future fashion manifesto
THE GROUP BEHIND THIS MANIFESTO

The Mistra Future Fashion research program was initiated in 2011 by Mistra, the Swedish Foundation for Strategic Environmental Research, to address the sustainability challenges of the Swedish fashion industry. The call was to take on a system approach and address changes in markets and business models, sustainable design processes and innovative materials, sustainable consumption and consumer behavior, the development of policy instruments, and the clarification of what is meant by sustainable fashion.

The program goals are:
- to support Swedish business in creating a circular economy for materials and products in fashion and clothing
- to have a decisive impact on policy and practice which encourage systemic change of the Swedish fashion industry

During phase 1 (2011-2015) the research program ran eight projects in various disciplines. The program continues with a second phase until 2019. The cross-disciplinary research group is expected to generate novel ideas, research and interpretation of results. The mix of researchers and industry participants ought to assure research quality and highly relevant results for industry and research. The consortium spans from universities to research institutes, from very small to very large companies involved in the production and retail of clothes, to stakeholders such as governmental organizations and policy makers. The long-term intent is to establish a continuation in some form of this systematic approach after next phase and be an enabler for the industry in the future.

For next phase, research and learnings from Phase 1 are built on to enable closing the loops of the fashion industry. The eight projects are transformed into four themes on circular economy: how to design for circular economy, how to promote a sustainable circular supply chain, how users can contribute to more sustainable fashion and how to increase textile fiber recycling.

Eight individual research projects in Phase 1:
- P1 Changing markets & business models: Towards sustainable innovation in the fashion industry
- P2 Clarifying sustainable fashion
- P3 Interconnected design thinking and processes for sustainable textiles and fashion
- P4 Moving towards eco-efficient textile materials and processes
- P5 Reuse, recycling and End of life issues
- P6 Fashion for the public sector
- P7 Sustainable consumption and consumer behavior
- P8 Policy instruments

Key challenges identified during Phase 1:
- a lack of established material (re-)flows and technologies to ensure high value reuse, material recovery, and fiber regeneration
- few and uncertain economic incentives for new business models encouraging pro-longed use of both fibers and clothes
- few established design principles and practices that focus on design for circularity
- lack of verified data sources as well as methods for assessment of environmental and social sustainability for the textile value chain as a fact based decision support to the implementation of robust management and control systems for sustainability
- the challenges involved in engaging and educating the consumer on her sustainability impact over the use-life of a garment
- the organizational as well as policy challenges involved in managing and influencing social and environmental impact in complex global supply chains

The program is hosted by SP Technical Research institute of Sweden. For total research program and operations please read Mid-term Progress report, available at our webpage.

www.mistrafuturefashion.com
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Front page photo: Miriam Ribul, DeNAture, Garment Prototype
FUTURE FASHION MANIFESTO

The Mistra Future Fashion research program deals with one of the key sustainability challenges of our times, how to achieve systemic, sustainable change in the fashion industry. This change is like a giant puzzle, where all pieces need to be re-shaped, finding new matching pieces and in time allowing a new design to appear. The Mistra Future Fashion consortium, comprising researchers and industry partners, goes after these emerging pieces. Four years into the program, research results and insights have been reviewed with the intent to see what picture appears. To this end, a Manifesto, describing which pieces of the puzzle are in place and which pieces that are still missing, a road map for further research and progress have been created. It aims to inspire, challenge and be food-for-thought for all actors in the system: producers, retailers, designers, marketers, politicians, users.

To quickly gain ground, there are particularly four areas that need to accelerate; 1) exploring multiple business models, 2) involving consumers, 3) enabling the designer and 4) inventing efficient recycling. The pervasive thread running through these areas is the garment. It needs the respect it deserves, by society, by producers and retailers, and by consumers. It is as a center piece and ought to be maximized to its full potential.

By wearing fashion we express our view of the world. If fashion today is perceived as expressing our support of unsustainable consumption behaviour and unawareness – we see that future fashion will turn into a powerful tool to spread awareness of sustainability and circularity.
A FRAGMENTATION OF PUZZLE PIECES

Addressing change requires understanding the Swedish fashion industry of today. Here some key characteristics of the industry are outlined, opportunities as well as challenges. This is not the complete picture, but an introduction.

Facts. The Swedish fashion industry with a turnover of SEK 237 billion (2013), almost forty percent of this is domestic market revenue, is largely made up of a few large players and a multitude of small businesses. 96% of enterprises in the industry have fewer than 10 employees. The vast majority of the manufacturing is outsourced to low-cost locations. A small group of domestic suppliers specialize in various parts of the production process: weaving, knitting, sewing and printing. Second hand and charity organisation handles a small share of discarded clothing (reuse) while the majority is incinerated as waste.

Collective opportunity. Social concerns and environmental impacts have stimulated various attempts to rethink the current way of business in the fashion industry. A range of initiatives and business models promote reuse, collective use and prolonged life-time of clothing. Examples are leasing and hire, clothing swap markets, clothing libraries, vintage sales of used own brand, and repair and redesign initiatives. A variety of organizations, initiatives and standards have emerged that address issues of sustainability and fashion, including STWI, BSCI, The Swedish Chemicals Group, GOTS, Higg Index, Sustainable Apparel Coalition, Better Cotton Initiative, Clean Clothes Campaign, Fair Wear Foundation, DressCode, NICE, Oeko-Tex®, SCAP, and Made-By. Many initiatives are generating social and environmental improvements, but they often lack scale and scope in order to bring about a more fundamental transformation of the fashion industry.

