Feasibility of conditional design

Organizing a circular textile value chain by design principles

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Executive summary

In recent years the increased awareness of the need for conservation of resources and environmental sustainability has brought a focus on the potential for a circular economy in textiles and fashion. Commissioned by the Region of Västra Götaland, a number of investigations were carried out during 2015-2019, related to redesign, reuse and recycling of textile materials and products, at the Swedish School of Textiles and Science Park Borås. These projects addressed measures and strategies that were considered essential for this purpose, i.e. collection and sorting, design for longevity and recyclability, remanufacturing, and a possible shift of selling offers from products to services and service systems, throughout with an aim to assess the feasibility of each such approach, technically and economically. The findings were consequently presented in a series of five reports, which are collected in this publication. It comprises the following titles:

1. Planning a Swedish Collection and Sorting Plant for Used Textiles – a feasibility study; and, as an annex, Collection and Legislation for Used Textiles and Clothing (commissioned by TEKO)
2. **Feasibility of Conditional Design - organizing a circular textile value chain by design principles**
3. Feasibility of Fashion Remanufacturing - organizing fashion value chains for circularity through remanufacturing (including redesign)
4. Feasibility of Servitization - transforming fashion value chains to circularity through service innovation

The objectives of the reports, where feasibility is a keyword, is to develop structures for circular processes in the textile industry, in order to create new business opportunities and use less planetary resources. The focus is to design for longevity, through conditional design, redesign and remanufacturing and service innovation, and to ensure that the resulting circular processes are technically, organizationally and economically feasible.

Planning a Swedish Collection and Sorting Plant for Used Textiles – a feasibility study

In the first report, the feasibility of collection and sorting of used textiles is assessed. The assessment was based on a model for the different flow directions in collection and sorting – collection by charity organizations, stores, municipalities etc. or directly from users, and sorting into export channels, second-hand stores, recycling and redesign facilities or even destruction by incineration. It was evident that realistic conditions, at that time (2015) at least, did not permit a profitable, fully commercial sorting facility. There was a need for further value-adding features, which must be developed in order to ensure the feasibility of such a centralized facility. Critical success factors, as proposed, are the following.

Voluntary and subsidized work is essential for economic feasibility, and must be supported by legislation, occupational measures or general practice. 2. Increased prime quality in incoming material will raise the income level of sold fractions. There are ways to achieve this, of which one is to convince consumers of providing less used material for collection – perhaps at the cost of shorter first-hand use. Another possibility is a sharing agreement with the charities, which carry out the first-tier sorting. It involves also measures to enable consumers to make more educated decisions. A certification system may also be helpful to achieve better quality. New actors should be encouraged to join the market. 3. Increased productivity in the sorting centre. 4. Increased value of output can otherwise be achieved by innovative sorting, cleaning, redesign and remanufacturing methods and development of new products. 5. Automated sorting may become increasingly appealing, as new sensors and devices for image-processing, identification, robotics and affordable control units become available. Technology development is needed regarding inexpensive sensors for identifying toxic additives in textiles and for fibre contents. 6. New business models, for example streamlined selling/purchasing by agents, who also provide training, packing etc., web services for used textiles brokerage, or financial recalculation of sustainability values, may become established. 7. Provision of parallel technical and administrative services, such as making a test bed available for new development projects, may as well be an opportunity.

Collection and Legislation for Used Textiles and Clothing

In addition to the report on collection and sorting a meta-analysis of the present situation of the used clothing network in six countries is presented in the second report. The analysis for each country comprises the total consumption of clothing, the collection structure, actors and volumes, a map of the reused clothing network, legislation, taxation, and revenue in the value chain.

The presence of large unified sorting centres increases the volume of used textiles in the market. Used textiles collection, in all the countries, is mainly arranged via traditional collection points like charities, textile banks, door-to-door etc. In-store collection and over-the-counter collections has increased collections in recent years. Sorting of the collected items typically takes place in domestic sorting plants with clearly defined sorting criteria. On an average ~10% of the sorted clothes are re-used in the native country of consumption while nearly 80% is exported to Africa and Asia.

Legislation around used clothing has been observed to be either mandatory or voluntary. In France, a mandatory Extended Producer Responsibility (EPR) scheme has been introduced since 2008, while the other countries have a voluntary EPR. However, certain bodies exist, responsible for setting out directives, guidelines and frameworks for their voluntary members. Taxation on used clothes is mainly in the form of VAT, however the charities are mostly exempted. Waste fees for post-consumer textile waste or landfill taxes exist in almost all the six countries.

Feasibility of Conditional Design - organizing a circular textile value chain by design principles

Conditional design is a concept that involves defining systematically the design elements that are relevant to apply in the design process for both longevity and recyclability. The report on conditional design focuses on the feasibility of service innovation, while intending to answer the following issues, having also in mind to maintain or increase the attractiveness of the products: 1) Can the design/construction phase decisively influence the characteristics of the product, so that the prerequisites for circular, sustainable flows will be significantly improved? 2) Which are then the key critical factors? 3) What is the future for different scenarios? 4) What is in that case a feasible way out for the concrete implementation of a strategy that positively affects the entire textile value chain?

It implies several actions, which can be carried out within a relatively short time frame. They include applying design principles of mono-material choices, modular design and redirecting the design of garments as a process that goes on during the life of the product (i.e. incremental design). It is however clear that it will take considerable time to form the conditional design processes into a mainstream principle for large volumes. The development and implementation of such principles will nevertheless have the impact of creating new innovation products and create new interesting business models, resulting in a growing small and local industry sector. Regional assets can be instrumental in the movement towards circularity, such as an educational centre for the implementation of design actions for synthesizing in value chains, development of media and communication addressing design for circularity in consumers' minds, or the establishment of an arena and facilities for realizing new ideas within the sector.

Critical success factors for design in relation to circularity are thus the following, 1) education of designers and design managers in all issues concerning the implications of design in achieving longevity and circularity, 2) development of a classification system covering design conditions for circularity, to enable the identification of the products already at the design phase; the recognition of the products in sorting phases enables automatic sorting for specific recycling processes, 3) further development of sorting (automatic) systems, 4) further R&D activities in all aspects of recycling processes, 5) further development of incremental design approaches and associated business models, aiming at longevity, and 6) development of an arena with the aim to inspire and educate designers to really demonstrate design's power to synthesize, i.e. identify problems – generate ideas – test the ideas – realize the ideas.

Feasibility of Fashion Remanufacturing - organizing fashion value chains for circularity through remanufacturing (including redesign)

Remanufacturing is practiced only at a very small scale in the fashion industry, despite the increasing need for a development towards dematerialization, higher revalue addition, ways to generate a high profit margin, and at the same time create more employment. A net positive environmental impact however, can only be made through remanufacturing at a larger scale. Yet, research investigations on this matter are insufficient, and knowledge of the practices regarding new value chain models, the associated processes and designers' approach to the product development process is still limited.

The report, based on three participatory action projects, aims to investigate how remanufacturing can be made feasible industrially, for sustainable competitiveness in the fashion industry, through detailed observation of a fairly large and successfully operating remanufacturing business. Key decision elements in different fashion remanufacturing value chain models, the associated critical success factors and the feasibility of fashion remanufacturing are addressed here. Three different fashion remanufacturing models were selected and analysed, namely scaled remanufacturing, distributed redesign and PSS (product service system) redesign-as-a-service. The study identifies the key decision making variables in each of these models, the critical success factors and also in connection assessing the feasibility of each model by constructing various scenarios. It is noted that there is currently no certification system or standard for remanufactured fashion products, which challenges their legitimacy.

Critical success factors for scaled fashion remanufacturing comprise the fraction of input materials obtained for remanufacturing (now very small), yield of remanufacturing processes (now low), remanufacturing process costs (now requiring subsidized workforce and zero cost of material), remanufacturing lead times (needing new tools and technologies) and market price of the remanufactured items. The future potential for scaling up fashion remanufacturing is likely dependent on growing from a redesign studio concept towards a mini-factory. To fuel such mini-factory key requirements comprise the supply of good quality material in considerable volume, high productivity and flexible remanufacturing systems and high demand and price propositions for the remanufactured products. Fashion remanufacturers should also consider collaborating with other collecting organizations, e.g. fashion retailers, acquiring more prime material input, creating a branding strategy and identifying 'new' customer segments, creating innovative design ideas, targeting more and innovative sales channels and, in order to synchronize the supply and demand, also extra resources, 'new' technologies (for disassembly, pattern development and cutting, manufacturing), and flexible remanufacturing systems.

The critical success factors for distributed fashion redesign comprise material cost (which may vary widely), material usage, redesign process cost and lead time, and subsidies obtainable. The future potential for establishing distributed fashion redesign is likely dependent on creating a strong inter-connected network of suppliers and value-adders regionally. Educational efforts are needed, also primarily in circular product development and design, circular production processes, and in circular local flows and establishment of collaborative networks.

The critical success factors for PSS redesign-as-a-service are identified as direct process costs, overhead costs, customers' willingness to pay, and PSS lead time. The future potential here is in developing both the technical solution and improving the customer satisfaction in a larger retail setting, for example by direct-to-garment printing or fun features for customers, like artwork, 3D visualizations, customization features, etc.

Feasibility of Servitization - transforming fashion value chains to circularity through service innovation

Servitization is a growing phenomenon to improve resource efficiency, leading to positive effects for the environmental and for society. It stands for the innovation of an organization's capabilities and processes to create mutual value through a shift from selling products to selling product service systems. In this context, product-service systems are one of the most effective instruments to attain a resource-efficient circular economy. It combines design principles, technology considerations, and marketing strategies into a business model for extending the useful life of a garment. In particular, the economic implications and feasibility will be assessed for such a business model, taking into account crucial factors, such as logistics flow, quality factors, key performance indicators (societal, environmental, economic), life-cycle discussions and the required competence-building. Servitization combines design principles, technology considerations, and marketing strategies into a business model for extending the useful life of a garment. This report demonstrates an economic feasibility assessment, by examining two examples of servitization for circularity in the apparel and fashion industry, and outlining potential business models, along with prospects for future research. Core elements for decision-making and the economic implications and feasibility of extending the useful life of a garment through servitization are identified here. Decision variables are typically choice of partnerships and scenarios, related to distribution channels, cost structures and revenue streams for creating additional value through extended producer responsibility, and how the servitization offer is marketed and communicated to customers. Critical success factors comprise direct service costs, partnership scenarios and the customers' willingness to pay, in the redesign-as-a-service scenario also direct process costs, overhead costs, customers' willingness to pay and PSS lead time.

Borås, 15 December 2019
The authors

Förord

Under 2014-2015 gjorde vi, på uppdrag av VGR, dels en förstudie avseende potentialer för re-design, dels en feasabilitystudie med titeln Re:design – planning a Swedish collection and sorting plant for used textiles. När projektet 2016 utvidgades till ett treårsprojekt beslutades att fortsätta serien med tre nya studier som en logisk följd av projektresultaten i tidigare arbeten.

Tre områden definierades enligt följande:

1. Re:Textile – Feasibility of conditional design (denna rapport)
2 The feasibility of re:design manufacturing
3. The feasibility of service innovations

Vi vill tacka VGR för möjligheten att genomföra dessa studier, baserat på den inriktning som fastställts i aktuell projektansökan. Utvecklingen mot cirkularitet går snabbt, och förutsättningarna för genomförbarhet av projektidéer förändras snabbt. Rapporten tar hänsyn till detta och har utformats så feasibility kan värderas med variabla parametrar i modellerna. Rapporten innefattar en sammanfattning på svenska men är i övrigt skriven på engelska för att tillgodose ett internationellt intresse.

