MODINT FIBER MATRIX

Guiding towards circularity

Report by Modint,
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MODINT.

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Summary

In 2020 Modint was searching for a publicly available tool for apparel and textile companies with the ambition to use more sustainable fibers in their collection to help buyers, product developers and designers to make more informed fiber sourcing decisions. The ultimate goal is to guide companies towards circularity and meeting targets as set by the industry and governments. There are several existing fiber benchmarks (the Higg MSI [1], Textile Exchange Corporate Fiber & Material Benchmark [2] and MADE-BY benchmark for fibers are summarized in this report). But since they do not fulfill all needs of the target group, Modint decided to develop its own benchmark, the Modint Fiber Matrix (MFM), which is publicly available accompanied by this background report.

This report serves as a background for the MFM. It describes the origin of the tool, the developed methodology (including used parameters and data) and provides examples of use.

The MFM focusses on the most used and commercially available fiber materials in the apparel and textile industry (cotton, polyester, man-made cellulosic fibers, wool, polyamide, linen and hemp) and ranks them as conventional, preferred, better and best options.

Solely raw material extraction and primary processing fall within the scope of the MFM. It is designed in such a way that only materials within a fiber category are to be compared (e.g., conventional cotton with organic cotton, and not conventional cotton with recycled polyester).

Five parameters were selected to rank the fiber materials; climate change, energy use, water use, land use and circularity. The circularity score is based on renewable content, recycled content and the recyclability of the fiber materials. Data was collected using the Modint EcoTool [3], literature and expert judgement. A weight factor was introduced to express the importance of each parameter. Next, a conversion table was developed in order to make data comparable and derive a single score. Based on this single score, the fiber materials are ranked as conventional, preferred, better and best options within their fiber category. This results in the Modint Fiber Matrix, which is shown in the figures 1 and 2 on the next page. One version of the MFM includes only generic fiber names [4] and one version includes examples of commercially available options for these fibers from specific suppliers, their brand names and/or relevant certification schemes.

The MFM will enable users to make more sustainable fiber material choices. Analyzing the current material mix is a great way to start and set goals for a certain percentage more sustainable materials (from the preferred, better or best section) in the next couple of years. Start with most used material by volume, a never out of stock collection or the part in your collection with the highest impact (Modint supports its members with risk-based assessments using the Modint EcoTool).

The MFM specifically focusses on more sustainable options for fiber materials, which is a first and important step to guide you towards a lower environmental impact and circularity. This is a crucial part of a bigger corporate responsibility strategy which addresses overall due diligence commitments. Contact Modint for more information or support implementing at info@modint.nl

MODINT FIBER MATRIX
GUIDING TOWARDS CIRCULARITY
Generic fibers

	BEST	BETTER	PREFERRED	CONVENTIONAL
COTTON	Recycled cotton	(certified) Organic cotton	Preferred cotton	Conventional cotton
MAN-MADE CELLULOSIC FIBERS	Lyocell with recycled content	Preferred viscose	Lyocell	Conventional viscose
WOOL	Recycled wool	(certified) Organic wool	Responsible wool	Virgin wool
POLYESTER	Mechanically recycled polyester	Recycled polyester from PET bottles	(Partially) biobased polyester	Virgin polyester
POLYAMIDE	Mechanically recycled polyamide	Chemically recycled polyamide	(Partially) biobased polyamide	Virgin polyamide
LINEN		(certified) Organic linen	Linen	
HEMP		(certified) Organic hemp	Hemp	

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Figure 1 Modint Fiber Matrix - generic fibers

MODINT FIBER MATRIX
GUIDING TOWARDS CIRCULARITY
Examples of fibers from specific suppliers and/or their brand names or relevant certifications. This is not an exhaustive list.

	BEST	BETTER	PREFERRED	CONVENTIONAL
COTTON	Recycled cotton (GRS)	Organic cotton (GOTS)	Preferred cotton Better Cotton (BCI) Cotton Made in Africa (CmiA) Cotton in conversion	Conventional cotton
MAN-MADE CELLULOSIC FIBERS	Lyocell with recycled content Refibra™	Preferred viscose Lenzing Austria Livaeco by Birla Cellulose™ Ecovero™	Lyocell Tencel™	Conventional viscose
WOOL	Recycled wool (GRS)	Organic wool (GOTS)	Responsible wool (RWS)	Virgin wool
POLYESTER	Mechanically recycled polyester (GRS)	Recycled polyester from PET bottles (GRS) REPREVE®	(Partially) biobased polyester Sorona®	Virgin polyester
POLYAMIDE	Mechanically recycled polyamide	Chemically recycled polyamide ECONYL® (GRS)	(Partially) biobased polyamide Sorona®	Virgin polyamide
LINEN		Organic linen (GOTS)	Linen	
HEMP		Organic hemp (GOTS)	Hemp	

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Modint is not affiliated or in any way officially connected with the brands and certifications mentioned or any of its subsidiaries and/or affiliates. We do welcome data from other sources to review for future editions of the MFM.

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Figure 2 Modint Fiber Matrix - brands and certifications

Chapter 1 Introduction

1.1 Modint

Modint [5] is the trade association for manufacturers and suppliers in the apparel and textile industry. Together with more than 400 members, we are building a valuable future for our sector by making a positive contribution to tackling relevant themes and by renewing and expanding the market. By applying technological knowledge, commercial spirit and creativity, we are passionately paving the road for sustainable development of the sector. Modint stimulates, facilitates, connects, and protects the apparel and textile sector.

Modint has an important social value and contributes to the economic importance, cultural heritage, creative and commercial spirit of the Netherlands. Modint designs a route to the future and offers its members more value than traditional lobbying and individual services. Modint focuses on the future market of its members, which contributes to good sustainable development of the sector. We do this together with members and with other stakeholders.

Modint believes that apparel and textile companies only have a future if corporate responsibility (CR) is part of their business operations. With our extensive knowledge, we help our members with CR and reduce the impact on the environment. We share our knowledge through webinars, workshops, our Modint EcoTool [3] (version 3.0), consultancy and education. An important part of CR is sustainable design and the use of more sustainable fibers. Modint members expressed their wishes for an easy-to-use fiber benchmark tool to support them when taking steps towards developing a more sustainable collection, using more environmentally friendly fibers, reducing the overall environmental impact of products and to work towards a circular apparel and textile industry.

