



mistra
future
fashion

the outlook report 2011-2019

mistra future fashion final program report



content

- directors' view.....4
- our partners6
- this is mistra future fashion8
- design for circularity10
- textile fiber impact12
- production impact.....14
- user 16
- alternative business models 18
- policy instruments 20
- end of life..... 22
- joint effort..... 24
- value to others 26
- publications 28
- program organization 33
- testimonial chairman of the board..... 34

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eight years of research

In your hands right now is an overview and packaged recommendations stemming from 8 years of research aiming at a systemic change in fashion. The Mistra Future Fashion Research Program has been delivering substantial amounts of research in the written form of reports, conference contributions, academic publications, and doctoral theses, all available at our website for reading. Additionally, the team of researchers have contributed in, and arranged, conferences, meetings, workshops, exhibitions as well as participation in expert groups and panels in various initiatives. Furthermore, we have developed new materials, tools and prototypes, and implemented new concepts together with industry partners.

'to make our research even more available we have packaged the main conclusions into 8 recommendations cards'

In order to make all of our research more visible and available we have packaged the main conclusions into recommendations on how one can contribute towards a systemic change in fashion. These are posted as recommendations cards from different angles: design for circularity; textile fiber impact; production impact; user; alternative business models; policy instruments; end of life; and joint effort. This is also the structure of this report.

So, how has the research matured and did we achieve our vision 'towards a systemic change in fashion'? The scope of Sustainable Fashion has grown rapidly since 2010 when Mistra defined

the call text for our research program. Within the topics of our four research themes (design, supply chain, user and recycling) one can notice that the research areas have both evolved and become more defined, and that the industry has taken initiatives to reform and change.

There are similarities with program coordination of vast cross disciplinary research programs and raising a child, in the sense of watching something mature and grow. Imagine that we started the research program path when receiving the research grant from MISTRA in 2011, as a rather young 'child'. (Not to be confused with the maturity or capability of the individual researchers within the program, who on the other hand are very skilled and knowledgeable within their area of expertise.) The "research program toddler" learned how to speak, listen and to respect each other over research disciplines.

A few years later the program knew how to create cross-disciplinary research projects, and around 2015 when phase 2 of the program started, similarities with a school child could be seen. The research program showed a new level of maturity, it could speak across disciplines, interact with various stakeholders outside of the program, and act more comfortably within the broader context of society and the wider world.

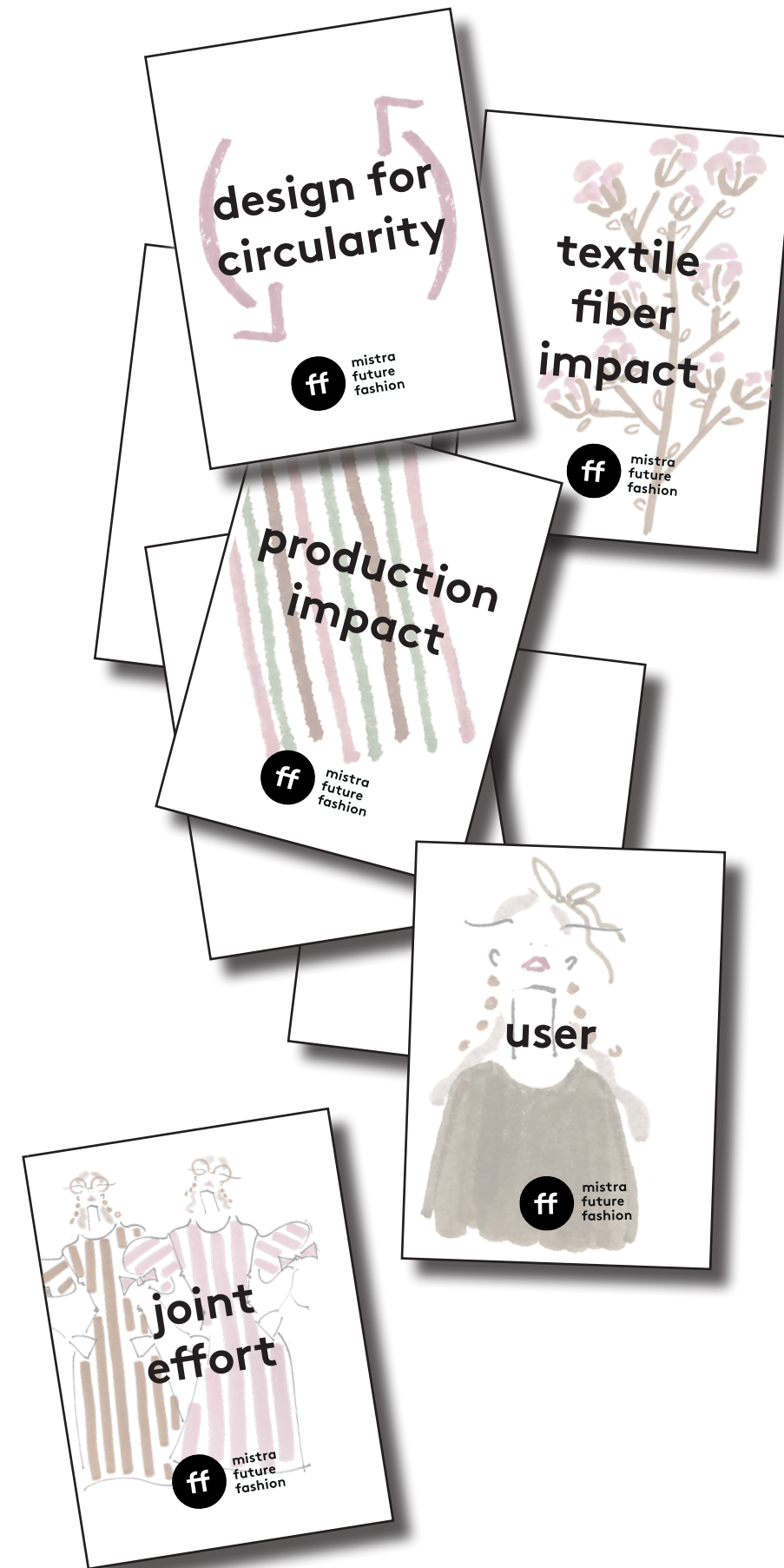
'the program's role has gradually grown and impact has been made globally'

The program's role has gradually grown and impact has been made globally, as can be viewed in this outlook. When we now leave this 'child', we see a 'teenager' exploring various new possibilities. And we do have high hopes for this 'teenager', contributing strongly to the systemic change needed within the whole fashion industry and the fashion user.

Although the Mistra Future Fashion Research Program as such is closed, its researchers still continue to develop new knowledge and insights for future sustainable fashion. Maybe more importantly, we now also see an industry that has started to act widely. Mistra Future Fashion research has shown that 80% of the climate impact from the average Swede's use of clothes comes from the production line. To us, this gives many prospects for improvement such as; the direct increase of fossil-free energy solutions in the production line, but also improved design for circularity, new business models for extended lifetime of garments (i.e. borrowing and leasing), new accounting systems to increased traceability, and better policy instruments for supporting the development of a second-hand market. To incorporate actions related to above, we believe that the systemic change is en route and that we together can improve the sustainability profile of fashion lifestyle in the future.

