nozzle openings in digital printers are significantly smaller than those used in spray dyeing. This means that digital printing often needs expensive speciality inks while spray dyeing can work with traditional dyes.

Alchemie*

Alchemie has developed a digitally enabled spray/jetting technology which in combination with their proprietary airflow technology is able to deeply penetrate the fibre. Their dyeing machine is called Endeavour and their finishing machine is called Novara. In addition to these two machines, Alchemie has developed a proprietary fixation process consisting of infrared radiation/heat which fixes the dyes to the fabric. Their high precision means they can dye to shape as well as simple patterns. The technology is compatible with traditional dyes and chemistry and can be used on polyester and cotton fabrics.

imogo*

imogo has developed a digitally enabled spray dyeing and finishing technology, which is used in their Dye-max (dyeing) and F-max (finishing) machines respectively. They use the capillary forces in the materials and the fibre's natural absorption to get deep penetration. Both machines are compatible with traditional dyes and chemistry and they are currently focusing on cellulosics. Fixation is done by traditional methods such as cold batching.

Image courtesy of imogo

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Disruptive Innovation - Machinery

Supercritical CO_2 Dyeing

In conventional dyeing, water is used as a solvent but in supercritical CO_2 ($scCO_2$)dyeing, $scCO_2$ replaces water as the solvent. In a supercritical state, CO_2 gets the dual advantages of having solubility like a liquid and flow properties like a gas. Due to its gaseous properties the $scCO_2$ can circulate in the dyeing vessel and deposit the dyes onto the textile yarn or fabric. When dyeing is complete, the high pressure vessel containing the $scCO_2$ is depressurised. As a result, the CO_2 reverts to its gaseous state and the dye, which cannot stay dissolved in a normal gas, drops to the bottom of the dyeing vessel. Both can be recovered and it is a closed loop waterless dyeing process. As a result, there is no water effluent and the process uses less energy and chemicals.

eCO$_2$Dye*

eCO$_2$Dye has developed a dyeing technology using $scCO_2$. The equipment is designed to dye a variety of yarns and threads on conventional cones or packages using $scCO_2$. Traditional dyes which are compatible with $scCO_2$ have been identified. The process uses existing CO_2 which is recycled after each dyeing process cycle. Pretreatment (e.g scouring) and dye removal from waste textiles with supercritical CO_2 is in research and development (R&D). The technology can be used to dye polyester and wool yarns.

Deven Supercriticals*

Deven Supercriticals has developed a dyeing and finishing technology using $scCO_2$. Rather than only introducing the dye in the dyeing vessel, they precoat the fabric with dyes and chemicals before it enters the dyeing vessel, using the $scCO_2$ to improve their solubility in $scCO_2$ with it before it enters the dyeing vessel. This makes their technology compatible with traditional dyes and can be used to dye polyester, cotton and cotton-polyester blends.

DyeCoo

DyeCoo has developed a waterless and process chemical-free supercritical $C0_2$ dyeing solution. Their technology uses reclaimed CO_2 as the dyeing medium in a closed loop process. The Fabric or yarn is loaded together with pure dye into the dye vessel where the liquid $C0_2$ is released. When pressurised, this CO_2 becomes supercritical ($sc\text{-}CO_2$). Thanks to the high permeability, the dyes are transported easily and deeply into fibres, creating vibrant colours. Their technology is applicable to both synthetic fabrics and yarns with a primary focus on polyester.

Ultrasonic Dyeing and Finishing

Ultrasonic waves are acoustic waves that create thousands of microscopic bubbles in a formulation which, when burst, release large amounts of energy. The pressure from the bursting of these tiny bubbles generates powerful jet-streams that are used to physically inject the fabric with the desired chemistries. This process means less water and chemistry is needed as well as fewer additional chemistries like binders.

Sonovia*

Sonovia has developed a compact ultrasonic finishing machine and process that embeds Sonovia's customised chemistries for finishing applications directly into the fabric. To date, Sonovia has developed antimicrobial and viral finishes as well as DWR, their technology is fabric agnostic.

* Fashion for Good Alumni - Fashion for Good have supported over 135 innovators through our projects and programmes. They continue to be a part of our alumni network with Fashion for Good providing continued ongoing support

Disruptive Innovation - Machinery

Indidye*
Indidye uses sound waves to bind their proprietary natural plant based dyes to cellulosic fibres. The dyes are extracted with a water based extraction process and then applied using the ultrasonic technology.

Foam Dyeing
Large foam bubbles carry dyestuff and when the bubbles burst, the pressure deposits the dye on the fabric/yarn. This results in lower water and chemistry usage and as a result it is a more efficient process than traditional dyeing.

Indigo Mill Designs*
Indigo Mill Designs has invented a novel way of applying indigo to cotton yarns, called IndigoZERO™. The dye is applied to the fibre using a foam system that minimises the uptake of water.

Dope Dyeing
A method of colouring man made fibres by incorporation of the colourant in the spinning composition before extrusion into filaments or fibres. While this is not a new technology, it has the potential to drastically reduce resource consumption in the colouration process.

We aRe SpinDye*
We aRe SpinDye orchestrates the dope dyeing of polyester yarns for fashion brands. Brands get a quality, compliance & traceability We aRe SpinDye®-certificate for all products they take off. This certificate also states Life Cycle Assessment (LCA)-based impact savings compared with traditional dyeing processes.

Gravure Printing
Gravure is different from other printing processes as it prints from depressed, ink-filled cells that are produced on the surface of a cylinder that is copper plated. The ink in these cells is transferred onto the fabric. The process is digitally controlled to engrave the roller and therefore highly efficient. Traditionally the gravure roller requires a transfer of the artwork onto a paper or film which is then transferred onto the material substrate. It is a mostly waterless process that uses less energy than conventional dyeing.

NTX: Cooltrans*
NTX: Cooltrans provides a digitally enabled gravure printing method for both artworks and block colours. Their technology is faster and more precise than other printing technologies and they use proprietary inks (material restricted substance list (MRSL), ZDHC and RSL compliant) that are manufactured in-house. Alongside this, for solid colour applications, their technology transfers from gravure to the material without paper or film. It can be used on all fibre types except polyolefins.