1.2 The Modint Fiber Matrix

This report serves as a background for the MFM. It describes the origin of the tool, the developed methodology (including used parameters and data) and provides examples of use.

In 2020 Modint was searching for a publicly available tool to compare the impact of different fibers, that could be useful to any apparel or textile company with the ambition to use more sustainable fibers in their collection. There are several publicly available environmental fiber benchmarks but not all of them consider the circularity level of the fibers or are not completely transparent about their methodology and used data. Therefore, Modint took the initiative to developing the Modint Fiber Matrix and make the benchmark and this background report publicly available.

This matrix focuses on the conventional, preferred, better and best varieties of the most used and commercially available fibers in the apparel and textile industry, addressing their environmental and circular performance. It was designed as a tool to help buyers, product developers and designers to be more informed in their fiber sourcing decisions and as a means to develop sustainable and circular material strategies.

A rise in the availability of more circular fibers is foreseen for the coming years. Relevant developments will be tracked for the future evolution of the MFM.

1.3 Goal of the Modint Fiber Matrix

The goal of the MFM is to be able to identify preferred, better or best options within a fiber category, based on environmental and circularity criteria. Sourcing these more sustainable fibers is a first step for companies to work towards a Dutch circular economy in 2050 and to integrate the United Nations Sustainable Development Goals (SDG's) [6] into their business strategies. A circular Economy is a critical factor for The Netherlands in meeting the requirements of the Paris Climate Agreement [7] [8]. The plan for a Circular Dutch Garment and Textile Sector clearly sets out the different milestones that need to be reached to succeed in 2050 [9] [10].

Chapter 2 Development of the Modint fiber matrix

In 2020 Modint initiated the development of the MFM, which is created in cooperation with Alcon Advies and Rethink Rebels. The methodology behind the MFM is based on the Modint EcoTool, which is founded on LCA principles. The Modint EcoTool is an environmental measurement tool which was developed in 2010 and last updated in 2017 (version 3.0). The tool provides more insight and understanding about the impact of materials and alternative, emerging, innovative and more circular fibers. The MFM was developed based on desk research and review of references including life cycle assessments, material safety data sheets [11] [12] [13] and additional literature. All used recourses can be found at the end of this report. When necessary, decisions were based on our own expert judgements, in this case explanations and considerations are described in the text.

2.1 Scope of the Modint Fiber Matrix

The MFM takes into account the production process of fiber materials from the origin of the raw materials to fibers ready to be spun, including recycled fibers. The impact in the following stages is not included: spinning, fabric manufacturing, dyeing and finishing, cut-make-trim (CMT), distribution, the use phase or end of life nor material performance, durability and quality. The different processing steps and the scope (in orange) of the MFM are visualized in figure 3. The MFM focusses only on the first step in the supply chain, mainly because this process is comparable for different options within a fiber category, which makes ranking of the fiber materials possible. The techniques for production of yarns, fabrics and garments are diverse, which makes a fair comparison difficult. In addition, choosing this scope for the MFM contributed to the user-friendliness of the tool by keeping it clear and practical. A wide use of the tool by different decisionmakers in the product development process will support progress, positive impact and contribute to the industry's larger environmental and circular strategy.

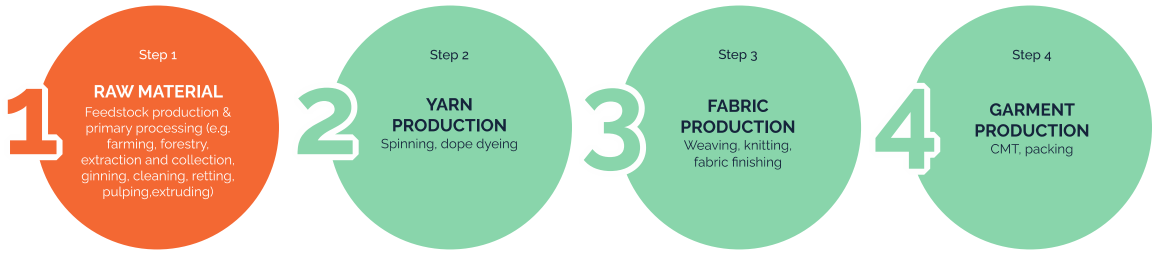

Figure 3 visualization of the processing steps in the textile supply chain, step 1 being the scope of the MFM

To calculate the end score of a particular fiber material, the impact parameters of its own fiber category were taken into account to create a ranking. Therefore, it is not possible to use the tool to compare for example conventional cotton and virgin polyester. Another reason to advise against comparing fibers from a different category is the scope of the MFM. Since this includes the raw materials and primary processing only, it gives no insight in the impact of the following processing steps. This also makes it not suitable to rate an end-product (e.g., a conventional cotton t-shirt vs. an organic cotton t-shirt). A rating for an end-product can only be made by taking the impact of the complete lifecycle into consideration (this can be done by use of the Modint EcoTool for example).

Chapter 3 Methodology of the Modint fiber matrix

3.1 Parameters

When creating a benchmark there are a lot of parameters which can be taken into account. A Life Cycle Assessment (LCA) on textile fibers might result in 20-25 different indicators which have to be reduced to one single score to make an easy comparison. Additionally, sufficient data needed for the execution of a proper LCA is not available, missing or not reliable (e.g., the toxicity impact data of many chemicals used in the textile industry is a challenge to find). Also, data from different sources might not be comparable and can not be made comparable when the original data sources are unknown or not publicly accessible.

Therefore, it was decided to create the MFM based on a limited number of parameters. The parameters were selected considering the need for information on and common questions from the industry: climate change, energy use, water use, land use and circularity (see table 1). It is our ambition to add more parameters in the future.

Climate change	CO2-eq. in kg
Energy use	MJ/kg
Water use	l/kg (water process + cooling)
Land use	m2/a/kg
Circularity	Degree of circularity (recycled materials/recyclability of materials/renewable materials)

Table 1 Selected parameters for the MFM - the unit of comparison is 1kg of fiber ready to be spun

3.2 Summary of other benchmarks

We are aware of the fact that other benchmarks are used in our sector and by our members. For this reason, desk research was done about these benchmarks to determine how they coincide with and differ from the principles and data in the MFM. In the next subchapters a summary of the following tools is given: The Higg Materials Sustainability Index (MSI), Textile Exchange Corporate Fiber & Materials Benchmark (CFMB) and the MADE-BY Environmental benchmark for fibers.