Mistra Future Fashion Management Team

September 2019



Dr. Åsa Östlund
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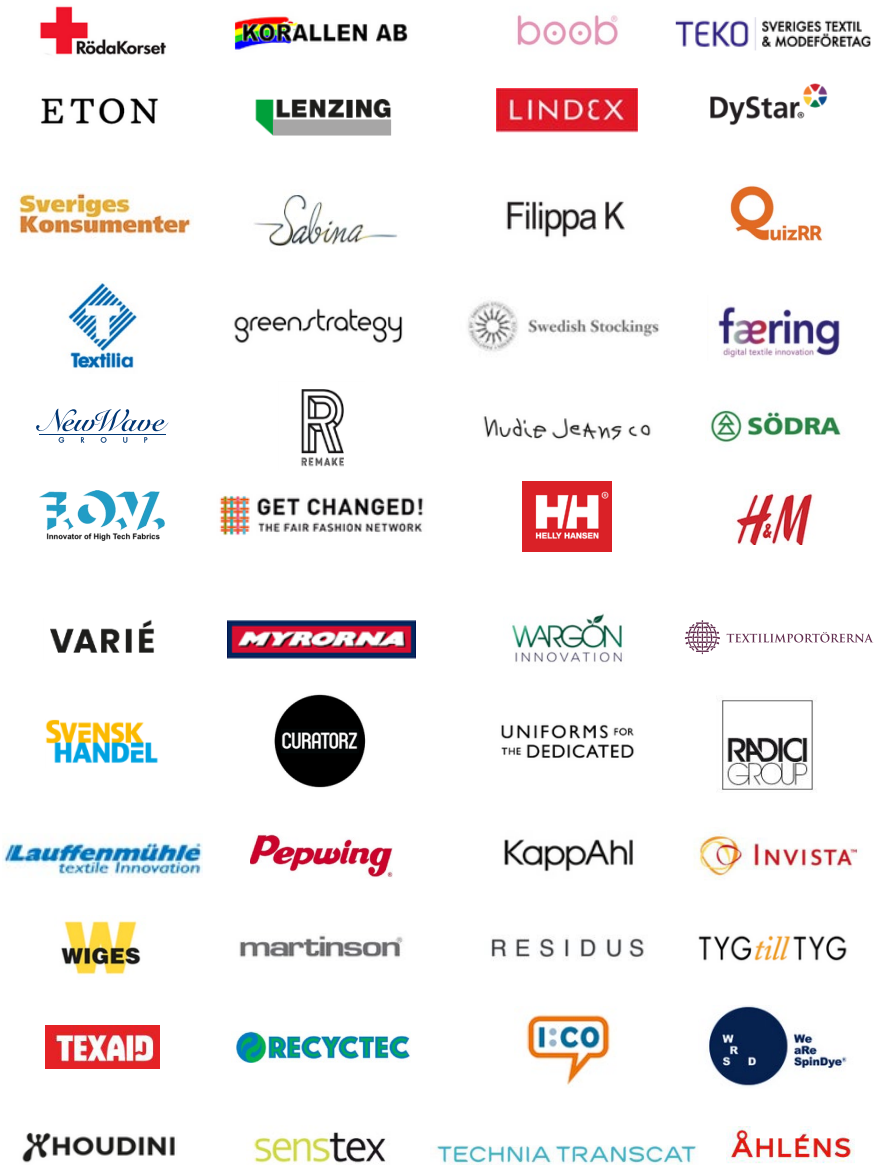
Malin Viola Wennberg
Communications Manager

our partners

	research partners	involved in theme	researchers	output
	BOKU	Recycling	Doris Ribitsch	Chemical engineering Textile fibre recycling
	Chalmers University of Technology	Design Supply Recycling	Greg Peters Anna Palme Bahareh Zamani	LCA Chemistry Fiber prototypes
	Copenhagen Business School	Design Supply User	Wencke Gwodz Esben R G Pedersen Kirsti Reitan Andersen Kristian S Nielsen Tina Joanes	Consumer behaviour Business models Local production
	IVL, Swedish Environmental Research Institute	User Recycling Supply	Maria Elander Hanna Ljungkvist	Policies
	KTH, Royal Institute of Technology	Recycling	Per-Olof Syrén	Chemical engineering Textile fibre recycling
	More Research	Supply Recycling	Björn Källman Hanna Rammsy	Viscose pilot production
	PlanMiljø	Supply User	David Watson Anja Charlotte Gylling Bjørn Bauer	Policies Business models
	re:newcell	Recycling	Christofer Lindgren Henrik Norlin	Chemical engineering Textile fibre recycling
	RISE	Design Supply User Recycling	Hanna de la Motte Gustav Sandin Albertsson Helena Wedin Finn Englund Åsa Östlund Hjalmar Granberg Tatjana Karpenja Siv Lindberg Sandra Roos Björn Spak Zengwei Guo Anna Rúna Kristinsdóttir Christina Jönsson Anne-Charlotte Hanning Desiré Rex	Nonwoven biobased materials Process analysis Consumer perception LCA Cellulose Chemistry Fiber prototypes Recycling feasibility Auto sorting Fiber benchmark Microplastics
	Stockholm School of Economics	User	Susanne Sweet Tina Sendlhofer	Market Supply chain strategy Business models
	Stockholm University	User	Claudia Rademaker	Consumer behaviour Business models
	International Institute for Industrial Environmental Economics at Lund University	User Supply Recycling	Naoko Tojo Åke Thidell	Policies Recommendations
	The Swedish School of Textiles	Design Recycling	Ellinor Niit Kate Goldsworthy Rebecca Earley Kay Politowicz Clara Vuletich	Design Textile Technology Strategic design Prototypes Design Guidelines
	Centre for Circular Design at University of the Arts London	Design Recycling		

a consortium with partners who share the program vision and actively contribute to the program goals

industry partnerships:



Mistra Future Fashion was a consortium based program built by partners who shared the vision and actively contributed to achieving the program goals.

The program covered a broad range of expertise and involved the most established **experts and progressive leaders within their respective research fields**. The research was organized around four themes and involved researcher partners from Sweden, Denmark, Austria and the United Kingdom.

The industry partners involved were a mix of relevant stakeholders from across the value chain such as producers, designers, retailers, waste managers and NGOs.

The consortium had two levels of industry partnership; Stakeholder partners, and Advisory Stakeholder partners.

Stakeholder partners include in-depth involvement in research tasks with inputs such as expertise, information-sharing, resources, equipment and materials.

Advisory Stakeholder partners actively follow research progress and provide input on shaping the agenda.

international network partnerships:



research for sustainable fashion

a research program with a vision of enabling systemic change leading to a sustainable fashion industry and society

sustainable fashion

The program focused on environmental and climate effects caused by global fashion sector and the changes required for future sustainable operations. The research **applied the principles of circular economy** and was structured around four themes – **Design, Supply Chain, User and Recycling**.

unique system perspective

The program held a holistic system approach for the fashion value chain, from fiber to recycling, and how it needs to change in order to become more circular. The research was **cross-disciplinary**, allowing comprehensive analyses and insights. New knowledge was verified in a holistic context, **ensuring sustainability also from a system perspective**.

consortium based

The program research rests on engagement with its consortium: research institutes, universities, government agencies, non-governmental organizations as well as companies within the textile value chain; from forestry, pulping and textile manufacturing to fashion retail and recycling. **The partners set the research scope**, participate in the research with intelligence, resources and materials, and agitate for implementation.

results leading to global competitiveness

Delivered results are scientific knowledge and novel solutions that **enable positive change** in the fashion sector in terms of its environmental performance and its global competitiveness.

platform for sustainable fashion

The initiator and the primary funding organization was **MISTRA, the Swedish Foundation for Strategic Environmental Research**, which provided a SEK 80 million grant. An additional SEK 30 million is co-financed by in-kind contributions from industry partners. The program had two four year phases with a total program period of eight years, 2011-2019.

delivered results are scientific knowledge, novel solutions and concrete recommendations

why

The global fashion industry faces multiple challenges when meeting modern requirements for sustainability, traceability and transparency. **Today's fashion industry means severe environmental impacts** from production, hazardous substances in garments, mass consumption and generation of large volumes of textile waste. **The majority of today's fiber production is unsustainable**, either as conventional cotton that requires high amounts of pesticides and water in places where water is scarce, or synthetic fibers such as polyester which is made of our planet's fossil resources.

The issue is also about providing the high volumes required. A challenge that will get worse with the continued global population growth. An annual volume of 100 million metric tons is estimated to be needed by 2020 (Eichinger, 2012), and very few nascent sustainable alternatives can meet those demands. However, new alternative **fibers sources is not enough since 80% of a garments climate impact stems from the total production phase**, such as fiber production, yarn production, weaving, dyeing, finishing, sewing, surface treatments, etc, due to its energy, water and chemical usage.