Digital Printing
Digital textile printing is an inkjet-based printing method which enables printers to print high-quality designs from a digital data file onto different fabrics. The ink is deposited in the form of minuscule droplets by the digitally controlled printing heads. It is a mostly waterless process and reduced energy use as no dye bath is needed.

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Disruptive Innovation - Machinery

Kornit
Kornit is an established digital printing technology company. They are classified as an innovator/innovative company as they have developed a single step printing solution which combines fixation, dry softening and full curing. It is fabric agnostic.

Ozone
Ozone, which is an alternative form of oxygen and a strong oxidising agent, can be used to clean / bleach the garment, it's most effective when used inside a washing machine to prevent the gas escaping and to allow for its correct neutralisation. At the end of the process, any remaining ozone is converted back into oxygen. Ozone pretreatment and finishing reduces water, chemistry and energy consumption and as a result there is also less effluent. Ozone is often used for finishing jeans and also has enhanced performance benefits such as achieving the right shade of blue faster and with lower costs.

Laser
Laser technology is most commonly used as an alternative to manual scraping in denim production; it can also be used to create vintage effects, whiskers, patterns, patches, and even intentional holes and tears in a (denim) garment. Used in combination with other technologies such as ozone, it can replace traditional processes like sandblasting and bleaching which are hazardous to workers' health.

Tonello and Jeanologia
Tonello and Jeanologia are both established players selling multiple industrial dyeing and finishing technologies with a strong focus on sustainability and denim. They both have ozone and laser technologies as well as several other more efficient washing and finishing processes that have enhanced performance benefits as well as environmental savings.

Image courtesy of Jeanologia

CHALLENGES OF SCALING DISRUPTIVE MACHINERY INNOVATIONS

The impact savings mentioned above raise the question as to why more textile mills have not switched to mostly dry processes yet. Below we will elaborate on the challenges of this transition.

Misaligned Incentives and Unequal Power Relations
Although brands have the greatest incentive and the most pressure to drive towards sustainability, efforts are often limited, and the industry expects the upstream supply chain to account for the costs and risks. This results in a misalignment of incentives for major innovation along the supply chain.

High Initial Investment
Investing in new processing technologies is expensive. Alongside this, the investment often falls to the manufacturers who do not always have committed offtake from brands. Increasingly, brands and manufacturers sign letters of intent (LOI), which include a commitment from the brand that they will purchase a certain number of products made using the new technology. Or recent collaborations include an innovator, manufacturer and brand partners jointly investing in a novel machine through a joint venture (JV) structure. The machine is installed at the manufacturer who is part of the JV.

That said, while initial capex for some technologies are high, payback times can be as short as 1 to 2 years as variable costs, from water, energy, and chemistry, are reduced[12].

Performance
As with all new technologies, there are risks around the technology's ability to meet minimum performance requirements for different applications at scale. In addition, mostly dry technologies can impact the handfeel of materials differently than wet technologies. Therefore it is important that the technologies are optimised to achieve the same handfeel as the industry is accustomed to after wet processing.

Incremental vs. disruptive innovation
Brands/manufacturers might feel they have to choose between investing in either incremental or disruptive technologies. Once they have gone down the route of incremental changes, this may form a barrier to invest money in disruptive technologies. Investments in new innovations have the potential to generate higher savings in environmental impact, however it comes with a greater risk. As a result, the direction taken by the brands/manufacturers depends on their strategic priorities and internal risk appetite.

Disruptive Innovation - Chemistry

Although great progress has been made when it comes to innovation in sustainable chemistry there are still a number of hazardous chemicals which can be found on ZDHC MRSL and RSL lists to which no similar performing, less harmful alternative has yet been found. As such, disruptive innovation in this space mostly focuses on finding competitive alternatives that could either replace a specific chemical in a solution or by replacing a solution with a new formulation. Examples of this could include formulations that are bio-based or based on a non-harmful chemistry like silicone. Figure 6 shows an overview of the disruptive technologies and innovators. Below an overview of some of the most used processes in the pretreatment, dyeing, printing and finishing.

PROCESSING STEP	DISRUPTIVE TECHNOLOGY	INNOVATORS
PRETREATMENT	Cationic treatment	Nano-Dye
	Enzymatic treatment	novozymes
DYEING/PRINTING	Natural dyes/pigments	Stony Creek Colors, Living Ink, Nature Coatings, IndiDye, Algaeing, Joy of Life, ever dye
	Microbial pigments	Colorifix, KBCols sciences, huue
	Dyes from Carbon Capture and Utilisation	Graviky Labs
	Recycled dyes	Dye Recycle
FINISHING	PFC-free DW(O)R finish	OSM Shield, Dryfiber, lamoral, Beyond Surface Technologies
	PFC-free waterproof membrane	dimpora
	Bio-based antimicrobial treat-ments	NordShield

FIGURE 6: OVERVIEW OF INNOVATIVE CHEMISTRY SOLUTIONS

Disruptive Innovation - Chemistry

TECHNOLOGIES AND INNOVATIONS

Cationic treatment

Chemistry innovations in pretreatment are more limited than in dyeing and finishing. An example of an incremental innovation in this space is cationic treatment. With this treatment, cotton is modified to have a permanent cationic, or positive charge, making the cotton "friendlier" to dye and so increases its dye uptake. Cationic treatments have the opportunity to enhance the dyeability of cotton but require advanced effluent treatment as they can cause eutrophication.

Nano Dye

Nano dye has a salt-free cationic treatment that potentially does not result in high eutrophication. Salt is commonly used in the pretreatment process which then ends up in the effluent water, impacting the local environment. Nano Dye's technology is a drop-in solution that changes the charge of a cotton molecule to the opposite charge of the dye to enhance dye uptake. It is used with cotton, other cellulosic fibres and blends.

Enzyme treatment

Conventional scouring is harsh on fabrics and the environment. Enzymes can be used to modify the fabric to become more receptive to dyes through processes such as bioscouring, they can be used in both pretreatment and finishing[13]. It is a more sustainable solution that allows savings in water, time and energy as well as a reduction in the usage of harmful chemicals which improves worker safety.

Novozymes

Novozymes produces and develops biological solutions for textiles including enzymatic scouring, also known as biopreparation or bioscouring.