3.2.1 Higg MSI

The Sustainable Apparel Coalition (SAC) is the apparel, footwear, and textile industry's leading alliance for sustainable production. The SAC developed the Higg Index [14], a suite of tools that standardizes value chain sustainability measurement for all its members. These tools measure environmental and social labor impacts across the value chain. With this data, the members can identify hotspots, continuously improve sustainability performance and achieve the environmental and social transparency consumers are demanding [1] [15]. Some parts of the suite are publicly available.

One tool, the Higg MSI, focuses on the following impact areas and parameters: global warming, eutrophication, water scarcity, abiotic resource depletion/ fossil fuels and chemistry. With the Higg MSI information, results on materials and/or production processes can be analyzed and compared to get an understanding of what is causing impact. The result is expressed in a MSI score for the above-mentioned parameters and with a paid subscription LCA scores are available. The eutrophication parameter especially affects the score of the natural fibers. The impact of chemistry is estimated and ranked on an arbitrary scale.

3.2.2 Textile Exchange CFMB

The CFMB (previously known as the Preferred Fiber and Materials Benchmark) from Textile Exchange enables participating companies to measure, manage and integrate progress towards more sustainable materials sourcing and to compare their scores with peers. The benchmark comprises of three sections: Section I: Strategy and Integration; Section II; Fiber and Materials Portfolio and Section III: Circularity. Companies follow a self-assessment process (by survey) to help identify the strengths and gaps where future progress can be made. For the MFM, especially section II is of interest. It includes cotton, wool, down, leather (pilot), man-made cellulosic fibers, polyester and polyamide.

Textile Exchange defines a preferred fiber or material as one which is environmentally and/or socially progressive, the use of which results in positive benefits in comparison to conventional production. Underlaying to the score a company receives for the answers they give in section II, is the table shown in figure 4. It ranks more sustainable fibers as level 4, while conventional fibers are ranked as level 1. The table outlines a set of weights, based on a methodology developed by Textile Exchange. As part of this methodology, data was combined from multiple sources and scoring structures (Gap Inc, SAC and Fashion Positive) and selected based on indicators considered to be relevant for the assessed materials within the scope of the benchmark. The exact data and methodology used are not publicly available. Same as for the MFM, the Textile Exchange benchmark also solely takes the first processing step, which is mainly the impact of the raw material, into account [16] [17] [18].

	Level 1 0.0 Conventional	Level 2 0.8 Improved	Level 3 0.9 Progressive	Level 4 1.0 Advanced
Cotton	Cotton	CottonConnect REEL, Responsible Brazilian Cotton, BASF e3, Cleaner Cotton, Field to Market, ISCC, myBMP, Better Cotton Initiative	Cotton made in Africa, Fairtrade, Organic Cotton	Organic Fairtrade Cotton, Regenerative Organic Cotton, bioRe, Recycled Cotton
Wool	Wool		ZQ, RWS, Organic Wool	Recycled Wool
Down	Down	IDFL, Traumpass	Downpass, RDS, TDS, Organic Down	Recycled Down
MMCF	Viscose Acetate	Viscose-FSC/PEFC Modal, Lyocell, Acetate-FSC/PEFC	Lyocell-FSC/PEFC Modal-FSC/PEFC	Recycled Cellulose / Cupro
Polyester	Polyester	Bio-based Polyester*		Recycled Polyester
Nylon	Nylon	Bio-based Nylon*		Recycled Nylon

Figure 4 Set of weights per fiber type - Source: Textile Exchange 2019 CFMB Scoring Methodology

3.2.3 MADE-BY Environmental benchmark for fibers

The Made By benchmark for fibers is still widely used. Unfortunately, this benchmark is not updated anymore due to the bankruptcy of Made By in 2018. In this benchmark fibers were ranked according to six criteria (LCA- approach with a limited number of parameters) which are shown in figure 5.

Parameter	Description	Units of Measure	Weight
Green house gases (GHG)	Carbon dioxide equivalents (incl fossil emissions without subtracting embedded carbon in product sequestration[1])	Kg CO_2 eq / kg fibre	20%
Human toxicity	• Acute toxicity • Chronic toxicity • Reproductive hazard • Carcinogenicity	LD/LC for oral, dermal, inhalation and skin irritation level Chronic toxicity score and skin sensitization level. The State of California Proposition 65 list for developmental hazard IARC Group	20%
Eco-toxicity	• Acute aquatic toxicity to fish • Eco-toxicity potential	LC50 96 hrs Based on Material Safety Data Sheet (MSDS) information	20%
Energy input	Total energy use including feedstock	MJ / kg fibre	13.33%
Water input	Water input	Kg water / kg fibre	13.33%
Land use	Yield	Kg fibre / ha	13.33%

Figure 5 Impact parameters MADE-BY environmental benchmark for fibers - Source: research report MADE-BY December 2013

This resulted in the benchmark for fibers in which fibers were ranked in classes A – E and a group of unclassified fibers. The MADE-BY benchmark for fibers is presented in figure 6 below.

MADE-BY ENVIRONMENTAL BENCHMARK FOR FIBRES — MADE-BY www.made-by.org

CLASS A	CLASS B	CLASS C	CLASS D	CLASS E	UNCLASSIFIED
Mechanically Recycled Nylon	Chemically Recycled Nylon	Conventional Flax (Linen)	Modal® (Lenzing Viscose Product)	Bamboo Viscose	Acetate
Mechanically Recycled Polyester	Chemically Recycled Polyester	Conventional Hemp	Poly-acrylic	Conventional Cotton	Alpaca Wool
Organic Flax (Linen)	CRAiLAR® Flax	PLA	Virgin Polyester	Cuprammonium Rayon	Cashmere Wool
Organic Hemp	In Conversion Cotton	Ramie		Generic Viscose	Leather
Recycled Cotton	Monocel® (Bamboo Lyocell Product)			Rayon	Mohair Wool
Recycled Wool	Organic Cotton			Spandex (Elastane)	Natural Bamboo
	TENCEL® (Lenzing Lyocell Product)			Virgin Nylon	Organic Wool
				Wool	Silk

More Sustainable → Less Sustainable

MADE-BY Benchmarks cannot be printed, circulated or copied without the accompanying MADE-BY logo and website.

bwe This Benchmark was made in cooperation with Brown and Wilmanns Environmental, LLC. For further information on this Benchmark see www.made-by.org/benchmarks

Figure 6 Overall ranking - MADE-BY environmental benchmark for fibers

3.2.4 Conclusion

All benchmarks in this chapter rank fibers more or less the same, except for the Higg MSI, in which natural fibers perform less due to the allocated weight of eutrophication. Each of the benchmarks is based on different (LCA) factors, but not all of them of them take circularity into account. An important new parameter is the ability of the fiber to perform in a circular system, therefore it was decided to include this as an important parameter in the MFM.