Fibre challenges. Global demand for clothing increases with population growth and a rapidly increasing middle class. Meanwhile, the production of textile fibres is responsible for global environmental impacts and faces significant resource constraints. Cotton and polyester constitute more than 90% of the textile materials. Cotton is problematic due to the heavy use of water, pesticides and fertilizers, and polyester because it is derived from finite fossil resources. At present there is experimentation with new fibres (paper, milk, seaweed, soy etc) and the Life-Cycle Assessment (LCA) shows these new materials are sustainable alternatives. The consumption of manufactured cellulosic fibres has steadily increased the last 5 years, but the current rate of demand is not fast enough to offset the production rate for cotton. Cellulose material has large potential and the dissolvent fabrics are waiting for new products to develop from their dissolvent pulp. Recent advances in LCA allow better characterization of impacts due to the use of water and ecosystem resources like forests. The LCA confirms a systemic change towards more forest-based fibres is justified, but more research is still needed.

Recycling challenges. Little collection and recycling of non-reusable used textiles occurs in Sweden. To increase recycling is a “chicken and egg” problem. Charities and other collectors of used textiles are mainly interested in used clothes suitable for direct reuse, because of a lack of technically feasible and economically viable recycling solutions for non-reusables. Meanwhile, technical solutions are under development, but these are suffering from a lack of supply of suitable textile waste in quantities that would make these solutions economically viable.

Fibre regeneration challenges. Fibre-to-fibre recycling faces several technical challenges. All textiles get worn in use and recycling processes must enable separation of blends and production of high quality fibres. Achieving this requires better understanding of textile waste and how this material can be remanufactured – for cotton into high quality natural fibres, for polyester into virgin quality fibres.

Research and technology opportunities. Current technology readiness level to achieve more sustainable recycled and recyclable fibres, is 3-5 on a scale up to 10, where 7-8 represents a level ready for implementation actions. The possibilities are great for further research and technology progress. Many research initiatives are ongoing: BioInnovation, SmartTextiles, Trash-2-Cash, to mention a few. The Mistra Future Fashion research program works closely with these, to assess and push for new opportunities, identify complementary research needs, close the material loops and contribute to systemic change.

Different language and claim standards. The connections between ecolabels and designer’s tools are most often rather weak. Further there is a lack of consensus regarding what should be included in a label to promote social sustainability. A label’s criteria must be salient for the consumer and industry alike to be efficient.

Design & designer opportunities. Today the designer has a limited role and commonly functions within limited scope of influence. Designers are often limited by their restrictive departmental roles. Most often the designer is missing relevant tools; influence beyond their section, knowledge and insight on their available options to sustainable decisions.

Policy opportunities. Today there is a lack of governmental policies support sustainable fashion. There are possibilities for different incentives to stimulate both companies and consumers. The current absence of incentives correlate with the low level of advancement within collecting and recycling in Sweden.
THE REPEATEDLY MISSING PIECE
- WHAT IS SUSTAINABLE FASHION?

The term sustainable fashion is widely used in communication today. The interpretation of its meaning most likely differs depending on interest, profession and level of knowledge. The concept can be perceived difficult to grasp due to its abstract description and the low possibility to assess garments’ direct impact. How does one behave sustainably as a consumer or even as a producer?

One of the most difficult questions to answer is what “sustainable fashion” is. Some may express it as an oxymoron, in the light of growing consumerism and the advancement of fast fashion. Some may express it is about producing clothes in an environmentally and socio-economically sustainable manner, but also to consume in a more sustainable way including behavioral patterns and attitudes. Sustainable fashion is also about aiming for a circular economy, i.e. the possibility to close the loop by looping everything in the value chain, by using bio based materials from sustainably managed resources or by recycling.

Showing respect for the garment
When envisioning a sustainable future, a new perspective on the garment appears. Showing respect to the garment becomes the golden ticket for sustainability; to enable profitable systems, sustainable consumption habits and a production process (including recycling) with circularity. Instead of earning money solely via one time purchases, it is about creating additional value throughout the whole value chain.

Figure: A model for how a circular fashion industry is envisioned in the Mistra Future Fashion research program.
There are several ways in which garments could be kept in use for a longer time. Manufacturers could help by creating more durable garments and by providing prolonging services. Consumers could help by using the garments for longer and by ensuring that unloved but reusable garments reach recycling systems. The impact of such changes could be large. To illustrate the effect, if an average garment stays in use 3 times longer than today, its carbon footprint is reduced by 65% and its water use by 66%.

The garment as a symbol of being sustainable conscious. By wearing fashion we as citizens express our view of the world. If fashion today is perceived as expressing our support of unsustainable consumption behavior and unawareness, imagine instead if what we wear could constitute a symbol of sustainable conscious and care. Future fashion will turn into a powerful tool to spread awareness of sustainability and circularity.

What can consumers do already today to act sustainably? First immediate action is to think about what they are wearing and their responsibility consequently for the garments. Instead of making “sustainable” choices only when they shop, consumers ought to reflect and act on how to optimize the length of use, including beyond their part of the usage period.