Fermentech Labs*

Fermentech Labs processes agricultural waste in a novel SSF bioreactor through which the cellulosic parts are pretreated & processed by proprietary microbes to produce enzymes such as cellulase, amylase and pectinase for applications like bio-polishing, desizing and bio-scouring.

NATURAL DYES/PIGMENTS

Natural dyes and pigments, from sources like algae and plants, have existed for centuries but have historically been overlooked by the fashion industry due to inferior performance, limited colour palette and higher prices than synthetic dyes. However, new disruptive cultivation, extraction and application processes have the potential to overcome these barriers and enable the (re)implementation of natural dyes at scale. Using natural dyes and pigments enables a shift away from synthetic chemistry and in some instances the feedstock used ie: plants, algae or waste means the dyes and pigments have the potential to be carbon negative.

DYES VS PIGMENTS

What is the difference between a dye and a pigment?

- Dyes are water soluble - like salt in water - and so can penetrate into a material and be held within it by chemical forces.
- Pigments are water insoluble - like sand in water - they must be disperse in a binder and are applied to the surface of the material.

Plant based dye

Stony Creek Colors*

Stony Creek Colors creates a pre-reduced plant-based indigo that can replace petrochemical based synthetic indigo dyes. They optimise indigo production in a renewable (and aniline - free) closed loop process. It can be applied on cotton, cellulosics, wool and silk.

Ever dye*

Ever dye has developed a novel dyeing process that includes a proprietary pretreatment in combination with natural pigments, that allows for dyeing at room temperature. The liquid pretreatment charges the surface of cellulosic fabrics/yarns negatively, enabling positively charged pigments that have been created out of minerals, nanocellulose extracted from vegetal waste and a positively charged proprietary organic molecule.

AN Herbals*

AN Herbals has developed a patented technology for extraction of powdered dyes from pharmaceutical (ayurvedic)/forest/food waste that allows dyeing of fabrics to be done without the use of any synthetic auxiliaries.

Image courtesy of Stony Creek Colors

* Fashion for Good Alumni - Fashion for Good have supported over 135 innovators through our projects and programmes. They continue to be a part of our alumni network with Fashion for Good providing continued ongoing support

Algae-based pigment

Living Ink*

Living Ink transforms waste microalgae material into a bio-based carbon black that can replace petroleum derived carbon black. The pigment is jet black and UV stable. It can be used for screen printing on cotton, cellulosics, blends, leather and polyester. Dope dyeing applications are in Research & Development (R&D).

Algaeing*

Algaeing uses microalgae to manufacture dyes and inks in a closed system that can be used with existing production machinery. It can be used to dye and print all types of fibre.

MICROALGAE VS MACROALGAE

What is the difference between microalgae and macroalgae?
Algae can be used as an input to create fibres and chemistries. It has received a lot of attention lately as products derived from algae have the potential to be carbon negative. Algae can be divided into two types; microalgae and macroalgae, the differences are explained below.

Microalgae	• Unicellular microorganisms, living in saline or freshwater environments, that convert sunlight, water, nutrients and carbon dioxide to algal biomass. • It can be grown everywhere if nutrients can be provided (e.g. can grow in tubes on arid land). • Final material chemistry and volume can be changed by controlling growth nutrients and other conditions (e.g. light).
Macroalgae	• Macroalgae is a term used for seaweed and marine algae attached to the sea bed. Outside of the textile industry, it has been used in other areas to produce biofuels, cosmetics and soil fertilisers to name a few. • It can only be grown in certain locations with specific conditions and usually grows in coastal areas. • There are three types of macroalgae: brown, red and green.

FIGURE 7: OVERVIEW OF MICROALGAE VS. MACROALGAE

Source: *Khan et al. (2018); FAO (2009), Usher et al. (2014), Campbell et al. (2019)*

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Disruptive Innovation - Chemistry

Woodwaste-based pigment

Nature Coatings*

Nature Coatings transforms Forest Steward Council (FSC) certified wood waste into high performing and cost competitive black pigments. Their pigments are a direct replacement for petroleum-based carbon black pigments. The pigments and 100% bio-based dispersions can be used for screen printing on cotton, cellulosics, blends, leather and polyester. Dope dyeing applications are in R&D.

Microbial pigments

Microbial pigments are either naturally occurring in organisms or artificially grown in genetically modified organisms (GMO). Once the naturally occurring microbe is identified or a genetically modified microbe strain has been engineered, the microbes get multiplied via fermentation by feeding them sugars and other feedstock. After this process the pigments are extracted to be used in traditional dyeing processes. Microbial pigments can replace synthetic pigments, and thereby reduce GHG emissions as well as the amount of potentially harmful chemistry used.

Colorifix*

Colorfix uses microbial pigment technology to produce, deposit, and fix colour onto textiles. They genetically modify microbes to produce a wide range of naturally-occurring pigments and ferment them using renewable feedstocks. Instead of extracting the dye from bacteria through an expensive downstream processing step, Colorifix utilises the fermented broth of the bacteria as the dye liquor. This innovative technology allows for dyeing various types of fibres and fibre blends.

Huue*

Huue uses microbial pigment technology to produce dyes and pigments, with indigo dye as its first product. After extracting the pigment from the bacteria and processing it, the bio-based dye can be used as a drop-in replacement for synthetic Indigo, with high purity and with the same performance. The pigments can be used to dye cotton fibres and any other substrates typically dyed with indigo.

Pili Bio *

Pili Bio uses microbial pigment technology to develop and produce biobased dyes and pigments. Their first commercially available product is indigo powder. In order to offer the same high-performance as fossil-based products, PILI combines fermentation and chemistry to produce drop-in dyestuff products with a biobased content ranging from 60% to 100%.

KBCols Sciences*

KBCols Sciences use microbial pigment technology, using non-GMO naturally occurring coloured microbes sourced from the soil, water and air, to extract different natural colours that can be applied in textiles and other applications. The pigments can be used to colour most natural and synthetic fibres.

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Disruptive Innovation - Chemistry

ALTERNATIVE DYES/PIGMENTS
There are many alternative sustainable dyes and pigments on the market or in development. These include pigments made from captured carbon and recycled dyes made from old textiles.

Pigments from Carbon Capture and Utilisation
Turning carbon emissions from industrial pollutants into industrial grade products. Using captured carbon as a feedstock means a shift away from synthetic chemistry as well as a reduction in greenhouse gas emissions.