Chapter 4 Fiber materials in the Modint fiber matrix

The MFM ranks fiber materials according to their use in a relative way. In this way fiber materials with comparable properties can be compared to each other and a choice on environmental criteria and circularity can be made.

4.1 Weight factor

A weight factor was introduced in order to express the importance of each parameter, as shown in table 2.

Parameter	Unit	Weight factor
Climate change	CO_2-eq. in kg	3
Energy use	MJ/kg	2
Water use	l/kg	1
Land use	m2/a/kg	1
Circularity	Degree of circularity (recycled materials/recyclability of materials/renewable materials)	2

Table 2 Selected parameters for the MFM including weight factors

The considerations behind the magnitude of the weigh factors are given below:

- Climate change is a topic of highest importance throughout society and industries with a high level of urgency and for that reason received the highest weight factor [19].
- In our industry, energy is used in most facets of the process. Between 80-90% of this energy is nonrenewable [20]. This is the reason why energy use was given a weight factor 2.
- The impact of water use and related water scarcity differs between geographical locations. This means that for some fibers the decision of where to source the fiber will influence the value. Therefore, we gave this parameter a weight factor of 1 to minimize the possibility unfair comparisons.
- Adverse effects of land use (e.g., competition with food production) is very much related to the location of raw material production. Since the MFM only compares fibers in the same categories, this factor has been set to what we estimate as world average.
- Besides the values of CO2-eq, water, land use and energy, a circularity score was introduced, based on renewable content, recycled content and recyclability of each fiber material. The circularity score is the sum of the percentages of these factors. Circularity will have a positive impact on all other categories and the ambition of the MFM is to drive circularity, but at the moment the technology is still limited. Therefore, the weight factor has been set to 2.
- Social conditions and animal welfare are not included as quantitative parameters for the MFM. They were however taken into consideration in the overall assessment when comparing preferred, better and best options of certain fiber types. If this is the case, you will find an explanation.

4.2 Data collection

The following types of fibers are included in the MFM:

- Cotton
- Polyester
- Man-made cellulosic fibers (MMCF)
- Wool
- Polyamide
- Linen
- Hemp

Data on fibers and their impact was collected using the Modint EcoTool [3] [21] (source of the data: eco-invent database (version 2.2) [22], the European ELCD database (2.0) [23] and industrial data (from Dutch producers, based on third party energy scans), from literature [24] [25] and reviewing expert opinions (with respect to circularity of the fibers). All refences to the used data are Included in the resources chapter. All collected data is shown in table 3.

At the time of writing this report, complete LCA data was not available for every fiber material included in the MFM. Since these fibers are commercially available and used by the industry, we decided to include them in the MFM, despite the lack of data. In this case you will find an asterisk (*) in the table and an explanation of our expert opinion below table 3. See the glossary at the back of this report for an explanation of certain fiber materials or categories (such as preferred viscose).

Fibers in the Modint Fiber Matrix		Parameters						
		Climate Change	Energy use	Water use	Land use	Renewable	Recycling**	Circularity score
		CO_2-eq. kg/kg	(MJ/kg)	(l/kg)	(m^2/a/kg)	%	%	
Cotton	Cotton conventional [26]	1,8	34,3	2120	13	100	5	105
	Preferred cotton [27]	1,04	34,3	182	21,5	100	5	105
	Organic cotton [28]	1	25,1	182	21,5	100	10	110
	Cotton recycled (mechanical)	0,324	6,8	0	0	100	100	200
MMCF	Conventional viscose [29] [30]	6,9	136,2	11	1,3	100	5	105
	Lyocell [29]	4,1	132,2	20	1,6	100	10	110
	Preferred viscose [29]	2,67	100,21	42	1,6	100	5	105
	Lyocell with recycled content	*	*	*	*	100	30	130
Wool	Wool	110	679,7	1091	261	100	40	140
	Responsible Wool	*	*	*	*	100	40	140
	Organic Wool	*	*	*	*	100	40	140
	Recycled Wool	0,96	17,4	10	0	100	100	200
Polyester	Virgin polyester [22]	3,22	89,4	0	0	0	5	5
	(partially) Biobased polyester [31]	*	*	*	*	20	0	20
	Recycled polyester (bottles) [32]	2,03	40	0	0	0	100	100
	Recycled polyester (mechanical)	0,304	6,1	0	0,05	0	100	100
Polyamide	Virgin Polyamide (PA6) [22]	9,3	122,1	14	0	0	25	25
	(partially) Biobased polyamide [33]	3,38	83,8	25	0	37	0	37
	Recycled Polyamide (chemical) [34]	3,268	28	11	0	0	100	100
	Recycled polyamide (mechanical) [22] [35]	0,304	6,1	0	0,05	0	100	100
Linen	Linen [36]	2,8	28,9	0	10	100	5	105
	Organic linen	*	*	*	*	100	5	105
Hemp	Hemp [36]	2,5	21,8	11	6,6	100	5	105
	Organic Hemp	*	*	*	*	100	5	105

Table 3 Collected data for fibers in the MFM

** For the recycling score we stated the percentage of recycled content (e.g., 100 for recycled polyester), or estimated the recyclability of the fiber based on current industrial practices [37].