Foreword

During 2014-2015 we carried out, on behalf of the Västra Götaland region (VGR), a pilot study regarding the potential for re-design, as well as a feasibility study titled Re:design – planning a Swedish collection and sorting plant for used textiles. When the project was expanded in 2016 to a three-year project, it was decided to continue the series with three new studies as a logical consequence of the results obtained in previous work.

Three areas were defined as follows:

1. Re:Textile - Feasibility of conditional design (this report)
2. The feasibility of re:design manufacturing
3. The feasibility of service innovations

We are grateful to VGR for the opportunity to carry out these studies based on the directions set in the current project proposal. The trend towards circularity is fast, and preconditions for the feasibility of project ideas are changing rapidly. The report takes this into consideration and has been designed to allow feasibility to be measured with variable parameters in the models.

The report contains a summary in Swedish but is otherwise written in English to cater to an international interest.

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Table of contents

Sammanfattning

Studien belyser följande frågor:

– Kan man i design/konstruktionsskedet på ett avgörande sätt påverka en produkts egenskaper så att förutsättningarna för cirkulära, hållbara flöden avsevärt förbättras?
– Vilka är i så fall de avgörande kritiska faktorerna?
– Hur ser framtiden ut i olika scenarier?
– Hur ser i så fall en framkomlig väg ut för att konkret genomföra en strategi som positivt påverkar hela den textila värdekedjan?

Bakgrund och problemställningar

Utvecklingen idag går stadigt i en riktning, som i stort försvårar genomförandet av cirkulära hållbara flöden. Det beror i första hand på följande:

– Kraftigt ökad konsumtion av textila produkter (från ca 90 mn ton 2016 till 200-250 mn ton 2050)
– Kraftigt ökad andel av polyester (oljebaserad) i producerade produkter. Detta har accelererat betydligt, sedan fast-fashion ideologin tog fart vid millennieskiftet. År 2030 beräknas polyesterandelen ligga upp mot 70 % av totala fiberproduktionen.
– Ökad komplexitet i enskilda produkter genom att plaggen konstrueras med flera ingående komponenter (olika textilmaterial, tillbehör etc.)
– Kemikalievolymerna ökar i och med ökad produktion
– Energiförbrukning ökar i takt med ökad produktion.

Våra avfallsfraktioner kommer i framtiden att direkt påverkas av ovanstående faktorer.

Om vi inte gör något

Att fortsätta enligt ”business as usual”-principen innebär att vi riskerar att hamna i en situation präglad av resursbrister och instabila materialmarknader, som allvarligt utmanar nuvarande affärsmodeller och dessutom orsakar betydande miljöproblem i en industri, som redan idag rankas som en av de mest negativt påverkande. Valmöjligheterna innefattar som de tre bästa alternativen, vilka kan påverkas i designskedet: 1) källreduktion av avfallet. 2) återanvändning, 3) återvinning och eventuell kompostering. Därnäst utgör det bästa alternativet, om inte något av ovanstående är möjligt, 4) förbränning med energiåtervinning.

Att skapa ett hållbart system för textil- och konfektionsflödena måste följaktligen både ”sluta cirklarna” och sakta ned tempot i volymutvecklingen. Det innebär produkter med bättre kvalitet, som **designats** för hållbarhet, är reparerbara, kan redesignas och återanvändas och vid slutet av sin livslängd återvinnas till nya fibrer eller andra produkter, och som dessutom uppskattas av konsumenterna, så att man väljer dem före traditionella ”fast-fashion”-produkter, som inte uppfyller kriterierna.

Hur kan design/konstruktion dramatiskt påverka utfallet och skapa förutsättningar för en positiv syntes? I olika studier har fastslagits att designprocessen är till mer än 80 % direkt avgörande.

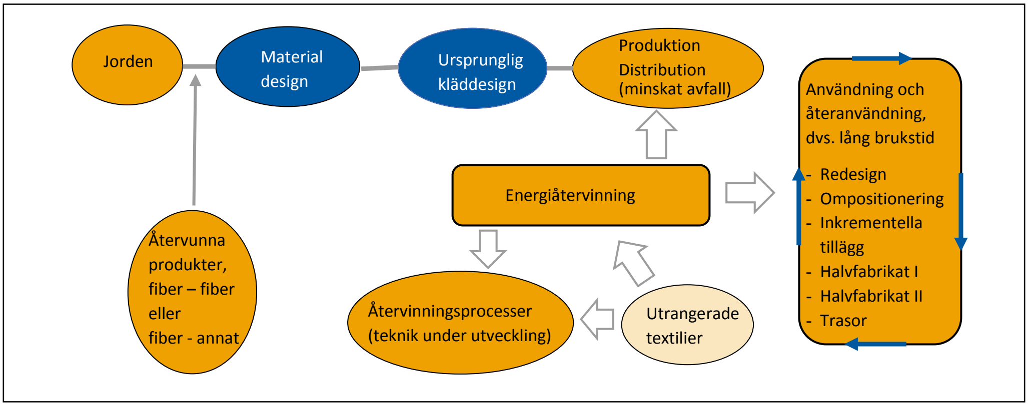
Conditional design

Designprocessen i dag drivs av villkor såsom estetik, funktionskrav, varumärkesidentitet, CSR-åtaganden, kostnadsoptimering etc. Följande villkor tillkommer för att ta hänsyn till cirkularitetskraven:

A. **Design for longevity (design för ett långt liv för produkterna)**
Alla kvalitetsaspekter, tidlöshet, design för re-design, inkrementalitet, etc.

B. **Design för recycling (fiber till fiber eller fiber till andra produkter)**
Så kallad upcycling eller downcycling till högre produktvärden.

Designens förmåga till syntes



Conditional design är ett begrepp som innebär att systematiskt definiera vilka designelement som är relevanta att tillämpa i designprocessen för båda ovanstående villkor, dvs. både **A** (lång brukstid) och **B** (återvinnbarhet). Följande frågor avser rapporten att besvara, med beaktande av att behålla eller öka produkternas attraktionskraft:

(Q1) Vilka är de explicita originaldesignvillkoren som syftar till reuse, redesign etc. för lång brukstid, "longevity?

(Q2) Vilka är de explicita designvillkoren som gör recycling praktiskt genomförbar?

(Q3) Vilka ekonomiska faktorer är avgörande för genomförbarhet (feasibility)?

(Q4) Vilka möjligheter finns för VGR att profilera sig på området och därigenom skapa synergier?

För att systematiskt analysera olika alternativ har följande designstrategier definierats.

Vilka är kraven på ursprunglig produktdesign för att få förutsättningar för återvinning av textilier?

A 100 % monomaterial	Hela plagget är tillverkat av ett monofibermaterial (t ex bomull) och accessoarer, som kan skiljas ut i den mekaniska återvinningsprocessen	Riktar sig till återvinningskrav (fiber till fiber)
Modulär	Plagget består av moduler, som är lätta att separera i en "re-"process. Varje modul är av monomaterial.	Riktar sig till både redesigns-, longevity- och återvinningskrav. Erfordrar separering av moduler.
C Inkrementell	Designen är gjord så att den kan uppdateras stegvis under plaggets livstid	En kombination av longevity och A eller B är optimal

Genom att tillämpa dessa strategier i designprocessen kan följande kritiska succéfaktorer avsevärt förbättras så att "feasibility" gradvis kan uppnås enligt följande:

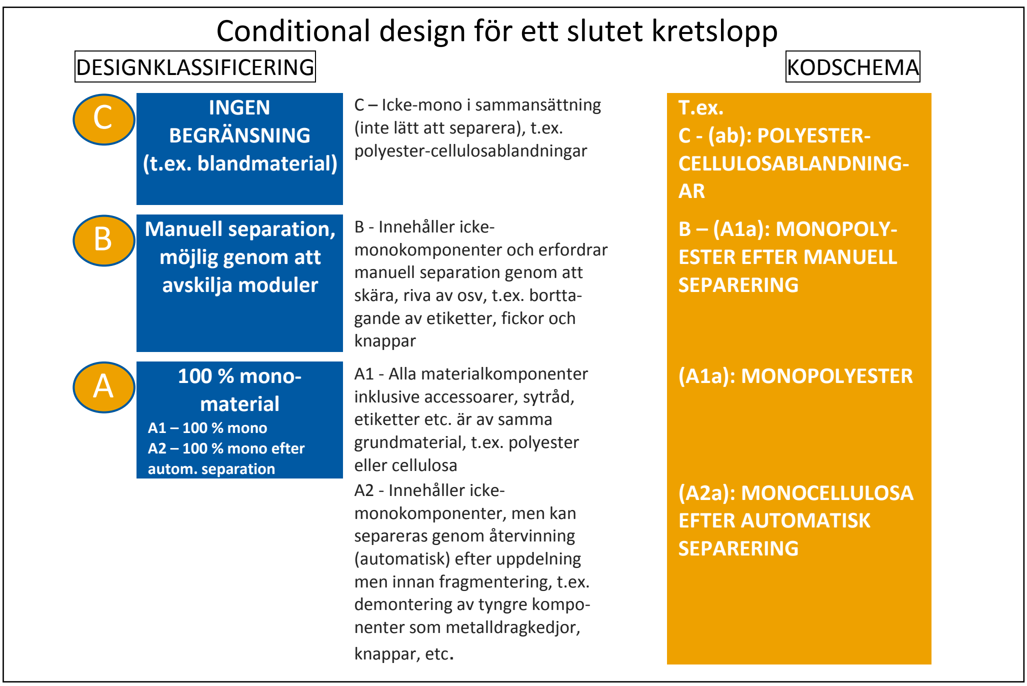
Lång brukstid:

– Kvalitetsprioritering i materialval
– Smarta konstruktioner (genomförbarhet i lokala produktionsprocesser)
– Moduluppbyggd design möjliggör både redesign och inkrementalitet (stegvis uppgradering) för värdeskapande under plaggets livslängd
– Utveckling av långvarig kundacceptans genom kreativa attraktiva designlösningar

Återvinnbarhet: I takt med att recyclingteknologin utvecklas kan följande förutsättningar för ekonomisk bärighet avsevärt förbättras:

– Högre utvinning (yield) ur avfallsfraktioner för avsedd recyclingprocess (monomaterial)
– Bättre volymer
– Lägre kostnader

Dessutom ger en systematik enligt dessa principer också förutsättningar för att skapa ett ramverk för en *produktklassificering,* avseende uppfyllda generella villkor för recyclingprocesser. Detta sker i designprocessen, där man har kontroll över alla ingående komponenter.



Genom att märka plaggen genom t.ex. RFID- eller DNA-teknik enligt dessa koder (kräver en standardiserad klassificeringskod) kan helautomatisk sortering av avfallsfraktioner uppnås. Dessutom torde en märkning av plagg som uppfyller recyclingkrav vara positivt från marknadsföringssynpunkt.

Ekonomisk bärighet

Eftersom det finns behov att skapa en modell, där flera re-processer kan prövas, har vi utvecklat en sådan. Den bygger på att ingående fraktion och dess kostnad, procent brukbart material, slutproduktens marknadspris samt restvärdet av övrigt ger utrymmet för processkostnader. Härigenom kan genomförbarheten (feasibility) bedömas. Självklart medger modellen möjlighet att variera ingående parametrar och därigenom testa vilka faktorer som behöver ändras för att uppnå ekonomisk bärighet.