New sustainable fibers in old production processes challenges the output as sustainable products. The overarching issue that needs to be addressed is the imbalance in efforts needed for production vs usage. In general there is **high environmental impact required for a short user phase**. Furthermore, modern consumption habits generate massive textile overload in the market and ultimately also problems with waste. This is result of the linear economy model, where 'take, make, waste' represents a broken design right from start.

vision: enabling a systemic change of the fashion industry and society

how

A **new model** is required in order to utilize the resources in the most efficient and sustainable way, and to minimize (hopefully eliminate) waste. **Policies are required that prompt the development of new market and business models allowing consumer behavior to be changed**. With the aid of information flow and digital technology developments, new consumer habits and demands may appear, along with **advances in sustainable production processes** and techniques, which also assume less geographical dependence.

We need textile fibers with lower environmental impact, but comparable in quality and price to existing, non-sustainable fibers. A circular model will involve more **advanced design processes incorporating sustainability impact procedures right from the design phase** – procedures that are based on intended usage and duration of use, which **ensure optimum usage via re-use and which enable separation and the regeneration of new fibers at the point of disposal**.

We hope to see a **future with recycled fibers from textile waste**, new sustainable production techniques and new consumption habits leading **towards new services such as leasing, re-design and borrowing**, which will encourage **flourishing new business in re-use, collection, sorting and recycling**. This will mean available alternatives and enable more sustainable actions.

design for circularity

Consider that the decisions made at the drawing board will affect the entire lifecycle of the garment. Always design for intended use and beyond.

Calculating for all Swedish clothing consumption, prolonging the active lifetime of a garment, by two will decrease its climate impact by half. Therefore, we must consider different ways to enhance its value at the point when users may think of discarding it.

The 'Service Shirt' concept was developed by R. Earley in 2018. The garment is designed as a deliberate extreme to have a total life length of 50 years. The garment lifecycle includes inhouse and external re-manufacturing processes,

various use cycles, moving between owners in rental and sharing contexts. The shirt becomes the lining of a jacket and then it is crafted into fashion accessories, before being chemically regenerated in the year 2068.

Another path explores how to reduce production impacts and retaining the value of the material after use. In other words, material longevity. One possibility is to develop materials with lower impacts during production, and avoid the barriers to recycling faced by conventional garments.

The 'Fast Forward Fashion' concept, developed by K. Goldsworthy, K. Politowicz and H. Granberg, explore how to tackle the faster end of



'Eternal Trench Coat' by Filippa K



Fast Forward Fashion 'Pulp-It' by Kay Politowicz, Kate Goldsworthy & Hjalmar Granberg

the fashion market with the development of a new bio-based nonwoven material. Compared to a woven or knitted fabric, nonwoven material can eliminate costly processes and impacts through a reduced production phase. Whereas the environmental impact of conventional clothes are mainly related to the number of uses, the impact of short-life clothes made with textile-like paper depends to a greater extent on the weight of the material.

Although not ready for full-scale production yet, in the future we might make clothing for paper recycling or composting. Different finishing treatments is a key factor improving performance, user acceptance and even ease of recycling and industrial composting.

We may intend our clothes to be 'slow' but for many reasons they end up being 'fast', and vice versa. The prototypes created in the project Circular Design Speeds, in collaboration with Filippa K, is an example of this paradox. The 'Eternal Trench Coat' was designed to be durable and for efficient recyclable at its eventual end. The polyester used is often associated with fast-fashion but can be considered slow due to its long lifetime. Through effective recycling this material can be fast in its recovery. The result is a durable product with an easy route to new material after a long life. This product made it to full commercialisation as well as the permanent collection of the V&A museum in London.



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Peters G et al. (2018) LCA on fast and slow garment prototypes. Mistra Future Fashion report series

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Roos S et al. (2019) Guidance for fashion companies on design for recycling. Mistra Future Fashion Report series

Granberg H et al. (2018) Crimping and welding of textile-like papers. Mistra Future Fashion Report series.

Goldsworthy K et al. (2019) Circular Design Speeds. Mistra Future Fashion Report series

Earley R et al. (2019) Circular Design Researchers in Residence. Mistra Future Fashion Report series

'the service shirt' by Rebecca Earley

textile fiber impact

The common separation into “good” and “bad” fibers, based on generic classifications of fiber types, is too simplified. A much more nuanced view is needed in which the separation rather is done between producers with or without appropriate environmental management, and poor or better uses of the fiber. This measurement must account for the environmental performance throughout the entire life cycle of the final textile product.

In other words, a t-shirt made from organic cotton or recycled material does not automatically become a more sustainable t-shirt compared to a fossil based textile product. Organic farming is a good start, but one must also calculate for

the resources used during the entire life cycle. If the factories completing the spinning, weaving, color and sewing part is run on fossil fuel the impact from these processes is larger than the impact from the textile fiber alone.

The differences between site specific suppliers of textile fibers are often greater than differences between fiber types. For example, the difference in climate impact between the best and worse cotton fiber is greater than the average difference in climate impact between cotton and viscose, see figure 1. Implementing best use practices throughout the production chain is right now a more pressing issue than fiber content.

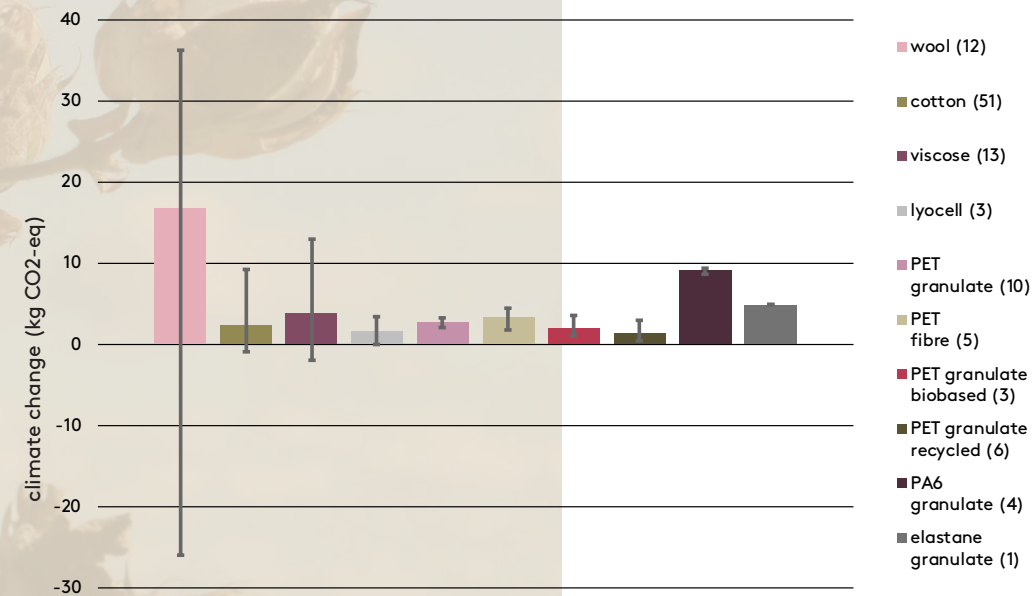


figure 1, climate impact comparison of fiber types and the standard deviation between different textile fiber producers

Consider that textile fiber production also relies on energy and materials, other than the raw material. Secondary flows, including production of heat, electricity, fertilizers, pesticides, chemicals, catalysts, and others often have a higher impact on a mass basis than the raw materials used as fiber feedstock. In a future scenario, the care label in our clothes will specify energy use, water scarcity and toxicity in addition to fiber content to give a complete picture.

At present, cotton is the most commonly used fiber in Sweden. However, cotton is also one of the most damaging textile fibers in terms of water scarcity and environmental impact. For garments consisting fully

or partly of cotton, water consumed in the irrigation of cotton cultivation is a clear hotspot with room for improvement. The dominance of water consumed in cotton cultivation is striking, totaling about 87% of the impact. Therefore, reducing the use of cotton fiber in textile products is one possible solution, either by mixing it with other cellulose fibers (eg produced from forest, such as lyocell, modal and viscose) or replacement with polyester fiber.

In choosing the textile fiber, set the fibers’ life cycle performance at center stage, including their fit-for-purpose and effects on subsequent production, user behavior and end-of-life options.



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Sandin G et al. (2019) Environmental impact of textile fibres – what we know and what we don’t know. The fiber bible part two. MISTRA Future Fashion report series

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production impact

At present, 80% of a garment's climate impact stems from the production phase, see figure 2. Furthermore, 92% of the toxicity impact stems from the production phase. In other words, most of the impact happens before the garment hit the store. Therefore, implementing best possible practice is crucial in the production chain, and the garments already produced must stay in use longer.