- Care for it to enable re-use by others
- Enable further use by providing it to resellers
- Consider transportation mode when shopping
- Ask producers for more information on their sustainable work
- Utilize wearing as statement of being sustainable
- Invest into garments that are of high quality (to enable long life-span)
- Ask social bodies for standardized infrastructure for worn-out garments/waste

Producer challenges on measuring sustainability. The industry faces several challenges how to measure environmental impact and it is thus assessed in many different ways. For example, there are many definitions of sustainable water use and there is not only one way to “do water” in LCA. Also there is improvement potential for standards for assessing environmental impact of clothing, so called Product Category Rules (PCRs). The shortage of PCRs for garments (vs several for yarn and textiles) hinder access to data and proper assessments.

Understanding the environmental impact of Swedish fashion consumption. It is the production process that causes the main environmental burden in the garment life cycle. There is largest environmental improvement potential through; 1) more sustainable fibres, 2) less energy intensive yarn and fabric production, 3) more sustainable wet treatment and 4) production of garments with longer life-span.
MULTIPLE SET OF PIECES CREATES A BIGGER MOVEMENT

Mistra Future Fashion concludes four key focus areas that require priority and each of them include multiple pieces that will move the progress forward; multiple business models possibilities, power of consumer involvement, redesign the design process and enable sophisticated after-use process. These focus areas also lie as base for further research in next phase of the program.
The opportunity is to evolve today’s business model into attractive new profitable ones that goes in tandem with sustainable thinking. Tomorrow’s system could enfold wide variation of products; super-fast, long-lasting use, upcycling; as well as multiple services for garment alternation. Today retailers earn money per sold item. What if they would find ways to double earned money on the same item? The key puzzle piece involves defining the garment’s purpose and expected time span for usage. By asking the right questions for consumer usage, additional ways to earn money ought to be explored. Potentially alternative business models will flourish.

Fashion brands need to embrace the innovative and value-creating potentials of sustainable business models, rather than perceiving sustainability solely as a compliance and risk management exercise. Sustainability can be a driver for exploring new business models within a single industrial setting, however ultimately sustainable fashion requires a transition away from the predominant models within the fashion industry, as well as supporting user practice and systemized optimal waste solutions for a circular economy.

New business models potentials for extending the usage period per item. If garment life-span in the hands of consumers increased by a factor of 3, the carbon and water footprints would be reduced by almost 70%, as revealed in the LCA of
5 fashion garments. As consumers start to realize this in their attempt to act sustainably, companies with innovative business minds ought to have a lot to win exploring new prolonged use business models.

Re-design, upcycling, tailoring services, licensing, libraries and collective consumption play an important role in promoting sustainable consumption. They are all examples of new business model that have the potential to radically change our current consumption patterns into a more sustainable one. Consumer Sharing is hyped as a disruptive and transformative force. It is based on the win-win narratives that promise environmental, economic and social sustainability, corresponding well to consumers’ motivation. For example, fashion libraries have potential to redefine the way of retailing and consuming fashion. Businesses can cash in multiple times on the same garment and consumers can reduce overconsumption through optimizing the utilization of fashion items. Today’s niche alternative business models provides also great evidence for positive sustainability benefits from societal aspect such as creating jobs, increased transparency on production and more engaged consumers.

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Asking the relevant questions - how is the garment intended to be used and how long is the estimate life length per item? The concept of Short-term versus Long-lasting usage allows producers to present new alternative business propositions. Short-term, items intended and designed for super-fast usage, and with fibre selection, production and recycling system that minimize environmental impact. A closed system that enables “sustainable” fast fashion, i.e. fast consuming without generating today’s level of impact when consuming.

Long-term, a design process with fibre and production with intent for longer technical life-span. It could also include sustainable supporting variations for consumers to prolong their usage per item. Services like re-design, repair, re-selling (second hand/vintage) becomes relevant business opportunities. With this type of approach, the sustainability focus by fashion companies ensures broader sustainable responsibilities, providing relevant tools to the consumer. Thus their sustainability efforts would then not just cover the production phase of the garments but also their delivery to the user and his/hers consumption.

Bringing consumers into the mindset of the usage purposes would also have a positive sustainability awareness effect and steer consumer user habits into more conscious consumption. Short-term fashion items would be market, sold, used and recycled with clear expressed intent and limited use. The opposite in direct relation to super-fast will be Long-lasting. By establishing these terms and their usage objectives, the two types of product category objectives will appear more clearly. Thus the items can play a role as tools for describing to consumers choices and why, both with intent to promote sustainable thinking.
The Internet of things; new digital consumer engagement, and e-commerce possibilities. Ideas like digital unique codes for long-lasting fashion item (digital usage history included), where possibilities for additional manufactural services can easily be included, such as leasing, design consultancy, re-design. The evolving e-commerce and its wide range of online inter-face possibilities, will work in favor for exploring new business models. It allows direct dialogue and enables consumers’ involvement in their daily experience on consuming fashion. It has clear energy savings by reducing the need of physical stores and lower CO2 emissions due to less one-by-one consumer transportations to stores.

More sustainable innovative investments by companies. Some fashion brands are more advanced than others in their sustainability innovation. These entrepreneurs’ hard-earned experiences serve as inspiration for the development of new business models. Unfortunately few Swedish companies are innovative driven beyond product development (i.e style and features). Key drivers for the majority of small-medium enterprises are their customers and suppliers, why sustainability efforts and relevant business implications are not prioritized (even called out as important). Niche models such as libraries show so far challenges to survival due to lack of scale possibilities, such as financial support, human resources and consumers’ awareness. All these are linked to its size, the influence and impact by small actors is highly limited. It is only when the big players create the norm where we can assess its full potential.