Graviky Labs*
Graviky's first product AIR-INK® is a range of inks and pigments made by end-of-use carbon emissions. The black pigment can be used for different printing processes such as screen, sublimation and digital. Graviky has tested AIR-INK on different surfaces such as paper, polyester and textiles. Dope dyeing applications are in R&D.

Farbenpunkt
Farbenpunkt developed the patented PERACTO technology for dyeing and printing. The dyestuff is processed to a very small size with an average diameter of below 500 nanometers. These very small dye particles easily penetrate textile substrates colorising the surface and subsurface completely. The bond is both mechanical and chemical, effective on various textile materials and blends.

Recycled dyes
Recycled dyes can be generated in two ways. Firstly, by transforming textile waste into a finely crystallised powder and utilising it for dyeing purposes. Alternatively, dyes can be chemically recovered from pre- or post-consumer waste and then used to redye different fabrics. Employing textile waste as a feedstock not only decreases the reliance on synthetic chemistry but also enables a more circular process, promoting sustainability and reducing waste.

Officina +39 : Recycrom*
Recycrom is a range of dyestuff produced by transforming used clothing, fibrous materials, and textile scraps composed of cellulosic fibres into a highly refined powder suitable for dyeing. This dyestuff has the ability to colour various cellulosic and natural fibres, as well as polyamide.

Image courtesy of Algaeing

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Disruptive Innovation - Chemistry

PFC-free DW(O)R finish

One of the biggest priorities of the fashion industry (and other industries) is finding PFC-free high performing durable water (and oil) repellency DW(O)R treatments. Instead of PFCs other synthetic chemistries (e.g. silicone) or bio-based solutions (e.g. waxes, wood etc.) can be used. PFCs need to be phased out as they have proven to be toxic and harmful to both humans and the environment, so shifting to these alternative solutions has multiple environmental benefits.

OSM Shield: ZERO*

OSM Shield's ZERO chemistry solution is a non-Perfluoroalkyl Substances (PFAS) high performance durable water and oil repellency technology which is free from all PFAS compounds and associated toxins. This chemistry technology will be available in a standard emulsion and can be applied using traditional application methods on all fibre types, but the focus is on cotton and polyester.

Dryfiber*

Dryfiber provides a completely fluorine free, and hence also PFC-free DW(O)R textile finish. The solution is silicon-based and can be applied through traditional finishing processes. The current focus is on synthetic fabrics.

PFC-free waterproof membrane

A microporous membrane is a very thin layer containing many tiny pores (thousand times smaller than a drop of rain). These membranes have waterproof and breathable properties; while they do not let water come through from the outside, they do allow water vapour, emitted through perspiration, to evacuate. Innovation lies within the production technology to provide high performance without using PFCs.

Dimpora*

Dimpora creates more sustainable, highly breathable and waterproof membranes. Based on polymers, the technology is PFC free and uses no Dimethylformamide (DMF) solvent. The company is further developing recyclable, bio-based and biodegradable membranes to close the loop for high performance gear.

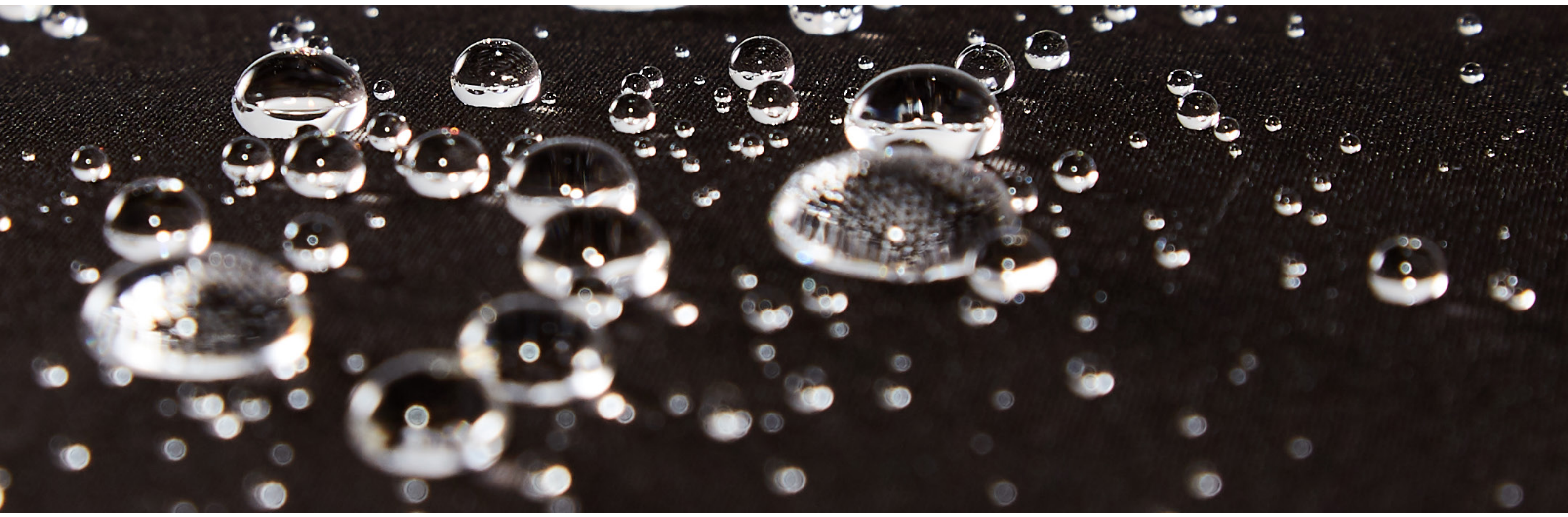

Image courtesy of OSM Shield

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Lamoral

Lamoral develops fluorine-free and >50% bio-based A-Line DWR and other finishes. They use an emulsion polymerisation of a plant-based polyalkyl, anchoring the polymers onto the fibre. The non-bio-based content is based on acrylates in a water-based emulsion. Their DWR is called and holds the OEKO-TEX 100 certification and is ZDHC listed.

Beyond Surface Technology (BST)

BST develops products that reduce the impact of textile chemical finishes on the environment. The finishes are bio-based as e.g. microalgaes or plant seeds and branded miDori. Their DWR is called and holds the GOTS 5.0 certification and is ZDHC listed.