Sammanfattningsvis kan sägas att gjorda beräkningar visar att det erfordras starkt förbättrade värden avseende t.ex. utvinningspotential (yield) resp. kostnader, speciellt för att uppnå bärighet i **recyclingprocesser.** *Denna förbättringspotential kan på ett avgörande sätt påverkas genom tillämpning av **conditional design.***

När det gäller möjligheterna för Re-projekt avseende **lång brukstid** (longevity) visar beräkningarna att det är lättare att uppnå ekonomisk bärighet och att designlösningar enligt ”conditional design-principer” kan få mycket positiva effekter. Optimala effekter uppnås genom en kombination av villkoren för **lång brukstid** och **återvinnbarhet.**

Marknad

Nästan alla svenska företag har anammat hållbarhet som ett bärande begrepp i sin företagspolicy. Man talar om recycling och cirkulära flöden, trots faktumet att recycling (eg. downcycling) idag utgör en mycket liten andel av konsumtionen (ca 5 %). Det har gjorts få studier som på djupet analyserar dagsläget för recycling. Nordiska ministerrådets rapport ”Gaining benefits from discarded textiles” är en av de få som på ett seriöst sätt kartlägger processerna och potentialerna. Genom att använda LCA-systematik har ett antal scenarier definierats och analyserats. Rapporten konstaterar också att recycling idag är huvudsakligen mekanisk och leder till downcyclade produkter av lägre kvalitet.

Slutsats: Med företagens engagemang för hållbara cirkulära flöden och den låga recyclingsnivån i nuläget bör det finnas stora möjligheter att vinna marknader förutsatt att verklig ”feasibility” kan uppnås. Dessutom kan en ökad medvetenhet hos konsumenterna verksamt skynda på utvecklingen.

Slutsatser från rapporten

Många av de föreslagna åtgärderna kan genomföras inom en relativt kort tidsram. De innefattar att tillämpa designprinciperna för val av monomaterial och modulär design och omrikta design av kläder till en process som pågår under produktens livslängd (dvs. inkrementell design).

Det är dock klart att det kommer att ta lång tid att forma conditional design-processer till en övergripande princip för stora volymer. Utvecklingen och genomförandet av dessa principer kommer inte desto mindre att ge effekt på skapande av nya innovativa produkter och att ta fram nya intressanta affärsmodeller, vilket resulterar i en växande sektor av små, lokala företag.

För Borås och Västra Götaland-regionen finns det många områden där regionen kan göra avgörande insatser i rörelsen mot en cirkulär ekonomi:

- Ett utbildningscentrum för Sverige och norra Europa för genomförande av designåtgärder för syntes i värdekedjor (alla utbildningsorgan, såsom HB, Proteko, Nordisk Designskola och oberoende utbildningsanordnare).

– Utveckling av media och kommunikation, som riktar sig till design för cirkularitet i konsumenternas medvetande och drar fördel av tidsfaktorn.
– Inrättande av en "DO TANK" för att förverkliga nya idéer inom området. Servicetjänster som inspirerande och förändrande faktor. Tvärdisciplinära åtgärder: textil - mode - inredning och arkitektur.
– Nytt blod i lokala företag; designkoncept som möjliggör nya produkter och nya affärsområden.
– I slutändan skapande av en ny progressiv "design för syntes"-miljö som drar uppmärksamhet till VGR och dess infrastruktur.
– Avknoppningar i lokala företag i fler branscher.

Rekommendation för vidare arbete

Kritiska framgångsfaktorer för design i förhållande till en cirkulär ekonomi:

1. Utbildning av designers i alla frågor som rör inverkan av design för att uppnå lång brukstid och cirkularitet. Designchefer drar också nytta av sådana kurser, som kan vara av värde för textil ledarskapsutbildning:

   a. Integration i designutbildning på designskolor på alla nivåer.
   b. Korta kurser som syftar till att erbjuda utbildning för designers redan i deras karriär.
   c. Att skriva en "designerbibel" för detta ändamål.

2. Utveckling av ett klassificeringssystem med hänvisning till designvillkor för cirkularitet. Det gör det möjligt att identifiera produkterna redan från designfasen. En ytterligare system för att identifiera produkterna i sorteringsfaser möjliggör automatisk sortering för bestämda återvinningsprocesser. Användningen av ID-systemet under designfaserna syftar till lång brukstid utan att det går ut över återvinnbarheten.

3. Vidareutveckling av sorteringssystem (automatiska).

4. Ytterligare FoU-verksamhet om återvinningsprocessers alla aspekter.

5. Vidareutveckling av inkrementella designlösningar och tillhörande affärsmodeller som syftar till lång brukstid.

6. Utveckling av en "DO TANK" i syfte att inspirera och utbilda designers att verkligen visa DESIGNENS KRAFT ATT SYNTETISERA, dvs. identifiera problem - lägga fram idéer - testa idéerna - förverkliga idéerna.

Summary of findings

The study highlights the following issues:

- Can the design/construction phase decisively influence the characteristics of the product, so that the prerequisites for circular, sustainable flows will be significantly improved?
- Which are then the key critical factors?
- What is the future for different scenarios?
- What is in that case a feasible way out for the concrete implementation of a strategy that positively affects the entire textile value chain?

Background and issues

The trend today moves steadily in one direction, which largely hinders the implementation of sustainable circular flows. This depends primarily on the following:

- Greatly increased consumption of textile products (from about 90 million tonnes in 2016 to 200-250 million tonnes in 2050)
- Greatly increased proportion of polyester (oil-based) in the produced products. This has accelerated significantly since the fast fashion ideology took off at the turn of the millennium. By 2030, the proportion of polyester is expected to be up to 70% of the total fibre production.
- Increased complexity of individual products as the garments are designed with multiple components (different textile materials, accessories, etc.)
- Chemicals volumes increase with increased production
- Energy consumption increases with increased production.

Our waste fractions will in the future be directly affected by the above factors.

If we do nothing

Continuing on the 'business as usual' basis means that we risk ending up in a situation of lack of resources and unstable world markets, which seriously challenge existing business models and additionally cause significant environmental problems in an industry that already ranks as one of those influencing most negatively. The options include the three best options, which can be affected in the design stage: 1) source reduction of waste. 2) re-use, 3) recycling and possible composting. Next, if none of the above is possible, the best option is 4) incineration with energy recovery.

To create a sustainable system for textile and clothing flows must therefore both 'close the loops' and slow down the pace of volume growth. This means products with better quality, **designed** for durability, that are serviceable, can be re-designed and re-used and at the end of their life recycled into new fibres or other products, and that are also appreciated by consumers, so they choose them before the traditional 'fast fashion' products, which do not meet the criteria.

How can design/construction dramatically affect the outcome and create conditions for a positive synthesis? In various studies was established that the design process is at more than 80% directly decisive.

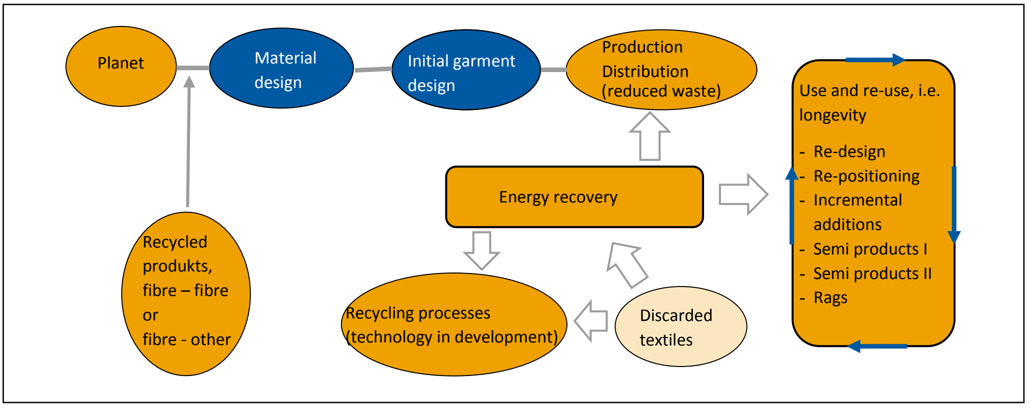
Conditional design

The design process today is driven by conditions such as aesthetics, functional requirements, brand identity, CSR commitments, cost optimization, etc. In addition, the following terms apply, in order to take the circularity requirements into account:

A. **Design for longevity**
All aspects of quality, timelessness, design for re-design, incrementality, etc.

B. **Design for recycling (fibre to fibre or fibre to other products)**
So-called up-cycling or down-cycling to higher product values.

Design's power to synthesize



Conditional design is a concept that involves defining systematically the design elements that are relevant to apply in the design process for both of the above conditions, i.e. both **A** (longevity) and **B** (recyclability). The report intends to answer the following issues, having also in mind to maintain or increase the attractiveness of the products:

(Q1) What are the explicit original design conditions aimed at re-use, re-design, etc. for longevity?
(Q2) What are the explicit design conditions that make recycling feasible?
(Q3) What economic factors are crucial for the feasibility?
(Q4) What opportunities are there for VGR to profile itself in the area and thus create synergies?

To systematically analyze the various options, the following design strategies were defined.

Which requirements must be set for the original product design to get favourable conditions for recovery of textiles?

A 100% Mono-material	The entire garment is made of a mono-fibre material (e.g. cotton) and trimmings, which can be separated in the mechanical recycling process	Addresses recycling requirements (fibre to fibre)
B Modular	The garment is made up by using modules, which are easily separable in a re- process. Each module is mono-material	Addresses both redesign (longevity) *and* recycling requirements. Requires separation of modules
C Incremental	The design is made so that it can be incrementally updated during the life of the garment	Combination of longevity and A or B is optimal

By applying these strategies in the design process, the following critical success factors can be greatly improved so that the feasibility will be gradually achieved as follows:

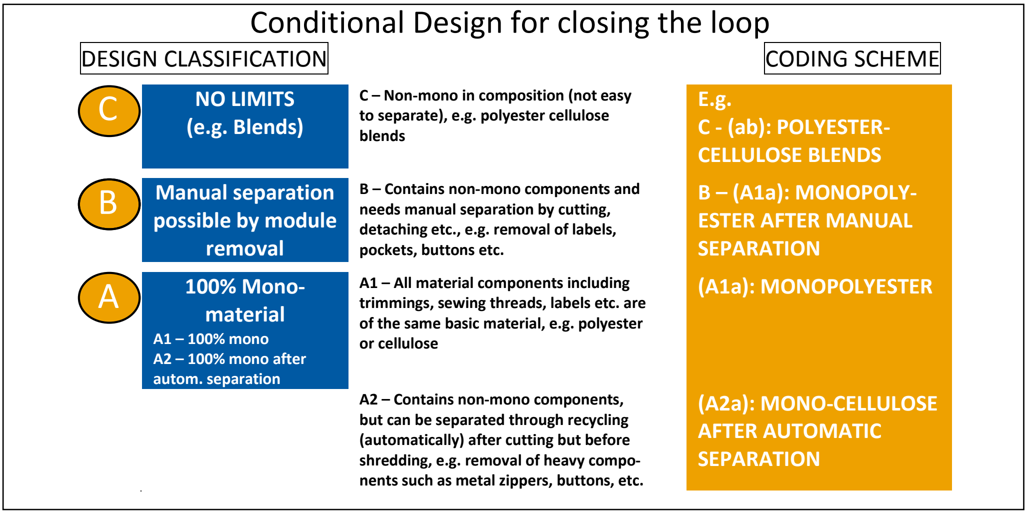
Longevity:

- **Give priority to quality in the selection of materials**
- **Intelligent design (feasibility of local production processes)**
- **Modular design allows for both re-design and incrementality (gradual upgrade) for value creation during the life of the garment**
- **Development of durable customer acceptance by creative attractive design solutions**

Recyclability: As the recycling technology develops, the following prerequisites for feasibility can be significantly improved:

- **Higher extraction (yield) of waste fractions for the intended recycling process (mono-materials)**
- **Better volumes**
- **Lower costs**

In addition, a systematic under these principles are also prerequisites for creating a framework for *product classification,* related to fulfilled general conditions for re-cycling processes. This is carried out in the design process, where all components are under control.