Out of all steps during production the wet treatment processes have the largest climate impact, see figure 2. This is due to the large amount of energy required to heat the process water, which often stems from fossil energy sources.

One way to reduce the impact of wet treatments is to completely avoid wet dyeing by adding color pigments already when the fiber is manufactured, so called dope dyeing, spin dyeing or solution dyeing. All fibers that are extruded (ie man-made fibers such as polyester, nylon, viscose, etc.) can be manufactured this way. Such dry dyeing technique is already available on the market, which means that a reduction in climate impact is a possibility by choice.

A reduction of water usage in the textile preparation phase has several positive effects: reduction in energy use, water use and reduced amounts of contaminated wastewater from the process.

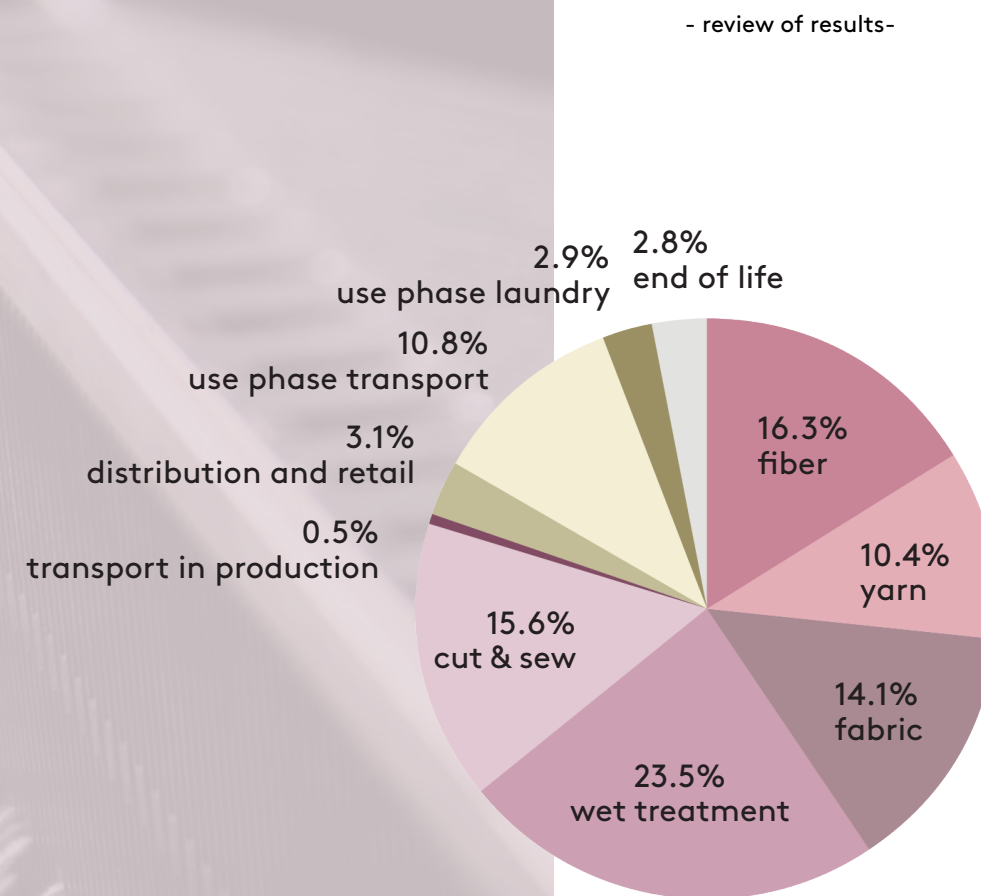


figure 2, climate impact per phase in entire life cycle, calculated for all Swedish clothing consumption



The risk of microplastics shedding from garments during production and use is minimized if: brushing is reduced, ultrasound cutting is applied in the cut & sew process and microparticles on fabrics are removed already at the production stage.

There is no support for the assumption that fabrics made from recycled polymers shed more than fabrics made of virgin polymers. It might instead be assumed that the concern of fleece material from recycled polyester, thought of as a main cause to the microplastics problem, is explained by the fact that fleece is a material traditionally made from recycled polyester bottles. Using an ultrasonic cutting machine

instead of regular scissors when cutting the fabric reduces the shedding with about 50%.

Consider the fact that 7 kg petrol is needed to produce one kg cotton t-shirts. This means that replacing fossil energy in the production chain is seven times more important than replacing fossil textile fibers. From a science perspective, it seems irrational to worry about 100g fossil content in a polyester t-shirt, but not consider the 1000g fossil fuels needed to produce a cotton t-shirt

Most positive impact within the production line can be done by switching to renewable energy, for both electricity and heat in the production process.

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Roos S et al. (2019) Supply chain guidelines: vision and ecodesign action list. MISTRA Future Fashion report

Roos S (2016) Advancing life cycle assessment of textile products to include textile chemicals. Inventory data and toxicity impact assessment. Doctoral thesis. Chalmers University of Technology

user

The carbon footprint of Swedish clothing consumption is about 330 kg CO2 eq. per person. Although this is only 3% of the total carbon footprint of an average Swede, the climate impact of clothing needs to be reduced to basically zero in a sustainable future.

The easiest way to reduce impact from clothing consumption is to extend the active lifetime of a garment and thereby offsetting new production. Hence, the most sustainable garment of today is already in our wardrobes.

Consider buying second hand, renting or borrowing when updating your wardrobe. To rent or borrow is particularly important for clothing expected

to be used only once or a few times, such as special-occasion wear. Calculate for intended numbers of use before purchasing newly produced. Always consider how to discard of the product once it has served its purpose.

At present, there is a discrepancy between attitude and action. A majority of users express an intent to act and consume in a more sustainable manner, but this intention is not reflected in their actual behavior.

In order to change user behavior a combination of information, individual goal setting, feedback and commitment has the greatest potential to reach a positive change in

terms of behavior. Comparing towards a group of users being exposed to only information about the impact of their consumer behavior, which gave 10% positive response, the combination of presented actions gave 60% positive response, see figure 3.

Even though setting group goals shows more potential than merely information, focusing on the individual gives a greater response. For example, a tool used to measure impact must be able to calculate for the individuals' impact as oppose to for example the impact from all citizen of a country. Furthermore, this tool should be able to suggest improvements tailored to the individual in question.

- review of results-

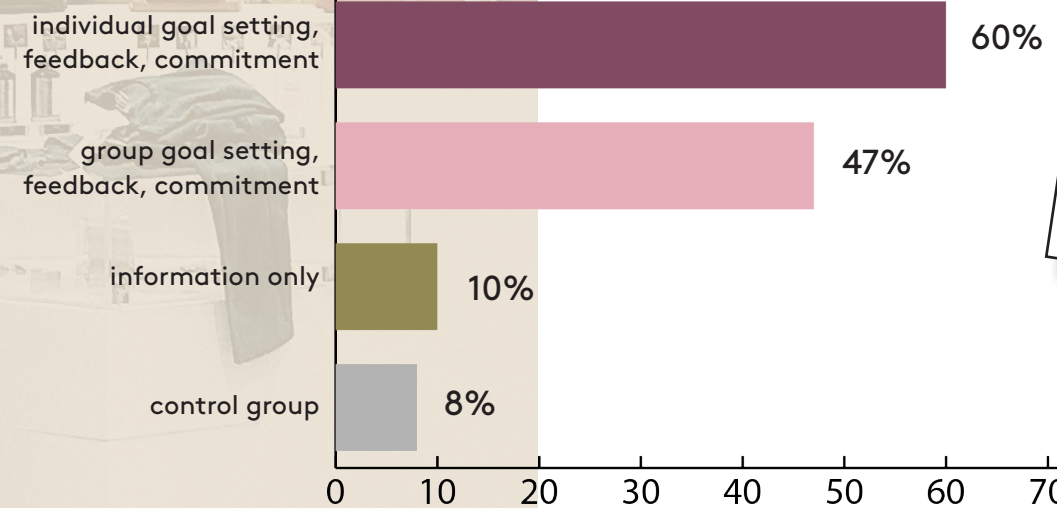


figure 3, positive response towards more sustainable consumer behavior in regards of textile consumption



Consider that user transport to and from the store accounts for 11% of a garment's total climate impact. Today, walking or taking the bike to a local second-hand store or to a clothing library is the least harmful choice when updating your wardrobe.

read more:

Gwozdz W, Nielsen KS (2017) Field report - Consumer Survey. A Mistra Future Fashion Report.