* Find below an overview and explanation of fibers that were included in the MFM based on expert opinions, due to the lack of (complete) LCA data:

Cotton

Preferred cotton: At this moment we rank Cotton made in Africa (CmiA), 'Better Cotton' from the Better Cotton Initiative (BCI) and in-conversion cotton as 'preferred cotton' options. You can find a short description of these materials and their scope in our glossary at the end of this document. The data used for the MFM is based on an available LCA study by CmiA [27]. Since CmiA and BCI have a partnership, their practices are comparable and CmiA may also be sold as BCI cotton [38]. The mentioned reports show a very low amount of 1 liter blue water per kg cotton, which is based on one specific region in Africa where the cotton is grown, and not representative for 'preferred cotton' in general. For this reason, the data for water use is adapted and estimated as the same amount as organic cotton.

Man-made cellulosic fibers (MMCF)

Lyocell with recycled content: The use of recycled content lowers the overall negative pressure on the environment. As this type of MMCF available on the market today is lyocell with 30% recycled content, we concluded that this is ranked as the 'best' option for the MMCF fibers in our matrix [39].

Wool

Responsible Wool: Modint supports the transitioning away from mulesed sheep wool. Besides this, the Responsible Wool Standard (RWS) includes other criteria for animal welfare, land management and social welfare. For this reason, we plead for (certified) responsible wool as a preferred alternative to conventional wool, without having exact LCA figures yet [40] [41].

Organic wool: organic wool production restricts the use of many synthetic chemicals in cultivation. It is derived from sheep on organically grown feed, that graze on land and are not treated with pesticides or dipped into synthetic pools [42]. For these reasons, we have concluded that, without having LCA data yet, this is the better choice for wool.

Polyester

(Partially) Biobased polyester: Some types of polyester consist of biobased or bio-derived base chemicals, e.g., glycol can be oil based but also derived from natural carbohydrates. It is expected that this biobased feedstock leads to a lower environmental impact compared to conventional virgin polyester, which is derived from nonrenewable sources [43] [33].

Linen

Organic linen: Linen can be grown without water, pesticides and chemicals, however, this does not guarantee the fact that some farmers do not use them. Certified organic linen ensures that the growing process is pesticides free and that hazardous chemicals such as alkali and oxalic are not used in the retting process [44].

Hemp

Organic hemp: There are no chemical sprays like fungicide, herbicide, and insecticide used during the farming of organic hemp. The crops are non-GMO (genetically modified organism) and use of pesticides is not allowed [44].

4.2.1 Remarkable data

Some of the data and information mentioned in the previous subchapters may raise questions. That is why we described the three most remarkable outcomes and their explanation below.

- Why is there such a big difference in water use between conventional and organic cotton?

Cotton, both conventional and organic, is a water-intensive crop. Many sources show different amounts of water needed, mostly dependent on the region where the cotton is grown. Some regions in the world are almost completely rainfed, while in other regions 10.000 liters of irrigated water per kg cotton are used. For this report we used an 'average' number (studies are always mentioned as references). Organic cotton is mainly grown in more attractive rain-fed regions and better water management is an important aspect of organic agriculture, just as crop rotation, which results in healthier soil that is able to retain more water. But still, the data included for organic cotton in table 3 is also based on one study and the exact water footprint will vary between locations where the cotton is grown [42].
Recently, critical articles gave new insights on above mentioned topic and shine light on possible flaws in research and the way in which the outcomes favor organic (or other types of preferred) cotton. We still included this data in table 3 and used it for ranking fiber materials in the cotton category, because we believe these reports give the best available data at the moment of writing this report. That being said, we will keep a close eye on developments and integrate new insights in future versions of the MFM. We very much welcome data from stakeholders [45] [46].

- Why does lyocell score less than 'preferred viscose'?

Based on the more sustainable character of the lyocell process, where solvents and processing water are reused as much as possible, it is easy to expect lyocell to have a lower environmental impact. However, when comparing the gathered data, materials classified as 'preferred viscose' in the MFM in general have a slightly lower impact when looking at climate change and energy use. These materials are more recently developed and production processes are constantly improved. On the other hand, lyocell does have a lower impact on water use. These facts combined, make that 'preferred viscose' is ranked as the 'better' option in the MFM and lyocell as the 'preferred' option for MMCF.

- Isn't mechanically recycled polyamide of less quality than chemically recycled polyamide? Why is it ranked as the 'best' option?

The scope of the MFM at this moment only takes the first processing step into account. Which means, only the environmental impact of the raw material. Due to the way of recycling, mainly the impact on climate change and energy use is higher for chemically recycled polyamide, which makes it a 'better' option in the scope of the MFM. We are aware of the importance of high-quality fibers in the context of a circular economy. Please read chapter 5.2 for more information and our vision on this topic. Moreover, the same is valid for the recycled options in other fiber categories.

4.3 Conversion of data

In order to make the data comparable and to derive a single score, a conversion table was developed (see table 4).

score	Climate change	Energy use	Water use	Land use	Circularity
1	<1	<5	<5	<1	200
2	1-2	5-10	5-10	1-2	190-200
3	2-4	10-15	10-25	2-5	175-190
4	4-6	15-20	25-50	5-10	150-175
5	6-8	20-30	50-100	10-15	120-150
6	8-13	30-50	100-200	15-25	90-120
7	13-20	50-75	200-400	25-50	60-90
8	20-50	75-100	400-1000	50-100	30-60
9	50-100	100-150	1000-5000	100-200	0-30
10	>100	> 150	> 5000	> 200	0

Table 4 Conversion table

By using this conversion table, we prevent that a fiber material scores extremely low, due to an exceptional score on one single parameter.

Based on the data, the conversion and the weight factors, a single score for each of the fibers was derived. Table 5 shows an example of the scoring methodology for conventional cotton. The same methodology is used to get a single score for every fiber in the MFM, as shown in table 6.

Conventional cotton		**Climate change** (Co2-eq in kg/kg)	**Energy use** (MJ/kg)	**Water use** (l/kg)	**Land use** (m2/a/kg)	**Circularity score**	**Single score**
Step 1	Collect data from table 3	1,8	34,3	2120	13	105	
Step 2	Score according to conversion table 4	2	6	9	5	6	
Step 3	Multiply by weight factor see table 2	x3	x2	x1	x1	x2	
Step4	Add up the weighted scores to get the single score	6	12	9	5	12	**44**

Table 5 Example of the scoring methodology for conventional cotton

The fiber materials for which no (complete) LCA-data is available, were ranked according to our expert opinion (these values are given in orange) taking into account the values of "comparable" fibers. The single scores of all fibers are presented in table 6.