By marking the garments by e.g. RFID or DNA technology according to these codes (requires a standardized classification code), a fully automated waste fraction sorting can be achieved. In addition, a marking of garments that meet recycling requirements should be perceived positive from a marketing standpoint.

Feasibility

Since there is a need to create a model, where several re-processes can be tested, we have developed such a model. It is based on the input fraction and its cost, the percentage of usable material, the end product's market price, as well as the selling value of residues, which together provide the scope for processing costs. Thereby the feasibility can be assessed. Of course the model allows the option to vary the parameters and thereby test the factors that need to be changed to achieve economic feasibility.

In summary, the calculations indicate that considerably improved values are required, such as for the yield potential (yield) and costs, respectively, especially for achieving feasibility in **recycling processes.** *This potential for improvement can be decisively affected by the application of Conditional Design.*

As for the opportunities of 'Re'- projects for longevity, calculations show that it is easier to achieve feasibility, and design solutions according to Conditional Design principles can have very positive effects. Optimum effects are achieved through a combination of the conditions for longevity and recyclability.

Market

Almost all Swedish companies have embraced sustainability as a fundamental concept in their corporate policies. They talk about recycling and circular flows, despite the fact that recycling (down-cycling) today represents a very small share of the consumption (about 5%). There have been few studies that in depth analyze the current situation for recycling. Nordic Council of Ministers' report 'Gaining benefits from discarded textiles' is one of the few which seriously chart the processes and potentials. By using an LCA scheme a number of scenarios are defined and analyzed. The report also notes that recycling today are mainly mechanical and leads to down-cycled lower quality products.

Conclusion: With the companies' commitment to sustainable circular flows and the low re-cycling level at present, there should be ample opportunities to win markets, provided real feasibility can be achieved. In addition, an increased awareness among consumers can effectively accelerate progress.

Conclusions from the report

Many of the proposed actions can be carried through within a relatively short time frame. Those include applying the *design principles* of mono-material choices and modular design and redirecting the design of garments as a process that goes on during the life of the product (i.e. incremental design).

It is however clear that it will take considerable time to form the conditional design processes into a mainstream principle for large volumes. The development and implementation of those principles will nevertheless have the impact of creating new innovation products and create new interesting business models, resulting in a growing small and local industry sector.

For Borås and the VGR region there are numerous areas, where the region can be instrumental in the movement towards circularity:

– An educational centre for Sweden and N. Europe for the implementation of design actions for synthesizing in value chains (all educational bodies, such as HB, Proteko, Nordisk Designskola and independent educational providers).
– Development of media and communication addressing design for circularity in consumers' minds. Taking advantage of the time factor.
– The establishment of a "DO TANK" for realizing new ideas within the area. Service as an inspirational and realigning body. Cross-disciplinary action: textile – fashion – interior and architecture.
– New blood into local companies; design concepts enabling new products and new business areas.
– Ultimately creating a new progressive "design for synthesizing" environment that draws attention to VGR and its infrastructure.
– Spin offs in local companies in more businesses.

Recommendations for further actions

Critical success factors for design in relation to circularity:

1. Education of designers in all issues concerning the implications of design in achieving longevity and circularity. Further, design managers are also beneficiaries of such courses, which can be valuable for textile management education:

   a. Integration in design education at design schools of all levels.
   b. Short courses aiming to provide education for designers already in their careers.
   c. Writing a "designers bible" for this purpose.

2. Development of a classification system referring to design conditions for circularity. This enables the identification of the products, already from the design phase. An additional ID system for recognizing the products in sorting phases enables automatic sorting for specific recycling processes. Applicability of the ID system during the design phases aimed for longevity without compromising recyclability.

3. Further development of sorting (automatic) systems.

4. Further R&D activities in *all aspects of recycling processes.*

5. Further development of incremental design approaches and associated business models aiming at longevity.

6. Development of a "DO TANK" with the aim to inspire and educate designers to really demonstrate DESIGN'S POWER TO SYNTHESIZE, i.e. identify problems – come up with ideas – test the ideas – realize the ideas.

1. Introduction and methodology

1.1. Background and Motivation

Previous feasibility reports have focused on collecting and sorting used garments in Sweden for existing national and international markets considering existing technologies. The reports concluded that there is feasibility in all aspects of reusing garments, including redesign and developing new business models. On the other hand, it was concluded that recycling the used product towards a circular flow is not feasible, having existing technologies and economic factors in mind.

Feasibility in the context of this investigation refers to the leeway for process cost, when the costs of input material, yield and output price have been taken into consideration.

In order to radically improve the potentials, it became clear that one very important aspect is the design process. In those processes it is decided what components and consequently which production processes will be used in forming the final product.

In the apparel industry little consideration is given to the problems occurring in the recycling phase when the products are designed. In fact, the final products are "contaminated" both regarding material composition at all levels and the use of different chemical treatments. As result, enormous quantities of material and value are disposed of at the end of the global textile value chain, as highlighted in Figure 1.

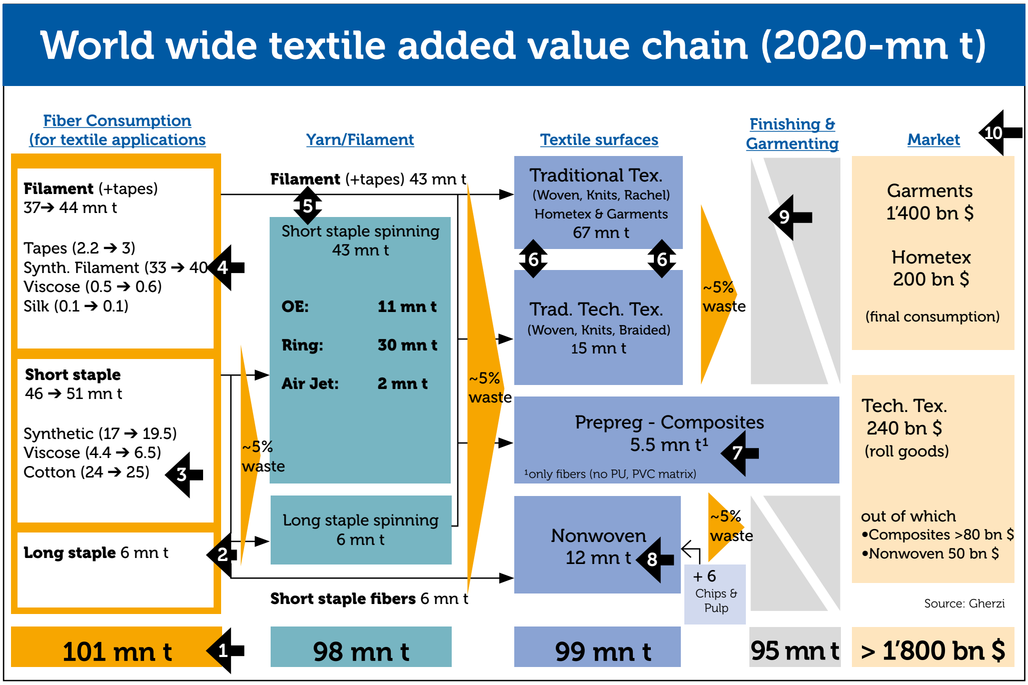


Figure 1. Forecast of global textile value chain volumes in 2020.[1]

This means that during the building up of value in the design and production of apparel products we also systematically reduce value of the product as a resource for recycling, i.e. we should consider the Reverse Value Chain. The motivation for measures in the direction of creating potentially high value end products from recycled materials is very important in order to reduce the value loss of the used garments. A higher value creates a basic foundation for profitable business and consequently economic growth, both for the VGR region and nationally.

Global production volumes for various fibres determine largely the proportional fibre content of trashed garments and garments to be recycled. Polyester is today the leading apparel fibre, followed by cotton and the other fibres. About 70 % of fibres produced in 2016 were synthetic, and their share grows in line with the overall fibre consumption, as the production volume of natural fibres is expected to stay the same.

[1] Gherzi, G. (2013). Opportunities within the textile value chain, ITMF Conference Report, Zurich

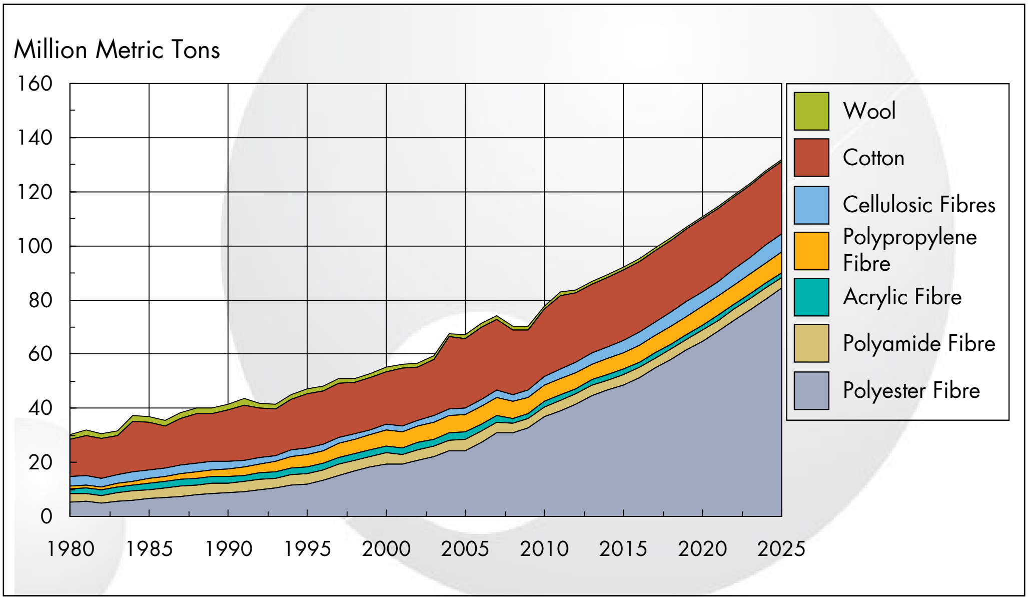


Figure 2. Forecast of global fibre production.[2]

In order to define the major effects the following structural issues are used in the report as conditional indicators:

- Less depletion of planetary resources concerning both raw materials and resources used for the production, such as water, and less harmful environmental impact, such as climate change and eutrophication.
- Increased economic and employment activities in the region
- Building up a knowledge base in order to strengthen the profile of Borås and the VGR region, including the University and Science Park of Borås.

1.2. Conditional Design Vision

The vision is to demonstrate the "design's power to synthesize" in order to go from fast fashion toward a world of true materiality, where we appreciate and cherish our limited resources and still can create business opportunities for innovative companies.

Conditional design aims to ensure a sustainable clothing supply by increased upcycling of used garments and fabrics. This calls for creative design and reshaping as well as appropriate facilities for collection, processing, storage, distribution and sale of such items. The vision comprises customer approval of the redesigned garments, the cooperation and support of the fashion industry, efficient 'reverse' logistics and attractive points of sale. Contributing factors are also a suitable classification system and a supportive cost-income structure.