Joanes T, Gwozdz W (2019) Think Twice – a social marketing toolbox for reduced consumption. Mistra Future Fashion Report series

Joanes T et al. (2019) Fostering sustainable clothing via social marketing tools. Mistra Future Fashion Report series

Sandin, et al. 2019. Environmental assessment of Swedish clothing consumption: Six garments – sustainable futures. Mistra Future Fashion report series

Nielsen KS, Gwozdz W (2018) Report on geographic differences in acceptance of alternative business models. Mistra Future Fashion report series.

alternative business models

Twice as many uses per garment life-cycle eliminated almost 50% of impact, regardless of impact category, see figure 4. In order to make this a reality we need business deriving value from already produced garments, for example pre-owned/second-hand apparel. New alternative business models within reuse, resale, rent and repair is urgently needed.

Previously, collection and sales of pre-owned/second-hand apparel and textiles in Sweden has mainly been voluntarily conducted by charity organizations due to expected lack of profit. However, recent research states that resale of garments does not necessarily equal a reduced profit or turnover for the textile industry.

Instead, there is opportunity to derive value from incorporating aspects of extending active life of apparel in business models, either through the same or consecutive users.

On an average, females and younger consumers are more likely to report having both used and intend to use alternative business models when acquiring new clothing. At present, reselling clothes online and traditional repair services are the most popular businesses used to prolong the active lifetime of clothes. Furthermore, selling pre-owned/second-hand clothes using a 'first buy experience' setting is a business model with growth potential. By replicating traditional selling models, actors have managed

to generate higher turnover. However, such business models requires qualified sorting to generate a desirable assortment, which makes this model demanding with regards to human capital.

Collective use, for example through rental, is another business model with potential to prolong the active lifetime of clothing. Nonetheless, from a climate impact perspective, it is important to consider the logistics to avoid merely shifting the impact origin. Increased customer transportation can offset the benefits gained from reduced production. Therefore, the location of clothing libraries is crucial, and collaborative consumption may not be suitable for all kinds of clothing.

Collective use through renting, leasing and clothing swaps has the ability to reach several user segments, both the more trend sensitive and the more style oriented consumers who favor longevity. Since there is no strong correlation between fashion, materialism and subjective-wellbeing user does not need to own garments in order to feel the rush of acquiring new. This means that the user could follow the latest trends, be 'fashionable', by using clothing libraries and still experience subjective-wellbeing

To further accelerate the change, users and companies need to act as co-producers, both need to contribute in changing the market.

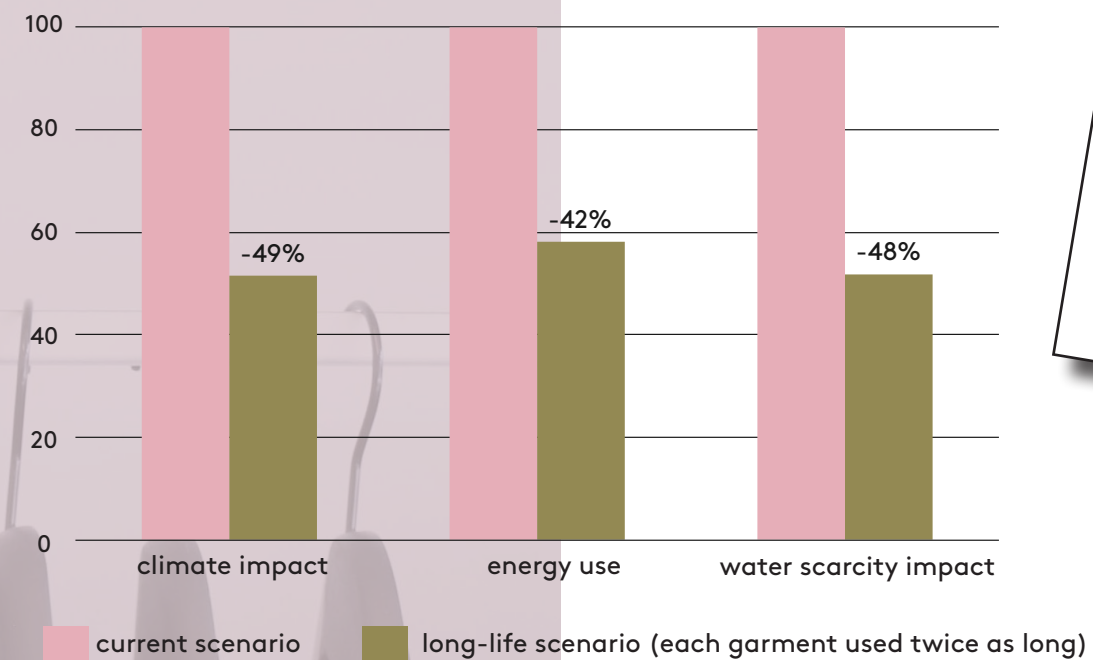
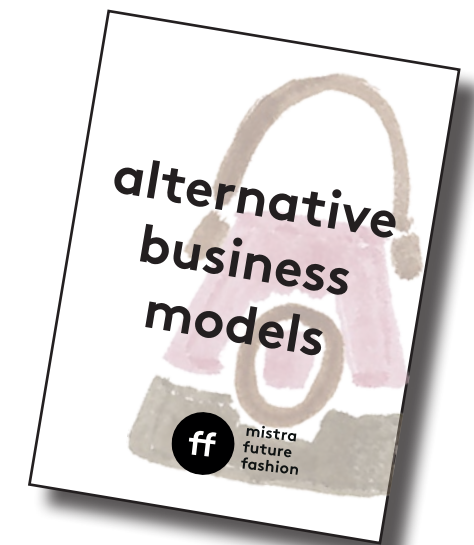


figure 4, impact reduction from long life scenario



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Zamani B et al. (2017) Life cycle assessment of clothing libraries: can collaborative consumption reduce the environmental impact of fast fashion? Journal of Cleaner Production, 162: 1368-1375.

Sweet S et al. (2019). The Swedish market for pre-owned apparel and its role in moving the fashion industry towards more sustainable practices. Mistra Future Fashion report series

Watson D et al. (2019). Policies supporting reuse, collective use and prolonged life-time of textiles. Mistra Future Fashion report series

Gwozdz W, Nielsen KS (2017) The relationship between fashion and style orientation and well-being. Mistra Future Fashion Report series

policy instruments

A low level of utilization of textiles and ineffective handling of textile wastes accentuates the depletion of resources in the value chain. Policy tools, such as labeling, wage subsidies, tax breaks, start-up funding and knowledge hubs are needed to enable the change to a circular system where textile is classified as a highly valuable resource.

At present, the most common waste management treatment for used textiles in Sweden is incineration with energy recovery. It is proved that a mandatory Extended Producer Responsibility (EPR) and a Refunded Virgin Payments system, i.e. a charge on virgin material, could have large positive impacts on fiber recycling as well as overall reuse and recycling of textiles.

On an EU-level, the Circular Economy Package was adopted in 2018 stating that all member states must collect textiles separately by 2025. In addition, member states must consider by 2024 whether specific targets should be introduced in regard to reuse and recycling. The Swedish Environmental Protection Agency has suggested that by 2025, the volume of textiles in the household waste shall be reduced by 65% compared to 2015.

The global quality of collected used textiles is reported to be decreasing and could be further affected by increasing collection rates with lower shares of high value materials, so called 'cream' (see figure 5). In addition, current markets

for second hand textiles are changing due to higher quality requirements and increasing competition with low-price new garments. The ideal scenario would be that the increasing share of non-reusable textile begins to raise real income for the collection and processing industry and not be the economic dead-weight it is today. This requires both technological advancements and development in new sorting and recycling technologies and increased demand for recycled fibers from the fashion industry in particular.