DW(O)R FINISH VS WATERPROOF MEMBRANE

What is the difference between a DW(O)R finish and a waterproof membrane?
Both technologies are used in increasing the protective properties of garments, mostly focusing on shielding from water but also from dirt and oil. The technologies can be combined for optimal performance.

DW(O)R finish	• The effective DW(O)R ingredient is applied via a liquid by running the fabric through and immersing all its surface in the active substances. The chemistry binds to the surface of the fibres. DW(O)R finishes make fabric water repellent, meaning that water landing on fabric will form drops that can be easily wiped off. However, longer contact with water or at a high pressure means the fabric will likely absorb the water and/or let it pass through. • One can think of a DW(O)R finish as a form of protection, like sunscreen applied to human skin to protect it from the sun. The finish wears off over time through movement, dirt and water, and therefore needs to be reapplied from time to time to remain effective.
Waterproof membrane	• A certain polymer (often polyurethane) is formed into a laminating layer (membrane or foam) which is then applied on to the textiles using adhesives. It is very durable, but therefore also difficult to recycle. • Membranes make fabrics waterproof, meaning that they are impervious to water even when pressure is applied. • One can think of a membrane as the human skin, that protects us from filling up with water when swimming in the sea.

FIGURE 8: OVERVIEW OF COATINGS VS. MEMBRANE

Sources: *Williams J. (2018), Loghin et al. (2018), Choudhry (2017)*

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Heavy metal free antimicrobial treatments

Creating antimicrobial finishes with the use of antimicrobial polymeric materials (e.g. chitosan) derived from bio-based sustainable sources (e.g. flax or wood, crab or shrimp shell waste from seafood industry).

Nordshield*

Nordshield creates antibacterial, antiviral, antimould and insect repellent finishes based on waste from the forestry industry. Nordshield forms a physical barrier on surfaces treated with their finish and therefore prevents microbial growth at the sources. The finish can be applied to cotton, viscose and blends.

CHALLENGES OF SCALING DISRUPTIVE CHEMISTRY INNOVATIONS

As seen in the previous chapter, there are many more sustainable chemistry solutions available. Some of the reasons these have not yet been implemented in the supply chain relate to the following challenges.

Performance

Finding innovations in chemistry with the same performance characteristics as traditional chemistry is challenging. If the performance of the more sustainable chemistry does not meet that of its traditional counterpart, it will in most cases not be adopted on a large scale. Some of the key performance characteristics challenging the fashion industry are listed below:

- ***Colour fastness of natural dyes*** - Performance of most natural dyes has often not met that of synthetic dyes. In addition, due to common impurities in natural dyes it has shown to be difficult to consistently reproduce a shade particularly across batches. As with synthetic dyes, natural dyes often need other chemicals to bond with the substrate and usually more dye is required to achieve the same depth of colour. As a result, 'natural' does not automatically equal better. Aside from challenges around colour fastness, natural dyes are generally available in fewer colours and shades than synthetic dyes.
- ***Durability*** - Some treatments meet performance requirements immediately after application but lose their effectiveness after wear and washing. Maintaining effectiveness after dry cleaning is especially challenging.
- ***Durable Water and Oil Repellency*** - DW(O)R is a key property for textile materials, especially for the outdoor industry. Historically, high performance has been achieved with the use of hazardous PFCs. The non-hazardous or bio-based solutions currently available have not shown to yet meet this performance across multiple testing criteria. Securing high oleophobicity scores has been particularly challenging.

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COLOUR FASTNESS

What is colour fastness?
Colour fastness is used as a key performance indicator to test the efficiency of dyes. It is defined as the ability of a dye to preserve the original colour throughout the manufacturing process and subsequent customer use.

The main forms of colour fastness include:
- **Washing fastness**: colour fastness to wash or washing fastness is the resistance of a material to change in any of its colour characteristics as a result of washing.
- **Rubbing/crocking fastness**: refers to the ability of textiles to resist colour transfer or staining when subjected to abrasion. It is categorised into two types: dry and wet rub fastness.
- **Light fastness**: the extent to which the colour on the fabric fades when exposed to light.
- **Perspiration fastness:** the extent to which the colour on the fabric fades when exposed to human perspiration.

To rate the washing, rubbing/crocking, and perspiration fastness the Grey Scale for Colour and/or the Grey Scale for Staining, Rated from 1 (very poor) to 5 (excellent), are used. For light fastness, the Blue Wool Scale, rated from 1 (very poor) to 8 (excellent), is to be used[14].

Supply Chain
The supply chain for the chemical formulations currently available is well established and allows for large scale production, while the supply chain of more innovative formulations is less developed and does often not yet allow for large scale production Therefore, although performance on a pilot scale has been proven, it can sometimes still be timely and challenging to scale these new technologies. This can cause difficulties when working with brands and manufacturers as they need large quantities (in the thousands of tonnes) for mass adoption. One potential solution to this is for innovators to collaborate with established chemical manufacturers or toll blenders with large production capacities and expertise in scaling.

Externalities and Pricing
Given the low prices of most commodities used in this industry and the industry's focus on economics, many sustainable alternatives struggle to present attractive business cases due to their higher costs. Tighter regulation could enable the industry to take into account the significant environmental externalities of current production processes.

Disruptive Innovation - Chemistry

Stickiness
Chemistries can be viewed as drop-in solutions which makes them easier to incorporate into the supply chain than for instance new machinery, this enhances their scalability. However, it also means that a supplier can easily switch to a competing chemistry even after integrating the original chemistry from an innovator.Therefore, the stickiness of chemistry solutions, both traditional and innovative, is believed to be low. This is troublesome for long-term security and survival, especially for innovators.

Impact Measurement
Current LCA (life cycle assessment) frameworks do not capture the full benefits of sustainable chemistry as they are focused on the consumption of e.g. carbon and water. However, the biggest advantage of more sustainable chemistries is that they are reducing toxicity and harmful chemistry, which is not captured in LCAs. Additionally, chemistry solutions often lead to downstream savings which are often not accounted for during LCA studies. Therefore, it is more difficult for chemistry innovators to effectively communicate about their impact and use impact as a factor to convince customers to adopt their technology. However, new upcoming regulations banning certain chemical compounds may help to overcome this challenge.