[2] Yang Qin, M. Global Fibres Overview, Tecnon OrbiChem

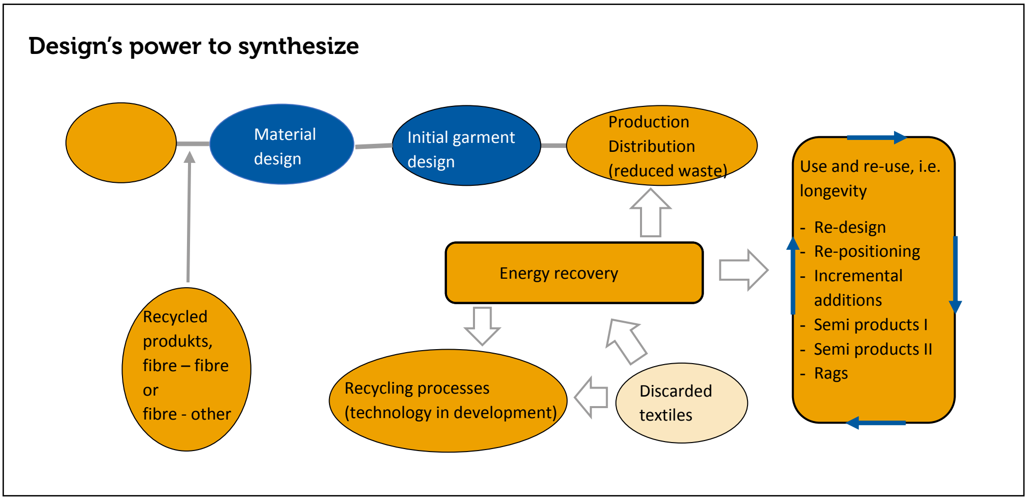


Figure 3. The key process.

1.3. Conditional Design Issues

This chapter deals with the structural "extra" design issues related to reaching more circularity in the textile flow.

Of course, each design process is already now driven by conditions such as:

– Aesthetics
– Functionality
– Consumer approval
– Brand policies
– CSR commitments
– Profitability

The additional design conditions related to re-design and circularity can thus be divided in two major groups:

A. **Aiming for longevity**

– all aspects of quality
– timelessness
– re-designability (incremental design)

A longer life of a product through good quality and attractive options to update the garment during its life mean less consumption of virgin products.

B. **Aiming for recyclability**

– Achieving more cycles through down-cycling or higher valued products through up-cycling.
– Achieving "full circularity", meaning an almost unlimited number of cycles. Either fibre to fibre or fibre to something else.

A systematic approach to define the main design elements that are relevant to both A (longevity) and B (recyclability)

In order to define the design issues that we work with in this study, we established three strategies, as visualized in Figure 4.

A 100%* Mono-material	The entire garment is made of a mono-fibre material (e.g. cotton) and trimmings, which can be separated in the mechanical recycling process	Addresses recycling requirements (fibre to fibre)
B Modular	The garment is made up by using modules, which are easily separable in a re- process. Each module is mono-material	Addresses both redesign (longevity) *and* recycling requirements. Requires separation of modules
C Incremental	The design is made so that it can be incrementally updated during the life of the garment	Combination of longevity and A or B is optimal

Figure 4. Conditional design strategies.
** Mono-materials shall comply with e.g. GRS (Global Recycling Standards). See section 4.3*

1.4. Objectives and Methodology

The aim of this feasibility study is to define what kind of design thinking strategies are required to obtain circular businesses in longevity and recycling of textiles. Furthermore, the study focuses on the role of various types of materials (mono-material, modular materials, incremental materials) in the recycling processes and how they are connected to the design processes for obtaining circular economy, as highlighted in the model in Figure 5.

The main objective of this study is to understand how mono/modular design affects the feasibility of circularity. What are the cost and price of technical innovation in the processes and what is the yield achieved for the consecutive process phases? In order to answer the main research question, the study seeks answers to the following sub-questions:

(Q1) Which are the original design conditions for achieving redesign capability for longevity, in order to extend the active life of a garment and replace a new purchase with a redesign?
(Q2) Which are the general conditions for achieving high value recycling options, ranging from traditional down-cycling to up-cycling, with focus on high value products?
(Q3) What are the economical and practical potentials of such applications, when observing existing and near-future technologies?
(Q4) What are the potential resources available in VGR for establishing such value chains?

An exploratory approach is selected for this research, which is also illustrated by examples and demonstrators. Theoretical analyses, primarily based on literature and references, use a qualitative approach to design a hypothetical model. Empirical case studies and company interviews are carried out to produce an experimental model for quantifying the findings and results. However, as highlighted earlier, this is a feasibility study rather than a comprehensive scientific research, and this paper does not attempt to present a complete and scientifically proven model for circular textile economy.

A hypothetical model is presented in Figure 5. The aim of the empirical part, described in the Appendix to this report, is to test this model with participating business partners and, as result, to specify various activities and to quantify the flows proportionately and financially.

FUTURE DESIGN STRATEGIES	CIRCULAR STRATEGIES IN VALUE CHAINS		EMPIRICAL CASES (SEE APPENDIX)
	REUSING FOR LONGEVITY (Slowing the loop)	RECYCLING (Closing the loop)	
A 100% Mono-material	MAINTAIN DESIGN CLASSIFICATION IF REDESIGNED	BEST	Houdini green jacket
B Modular	MAINTAIN DESIGN CLASSIFICATION IF REDESIGNED	GOOD (Needs easy separation techniques and apt product design)	Icebreaker woolen T-shirt (possibility to modularize by removing logo) Houdini black pullover, Houdini corduroy trousers (possibility to modularize the pocket attachments)
C Incremental (blends)	Optimal	Combine with A or B	Our Legacy jeans – new style by flipping the pockets (pockets attached with microwave dissolvable sewing threads) Klattermusen loops for attaching pockets

Figure 5. Strategies for design and applications

2. Design for longevity

According to WRAP, the Waste and Resources Action Programme, designing clothing for longevity provides the "...single largest opportunity to reduce the carbon, water and waste footprints of the clothing in the UK"[3]. Frequently the emphasis for WRAP and others is on the impact that designers can make; the decisions made during design are known to potentially lengthen the lifetime of a garment during use. Claxton et al. (2015)[4] highlight that the target lifetime for clothing in many cases may be extended from 3 to 5 years if longevity factors were incorporated during design.

There are several aspects to design for longevity. According to Laitala et al. (2015)[5] design for longevity means that production teams need to consider the development of garments in relation to their empathetic and aesthetic qualities, which consumers require alongside effective physical and technical attributes. In maximizing longevity it is acknowledged that

[3] WRAP (2013) 'Design for longevity: Guidance on increasing the active life of clothing', Banbury, UK: WRAP. Available online
[4] Claxton, S., Cooper, T., Hill, H. & Holbrook, K. (2015), Opportunities and challenges of new product development and testing for longevity in clothing, In PLATE conference proceedings, Nottingham, UK, 17-19 June.
[5] Laitala, K., Boks, C., & Klepp, I.G. (2015) Making clothing last: A design approach for reducing the environmental impacts. International Journal of Design, 9 (2), pp. 93-107

durability needs to be considered in terms of both its physical and empathetic qualities. If poor quality materials and inexpensive construction processes are employed, then the physical durability of a garment is compromised.

Apart from considering design for durability for ensuring physical and technical robustness of the garment – by taking care of the initial material quality, its structural stability, pilling and wash fastness properties, design for longevity should take into account both emotional qualities that garments can provide, and also designing supporting services and systems[6].

Notably these areas include:
- Supporting consumers through communication and after sales services,
- Consideration of the role of design and production teams in considering aesthetic design including colours and styles, or addressing size and fit concerns.

Apart from that, there has been in the recent years an increase in interest to explore novel garment design "strategies" and approaches to extend the longevity of garments[7]. This goes beyond the typical approaches adopted so far to reduce waste focused on slowing consumption by offering higher garment quality, timeless design or co-creation methods. Instead these design-led approaches aim at exploring the notion that fashion designers and consumers can visualize fashion garments as *living products,* which are designed to evolve, transform and grow for a long life. Such novel design-led approaches underpin, among other principles/methods, modularity and incremental garment design/construction, and intends to synthesize a change towards garment longevity.

In light of the growth of a circular economy the challenge facing the fashion industry is how to adapt the existing product design and development model and explore a fashion system where other, so that more diverse design approaches can prosper.

In this study we concentrate on the "power of synthesis" of two such novel garment design-led approaches (modular design and incremental design) (cf. Figure 4).

Together with highlights of the key processes and basic design principles underpinning these design-led approaches, the experimental work also specifies how and where they contribute in achieving the aims of designing in a circular economy. The "power" of these novel-design led approaches is measured in terms of the opportunities for improving redesignability of the garment.

2.1. Description of foreseen products

Through various design for longevity-led approaches it is possible to address the aesthetic value required for fashion garments and to develop products that transcend fashion seasons. The exemplar cases below are representatives of foreseen products designed, based on such design-led approaches, but must not be considered exhaustive in its list.

[6] Laitala, K., Boks, C., & Klepp, I.G. (2015) Making clothing last: A design approach for reducing the environmental impacts. International Journal of Design, 9 (2), pp. 93-107
[7] Gwilt, A. (2014). A practical guide to sustainable fashion. London: Bloomsbury Publishing.

Garments can be developed to be *Multifunctional or Transformable.* For wearers these products can be an attractive choice, since they are seen as individual, timeless or unique pieces that can be personalized. The level of connection between the wearer and a multifunctional garment can vary, and this is because of the ways in which engagement is encouraged. For example a transformable garment can be worn differently, which provides the wearer with two or three products in one.

a. Garments could be such that they may purposefully change with age, becoming different and more engaging through use.
b. Garments can be developed to be detachable or completely modular that can be biodegradable or disposable. For wearers this eliminates the necessity for washing and also creates a possibility for designers to transform the original properties during the use cycle.

2.2. Basic garment design and construction delimitations (conditional design principles)

Although designing for longevity can be achieved in many ways, it is a combination of the design-led approaches that helps extend the lifetime of a garment. Using appropriate and considered materials and construction techniques in the manufacture of the garment plays an important contribution in enhancing durability through use. We, in this study, categorized these approaches into two primary design conditions.

1. Modular garment design

Modular garment design refers to the development of a range of detachable features for use with fashion garments that can facilitate replacement, repair or even adaptation, by creating novel attachment system. Such modularity can be devised in the method of construction by making the garment components (sleeves, front and back panels, collars and cuffs, etc.) (de) -attachable either manually or via automatic separation technologies. More creative forms of modularization can be achieved by making the garment ornamentation, prints and colour modular, i.e. can be easily separated from the garment. Advanced technologies, such as laser-cutting, ultrasonic bonding, 3D printing etc. can be used to enable such garment modularity.

2. Incremental garment design

Incremental design in terms of designing for longevity stands for designers to consider the key attributes – or micro design elements: garment form; garment proportion and silhouette; garment details; color; fabric; ornamentation and print; themed references; and genres in fashion[8] – involved in garment design gets incrementally updated leading to garment life extension.

Here it could be suggested that in terms of design for longevity it is important to reflect on the key attributes in terms of the contribution to extending the lifetime of the garment.

[8] Seivewright, S. (2007) Basics Fashion Design: Research And Design. Lausanne: AVA Publishing SA.