Fibers in the Modint Fiber Matrix		Parameters					
		CO_2-eq.	Energy use	Water use	Land use	Circularity score	Single score
Cotton	Cotton conventional	6	12	9	5	12	44
	Preferred cotton	6	12	6	6	12	42
	Organic Cotton	6	10	6	6	12	40
	Cotton Recycled (mechanical)	3	4	1	1	2	11
MMCF	Viscose	15	18	3	2	12	50
	Lyocell	12	18	3	2	12	47
	Preferred viscose	9	18	4	2	12	45
	Lyocell with recycled content	9	16	3	2	10	38
Wool	Wool	30	20	9	10	10	79
	Responsible Wool	27	18	9	10	10	74
	Organic Wool	27	15	6	10	10	68
	Recycled Wool	3	8	2	1	2	16
Polyester	Virgin polyester	9	16	1	1	18	45
	(Partially) Biobased polyester	6	12	2	2	18	40
	Recycled polyester (PET bottles)	9	12	1	1	12	35
	Recycled polyester (mechanical)	3	4	1	1	12	21
Polyamide	Virgin Polyamide	18	18	3	1	18	58
	(Partially) biobased polyamide	9	16	3	1	16	45
	Recycled Polyamide (chemical)	9	10	3	1	12	35
	Recycled polyamide (Mechanical)	3	4	1	1	12	21
Linen	Linen	9	10	1	4	12	36
	Organic linen	6	8	1	4	12	31
Hemp	Hemp	9	10	3	4	12	38
	Organic Hemp	6	8	2	4	12	32

Table 6 Weighted scores for fibers in the MFM

4.4 Results

Based on the single scores, the fiber materials are ranked within their fiber category as conventional, preferred, better and best. This results in the Modint Fiber Matrix which is shown in the figures 1 and 2 below. One version of the matrix includes only generic fiber names [4] and one version includes examples of commercially available options for these fibers from specific suppliers, their brand names and/or relevant certification schemes. This is not an exhaustive list of examples and may be updated in the future. Modint is not affiliated or in any way officially connected with the brands and certifications mentioned or any of its subsidiaries and/or affiliates. We welcome data from other sources to review for future editions of the MFM. Please contact Modint at info@modint.nl if you would like to share data or suggestions.

MODINT FIBER MATRIX
GUIDING TOWARDS CIRCULARITY

Generic fibers

	BEST	BETTER	PREFERRED	CONVENTIONAL
COTTON	Recycled cotton	(certified) Organic cotton	Preferred cotton	Conventional cotton
MAN-MADE CELLULOSIC FIBERS	Lyocell with recycled content	Preferred viscose	Lyocell	Conventional viscose
WOOL	Recycled wool	(certified) Organic wool	Responsible wool	Virgin wool
POLYESTER	Mechanically recycled polyester	Recycled polyester from PET bottles	(Partially) biobased polyester	Virgin polyester
POLYAMIDE	Mechanically recycled polyamide	Chemically recycled polyamide	(Partially) biobased polyamide	Virgin polyamide
LINEN		(certified) Organic linen	Linen	
HEMP		(certified) Organic hemp	Hemp	

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Figure 1 Modint Fiber Matrix - generic fibers

MODINT FIBER MATRIX
GUIDING TOWARDS CIRCULARITY

Examples of fibers from specific suppliers and/or their brand names or relevant certifications. This is not an exhaustive list.

	BEST	BETTER	PREFERRED	CONVENTIONAL
COTTON	Recycled cotton (GRS)	Organic cotton (GOTS)	Preferred cotton Better Cotton (BCI) Cotton Made in Africa (CmiA) Cotton in conversion	Conventional cotton
MAN-MADE CELLULOSIC FIBERS	Lyocell with recycled content Refibra™	Preferred viscose Lenzing Austria Livaeco by Birla Cellulose™ Ecovero™	Lyocell Tencel™	Conventional viscose
WOOL	Recycled wool (GRS)	Organic wool (GOTS)	Responsible wool (RWS)	Virgin wool
POLYESTER	Mechanically recycled polyester (GRS)	Recycled polyester from PET bottles (GRS) REPREVE®	(Partially) biobased polyester Sorona®	Virgin polyester
POLYAMIDE	Mechanically recycled polyamide	Chemically recycled polyamide ECONYL® (GRS)	(Partially) biobased polyamide Sorona®	Virgin polyamide
LINEN		Organic linen (GOTS)	Linen	
HEMP		Organic hemp (GOTS)	Hemp	

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Figure 2 Modint Fiber Matrix - brands and certifications

Chapter 5 How to use the Modint Fiber Matrix

The material mix is one of the biggest drivers of a fashion brand's environmental footprint and comes with implications for climate change, waste and biodiversity. Across segments it can determine up to two thirds of a brand's impact on water, energy and land use, as well as its air emissions and waste [47]. The MFM will enable you to make more sustainable material choices in your collection with a focus on preferred, better and best materials.

It is estimated that over 80% of all product-related environmental impacts are determined during the design phase of a product [48]. Through the MFM you get a clearer understanding how the fiber material mix deals with crucial aspects of the production chain in terms of environmental impact and can create necessary change. This knowledge and transparency are the way towards a more sustainable textile sector.

5.1 Examples of use

There are different ways to make use of the MFM. You can start by analyzing the materials you are currently using. What percentage of the fiber materials are ranked in the preferred, better or best section of the MFM? Can you set a goal for the use of more sustainable materials in two or maybe five years?

One starting point would be the most used and important fiber material in your collection. For example: if you have a large part of cotton in your material mix, this is a place to make great impact. If you would like to change this towards a more sustainable mix you can easily look in the MFM for the preferred, better or best options of cotton and discuss with your manufacturer or supplier what options they can offer for your products. A different option is to start with your basics or never out of stock collection.

Another approach would be a risk-based selection of the fiber materials which can be improved. Modint supports its members by calculating the impact of materials, processes or products, using the Modint EcoTool. By making a risk analysis of your products, you can map the hotspots in your assortment. This will enable you to improve products that have the highest impact on the environment and choose more sustainably ranked fiber options in the MFM to replace the current ones.