Driving the Transition

This document provides a snapshot in the processing innovation landscape, touching briefly on incremental solutions and diving into the disruptive technologies that exist in both chemistry and machinery.

It is evident that there are a number of solutions that have the potential to save significant amounts of water, energy and chemistry which results in a positive environmental impact as well as long term cost savings. It is an area that is constantly evolving and one in which it is clear that collaboration is key to success. Fashion for Good is pleased to be working together with our brand and manufacturing partners as well as our global network of innovators to accelerate the adoption of these technologies into the apparel and footwear supply chain.

If you would like to learn more about our current projects in this space please visit our website - www.fashionforgood.com

Appendix

Below an overview of commonly used processes in pretreatment, dyeing, printing and finishing can be found.

Pretreatment

PRETREATMENT TYPE	DESCRIPTION	FUNCTION
Singeing	Burning projecting, loose and hairy fibre ends away with gas flames or a hot plate. Most often performed on cotton fibres.	To get rid of small fibres. It makes the fabric smoother, aids in better application of dye and printing and improves rubbing and washing fastness.
Desizing	Removing of sizes and other substances applied as weaving aids. Uses enzymes, chemicals or hot washing, depending on the type of size.	To increase absorbency and reduce chemical consumption in subsequent processes. Usually only used for spun yarns.
Scouring	Removing of natural or foreign impurities, or processing aids (waxes, lubricants, marker dyes) applied during yarn and fabric production.	To increase absorbency and improve handle.
Bleaching	The process of removing natural colourants from the substrate.	To remove coloured impurities from the fibre and increase the whiteness of the fabric.
Mercerising	Treating cotton yarn or fabric, under tension, in a concentrated solution of caustic soda.	Done primarily to obtain a high lustre on the fibre/fabric. An added impact is an increase in tensile strength and that the required shade can be obtained using less dye.
Optical Brightening	An Optical Brightening Agent (OBA) is a chemical compound that is incorporated into various textiles during garment production. It is specifically employed during the bleaching process to enhance the brightness and whiteness of the fabric.	Avoid visible colour impurities (yellowish hue) and obtain a bright white
Heat Setting	Passing fabric through a heating zone for a time to make it dimensionally stable. Can be carried out as a pretreatment or post-treatment.	To stabilise the dimensions of synthetic fibres so they will not shrink or become distorted during wet processing or consumer use.
Bio-polishing	Treatment with enzymes used on cotton/ cotton rich fabrics that removes short protruding fibres. Can also be applied as a post-treatment.	To get rid of small fibres. It makes the fabric smoother, aids in better application of dye and printing and improves rubbing and washing fastness.

Sources: *Andrew Filarowski CCol ASDC,* Technical Director, Society of Dyers and Colourists (SDC), www.sdc.org.uk

FIGURE 9: OVERVIEW OF DIFFERENT PRETREATMENTS AND FUNCTIONALITIES

Appendix

Colouration

COLOURATION METHOD	DESCRIPTION
Dyeing	Dyeing is the application of dyestuff on textile materials such as fibres, yarns and fabrics with the goal of achieving colour with desired colour fastness. The dyestuff used is either a dye or pigment. The key difference between these two is that dye chemically binds to the substrate while pigment does not. The most used dyeing processes can be found below: **1. Dope dyeing**: A method of colouring man made fibres by incorporation of the colourant in the spinning composition before extrusion into filaments or fibres. While this is not a new technology, it has the potential to drastically reduce resource consumption in the colouration process. **2. Continuous dyeing**: In continuous dyeing, textiles are continuously fed through a dyeing range. The process is done in stages: dye application, dye fixation, and washing **3. Batch dyeing**: Batches of material are treated in large machine baths of various types, e.g. jet, jig, paddle, winch, pad-batch
Printing	Traditional textile printing is the controlled process of applying defined areas of colour onto fabric. The printing process usually includes: 1. Pretreatment 2. Application of colourant in a controlled way to the fabric surface. Both dyes and pigment can be applied. Pigments are applied in a print paste with a binder and are held with this binder on the surface of the fabric. They can therefore be applied to all fibre types. Dyes are applied in a print paste with chemicals to provide the viscosity to apply them and create a stable pattern but penetrate the fibre and are held within the fibre. They are therefore fibre specific. 3. Fixation and wash off. The most widely used printing processes can be broadly divided into three categories: **1. Screen Printing - Rotary and flat bed**: a print paste is passed onto a substrate through a mesh or screen which has some open and some blocked areas. The eventual design obtained on the substrate depends on the open areas of the screen **2. Transfer Printing**: A design is first digitally printed onto a flexible non-textile substrate and later transferred by a separate process to a textile **3. Digital Printing**: A relatively new technology (when compared to screen and transfer printing) which prints from a digital image directly to a substrate with speciality inks

Sources: *Textile Engineering an Introduction By Yasir Nawab, Environmental aspects of textile dyeing, Clothing Technology, 6th edition, Hannelore Eberle, Europa Lehrmittel 2013,* Proprietary research with privileged access, contact Fashion for Good for more details if needed. *Andrew Filarowski from the Society of Dyers and Colourists*

FIGURE 10: OVERVIEW OF COLOURATION PROCESSING

Appendix

Finishing

FINISHING TYPE	DESCRIPTION[15]
Durable Water and Oil repellency DW(O)R	• Applied to make the fabric water/oil-resistant • Achieved by giving the fabric a hydrophobic/low surface energy finish
Flame retardancy	• Applied to make the fabric non-flammable or difficult to ignite • Achieved by suppressing the release of inflammable volatiles, so that instead of flaming, the materials will degrade and char
Stain resistance	• Applied to make fabric resistant to stains • Achieved by changing the surface energy of the fibre so as to discourage stain particles from clinging • A degree of water and oil repellency is also important
Easy care	• Applied to reduce wrinkling and shrinking when textiles are laundered • Achieved by the application and fixation of chemicals which reduce the sensitivity of the fibre to moisture and to creasing
Softening	• Applied to impart softness, smoothness and flexibility (for manufacturers as well as consumers) • Achieved by applying softening agents, either as a temporary dressing or as a durable polymer finish
Antistatic	• Applied to reduce or eliminate the buildup of static electricity • Achieved by applying a hygroscopic chemical or by a treatment that renders the surface hydrophilic
Antimicrobial	• Applied to inhibit the growth of bacteria, mould and fungi on fabrics. This keeps the fabrics hygienic and prevents odours • Achieved by depositing biocides and/or solutions containing heavy metals on fabric
Biopolishing	• Applied to enhance fabric quality by decreasing the pilling tendency and fuzziness of (cellulose) knitted fabric • Achieved by applying enzymes to cellulose fabrics
Laser	• Applied to create engravings, certain washes or worn-out looks • Achieved by applying laser technology to fabrics