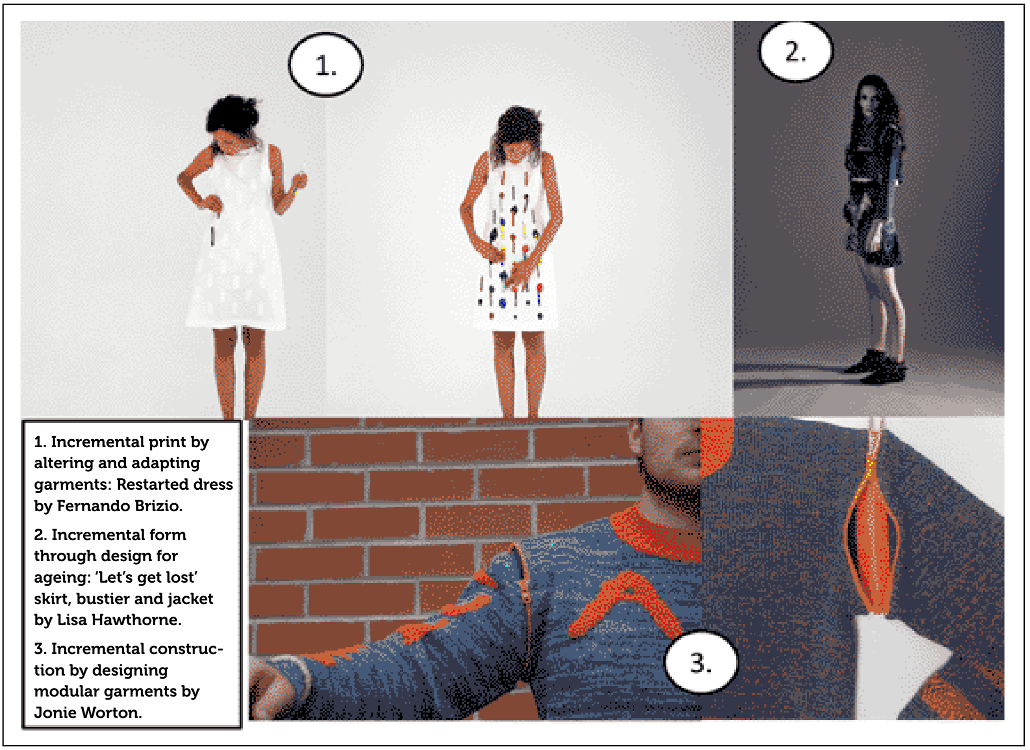


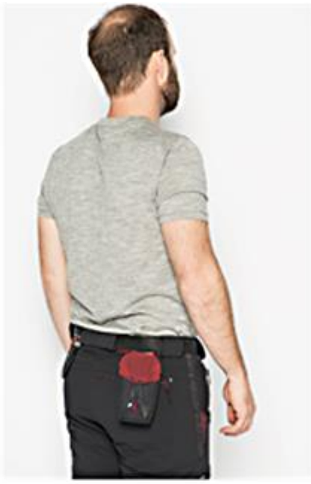
Figure 6. Incremental design exemplified. Footnote[9] details the incrementalism in the three cases.

[9] 1. Portuguese designer, Fernando Brizio's renewable dress incorporates small pen-shaped pockets, which hold uncapped marker pens that release water-soluble ink and stain the garment. The temporary colourful pattern can be removed by washing.
2. Graduate student Lisa Hawthorne (at Chelsea College of Art and Design) has developed a range of textiles that are designed to reveal embellishment details as the garment ages. As the natural fabrics wear, the embellishments that are buried in the fabrics begin to appear.
3. Bob and John's interchangeable knitwear. Designer here wants wearers to interact and connect with their garments by choosing sleeves to suit different contexts.

Modular

Modular design, or modular construction, is a design strategy that subdivides a system into smaller parts, modules that are created independently and then can be used in different systems. This modular garment is made from scarves from Lindex.

Incremental



These pants from Klättermusen (Mithril) are designed for longevity and functionality. Their functionality can be changed by attaching and de-attaching pockets and gear-loops of different kinds. In this way it also fits under the category modular.

Monomaterial

This outfit from Houdini has been assembled with monomateriality in focus. The jacket achieves classification A1 from the coding scheme; the sweater can with few alterations be classified as A2 and the pants are classified as A2.

Figure 7. Examples of modular, incremental and mono-material design.

Item	Classification	Highest possible classification	Cost implications	
			BOM	Production
1. Houdini C9 jacket (Green jacket)	A2. Polartec® Alpha Insulation, 100% polyester. Teijin C9 ripstop, 100% recycled polyester. Zipper: Polyester ribbons with metal closer.	A1. Zipper closing mechanism needs to be made of metal	No changes	No changes
2. Houdini Wooler Hoodie (Black sweater)	B. 100% mulesing-free merino wool, Wooler GridMerino 17.5 microns. Zipper: Polyester ribbons with metal closer. Pocket liners: Polyester	A2. Zipper closing mechanism needs to be made of metal. Zipper: Wear2 assembly technology	Wear2thread	Same production time, more expensive thread
3. Houdini Commute Pant (Blue trousers)	A2. 100% polyester, Bluesign certified, 282 g/m^2	A1.	Wear2thread	Same production time, more expensive thread

Figure 8. Details of Houdini's mono-material and modular design

Garment form, proportion, silhouette and details

The garment form and silhouette, or the more subtle design details should all be deserving particular attention when designing for longevity. Products can be altered into a secondary design, for example through simple or complex transformative processes, which can then be reversed to return to its original form[10].

Garment color, ornamentation, print and construction

The construction methods applied may include the use of inlays (e.g. excess fabric in seam allowances) to enable the wearer to adapt, alter or repair the garment in a later stage. Another way is that at the design stage garments can be developed to make use of deflective devices such as intentional stains, rips, tears and holes, which provide the fashion designer with the opportunity to develop clothes that embrace future damage, leaving it untouched and unnoticed[11], e.g. Levi 501 jeans in the 1980s[12]. Alternatively garments may be designed and manufactured using appropriate and considered materials and construction techniques that make an important contribution in enhancing durability through use, or provide scope for value-added redesign processes at a later stage.

3. Design for recyclability

The Conditional Design approach has a considerable impact on the main factors that are a prerequisite to achieve feasibility in the recycling processes. The most important factors are related to

– enough gross volumes in the fractions sorted to recycling
– high yield of the fibre content that is aimed for the anticipated recycling process
– low cost for the fractions

All these factors can be positively impacted by integrating the mono-materiality and modularity and applying separation technologies already in the design phase.

In this chapter we deal only with post-consumer waste.

3.1. Description of foreseen products

Recycling of textiles is conducive to production of a large assortment of products, some of which have been referred to in Table 1 below, viz. fibres and yarn, felt and non-woven materials, insulation, wipers, etc. Increasingly recycled fibres are being used in new garments, denim products, shoes etc. Primarily cotton and polyester are recycled to produce yarn, but also wool, nylon and other materials are recycled for this purpose. Cotton and other natural fibres may be regenerated into viscose or Lyocell fibres. Due to the technology used, recycling is commonly categorized as mechanical recycling or chemical recycling.
There are now brands of recycled material, as described below. Recycled materials are to a substantial extent also used in high-quality clothing from well-known manufacturers and brands (H&M, Patagonia, Levi Strauss, Adidas etc.[13].

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10 Quinn, B. (2002) Techno Fashion. Oxford: Berg
11 Gwilt, A. (2014) A Practical Guide to Sustainable Fashion. London: Fairchild
12 Wilson, E. & Taylor, L (1989). Through the looking glass. London: BBC books
13 Leonas, K.K. (2017). The Use of Recycled Fibers in Fashion and Home Products. In S.S. Muthu (ed.), Textile and Clothing Sustainability, Springer, Singapore

3.1.1. Mechanical recycling

In the mechanical recycling process the discarded textile is opened up, trimmings etc. are removed and apparel is disassembled. The process then continues with cutting into smaller pieces and repeated shredding processes until the desired fibre content is achieved. This content has characteristics, such as fibre length, strength, polymer and colour, and determines the quality that will be appropriate for the new anticipated product. The technology for mechanical recycling is well established and offers possibilities for relatively moderate investments. All three success factors mentioned in the introduction above can be positively impacting the results.

The "High-Graded Fibres" obtained can be respun into yarns used in fabrics for apparel, bed linens, upholstery and interior textiles.

"Medium and Low Grade Fibres" is commonly used in products like filters, acoustic products, composites/FRP, automotive interior, furniture padding, roofing felts, carpet backings, blankets, horticultural products, etc. There are numerous companies in this field, representing both what is considered as down-cycling and more examples in the category described as upcycling.

Typical examples of mechanical "high grade" recycled material is represented by a.o.

- Martex Fiber and their company Jimtex Yarns use reclaimed cotton products to make their ECO2Cotton®.
- EcoAlf. They are an apparel brand for eco-products that use both mechanically recycled cotton and wool and also chemically recycled polyester from mainly plastic bottles and fishing nets.

3.1.2. Chemical recycling

Most recycling programmes in this category deal with polyester from plastic bottles and other plastic materials, such as fishing nets, and other plastic waste (e.g. Adidas campaign "For the Oceans). However, there are some interesting projects going on to recycle discarded post-consumer textiles using chemical methods. Some of these are described in chapter 7.2.

Examples of companies dealing within this category:

- Unifi: REPREVE is a brand of recycled polyester fibres mostly from post-consumer waste.
- Teijin: ECO CIRCLE™ is a polyester fibre produced from recycled polyester products in a closed loop.
- Aquafil ECONYL®: Nylon 6 fibres are produced both from pre- and post-consumer waste.
- re:newcell, Sweden: Textiles with a high cellulosic content is transformed into recycled dissolving pulp ("re:newcell pulp"), which can then be used for the production of viscose, Lyocell etc.
- The Infinited Fiber Company: In a new process developed by the VTT Technical Research Centre of Finland they anticipate to produce, in 2018, 50 tons of new cellulose fibres recycled from cotton.

3.2. Basic design and construction delimitations (conditional design principles)

For processing the material in recycling a number of conditions must be met. There are general logistical constraints, for example that sufficient quantities of input material must be collected and managed to justify the investment in recycling facilities. We focus here on the delimitations and constraints of conditional design for recycling.

Materials should preferably be of a mono-fibre type, viz. the different parts of a garment, including trimmings, sewing thread, labels etc., are made of the same material, be it cotton, polyester or other alternatives. The next best option is to use easily separable components, which allow for automated separation. This comprises fabric of separable layers, metal buttons and zippers etc. The two cases are classified as A1 and A2, respectively, as proposed in this report.

The third option is to use materials that can be separated manually, by cutting and tearing labels, buttons, zippers etc. off. This is represented by proposed class B in this report.

The fourth alternative, class C, comprises material blends and intricately composite designs. In some cases separation is possible by, primarily, chemical methods. Several research efforts are directed at separating cotton and polyester chemically into mono-material components for recycling,[14] and also eliminating spandex contents from nylon/polyamide in a chemical dissolving process. To a minor extent mechanical processing by garneting may yield usable material out of composites, provided the properties of the composite are conducive for it.

It is essential that compliance with the relevant standards (cf. section 4.3 below) also for recycling, such as GOTS, the Global Organic Textile Standard and GRS, the Global Recycled Standard, is considered in the planning and design phase, in order to facilitate efficient and credible recycling in a later phase of the life of the textile product.

4. General processes required

4.1. Current secondary supply chains for apparel products

For post-consumer apparel, recycling options focus on recovery and conversion of the textile materials themselves. Ancillary items, such as buttons, zips and metal or plastic adornments are removed early in the process[15]. Figure 9 illustrates the current secondary supply chain for apparel products.