The next research phase will study Swedish brands’ collaboration with international suppliers on sustainability issues, assessing supply chain hurdles and opportunities in designing closed-loop industrial networks. In recognition of the diversity of the fashion landscape, the research will emphasize three categories of business models: - collaborative consumption, upcycling, and local fashion production.

Further the program will list and evaluate supporting instruments, actions and initiatives for making reuse of textiles more mainstream and increasing the demand for textiles for reuse in Sweden. In addition, research will provide impact assessment and recommendations for policy. In addition, new business models in a sharing economy, will be reviewed in order to understand if, when, and how sharing economy business models generate value for business and society.
Let’s invite consumers in, involve them and make them part of bringing the puzzle pieces together. Level of consumer awareness differs, some consumers first need to realize the old puzzle is damaged and there is no going back, for others some pieces correspond to habits they already adopted and they can thus ship in on shaping. To overcome awareness barriers and utilize the power of consumers’ consciousness, consumers need to be exposed to more sustainable behavioural strategies.

By presenting more sustainable options consumers’ engagement would increase. There is an attitude behaviour gap among consumers. Sustainability is already highly relevant and exists on consumers’ radar screen, especially among youth. But, this view has not yet impacted their shopping and consuming routines to any larger extent. The key barrier is finding sustainable options, i.e. the consumers have a perception that sustainability clothing is not yet widely available on the market. It is simply not visible enough, the spread and mainstreaming of sustainable clothing must thus be promoted more strongly. The study from phase 1 verifies that showing consumers alternative behavioural strategies seem to work. Actions, such as retailers’ in-store textile recycling programmes, with intention to decrease consumers discarding of unwanted clothes and extending the life of garments, have proven to play out well.

Consumers want to act sustainably but have the perception that sustainable clothing are not yet available on the market.
Effective communication and digital engagement tools. When dealing with attitude behavior gap social marketing approach have shown to be effective, in contrast to information-based campaigns. Via social marketing activities consumers can partake in creating awareness around sustainable consumption. The trend of data collecting with smart consumer oriented applications works like a direct high-way to consumers mind and life. Digital solutions with sustainable objectives, such as tracking ticket per garment, could also bring new added value to consumers. Tracking tickets, similar to tracking apps used in health category, that covers its fibre content and history of use and care. Situational factors, especially staff’s attitudes towards sustainability issues also matter. Thus marketing communication that promotes sustainability needs to be incorporated in all consumer touch-points in order to achieved intended effect.

How long a garment is used and what transport mode used when shopping, matter more than lowering the washing temperature. One of the surprising findings in the LCA in phase 1 was that 25% of climate impact comes from consumer transport to and from the store. Consumers often go by bus or car and buy only a few garments each time. In addition, the study also showed that the assumption that that consumers could considerably reduce climate impact by lowering washing temperature turned out to be wrong, giving only a 1% reduction of the full climate impacts of a garment. Consumers should instead of concern on washing temperature they ought to reflect on how to prolong their garments life, either by themselves or used by someone else. The Upcycling route opens up for garments care documentation, which can be translated into monetary value. Well-kept items can be re-used by new owners again and again.

Consumers are motivated by quality of life enhancers. There is a high potential to change consumer behavior towards more sustainable fashion consumption by the trigger of enhancing quality of life simultaneously. Based on results of phase 1 we have learnt that guilt is no successful motivator to enhance sustainable consumption. It indicated also that consumer’ personal characteristics had impact on their general sustainability awareness and use of the recycling programs. Sustainable fashion pioneers demonstrated significantly more sustainable consumption patterns throughout all phases and are simultaneously more satisfied with their life. Summarizing these results it becomes clear that the understanding of consumption as quality of life enhancer needs to be reconsidered and the benefits of more sustainable ways of consumption for individual consumer quality of life need to be examined.

Next phase’s research will continue on defining sustainable fashion consumption and defining it further how to make more environmentally or socially friendly fashion consumption choices. New angles on the question of why consumers should behave more sustainable; how to identify sustainable choices and showing sustainable behavioral alternatives, and business models for reuse, upcycling and sharing relevant to consumers.
Having sustainable resources at hand is a giant puzzle piece but should not be considered in isolation. Most fashion brands and fashion designers are missing the opportunities to think bigger; meaning transformative actions that can ‘disrupt’ the existing fashion system. This proposes a new role for the designer within business: bringing them closer to the sustainability activities within the brand, and closer to its communities. This context requires new practices for the fashion designer and new skills.

The impact of the designer’s and the procurer/buyer’s choices are together are very high. Design decisions can account for up to 90% of the environmental impact of clothing. Therefore a designer ought to responsibly influence all decisions made in the creation of each garment, and weigh up the relevant, sometimes competing, design and environmental aspects. With better definitions and more in-depth LCA methods the evaluation of garments will be more accurate and reliable. This would improve the decisions process for the designer. The LCA outlines that the major environmental impacts occur in the production phase, in the many steps from fibre to garment, but, if the designer can improve the durability of long-lasting fashion or the optimization of resource use for fast-fashion, the designer will reduce the impacts in the production phase.

For real, lasting, holistic and systemic change, the sustainability work should not only take place in the sustainability department, nor only be limited to supply chain and buying offices. The organizational changes for sustainable thinking ought to be implemented throughout the organization and with a clear focus on the collaboration between Design, Marketing, Supply Chain and Management.