Sources: *Textile Engineering an Introduction By Yasir Nawab*, Proprietary research with privileged access, contact Fashion for Good for more details if needed

FIGURE 11: OVERVIEW OF COMMONLY USED TRADITIONAL FINISHES

Key Terms

- **AATCC** - the American Association of Textile Chemists and Colorists develops the test methods the textile industry uses to ensure product quality.
- **AFIRM** - the Apparel and Footwear International RSL Management Group is a brand driven membership organisation of apparel and footwear companies collaborating to promote chemicals management in the global supply chain. AFIRM's focus is on the continuous advancement of chemicals management including phasing out or limiting restricted substances to established limits in apparel, footwear, and accessories.
- **Apparel Impact Institute** - (Aii) is a collaboration of brands, manufacturers and industry associations – including the Sustainable Apparel Coalition (SAC), the Sustainable Trade Initiative (IDH), Target, PVH Corp., Gap and HSBC Holdings plc. - that have come together to select, fund and scale high impact projects that dramatically and measurably improve the sustainability outcomes of the apparel and footwear industry.
- **Low pressure vs atmospheric plasma** - cold plasma technologies can be divided into low pressure plasma and atmospheric plasma. The former happens in a vacuum chamber and therefore provides higher performance and reproducibility, while the latter is more compatible with the textile industry as it does nor require a vacuum chamber and thus allows for continuous processing
- **Bio-based** - wholly or partly derived from materials of biological origin, excluding materials embedded in geological formations and/or fossilised.
- **Bioscouring** - application of enzymes and their components to remove natural and added impurities.
- **Binder** - add or stick to something any substance that causes the components of a mixture to hold together.
- **Bluesign** - bluesign eliminates harmful substances at each step of the supply chain. It certifies that textile products are safe for the environment, workers, and customers. The Bluesign certification applies to chemicals, processes, materials, and products.
- **Capillary force** - capillary force is the process of a liquid flowing in a narrow space without the assistance of, or even in opposition to, any external forces like gravity.
- **Chemical Manufacturer** - a workplace where chemicals are produced for use or distribution. A chemical manufacturer has a legal obligation to evaluate the hazards of chemicals that they produce or distribute.
- **Chitosan** - an environmentally friendly agent that is used to achieve the antimicrobial properties of textiles. Nowadays, the binding of chitosan to the textiles has been thoroughly researched due to the increasing demands on the stability of achieved properties during the textile care processes.
- **Clean by Design Programme** - Clean by Design is a programme to use the buying power of multinational corporations as a lever to reduce the environmental impacts of their suppliers abroad. Clean by Design focuses on improving process efficiency to reduce waste and emissions and improve the environment.
- **Colour Fastness** - the ability of a dye to preserve the original colour and not stain adjacent fabric during industrial processing and subsequent customer use.
- **Curing** - the process by which resins or plastics are set in or on textile materials, usually by heating.
- **Drop-in solution** - solution that is easily integratable or requiring only insertion to be ready for use.
- **Drying** - liquid is vaporised from a product by the application of heat. Heat may be supplied by convection (direct dryers), by conduction (contact or indirect dryers), radiation or by placing the wet

material in a microwave or radio frequency electromagnetic field.

- **Durability** - how long and in what conditions a treatment stays effective on the garment.
- **Effluent** - liquid waste or sewage discharged into a river or the sea.
- **Energy Milieu** - in the context of MLSE®, Energy Milieu refers to the highly reactive molecular soup created by quantum mechanical forces acting within specific reaction zones, where fabric gets treated. This milieu consists of photons (a particle representing a quantum of light), bosons (a subatomic particle), gluons (a hypothetical massless subatomic particle) and quarks (any of a number of subatomic particles carrying a fractional electric charge) mixed with nano sized constituent particles, virtually instantaneously, ablated from the fabric substrate itself and reconstituted within the fabric.
- **Enzymes** - an enzyme is a substance produced by a living organism which acts as a catalyst to bring about a specific biochemical reaction.
- **Eutrophication** - eutrophication is when there are too many nutrients in a body of water which can then disrupt the ecosystem.
- **Exhaustion** - the proportion of dye or other substance taken up by a substrate at any stage of a process to the amount originally available.'
- **Fermentation** - the chemical breakdown of a substance by bacteria, yeasts, or other microorganisms, typically involving effervescence and the giving off of heat.
- **Fixation (dye)** - fixation is the bonding of the dye to the textile to ensure it remains on the textile.
- **Forest Stewardship Council (FSC)** - FSC is a non-profit organisation that promotes responsible management of the world's forests. FSC certifies forests all over the world to ensure they meet the highest environmental and social standards. Products made with wood and paper from FSC forests are marked with their 'tick tree' logo.
- **Full Curing** - a process during which a chemical reaction (such as polymerisation) or physical action (such as evaporation) takes place, resulting in a harder, tougher or more stable linkage (such as an adhesive bond) or substance.
- **High Frequency Electric Discharge** - electrical conduction through a gas in an applied electric field.
- **Ionised** - converted (an atom, molecule, or substance) into an ion or ions, typically by removing one or more electrons.
- **ISO** - International Organization for Standardization is an independent, non governmental international organisation with a membership of 165 national standards bodies.
- **Joint Venture** - a business arrangement in which two or more parties agree to pool their resources for the purpose of accomplishing a specific task.
- **Liquor Ratio** - the ratio of the weight of liquid used in any treatment to the weight of material treated.
- **Metering** - accurate measurement of on-site energy and water use, which is critical in accounting for current costs and recognising the benefits of efficiency measures.
- **Microbe** - a microorganism or microbe is a microscopic organism, which may be single-celled or multicellular. The microbes most commonly associated with the production of materials for consumer textiles include yeast, bacteria, fungi and algae.
- **Microporous** - characterised by very small pores or channels with diameters in the micron or nanometre range.
- **Mordant** - a chemical that fixes a dye in or on a substance by combining with the dye to form an insoluble compound.
- **Neutralisation** - the act of making a substance neutral.
- **Nozzle** - an attachment to the end of a spray rod or hose that causes the liquid to be delivered finely and evenly as a spray.
- **OEKO-TEX** - International Association for Research and Testing in the Field of Textile and Leather

Key Terms

Ecology consists of 17 independent research and test institutes in Europe and Japan. They are responsible for the joint development of test methods and limit values which form the basis for our standards.