[14] E.g. Peterson, A. (2015), Towards Recycling of Textile Fibers - Separation and Characterization of Textile Fibers and Blends, Chalmers, Gothenburg

[15] Options for recycling (Morley et al, 2014)

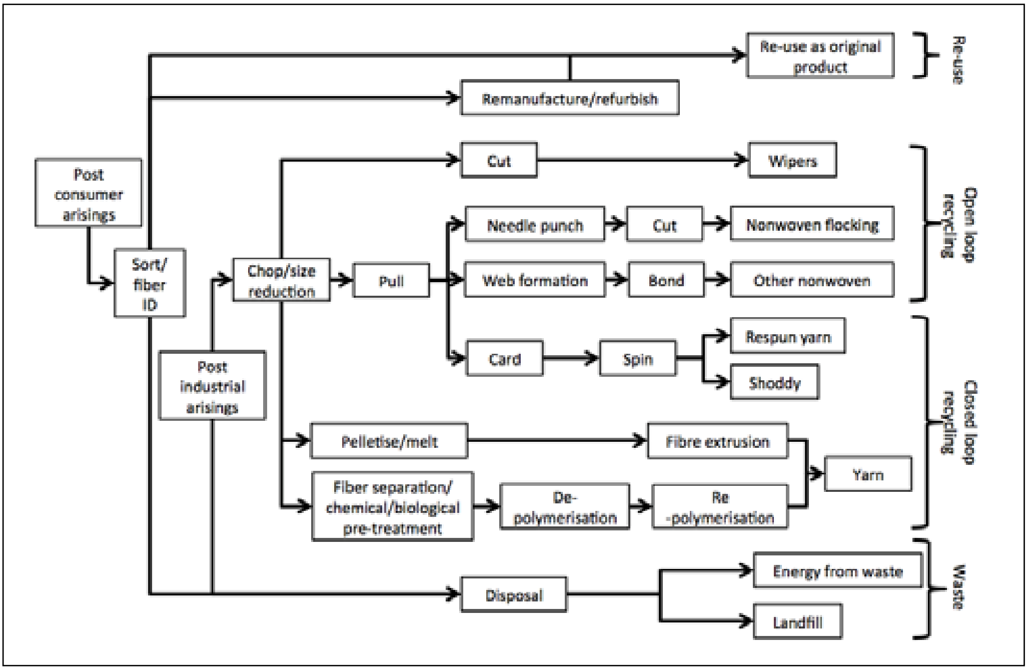


Figure 9. Current secondary supply chain for apparel products [16]

4.2. Reverse logistics considerations

Reverse logistics denotes the logistics processes aimed at recreating value of a product after its primary end of use, thus comprising returns management and flows of material for reuse, redesign and recycling. Reverse logistics is often described or defined as 'the process of planning, implementing and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value, or proper disposal' (Rogers & Tibben-Lembke, 1998)[17], although a point of recovery may replace the point of origin.

Reverse logistics processes should not have its starting point at the recycling stage, as they are to a large extent a result of product and service decisions taken at the design and planning stage of the product and service concept (Bernon and Cullen, 2007). This is a parallel to the observation that 'design for redesign' is essential for efficient treatment of textiles for a second period of use.

For textiles the usual recovery situations (de Brito & Dekker, 2002)[18] in reverse logistics apply, viz.

– product recovery (products may be recycled directly into the original market or into a secondary market, or repaired and sent back to the user under conditions of warranty),

[16] Morley, N., Parker, D., Slater, S., Symington, H. & R. Waugh, (2014), Apparel and Footwear Recycling Innovation, Investigation and validation of potential apparel and footwear recycling projects for the Sustainable Apparel Coalition, 26 sept 2014, Oakdene Hollins, UK, ref: SAC09 384.docx
[17] Rogers D.S. and R.S. Tibben-Lembke (1998) Going Backwards: Reverse Logistics Trends and Practices, Reverse Logistics Executive Council, USA.
[18] de Brito, M.P. and R. Dekker (2002), Reverse Logistics – a framework, Econometric Institute Report EI 2002-38, Erasmus University Rotterdam

– component recovery (products are dismantled and parts can be re-manufactured into the same kind of product or different products),
– material recovery (materials are recuperated and recycled into raw materials), energy recovery (incineration).

Thus in the scope of this report, reverse logistics is essential for the network design. It can be noted that product recovery applies to the re-use and re-design loops, both for mono-material and multi-material garments. Component recovery requires automatic separation, which can apply to metal components, zippers etc., i.e. design code A2, or manual separation, such as cutting off trimmings, pockets etc., giving the material design code B. Material recovery applies to the recycling loop, straight-forward for material of design code A1, while code A2 and B are feasible after separation. Design code C implies in practice garments of two or more inseparable materials, making energy recovery in many cases the only reasonably feasible option.

4.3. Standards for recycling

For many reasons, such as consistency, product communication, certification or safety, it is advisable to comply with standards. Several standards relevant for textiles in a recycling or redesign chain are provided by Textile Exchange, a global nonprofit organization with the aim to assist textile industry in sustainability matters. Relevant Textile Exchange standards[19] comprise the Content Claim Standard (CCS) providing means to track materials through the supply chain, ensuring accurate content claims, the Organic Content Standard (OCS) and the Global Recycled Standard (GRS), which use CCS to track material in the supply chain (certified organic and recycled input material, respectively, and the Recycled Claim Standard (RCS), which also uses CCS to track recycled material through the supply chain and verifies recycled input material.

The Global Recycled Standard[20] is an international standard, which also sets requirements for third-party certification of recycled content, chain of custody, social and environmental practices and chemical restrictions. The objectives of the GRS are described as 'to define requirements to ensure accurate content claims, good working conditions, and that harmful environmental and chemical impacts are minimized'. GRS is based upon requirements of the Global Organic Textile Standard (GOTS)[21], the international textile processing standard for organic fibres, which includes ecological and social criteria. It classifies the material at three levels: gold standard – products contain 95% to 100% recycled material, silver standard – products contain 70% to 95% recycled product, and bronze standard – products have at least 30% recycled content. The tracking and tracing feature of the standard ensures that the contents description is correct.

[19] TE Standard Setting and Revision Procedures, rev. Dec 14, 2016. Available at http://textileexchange.org/wp-content/uploads/2016/01/TE-Standard-Setting-Principles-and-Procedures-2016.pdf (accessed 23 Jan. 2017)
[20] Global Recycled Standard, v3 August 5, 2014. Available at http://textileexchange.org/wp-content/uploads/2016/01/Global-Recycled-Standard-v3.pdf (accessed 23 Jan. 2017)
[21] Global Organic Textile Standard (GOTS), Version 4.0, 1 March 2014, Global Organic Textile Standard International Working Group (IWG). Available at http://www.global-standard.org/images/GOTS_Version4-01 March2014.pdf (accessed 23 Jan. 2017)
[4] https://higg.org

Also the GRI standards can be worth mentioning. The Global Reporting Initiative issues standards for the reporting of sustainability achievements. Thus while not addressing textile recycling specifically, the GRI Standards 'create a common language for organizations and stakeholders, with which the economic, environmental, and social impacts of organizations can be communicated and understood'[22]. The reporting standard for materials[23] is essential in the present context, as it sets out e.g. how to inform about the percentage of recycled and reclaimed products in products sold. The GRI standards are available via the website www.globalreporting.org/standards.

Also the manifold textile standards issued by the International Organization for Standardization (ISO) and its Technical Committee TC 38[24] are useful in certain situations in the reverse chain. Most of them address chemical and other test methods.

4.4. The Higg index

The Higg Index is a self-assessment tool for evaluating the social and environmental sustainability impact from apparel, footwear and textile value chains. In this context it is therefore also a significant design tool. It is widely adopted and currently represents 40 percent of the world volumes of such products. The modules in the Higg Index are

- Brand module
  - Social and labour,
  - Environmental
- Facilities module
  - Social and labour
  - Environmental
- Product module
- Material Sustainability Index

Figure 10 illustrates scores from the Higg index where 100 points on the x-axis indicates no unnecessary environmental impact. That is, the company's operations regarding environmental sustainability impact are on par with the Brundtland commission's definition of sustainability: *Sustainable development requires meeting the basic needs of all and extending to all the opportunity to satisfy their aspirations for a better life*[25]. Score 0 indicates that the company have yet to start measure their environmental sustainability impact and take action towards reduced environmental impact.

For the purpose of framing end product recyclability into an accepted framework and to increase the chances of result scalability, the most relevant modules and indicators in the Environmental Brand Module from the Higg Index have been used[26]. The most relevant module for the Re-textile project is the Brand Environmental Module and specifically Care and Repair and End of Use Indicators.

[22] GRI 101: FOUNDATION 2016, GRI,Amsterdam
[23] GRI 301: MATERIALS 2016, GRI,Amsterdam
[24] Standards catalogue, www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_tc_browse.htm?commid=48148
[25] http://www.un-documents.net/ocf-02.htm#I
[26] Higg.org

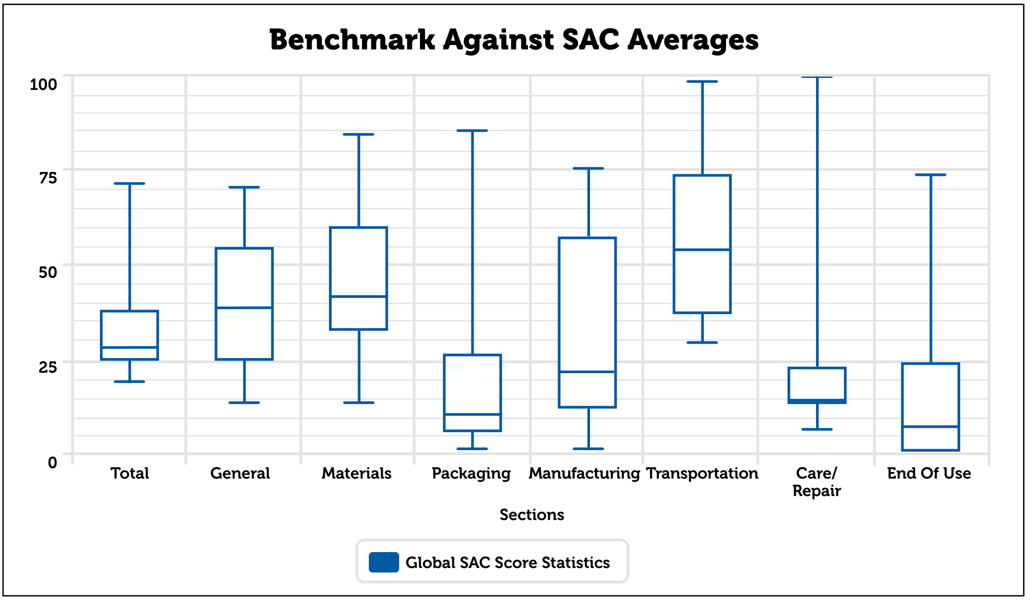


Figure 10. Environmental sustainability impact, Brand Module, Higg Index

4.5. Case study: Results from the Re:denim project

Re:denim is a collaboration between Re:textile and Lindex AB. The purpose of the Re:denim project is to remanufacture dead-stock from Lindex AB into commercial items, figure 11. Even though the re:demin project has focus on remanufacturing and not on conditional design, a few conclusions can be drawn that are applicable in a conditional design context.

Figur 11. Inspiration, jeans to be remade and design suggestions for one of the models in the Re:denim-project.

4.5.1. Applicability of results from redesign to conditional design

When a new logic is introduced into a system it comes with several challenges. In this particular case, challenges primarily concern the structure of the organization and of the system surrounding it. The current system is built on the conventional linear system and is not prepared for circular flows. In the Re:denim project a few key areas for improvement have been identified:

1. Organizational learning process and required competence: The general level of knowledge about how to create circular systems in general, and to remanufacture garments in particular is low. If a company wants to implement a circular model it needs to establish processes that support learning and employee development. Usually, the issue is not that companies do not want to design for circularity but that there structures in the system that hinders them to do that. For example, in buyer driven organisations, like many of the major retail chains are, the sustainability team need to sell their message to both the buyers and the customers. One of the conclusions regarding organisational skills is that if an organisation wants to move towards circular flows, the entire organisation needs to be on board. Here are three examples of tools that can help companies to create a framework for circular thinking.