However, for use of recycled materials, while the Global Recycle Standard fees are relatively low, switching to recycled content fabrics will generally cost the producer

money. Brands claim that recycled content fabrics currently cost around 5-15 percent more than the equivalent fabric from virgin fibers, dependent on the fiber type. Thus, the modulated EPR fee would need to be larger than this in order to provide an incentive and have an impact on the market share of products with recycled content.

A immediate need for collectors and sorters is regulatory actions to reduce the administrative burdens related to collection, storage and shipment of textile waste. Today, countries and regions have very different requirements and regulations, which is challenging for all industry actors. Hence, synchronization is needed, both across Europe and globally.

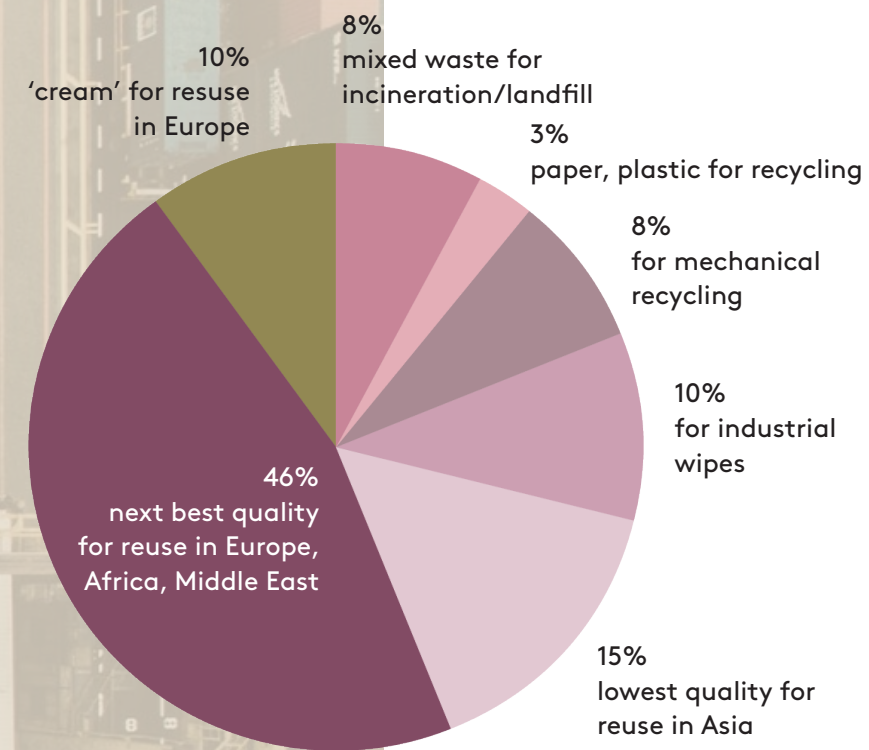


figure 5. typical composition of collected textiles in Sweden, measured by weight.



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Elander M et al. (2017) Impact assessment of policies promoting fiber-to-fiber recycling of textiles. Mistra Future Fashion report series

Ljungkvist H et al. (2018) Developments in global markets for used textiles and implications for reuse and recycling. Mistra Future Fashion report series

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Roos S et al. (2019) Guidance for fashion companies on design for recycling. Mistra Future Fashion Report series

Watson D et al. (2019) Policies supporting reuse, collective use and prolonged life-time of textiles. Mistra Future Fashion report series

end of life

Consider that recycling, both chemical and mechanical, should be the last step after the point when reuse, repair and resale are no longer feasible. The five-step waste hierarchy, see figure 6, introduced by the European Union (Directive 2008/98/EC), clarifies waste prevention, as the preferred option, followed by reuse, recycling, recovery (including energy recovery) and safe disposal as a last option.

When recycling is motivated, it is crucial to avoid pitfalls like ineffective logistics or processes. It is important that the environmental load from the recycled product is less than for the virgin product that is replaced. Recycled materials should not simply be added to a growing market but replace virgin materials.

Use mono-materials to ease the chemical recycling process. Currently, textile recycling processes must handle a plethora of different fibers and chemicals, such as dyes, additives, finishing etc., as well as degraded fiber qualities caused by the use phase. In chemical recycling, it is likely that fiber blends must be separated to recycle and restore each fiber type into valuable recycled fibers.

To minimize the costs of recycling processes, both environmental and economical, it is important to implement end-of-life knowledge already at the design stage. Decide from the start how the product should be used, for how long it should be used and how it should be recycled when time comes.

Greater transparency is needed in a circular textile value chain, where tagging could be a solution. Universally accepted tags could be of great value not only in the end of life stage, but throughout the entire life cycle. Apart from accessible information about the exact fiber composition, needed in a sorting line, it could also contain data about the designer, care-instructions and previous owners for added value in future resale.

Large-scale automated sorting of textiles, using a mixture of different analyzing methods such as tagging (RFID), spectroscopic sorting (NIR) and ocular manual sorting, will likely be essential to sort streams accurately into the most suitable and sustainable

end-of-life option; including both repair, reuse, resale and recycling.

To establish circular and resource efficient material streams, an interdisciplinary joint effort is needed. Coordinated tools to overcome the current “chicken-or-egg” situation, with the difficulty of sequencing actions where each seems to depend on others being done first, is needed. An example is the lack of pure and large waste streams to motivate upscaling of specific recycling processes, and the simultaneous lack of large scale recycling processes that motivates improved sorting facilities. A systemic view is crucial.

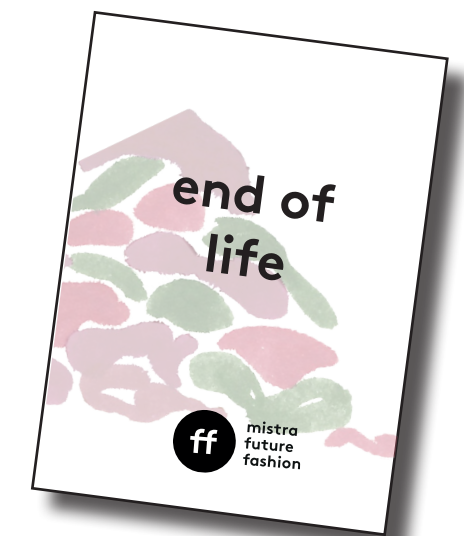
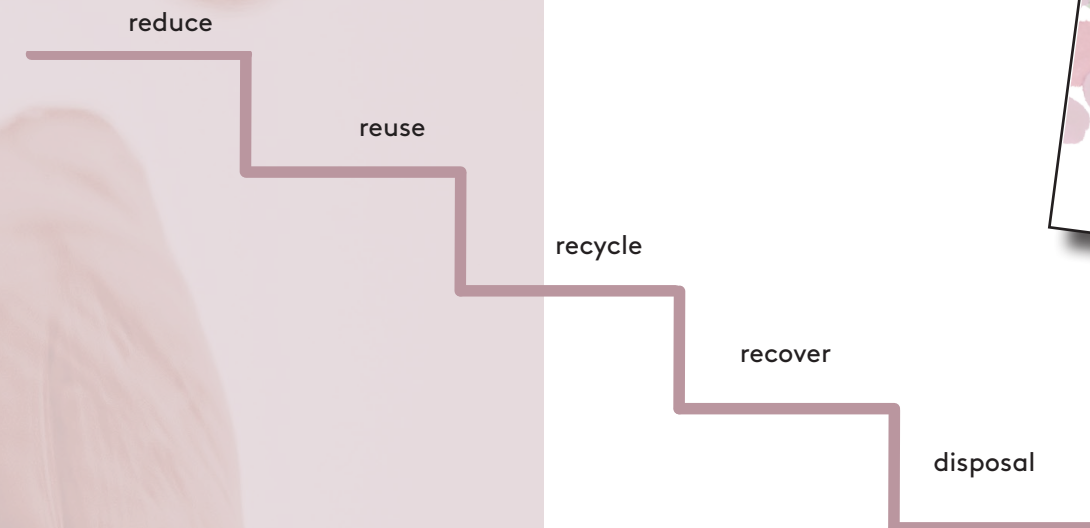


figure 6, EU waste hierarchy

- review of results-



read more:

Sandin G, Peters G (2018) Environmental impact of textile reuse and recycling – A review. *Journal of Cleaner Production* 184

Englund F et al. (2017). Textile tagging to enable automated sorting and beyond. *Mistra Future Fashion report series*

Peters G et al. (2019) Environmental Prospects for Mixed Textile Recycling in Sweden, *ACS Sustainable Chemistry & Engineering* 7 (13), 11682-11690

de la Motte H, Palme A (2018) The development of the Blend Re:wind process. *Mistra Future Fashion report series*

Roos S et al. (2019) Guidance for fashion companies on design for recycling. *Mistra Future Fashion report series*

joint effort

In order to reach a systemic change in fashion, both in terms of industry and society, a joint effort is needed. Bringing experts from different disciplines together takes a lot of effort from all participants, but gives back the more complete picture. Nevertheless, between academics, scientists and industry stakeholders co-creation can be possible and highly beneficial after building trust, shared goals and deeper understanding, along with common tools.