- **Oleophobicity** - refers to the physical property possessed by a material that is characterised by a lack of affinity to oils.
- **PFAS** - per- and polyfluoroalkyl substances are a diverse group of human-made chemicals used in a wide range of consumer and industrial products. Many PFAS are resistant to grease, oil, water, and heat.
- **PFC** - perfluorochemicals (PFCs) are a group of chemicals used to make fluoropolymer coatings and products that resist heat, oil, stains, grease, and water
- **Quantum Mechanical Energy** - quantum mechanics, science dealing with the behaviour of matter and light on the atomic and subatomic scale. It attempts to describe and account for the properties of molecules and atoms and their constituents—electrons, protons, neutrons, and other more esoteric particles such as quarks and gluons. These properties include the interactions of the particles with one another and with electromagnetic radiation(i.e., laser light, X-rays, and gamma rays).
- **Polymeric material/polymer** - materials made of long, repeating chains of molecules. The materials have unique properties, depending on the type of molecules being bonded and how they are bonded.
- **REACH** - Registration, Evaluation, Authorisation and Restriction of Chemicals is a European Union regulation which addresses the production and use of chemical substances, and their potential impacts on both human health and the environment.
- **Reactive** - capacity of an atom or molecule to undergo a chemical reaction with another atom, molecule, or compound.
- **Society of Dyers and Colourists (SDC)** - a membership organisation and educational charity committed to education in the science and application of colour.
- **Substrate** - the surface or material.
- **Supercritical/pressurised gas** - a supercritical fluid is a highly compressed fluid that combines the properties of gases and liquids.
- **Surface Activation** - alter the chemistry of surface introducing chemical groups or charges on the surface.
- **Toll Blender** - a service whereby the production of (complex) chemical products is outsourced to a third party company (blender).
- **Wash off** - with traditional wet processing, washing baths are used at the end of each pretreatment, dyeing, and finishing step to remove excess unfixed chemicals from the fibre.
- **ZDHC** - Zero Discharge of Hazardous Chemicals Foundation oversees implementation of the Roadmap to Zero Programme and is a global multi-stakeholder initiative of more than 160 contributors within the fashion and footwear industry.

Notes & References

1 Note, it is not possible to dive into all technologies in great detail and Fashion for Good acknowledges that this is a complex space

2 Aii (2023). Taking Stock of Progress Against the Roadmap to Net Zero. Available at: https://apparelimpact.org/wp-content/uploads/2023/06/Aii_RoadmapReport-615-1.pdf

3 Aii (2023). Taking Stock of Progress Against the Roadmap to Net Zero. Available at: https://apparelimpact.org/wp-content/uploads/2023/06/Aii_RoadmapReport-615-1.pdf

4 Except for printing

5 IntechOpen Textile Dyes: Dyeing Process and Environmental Impact

6 'What Brands Need to Know About Antimicrobial Fabrics and Textiles', 'Disinfecting for Covid-19: The role of the US EPA' ,'Hand Sanitisers and face masks'

7 'What Brands Need to Know About Antimicrobial Fabrics and Textiles', 'Disinfecting for Covid-19: The role of the US EPA' ,'Hand Sanitisers and face masks'

8 Antimicrobial Textiles from Natural Resources: Common and nano-antimicrobial textile finishes

9 NanoImpact: In vitro skin toxicity of CuO and ZnO nanoparticles: Application in the safety assessment of antimicrobial coated textiles

10 Fashion for Good and Apparel Impact Institute 'UNLOCKING THE TRILLION-DOLLAR FASHION DECARBONISATION OPPORTUNITY: Existing and innovative solutions'

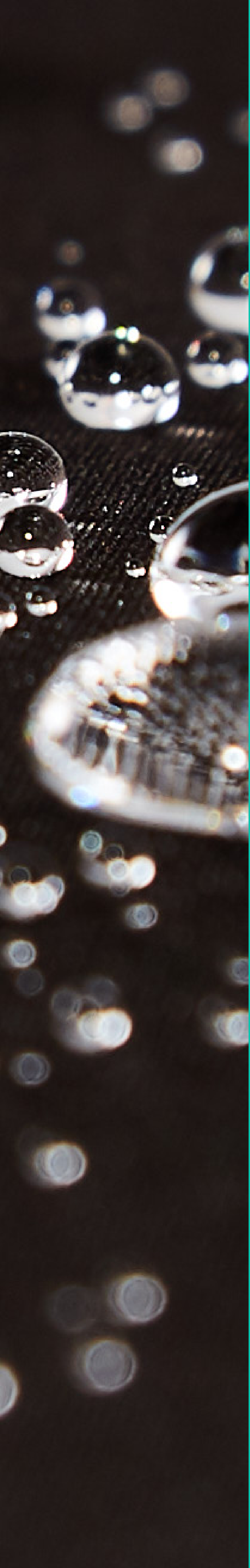
11 GWP measures how much energy (outgoing Infrared Radiation) the emissions of 1 ton of a gas will absorb over a given period of time, relative to the emissions of 1 ton of carbon dioxide (CO_2). The GWP values illustrated in the graphs excludes biogenic carbon, which is the carbon which is absorbed, stored and emitted by organic matter like soil, trees, plants and grasses.

12 Innovator Reported

13 Enzymes for biopreparation, Nozoymes

14 Chapter 31 'The Care of Apparel Products', Rin Textile Fashion; Materials, Design and Technology, .K.NayakR.Padhye, 2015, Pages 799-822

15 Proprietary research with privileged access, contact Fashion for Good for more details if needed



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