3. DESIGNING WITH INTENT

- Enable the designer with the relevant opportunities and tools to explore their full potential in all design decisions
- Use of strategic design thinking can both significantly improve the environmental impact of existing products (41%) but also create break-through innovations
- Start from the garment’s intentional life-span and design to optimise its usage, including recycling, in the design process

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Strategic Design Thinking enables environmental improvements for current products. If strategic design thinking is used to re-imagine current products, a products’ environmental performance would be improved by up to 41% (measured using the Higg Index 2.0). The greatest improvement comes through changes on how to make the product more easily recyclable and sourcing alternative materials and coatings. This was learnt during phase 1 throughout close interactions with design teams. For instance, one company generated a higher level of understanding around sustainable design in their staff, with a 7% increase in their everyday decision-making. Further learnings, depending on the scale of the company and where it is based, are that tools need to be flexible and adaptable. Designers and managers also need measurement tools like the Higg Index to gauge the effectiveness of these new design decisions; to argue for change using quantitative data outcomes.

Using Strategic Design Thinking for exploring innovative circularity. The ‘length and speed’ of the cycle also needs to be considered. Different material and design approaches are needed for a short-life (fast fashion) product, designed for efficient recovery of material resources, compared to a long-life (suitable for extended life services) garment, which needs to be designed for durability. For example, the design research in phase 1 included new design concepts for advanced sustainability thinking. Prototypes were made in order to inspire and enable further discussion on the role of the designer and potential design models. First – three prototypes focusing on innovation in Material, Product and Process in order to understand cyclability and fast & slow speeds of fashion products (SeamsDress, A.S.A.P., DeNature). Second, for innovation in Social, Systemic and Economic realms, three prototypes for fashion services (Fast ReFashion, Library

‘Length and speed’ of the cycle also needs to be considered
Jumper, Smorgas Board). Last, The Self and Shifting Mindsets; presents new roles, skills and mindsets for designers, moving from sustainability to social equity. **To generate new system change ideas.** By thematically clustering design ideas a new way of tackling the challenges ahead can be discovered – through connected innovation in “Materials, Business Models and Mindsets”. It leads to ideas (found in the centre of a Venn diagram below) about how to propose more challenging and disruptive design research towards systemic change in the industry. See figure.

**Tools to enable insight & learning.** Enabling strategic design thinking can be done with tools that raise relevant questions and trigger new thoughts. Accessible tools like online platforms allow engagement by a range of communities – the next generation of consumers, designers and researchers are at school.

The Black Hack Chat
Earley, Ballie (2014) The Design Journal

Elastic Learning Tools
Earley, Harvey (2015) in Cultures of Resilience by Manzini, and Till.

A range of sophisticated tools and resources for the design community are presented in an accessible Textile toolbox, including exhibitions and a global web platform

**Future Fashion Manifesto, 2015**
In the next research phase we will continue the exploration of speed related design processes and how design can help to develop the emerging business models for extending life services in Sweden and beyond. Short-life and long-life garment prototypes (one per each variant) will be developed, and each prototype assessed using LCA, relevant recycling models will be explored as well as potential business models. This research will be the base for the development of tools and guidelines for designing a circular economy.

Alternative sustainable fibres enabling designers and fashion companies with the right tools at hand; using sustainable fibres in the design process, is an ultimate aim and would mean huge impact reduction in the production process. Regarding new fibre alternatives, the sustainability of the key new fibre CelluNova, (with origin from forest products industry), is much better then for cotton. The findings to date support the contention that some forest-based fibres are even quality-wise comparable to cotton. These forest-based fibres therefore deserve increased industry attention. Furthermore, tests on the feasibility of the wood based fibre Tencel® (designed and patented by Lenzing AG) has been conducted, a fibre that is already available on the market and thus could be readily implemented. The results from washing, performance and comfort testing prove this fibre to be a viable alternative to cotton in the Swedish health care sector. LCA results show that a dress with polyester blend (Tencel) gave a lower environmental impact compared to cotton/polyester blend. Replacing cotton with Tencel leads for example to reduction in water use impacts on account of using a biomass resource from non-water stressed regions, so this result supports increased investment in forest cellulosic fibre by the textile industry.

In next phase more research will be conducted in how to promote a sustainable circular supply chain in the design and production process. Further assessments will be made on potentials in development of sustainable textile fibres as well as technology. Further we will assess different scenarios for potentially more sustainable production, production location impact and differences (including local), as well as business model innovations, and politics and policies in the textile life cycle. Screening and developing circular textile flows will be conducted, and we will generate Supply Chain communication guidelines in order to enable for Swedish fashion companies to steer towards sustainability.
The final piece in the puzzle deals with the phase after a garment has been discarded. To achieve a circular flow of materials, the discarded textiles must be recycled into new textiles. Today there are no large scale industrial processes for recycling of textiles. This will lead to an open loop system, where input of virgin materials is required. Keeping the goal of reaching circularity in mind it is important to develop textile recycling in order to close the loop and utilize the recourses better, i.e. the garment is viewed as a high-value resource.

**Optimize resources via regeneration.** The fashion industry urgently needs to make more effective use of textile fibre at every step in the value chain. With respect to the end of life stage this can be achieved by shifting treatment of used textiles further up the waste hierarchy. Used textiles need to be redirected from incineration where the majority ends today in Sweden, towards reuse and, where products are no longer fit for reuse, towards material recycling. Recycling is most environmentally beneficial and most value is retained where textiles are recycled back into fibres for new textiles. However, Swedish textiles waste is exported, and almost entirely comprises down-cycling. Either as industrial rags or mechanically shredding turning it to degraded textile fibres of low quality, which are subsequently used for low grade non-wovens, such as upholstery fill, insulation materials etc. Such down-cycling does little to offset demand for virgin fibres and associated security of supply issues, has far lower environmental benefits than fibre to fibre recycling and makes sub-optimal use of high value fibres.