In order to know where to start the work, one must measure the present state of the industry. Measuring 'sustainability' is a complex task. Life Cycle Assessments, the total impact of a garment throughout

its entire life, is one way of concertizing garment impact. A Life Cycle Assessment relies on data from all stakeholders throughout the complete life-cycle, from crop cultivation, production, user behavior and disposal, this is why collaboration between research disciplines and society is crucial.

The total climate impact of Swedish clothing consumption is about 3.3 million tonnes of CO2 eq. per year, which is 327 kg CO2 eq. per capita or about 3% of the consumption-based carbon footprint of an average Swede. This might seem low, but as the 2-degree goal stipulates that climate impact must be close to zero by mid-century, there will be little or no room for any greenhouse gas emissions

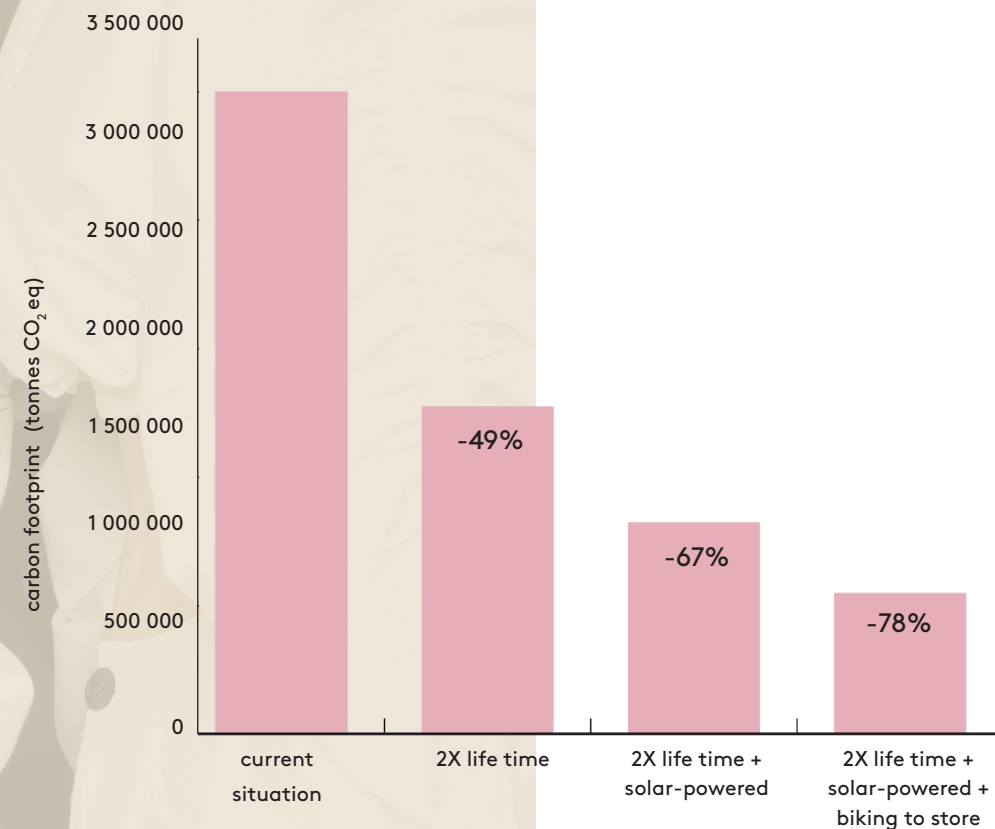


figure 7, climate impact reduction from combining efforts

arising from the production, transportation and laundering of clothes.

Lowering the carbon footprint of Swedish clothing consumption is possible by combining effort from both user and producers, globally. If we can prolong the active lifetime of a garment by 2, make sure the garment is created in a production chain running on solar-power and make sure the user walk or take the bike when acquiring new clothes, the total decres in climate impact will be 78%. See figure 7.

No single actor can change the industry and society alone. However, by implementing research results and improve collaboration a better and

more sustainable fashion system will happen. Within the Mistra Future Fashion program researchers from several different disciplines have worked together to measure, concertizes and improve. In addition, the results have been implemented and tested together with industry partners and societal actors. It is not an easy task, but the reward of doing so is great.

A systemic change is needed. It is possible, but it will take collaboration and a coordinated joint effort to make it happen.

- review of results-



read more:

Roos S et al. (2019) Guidance for fashion companies on design for recycling. Mistra Future Fashion report series

Roos S et al. (2019) Supply chain guidelines: vision and ecodesign action list. Mistra Future Fashion report series

Sandin G et al. (2019) Environmental assessment of Swedish clothing consumption: Six garments – sustainable futures. Mistra Future Fashion report series

Goldsworthy K et al. (2019) Circular Design Speeds. Mistra Future Fashion Report series

Earley R et al. (2019) Circular Design Researchers in Residence. Mistra Future Fashion Report series

value to others

moving research forward

Enabling new knowledge to be leveraged and utilized has been the key focus of the Mistra Future Fashion program, i.e. bringing 'Value to Others'. It is about making sure the research conducted also gets implemented, whenever and wherever relevant.

international networks

Engaging in international networks aims to enable further use of the research results. In March 2017 Mistra Future Fashion was Affiliate Partner during the birth of the innovation hub 'Fashion for Good' in Amsterdam. In May 2017, Mistra Future Fashion became Affiliated Partner and a research science partner to Ellen MacArthur Foundation's textile initiative 'Circular Fibres Initiative', where several researchers contributed with data and knowledge input for the report 'A textile Economy - Redesigning Fashion's future'.

exhibition 'Fashioned from Nature'

Fashioned from Nature is an exhibition that explores the relationship between fashion and nature from 17th to 21st century. On display is a prototype top and samples of paper-like textile developed by researchers at University of The Arts London and RISE within the MFF program. The exhibition has so far been shown at Victoria and Albert Museum in London and at the Natural History Museum of Denmark in Copenhagen.

feeding in to Textile and Fashion 2030

After eight years of research Mistra Future Fashion is a rich source of results on how to create a more sustainable fashion system. Therefore it is great to be able to feed in to the Swedish national platform called Textile and Fashion 2030.

Higg Materials Sustainability Index

Developed by the Sustainable Apparel Coalition, the Higg Index is a suite of tools that enables brands, retailers, and facilities of all sizes to accurately measure and score a company or product's sustainability performance. In 2020, toxicity data from MFF researcher Dr. Sandra Roos is planned to be implemented into the Higg Materials Sustainability Index (Higg MSI) to calculate a quantitative chemical toxicity score for each material used in clothing production.

the UNFCCC Fashion Industry Charter for Climate Action

In early 2018 the first global discussion on climate action within the fashion sector was held at the UN Climate Change secretariat (UNFCCC) in Bonn. Mistra Future Fashions program director 2015-2018 Sigrid Barnekow was invited to act as moderator of the discussions next to Patricia Espinosa, UNFCCC Executive Secretary and Niclas Svenningsen, Manager for Strategy & Relationship unit at UNFCCC. During the 2018 Textile Sustainability Conference in Milan, the UNFCCC 'Fashion Industry Charter for Climate Action' was presented. The charter is designed to align with the Paris Agreement and includes greenhouse gas emission reduction as well as a decrease in coal-driven power generators. The complete 'Fashion Industry Charter for Climate Action', which contains the vision to achieve net-zero emissions by 2050, was launched at COP24 in Katowice, Poland, in December 2018.