By this means the MFM can enable you to make a better mix of your sustainable materials and actively reduce your negative impact on the environment.

5.2 More opportunities of sustainable and circular development

A next step is to integrate circular design and eco design principles [49], where the complete lifecycle and use phase of a product is taken into account. Eco-design considers environmental aspects during all stages of the product development process, striving for products which make the lowest possible environmental impact throughout the product life cycle.

The MFM addresses the raw material phase, but it is very important to also assess the impact of the other processing steps in order to have a more holistic view of the level of sustainability throughout the complete supply-chain (raw material, yarn production, fabric production, garment production, use-phase, end-of-life).

Circular business models such as rental, reuse and repair will enable you to keep products and its materials longer in a closed or open loop and will reduce the need for raw materials.

The MFM is explicitly focused on more sustainable options for fiber materials, as a first and important step, to guide you towards a lower environmental impact and circularity. A sustainable raw material strategy is a crucial part of your bigger CR strategy which addresses overall due diligence commitments. But even the choice of a more sustainable material has more layers and complexity to it. Think about the use of mono materials, minimizing your overall use of materials and the possible decrease in quality when using recycled materials. If you would like to know more or need help implementing, please contact Modint for support and more information via info@modint.nl.

Glossary

BCI (Better Cotton Initiative)
Launched in 2005, BCI seeks to establish better and more sustainable practices in the field of cotton cultivation. Collaborating with organizations and stakeholders across the cotton supply chain, BCI promotes 'Better Cotton'. Farmers must meet the core requirements of the Better Cotton Principles and Criteria in order to become licensed to grow and sell their cotton as Better Cotton, which in short means it is produced in a more economically, environmentally and socially sustainable way [50].

Benchmark
A point of reference against which a standard or a criterion may be measured. Outcomes can be evaluated against specified activity and compared as a means to measure best practice performance.

Biodiversity
The term given to the variety of life on Earth. It is the variety within and between all species of plants, animals and micro-organisms and the ecosystems within which they live and interact [51].

Chemistry
The branch of science that deals with the properties, composition, and structure of elements and compounds, how they can change, and the energy that is released or absorbed when they change [52].

Circular Economy
A circular economy is an alternative to the traditional linear economy (make, use and dispose). Under a circular economy, products, components and materials are kept in use for as long as possible to extract the maximum value and after their usable life, they are reused, repaired or recycled [53].

Closed-loop system
System in which products, components or materials are reused or recycled in the same or similar products, components or materials with minimal loss of quantity, quality or function. The input flow comes from the same chain as the one in which it is reused [54].

Cut-Make-Trim (CMT)
Processing step which includes the following:
Cut: where material is cut into patterns and made ready to sew. Make: where the patterns are sewn together to create a garment. And trim: where garments are finished, threads and small imperfections are removed and final quality control and packing occurs [55].

Cotton Made in Africa (CmiA)
Internationally recognized standard for sustainable cotton from Africa. Since 2005, CmiA has been committed to protecting the environment while improving working and living conditions for smallholder farmers and ginnery workers [56].

Durability
The ability to endure. In terms of product, it represents long-established 'good' design qualities, like efficiency and timelessness as well as quality and performance [57].

Dyeing
The process of adding color to textile products like fibers, yarns and fabrics. Dyeing is normally done in a special solution containing water, dyes and particular chemical material [58].

Eco-Design
Eco-design considers environmental aspects at all stages of the product development process, striving for products which make the lowest possible environmental impact throughout the product life cycle [49].

End of life
In the context of manufacturing and product lifecycles, it is the final stage of a product's existence after the use-phase.

Eutrophication
The gradual increase in the concentration of phosphorus, nitrogen, and other plant nutrients in an aging aquatic ecosystem. Eutrophication occurs naturally over centuries as lakes age and are filled in with sediments. However, human activities have accelerated the rate and extent of eutrophication through discharges of limiting nutrients, such as nitrogen and phosphorus, into aquatic ecosystems [59]. Eutrophication sets off a chain reaction in the ecosystem, starting with an overabundance of algae and plants. The excess algae and plant matter eventually decompose, producing large amounts of carbon dioxide. This lowers the pH of seawater, a process known as ocean acidification. Acidification slows the growth of fish and shellfish and can prevent shell formation in bivalve mollusks. This leads to a reduced catch for commercial and recreational fisheries, meaning smaller harvests and more expensive seafood [60].

Fiber
The fundamental component that is used in the assembly of textile yarns and fabrics [61].

Finishing
A process used in manufacturing of fiber, yarn, fabric, or clothing. In order to impart the required functional properties to the fiber or fabric, it is customary to subject the material to different types of mechanical and/or chemical treatments.

Ginning
A process that separates the cotton from the seeds and other foreign matters, ensuring fiber quality is preserved.

GOTS (Global Organic Textile Standard)
The worldwide leading textile processing standard for organic fibers, including ecological and social criteria, backed up by independent certification of the entire textile supply chain [62].

GRS (Global Recycle Standard)
A standard developed to ensure greater sourcing clarity on recycled materials right through the production supply chain. It is intended for companies that wish to make a content claim on the

amount of recycled material in the final product. It is based on the certification of the full chain of custody for recycled products, incorporating environmental and social criteria [63].

Higg Index

The self-assessment tool developed by the Sustainable Apparel Coalition empowers brands and retailers to measure their environmental and social and labor impacts and identify areas for improvement. Higg delivers a holistic overview of the sustainability performance of a product or company [14].

In-Conversion Cotton

Cotton that has been grown according to organic standards but may not be labelled as 'organic' yet. Establishing an organic management system requires an interim period, known the "in-conversion" period. This varies in time based on the organic standard being applied but is up to 36 months. During that time, farmers implement all the practices required to achieve organic certification (including not using inputs and practices prohibited in organic farming) and are audited annually by certification bodies as per international organic agriculture standards. In-conversion cotton is the output of the farms during this conversion period. Purchasing 'organic in-conversion' cotton is a great way to support farmers making the difficult transition to organic [64].

LCA (Life Cycle Assessment)

A systematic set of procedures for evaluating the sustainable impact of products throughout its life cycle. E-LCA comprises environmental aspects and S-LCA the social impact.