4. TOWARDS NEW HEIGHTS IN RECYCLING

- An understanding of how materials break down in use phase is basic and essential knowledge in the development of new technology for the regeneration of recycled fibres to high quality
- In order to optimize garment’s lifetime an established profitable collecting structure is needed, which prevents garments are lost prematurely as waste
- To minimize the waste of worn-out clothes and instead utilize the fibres back as resource (regeneration) new technology is needed that allows automatic sorting and chemical dissolution of the fibres
Findings from Phase 1 research show that chemical recycling is as a better solution for recycling of used textile fibres, compared to mechanical fibre-to-fibre recycling. This is due to the large degradation caused by laundering and use both on molecular level and fibre level. This is true for both of the two largest fibre types, cotton and polyester. Due to the large chemical differences between polyester and cotton, fibres of virgin quality can only be achieved if the materials are recycled in separate processes.

**When designing a recycling process for cotton**, it may be utilized that cotton is the most pure natural source of cellulose. Cellulose is also the main constituent in so called man-made cellulosic fibre, a group of fibre, where the two most well-known fibres are viscose and Tencel. This opens up for that cotton could be recycled through integration into the existing production of man-made cellulosic fibres. Today man-made cellulose fibres are mainly produced from wood, which is processed into the special grade of pulp called dissolving pulp. The idea of integrating cotton into the viscose industry has been in focus during Phase 1, in terms of recycling. Before initializing large investments in such a technological change, basic material knowledge must be established. Thus basic properties of post-consumer cotton, well known to the viscose industry has been studied in order to provide a background to larger investments. It was found that some characteristics change considerably, while others remain stable during laundering. To integrate cotton into the viscose industry, it is also key to understand differences in how cotton and dissolving pulp react the chemical treatments. In Phase 1, it was shown that acid treatment of dissolving pulp and used cotton gave very similar results, giving positive indication for the possibility to mix cotton with dissolving pulp. Mixing will not lead to a completely circular flow, but it is an important first step to achieve recycling. To face the whole chain from fibre-to-fibre the Post-Consumer-Cotton project was launched in the end of Phase 1. In this project Chalmers, Swerea and SP collaborated to perform the whole recycling process from fibre-to-fibre. Cotton sheets, used at hospitals, and kindly provided by Textilia were dissolved, and spun into new fibre s using the CelluNova method. All steps of the process needs optimization before it can be considered industrially, but the positive result show that is it possible to recycle cotton using this method.

Recycling of Polyester. The research in Phase 1 also showed that polyester is degraded during laundering. To recycle polyester, it may either be re-melted or it needs to be degraded and synthesized again. The second approach requires both more energy, and is also more costly than the first. However, due to the degradation during laundering, it was found that the melting approach is not feasible for used polyester textiles. This result show the importance of understanding the waste before choosing recycling method. Today, recycled polyester is marketed in-stores, however this polyester is recycled from PET-bottles, not polyester textiles. PET bottles have much longer polymers (higher degree of polymerization) from the beginning, and may thus be recycled through melting. The only commercial recycling route of polyester is performed by the company...
Teijin in Japan who has a closed loop recycling system with connected partners from over 150 brands to ensure the right quality of the textile waste. This process also build on the principle that the polyester must be first degraded and then resynthesized to ensuring the recycled fibres to be of the same high quality as virgin fibres.

In Phase 1’s research the degradation of polyester was achieved using two different approaches: one using a new technique utilizing an eco-friendly nanocatalyst, more suitable for pure polyester, and one developed for separation of cotton and polyester. The material properties of cotton and polyester complement each other, and thus mixes of cotton and polyester are one of the most common textiles mixes. Recycling of cotton and polyester will therefore be much benefitted from a simple separation process designed to fit in a larger recycling industry. A pilot study in phase 1 concerning separation of cotton and polyester, where the polyester is degraded and the cotton remains unaffected, showed very good results and more research concerning this will be conducted in next research phase.

**Sorting technologies.** Another issue emphasized during Phase 1 was the current problems with inefficient and inadequate sorting technologies. Thorough material sorting is central in textile recycling in order to facilitate mechanical and chemical recycling. Most textile sorting is performed outside the Nordic countries, where labor costs are lower since the sorting process is currently highly labor intensive. High levels of automation are required if sorting is to become economically viable in the Nordic region. In the future, we need development of new methods for automatic sorting, i.e. new detection methods and new marking of textiles. We will in phase 2 initiate and merge ongoing work on automatic sorting technologies to speed up the process for finding effective and economically viable solutions. The focus will be on technical development based on experience for wood sorting and sorting performed at existing non-textile recycling plants. Design of textiles which are better suited for recycling i.e. by avoiding certain fibre blends will also be a key element of work and will assist in optimizing sorting and subsequent recycling of textile waste. In addition, this task will be coordinated and have close interaction with the Horizon 2020 project Trash-2-Cash.

**Super-fast fashion alternatives** made of cellulose/paper-cloths would enable a closed recycle process with fast speed. The purpose of the garment is short-term usage and intended to immediate after final use go to recycling, in garment-to-garment process.