TEDx talks

In July 2018 Leslie Johnston, Executive Director at C&A Foundation gave a TEDx talk titled "Why recycling our clothes won't save the world" where she used the MFF report 'Developments in global markets for used textiles and implications for reuse and recycling' in highlighting what actually happens to the clothes we no longer use. At present, most clothes will not be reused or recycled, therefore we are in need of harmonized global actions in reducing textile waste and making sure we actually can recycle what is collected. Furthermore, in May 2019 Mistra Future Fashions' Communications Manager, Malin Viola Wennberg, gave a TEDx talk titled "A future sustainable fashion system" based on 8 years of research from within the program.

Blend Re:wind

After six years of research within textile recycling MFF revealed unique results in November of 2017. New viscose filaments from cotton was demonstrated, produced by a successful chemical recycling process of polyester/cotton fiber blends. These results are an important milestone towards the future of global textile recycling systems necessary to enable circularity for fashion and textiles. The process is called Blend Re:wind – and it generates three circular outgoing product streams. Cotton is turned into new high quality viscose filaments and polyester into two pure new monomers.

"As the leader of a foundation focused on making fashion a force for good, I have been both informed and inspired by the thoughtful reports produced by Mistra Future Fashion. They have brought data, insights, and clarity to the many, diverse actors working to positively transform the fashion system. Thank you, Mistra Future Fashion, for your valuable contributions to this field."

- Leslie Johnston
Executive Director
C&A Foundation



"Chemistry is one of the impacts the Higg Product Tools measure, but currently the tools only offer a qualitative approach based on management practices to assess potential chemical impacts in products. The Sustainable Apparel Coalition has wanted to add a quantitative method as soon as a reliable approach became available. SAC is now happy to be working with RISE IVF to implement the Mistra Future Fashion method, which has been accepted by SAC members as a promising method for quantitative chemistry assessment. The purpose of the project is to complete chemical datasets in the Higg Product Tools by adding chemical recipe and USEtox factors to generate a quantitative impact assessment in order to show the comparative significance of textile chemicals and to make the Higg Product Module compatible with other LCA-based initiatives. This will further enhance the Higg Index, making it more reliable for companies seeking to understand the impacts of their products and identify where they can make sustainability improvements."

- Julie M.H. Brown
Director, Higg Index
Sustainable Apparel Coalition



United Nations
Framework Convention on
Climate Change



x = independently organized TED event

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testimonial chairman of the board

This testimonial by the chairman of the Mistra Future Fashion Board, Nick Morley, is an expression of his personal reflections by the end of these eight years by the Board.

First, I have a very easy and pleasant task. That is to pay tribute to and thank on behalf of MISTRA and the programme board, all of the management team, the researchers and business participants involved in the programme, both past and present. We wish you well as you take that research forward and we look forward to seeing how industry and also the national programme will develop and use it.

The most obvious change in approach to sustainability over the past eight years has been the adoption of the circular economy objective, originally conceived as a design methodology and then as an economic model. Material circularity we know is not enough, and we need to add riders about energy, chemicals, speeds, about the stocks we are creating as well as the flows. The circularity of apparel is not great. That idea has reinvigorated mechanical recycling in areas such as denim, where ten years ago we might have thought it was a declining industry, a remnant of the past. It's spawned research in differing approaches to chemical recycling, some of whom are now commercially available.

Some of the challenges now to the recycling sector are new – for example large scale financing; recycling of complex blends – MFF's research has shown that even promising approaches

to recycling blended elastane, nylon are difficult and at an early stage. The materials innovation challenge in fashion is probably more to develop recycling-compatible substitutes to these materials than to develop completely new ranges of more sustainable fibres.

To this overall circularity goal, with its riders about renewable energy and recycling of chemicals, I want to add three areas that need our attention:

the environmentally optimised supply chain

Ten years ago there were relatively few clothing LCAs, even fewer life cycle inventories, but they were used to launch sustainable material selectors. We know now that this was naïve due to variability of production. It's not what you make but how you make it. We have an increasingly clear picture of the main impacts in the supply, where and how they occur. There are an increasing number of initiatives publishing information on individual factory sites, which leads to transparency cross the production. In short there is no reason why companies cannot build supply chains where the environmental impact has been optimised, by which we mean minimised. We've been a part this information provision and analysis.

What would the human and environmental impact be if companies did this? How would the supply chain change? Presented with the scale of beneficial impact, what will companies do? If for example, there was no dyeing

industry in Bangladesh and that all took place in say Estonia or Portugal, what would be the human and environmental equations? Would it be a good or bad thing for Bangladesh?

every garment wanted

Looking back 100 years hence will people think of us as being the offshore generation? A period when the expansion of world trade made it possible to offshore production, which was previously done close to market. It has become very cheap to make large volumes of clothing. Long lead times and guesstimating consumer demand meant that in the end producers must push clothing onto consumers using sales and discounting. All this contributes to the problem of continued volume growth and consumption of clothing that wipes out the environmental gains in production processes. At the same time there are fewer financial gains, as excessive stock management wipes out the gains from cheap production.

Will people look back and ask why did we do this? By 2015 it was clear it made no environmental sense. By 2019 it was clear that in many parts of mainstream fashion the main financial gains were over and that it made decreasing economic sense. And yet many brands persisted in this strategy, churning out AW20, SS21, pursuing volume growth in a saturated market, believing that it would actually deliver increased profit. Will future generations think that we were actually deluded?

A solution is that instead of pushing clothing onto customers, we allow customers to pull clothing out of the supply chain. Every garment is really wanted. The end of sales. The digitisation of fashion information, both from consumers and along the supply chain, mass customisation, the growth of technologies such as digital printing, Industry 4.0, all of these together can make the supply chain more responsive and geographically closer to the consumer.

Researchers such as Prof Steve Evans at Cambridge University's Institute for Manufacturing envisage a factory on every street corner. Isn't the digital microfactory a beguiling and attractive vision for apparel?

reuse reinvented

A surprising thing that we didn't predict ten years ago is the success of sophisticated forms of reuse. Reuse would remain the same, selling some clothing in the home country, packaging up the rest to be shipped to Africa or the former Soviet Bloc. But now sophisticated versions of reuse are a growth trend, successful businesses. The conventional textile recyclers will need to reinvent themselves with added value services for brands and consumers. Conventional reuse may just become a minority interest.

Perhaps we will look at this is the future in the same way we used to look at shoddy manufacture in the past – part of a mature, old agenda. Whereas the forward looking textile recyclers

will become the new actors, providing contracted out sustainability services to brands. Others will shrink and diminish.

At the same time the international flows associated with used textiles will change. We may see a reversal of flows. Instead of flows of clothing out from developed countries, we will see flows of purer post-industrial waste into developed countries, a greater divergence in value between pure and blends, with low value clothing blends becoming increasingly valueless as they compete with burgeoning Chinese clothing exports for the shrinking reuse markets in Africa and Asia.

Time doesn't permit me to explore other areas that have developed. Microplastics is a glaring omission, a field where we are still at a very early stage of understanding the problem and proposing solutions, where MFF has made some contribution. We've barely touched on design and on consumer behaviour. Amongst so many fascinating and important research possibilities I trust that we won't lose sight of our end goal: dignified work, responsible stewardship and an exciting future for sustainability in fashion.

Nick Morley
Chairman of the Board

September 2019



The current system for fashion is broken. Given the environmental impact and challenges linked to design, production, usage and recycling, a new model is required.

Mistra Future Fashion was a research program that focused on how to turn today's fashion industry and user habits toward sustainable fashion and behavior. Guided by the principles of the circular economy model, the program operates cross disciplinary and involves 60+ partners from the fashion ecosystem. Its unique system perspective combined new methods for design, production, use and recycling with relevant aspects such as new business models, policies, consumer science, life-cycle-assessments, system analysis, chemistry, engineering etc.

MISTRA was the initiator and primary funder covering the years 2011-2019. The program was hosted by RISE Research Institutes of Sweden in collaboration with 15 research partners.