Man-made cellulosic fibers (MMCF):

Fibers made from natural cellulose polymers, extracted from plants. The macromolecule which has been synthesized by nature may be used as such or may be chemically modified. To enable cellulose to be spun, it has to be dissolved. In practice, this is done by one of the following processes: viscose process, cuprammonium process, acetate process or lyocell process [65].

More sustainable material

More sustainable materials have a proven lower environmental impact compared to conventional materials in the same fiber category. This includes materials in the Modint Fiber Matrix ranked as preferred, better and best.

Microplastics

Fragments of any type of plastic less than 5 mm in length. They enter natural ecosystems from a variety of sources, including cosmetics, tyers, synthetic clothing and industrial processes [66] [67].

Mulesing

The practice of cutting off pieces of skin and flesh of a domestic sheep in order to prevent flystrike. The practice is usually performed with an animal physically restrained, without anesthesia and is physically and physiologically painful for the animal. It is common in the Australian wool industry [68].

Organic cotton

Organic cultivation restricts many synthetic chemicals, disallows the use of genetically modified seeds and increases soil fertility. It generally implies 95% less water consumption (largely due to production in rain-fed countries), fair labor practices or fair price to the farmer [42].

Organic wool:
Organic wool production restricts the use of many synthetic chemicals in cultivation, it is derived from sheep on organically grown feed, that graze on land and are not treated with pesticides or dipped into synthetic pools [42].

Paris Agreement
A legally binding international treaty on climate change. It entered into force on 4 November 2016. This goal is to limit global warming to well below 2, preferably to 1.5 degrees Celsius, compared to pre-industrial levels. To achieve this long-term temperature goal, countries aim to reach global peaking of greenhouse gas emissions as soon as possible to achieve a climate neutral world by mid-century [7].

Preferred cotton:
A category in the Modint Fiber Matrix which includes CmiA, BCI-cotton and in-conversion cotton. These varieties of cotton have a lower environmental impact compared to conventional cotton, due to cultivation practices.

Preferred viscose:
A category in the Modint Fiber Matrix, which include Lenzing viscose Austria, Lenzing Ecovero™ and Livaeco by Birla Cellulose™. These are relatively new fibers, they have a lower environmental impact than conventional viscose and lyocell and are therefore ranked as 'better' in the MFM.

Product Life Cycle
Refers to all life cycle stages of a product, from extraction of raw materials to production, transportation, use, recycling and final disposal. Usually, a product's life cycle involves energy and water consumption, liquid discharges, gaseous emissions, solid wastes, etc. [69]

Raw material
Crude, unprocessed or partially processed material used as feedstock for a processing operation [70].

Recycled fibers
Any kind of fiber that underwent a recycling process. It offers a low-impact alternative to virgin fiber sources, with reduced level of energy and chemical consumption.

Recycling
Recovering materials and resources from discarded products and reusing them to make products [71].

Renewable Resources
Any type of resources that are naturally replenished by the environment over relatively short periods of time with or without human interference [72].

STANDARD 100 by OEKO-TEX®
An international testing and certification system for textiles, through which every component of an article, i.e., every thread, button and other accessories, has been tested for harmful substances and which confirms that the article therefore is harmless for human health [73].

Supply Chain
Network of entities, directly or indirectly interlinked and interdependent in serving the same consumer or customer. It comprises vendors that supply raw material, producers who convert the material into products, warehouses that store, distribution centers that deliver to the retailers, and retailers who bring the product to the ultimate user. In the textile industry, the supply chain covers the operations from the sourcing of raw materials to retail [73].

Sustainability
The physical development and institutional operating practices that meet the needs of present users without compromising the ability of future generations to meet their own needs, particularly with regards to use and waste of natural resources [74]. Sustainability presumes that resources are finite and should be used conservatively and wisely with a view to long-term priorities and consequences of the ways in which resources are used. Sustainable practices can support individuals, organizations and companies to take into account the environmental, social and economic point of view [75].

Sustainable Development Goals (SDGs)
The SDGs were adopted by the United Nations in 2015 as a universal call to action to end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity. The 17 SDGs are integrated—they recognize that action in one area will affect outcomes in others, and that development must balance social, economic and environmental sustainability [6].

Textile Exchange (TE)
Formally known as Organic Exchange (OE), TE is a non-profit, membership-based organization. It can provide an initial sustainability assessment for companies in order to develop a long-term plan. This work includes verifying the supply chain in order to demonstrate how the material is sourced, processed and manufactured. TE consults companies to determine which is the most sustainable fiber/material to use and helps them to formally trace the integrity of their materials and manufacturing processes [2].

Transparency
With reference to an organization, it involves clear and honest communication of the activities of a business as well as future goals, to all stakeholders involved.

Use phase
Life cycle stage where a product is ‘in-use’ by the consumer, usually related to wear and laundering.

Verification / verified
The use of objective evidence to confirm that specified requirements have been met. Whenever specified requirements have been met, a verified status is achieved [76].

Waste
Any substance or object which the holder discards or intends or is required to discard. In waste planning there are various categorizations of waste (e.g., municipal solid waste, controlled waste, hazardous waste etc.) [54]

Water Footprint
The water footprint is an indicator of freshwater use that looks at both direct and indirect water use of a consumer or producer. The water footprint of an individual, community or business is

defined as the total volume of freshwater used to produce the goods and services consumed by the individual or community or produced by the business. The water footprint has three components: green, blue and grey.
Green water footprint is water from rainfall that is stored in the root zone of the soil and evaporated or incorporated by plants. It is particularly relevant for agricultural, horticultural and forestry products.
Blue water footprint is water that has been sourced from surface or groundwater resources and is either evaporated, incorporated into a product or taken from one body of water and returned to another, or returned at a different time. Irrigated agriculture, industry and domestic water use can each have a blue water footprint.
Grey water footprint is the amount of fresh water required to assimilate pollutants to meet specific water quality standards [77].

Yarn
An assembly of fibers or filaments having a substantial length and relatively small cross-section, with or without twist, being the end-product of spinning and winding process [65].

Resources

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Authors:
Anton Luiken - Alcon Advies
Rachel Cannegieter - Rethink Rebels
Nikki Bosboom - Modint
Miriam Geelhoed - Modint

Peer reviewed by: Dr. ir. Natascha M. van der Velden PhD

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