**Further research needed:** Additionally, we will focus on the association of recycling findings with other research fields of the research program. This will include work on initiatives that can increase collection rates of used textiles, particularly in Sweden which has the lowest used textile collection rate in the Nordic countries at just over 20% compared to approx. 45% in Denmark. This will include investigation of both mandatory and voluntary Extended Producer Responsibility (EPR) systems where importers and retailers of textiles are responsible for collection of textiles.
following use. These options have already been investigated under a project for the Nordic Council of Ministers. In next phase this work will continue and investigate the advantages and disadvantages of voluntary and mandatory systems and various design options further.

Further research during next phase will investigate three of the technical obstacles that limit closed-loop recycling: fibre degradation, complex fibre blending, and de-dyeing and fibre quality aspects. The research will focus on separation and characterization of cotton from a cotton/polyester blend, to understand how the separation will effect subsequent fibre regeneration. The objective will deliver insights and thorough understanding of used cotton, a key factor in the development of new recycling methods. The research will be performed in close collaboration with re:newcell, a textile recycling company working towards a demo-plant in Sweden, which will ensure application of science. The collaboration will benefit the Swedish industry and business position in the field of textile recycling.

Toxicity impacts are habitually excluded from LCA studies, it is a common approach to neglect use of chemicals in LCA due to lack of data. It is concluded that the total environmental performance ranking of textile products can be affected by including the toxicity impact potential of textile chemicals in LCA studies. Further research in next phase will assess different approaches to manage chemicals in the textile industry. LCA has the potential to significantly improve how chemicals are managed in the textiles industry compared to existing approaches such as Cradle to Cradle and Restricted Substances Lists.
PARTICIPATING RESEARCH INSTITUTIONS PHASE 2

- Chalmers University of Technology, Chemical Environmental Science (CES)
- Chalmers University of Technology, Division of Forest Products and Chemical Engineering
- Copenhagen Business School, Centre for Corporate Social Responsibility (CBS CSR)
- Invenio
- IVL Swedish Environmental Research Institute
- Malmö University, Department of Global Political Studies
- PlanMiljö
- renewcell
- SP Technical Research Institute of Sweden, Department of Sustainable Built Environment
- Stockholm School of Economics, SSE Institute for Research
- Swerea IVF, Materials Department, and Methods Department
- University College of Arts, Crafts and Design Stockholm (Konstfack)
- University of the Arts London

A SELECTION OF OUTPUTS FOR FURTHER READING


This article investigates the every-day street-level practice of green public procurement (GPP) in Sweden. The analysis shows that the direct factors that influence the local outcome of GPP comprises factors on the local level: political commitment and environmental knowledge, the organizational structure of local government and the local interpretation of the regulatory framework. This study shows that a decentralized structure has possibilities of furthering ambitions of buying green if there are committed politicians and public officials, an optimal level of internal centralization and an external support structure of knowledge and enabling rules.


There are many different approaches to the assessment of wateruse in LCA at the inventory, midpoint and endpoint level. The article summarizes the strengths and weaknesses of each.


This licentiate thesis brings together chemical, textile and LCA competence for the first time and shows the importance of including quantitative assessments of chemicals in LCA of textiles. The findings were to be presented at the SETAC conference in May 2015.


This article discusses the implications of that LCA is used for policy development for textile products in parallel to other chemicals legislation. The differences in background assumptions in assessment methods and how that affects the resulting assessment of different textile chemicals is explained. The editor is the main author of the current LCA methodology for chemicals assessment.


Target audience for the article is sustainability analysts for the textile industry and others making use of forest resources. The article pedagogically demonstrates novel approaches to water and biodiversity impact assessment of textile products. Examining difficult impact indicators, this work supports the contention that some forest-based fibres are superior to cotton. They therefore deserve increased industry attention.


Target audience: Analysts and decision-makers in industry, NGOs, the government sector and the consultants that support the Value for users: Many actors in the fashion industry want to move from simplistic single issue indicators to broader sustainability assessment of their products, for example adding social indicators to established environmental indicators, or vice versa. This is relevant when designing eco-design processes or Eco label standards. Bringing multiple indicators together in a consistent framework is made easier by reading this paper first. A more consistent indicator will provide information that is more accurate about the sustainability of a product.


Target audience: Textile industry members, students, policy makers who need an introduction to carbon footprinting; sustainability assessment practitioners who are making the transition to assessing textile and fashion products. By describing carbon footprinting methodology, the standards behind it, and showing some sample results, this chapter provides an entry point to life cycle assessment for people who may have only heard about Cradle to Cradle and who are wondering what key open-source alternatives exist in the marketplace of ideas. It also discusses the methodological challenges in a way that aims to sharpen the attention of practitioners on issues that may need extra care for fashion product analysis compared with other products to which carbon footprinting and LCA are applied.


This article busts the false myth that unbleached garments must be environmentally superior to bleached garments. To reach out to the intended target group, the textile industry, this article is published in a journal with the textile industry as target audience. The impact on the textile industry audience and chance that the industry will take action based on these new scientific facts, is expected to be much higher, than, if in contrast the work would be published in an environmental science

Target audience: Textile industry members, students, and policy makers. Demonstrates the relatively recent entry of the textile industry into the world of life cycle thinking and summarizes some of the key technical challenges standing in the way of a sustainable textile and fashion industry. The chapter describes some of the recent scientific and engineering breakthroughs that have occurred in response to these challenges. It also proposes a list of priorities for research and development activities based on current challenges.


The article describes how a fashion designer tries to integrate sustainability in her work. The purpose is to point the way to insights about personal experiences, challenges and opportunities experienced by the fashion entrepreneur, Rachelle Kollerup.


Target audience: Scholars, practitioners, and students. The study demonstrates that post-retail responsibility of fashion is an emerging field in the fashion industry that offers several business opportunities to fashion companies, but also requires rethinking of existing value propositions and engagement of a wider stakeholder group in order to find sustainable solutions for garments’ end of life. This paper contributes to research by advancing understanding of fashion industry’s role in the end-of-life of their products and the associated opportunities and challenges.


Target audience: Scholars, practitioners, and students. The special issue provides a comprehensive overview of new business models for sustainable fashion. Moreover, the special issue highlights some of the barriers and obstacles for addressing sustainability in saying and doing. The special issue thereby supplements other work being done in the MFF project (e.g. Andersen and Pedersen, 2014). The special issue also includes a teaching case that can be integrated in courses on sustainability and CSR at universities and business schools.


This article identifies entry points to enhance sustainable consumption through the analysis of sustainable fashion pioneers (lead users). The identified pioneers have clear strategies on how to behave in a more sustainable way in their fashion consumption. The findings were important to design further studies on a broad set of consumers, and a first step in identifying important triggers and catalysts to promote a more sustainable fashion consumption.


This article builds upon the Bly et al (2014) article in the analysis of sustainable fashion pioneers. Wellbeing can be used as catalyst to promote sustainable fashion consumption instead of guilt to motivate consumers towards sustainable fashion consumption.


The report provides knowledge and understanding of consumer’s relation and perceptions on sustainable fashion. Consumers are ready to walk their talk, but need to get sustainable behavioral strategies. The target audience for this popularized report was industry policy-makers and NGO’s with an interest in sustainable fashion consumption. The report was presented and released at Mistra press meeting that was well attended and the results have been valued, by in particular SME retail companies.


The results of the study of consumers and personnel’s perception of the Weekday and I:CO’s in-store recycling scheme was presented for Weekday and H&M. Insights from the study on relevant factors for increase of awareness, use intention, and use of in-store recycling was presented and discussed.


This sub chapter gives recommendations for consumers and retailers around extending life of a garment and rethinking a domestic costs. The insights drawn from a conference workshop at European Academy of Design, EAD2010. The insights form part of an article in the internationally #1 rated design journal, and argues that craft will play a ‘central role for empowerment through social development, innovation and entrepreneurship. In order to facilitate this, there is a need to explore how craft practices can act as tool for empowerment’. The workshop and resulting publication convincingly explored the notion of users being supported by designers in the upcycling of items from existing wardrobes, and contributes both to research and practice knowledge in the design field on how craft practices can act as tools for empowerment.


This conference paper and workshop adds granularity to the currently generic and broad concept of designing for circularity. It requires a proactive, and embedded design approach, where materials are designed with end-of-life recovery in mind at the outset. Designing in order to enable fully joined up cycles of material use is the ultimate aim, but the ‘speed’ of the cycle also needs to be considered in order to make informed and appropriate design choices.


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Chemical and ultrastructural changes in cotton cellulose induced by laundering and textile use. Cellulose 21:4681-4691. Palme A, Iadstrom A, Nordstierna L, Breid H (2014). This article correlates the number of washing cycles for cotton fabrics with the extent of cellulose degradation, increases knowledge post-consumer material properties and understanding for the chemistry needed for efficient recycling.


This report includes the current and future potential recycling technologies for textile recycling (i.e. excl. reuse of textiles) and delivers a prognoses and guidelines through LCA showing the most beneficial recycling methods from an environmental view for different textile materials, with the focus on alternatives within cotton and polyester recycling. This is a public report delivered from researchers within program (PS and P4) (together with a few external researchers) to the Swedish EPA (and KemI) as a research assignment on analysis or opportunities in future textile recycling. The report will be added into their recommendations to the Swedish National Government on textile waste handling during 2015.

TextiliaTvNo has bought tens of thousands hospital gowns based on the research reports and results from Mistra Future Fashion studies. The possible improvement of current design of patient clothing (night gown) with respect to appearance, functionality and fit, was investigated together in Linköping University master thesis.

Livscykelanalys av Tencelfiber, Roos, (2012), Mistra Future Fashion/Swerea IVF report 23497 on commission of TvNo


Based on a case study of a high end Scandinavian fashion brand Filippa K the article highlights the main issues, challenges and opportunities the brand can encounter in integrating this strategy into its existing business model.

The Sociolog.dx Experience: A Global Expert Study on Sustainable Fashion, Pedersen, E.R.G. and Andersen, K.R. In May 2013, CBS hosted a five-day global expert interactive online forum event in collaboration with GfK (Growth from Knowledge). Thirty-six participants from business, academia and civil society, took part in this expert study, sharing ideas about improving the social, environmental and economic footprint of the entire fashion supply chain (design, manufacturing, transport, consumption etc.). A full overview of the learnings and recommendations is published in this MFF report. Pedersen, E.R.G. and Andersen, K.R. (2014).

Prototypes


SeamsDress [Dress and samples]; Goldsworthy, K. (2014)


Shanghai Shirt [Heat transfer print on polyester shirt]

Redressing Activism [Headpiece, Shirt, skirt and shoes]; Earley, R., Harvey, B. and Child, E. (2014)

A Jumper to Mend, A Jumper to Lend [Library jumper / mended jumper and kit]; Harvey, B. (2013)

Sweaver [Collection of woven samples]; Landalv, J. (2014)