– Higg Index in which the Design and Development module includes circularity[27].
– Tedten –a toolbox for sustainable design considerations[28]
– Circular Design Guide – A general tool for circular design[29]

2. Design process: Lindex is, as many other companies within the apparel- and textile industry, a buyer driven organization, which operates a branded retail chain with a full price production model. Design processes in such organizations are relatively fast, typically the designers produce sketches or illustrations of garments that are sent to the suppliers or production offices, who make up the garments through a sample and counter sample process. This process allows for limited influence from the designer and product developer on the final product regarding material, bonding technology and accessories. Also, the producing companies have limited possibilities to choose materials that are adapted to circular flows. At the 2016 autumn Premiere Vision, which is one of the larger fabric fairs in Europe, there were very few suppliers that promoted a circular option of fabrics.

3. Production processes: In the case study, the original garments are manufactured in a typical mass production setting, often in the far-east but also in Turkey and Europe. Manufacturing prices can be kept low because of large volumes and efficient production. These garments are then remanufactured in Sweden in a non mass-production setting. If the brand expects the same mark-up on the remanufactured garment as from the original, the retail price of the remanufactured product will be significantly higher. Maybe so high that the original brand cannot fit it into their value proposition but needs to establish a second brand. Similarly, consideration regarding a brand's value proposition needs to be taken into account, when garments with incremental properties are designed.

4.5.2. Relevant Higg indicator

USE-B-2.1: Brand has design standards in place to provide guidance/incentives for design considerations to maximize product features that are repairable and upgradable (e.g., replacement buckles, zipper pulls, components, and accessories). Since products are inherently repairable, it is important for brands to have a policy in place that encourages a design for repairable features where applicable. This indicator is about the company having design poli-

[27] http://apparelcoalition.org/product-tools/
[28] http://www.tedresearch.net/teds-ten-aims/
[29] http://circulardesignguide.com/methods

cies or standards that encourage designers to utilize repairable components where possible. Rissanen and Gwilt (2011) detail methods for this.[30]

5. Benefits for society/companies/environment

Benefits of recycling to the society and the environment are clear in the long run. Materials are re-used, energy saved and environmental conditions are enhanced. Apparel companies may find recycling a new and exciting area which contributes to their brand image. Feasibility of apparel recycling, however, seems to be doubtful to the organizations and companies involved in the recycling process, at least with the current technologies and business models. One of the solutions could be conditional design, as discussed throughout this report. Besides making apparel recycling economically feasible, it would create new business opportunities to the recycling industry, and pave the way to circular economy.

Systems and technology are needed for making textile recycling possible, together with various players interested in organizing after-use recovery, sorting and defibrating. However, without consumers interested in returning the used products, recycling will never be possible. Statutory means, financial rewards and social responsibility may be considered as means for motivating consumers.

As a foundation regarding conditional design benefits for society and environment, we have in this report used the United Nations Sustainability Goals (table 1) as a framework. The goals where the project may have direct and indirect impact in line with the goals will be discussed.

[30] Alison Gwilt, Timo Rissanen (2011) Shaping Sustainable Fashion: Changing the Way we Make and Use Clothes, Routledge

Sustainable Development Goals	Direct impact	Indirect impact	Negligible impact
Goal 1. End poverty in all its forms everywhere			x
Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture			x
Goal 3. Ensure healthy lives and promote well-being for all at all ages			x
Goal 4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all			x
Goal 5. Achieve gender equality and empower all women and girls			x
Goal 6. Ensure availability and sustainable management of water and sanitation for all			x
Goal 7 Ensure access to affordable, reliable, sustainable and modern energy for all			x
Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	x		
Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	x		
Goal 10. Reduce inequality within and among countries			x
Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable			x
Goal 12. Ensure sustainable consumption and production patterns	x		
Goal 13. Take urgent action to combat climate change and its impacts		x	
Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development		x	

Table 1. UN sustainability goals[31]

5.1. Statutory means

The principal competent authority in Sweden regarding waste and recycling is the Swedish Environmental Protection Agency (SNV). Producer responsibility legislation in the field has already been imposed in Sweden (with the Swedish Board of Agriculture as competent authority, from 2019 transferred to SNV) for enabling recycling of, a.o., PET bottles and metal cans, containing different kind of beverages[32]. Packaging must be included in an approved recycling system before the products can be marketed. The firms marketing beverages need to join the existing recycling system Returpack or may also set up a system of their own, subject to approval by the governing authority. The regulations have detailed specifications regarding EAN codes, labelling etc.

Importers and producers included in an approved recycling system must pay an annual fee of SEK 10 000. Those not participating may have to pay annual fees up to SEK 50 000.[33] Single stores receiving the beverage containers do not pay a fee.

SNV now works on similar legal measures to be imposed for making recycling of garments possible, to some extent based on the Nordic policy documents and reports on the prevention of textile waste, including proposals about extended producer responsibility, tax on

[31] http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E
[32] Förordning (2014:1073) om producentansvar för förpackningar, Svensk författningssamling 2014:1073
[33] The Swedish Board of Agriculture, http://www.jordbruksverket.se/swedishboardofagriculture/engelskasidor/trade/petbottlesandmetalcans.4.584a812513a8740bea18000916.html

hazardous chemicals in textiles and certification of recycling[34], of which the two latter were not carried on by SNV. Measures were proposed to the government in November 2016[35], including the following:

- Support to the Swedish textile and fashion sector for the development of sustainable business models.
- Measures to facilitate recovery of textiles from the public sector.
- Relevant information to consumers.
- Mandatory separation of textile waste.
- Producer responsibility.

There were also a number of measures considered but rejected for the proposal, such as extended requirements for the sector's sustainability reporting, mandatory sale of second-hand products, strengthened support for research and development, new taxes on CO2 emission and on textiles, and to prohibit incineration.

5.2. Financial reward

A synthesis by conditional design of the textile (reverse) value chain will bring business opportunities to committed enterprises. The prices of dissolving pulp and polyester chips produced by the recycling process need be competitive with virgin production. With the current process this is not the case, as to be demonstrated by a financial model later in this report. Most apparel products today are made of blended fabrics (primarily cotton and polyester) together with different accessories, which increases the cost of handling and lowers yields throughout the process. Conditional design, however, can change this and create a financial reward to the recycling companies.

The consumer is an integral part of the circular economy. Like with plastic bottles and metal cans, a deposit fee paid to the consumer can also be applied. The fee is part of the sales price of the garment, paid back when the product is returned.

Example case: Re:sneaker

From discussions in different workshops throughout the Re:textiles project, one of the more motivating options for companies is the possibility to charge customers another round of money for upgrades to products during the products' life-cycle.

Figure 12 illustrates an example of incremental design, where a pair of white sneakers can be updated using a digital printer. Different prints may be added to a shoe, as long as the material in the shoe contains 50 percent or more cotton fibres. The foundation of this concept has been tested during "Kretsloppsveckan 2016 in Borås" in September, and it has been used in workshops with students at the Swedish School of Textiles and industry during the autumn of 2016. Remarkably, students and participants in workshops were willing to pay up to 700 SEK for an upgrade to a sneaker, if the print has a clear sender (artist/brand etc) and 250 SEK if it was just an unbranded print.

[34] Watson, D. and N. Kiørboe (2015), EPR systems and new business models: - reuse and recycling of textiles in the Nordic region, Nordic Council of Ministers, ANP 2015:721, Copenhagen
[35] Förslag om hantering av textilier – Redovisning av regeringsuppdrag, NV-06147-14, Naturvårdsverket

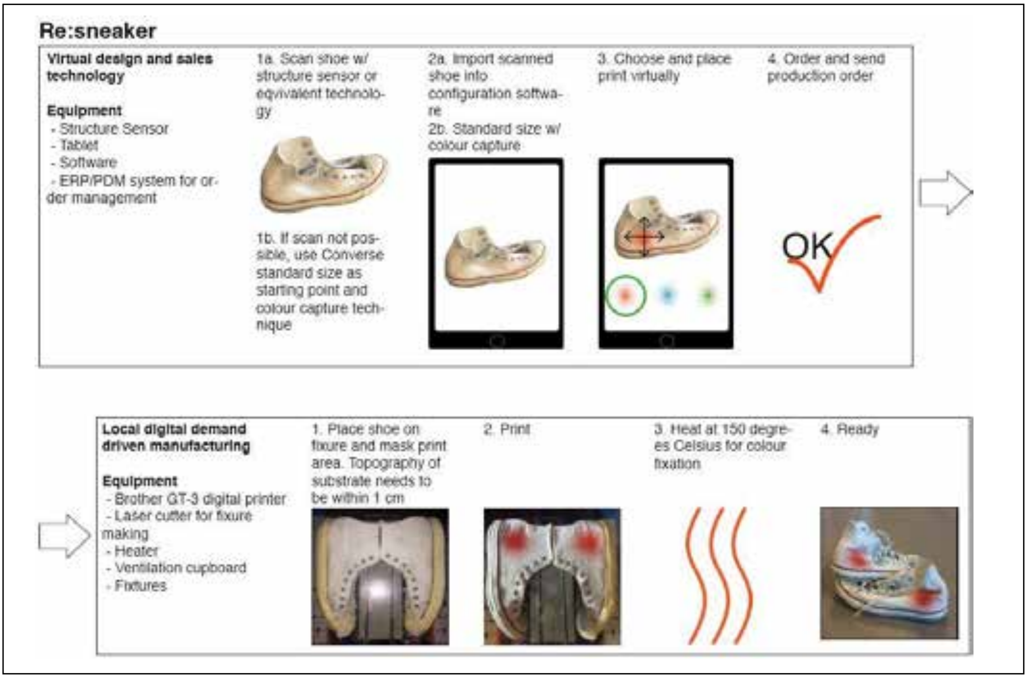


Figure 12. Re:sneaker

5.3. Social gratification

Besides financial reward, social gratification can also be used for motivating consumers. Social and environmental responsibility issues are well known and the general feeling of responsibility is quite strong among consumers. This can be further enhanced through publicity and campaigns, and it supports goal number 12 of the UN sustainability goals. . The re:sneaker (figure 12) concept with incremental upgrades is beneficial from a societal point of view, since it produces income to workers at the place of manufacturing and at the place where the upgrade takes place. Such dynamics helps to support the development of UN sustainability goal no 8, no 9 and no 12 (table 1).

Garment brands as well as retail brands can capitalize on the concept of social gratification. Recyclable collections can be marketed with social and environmental values and this in turn can be used for brand building. Patagonia is an US outerwear company with strong environmental and social values connected to their brand. They urge the consumers to return all Patagonia products after the end of their useful life to them by post or by dropping them at one of their stores. There is no reward to the consumer, but as they say in their web site *'you'll gain the satisfaction of knowing that your old Patagonia clothing will not end up in a landfill or an incinerator'.*[36]

[36] http://www.patagonia.com/recycling.html

5.4. Environmental effects

The foundation of conditional design is to propose and evaluate methods to enable increased recycling rates of textile fibres. If increased recycling rates can be achieved it has opportunities for reduced environmental impact in the for the garment sector measurable impact areas: climate change, eutrophication, abiotic resource depletion (fossil fuels), water resource depletion, and chemistry[37], these correspond well with the planetary boundaries[38 39].

As mentioned earlier, the re:sneaker case helps to directly support the UN sustainability goals no, 8, 9 and 12. The objectives of the project include to identify methods for better design that increases circularity in apparel and fashion value chain, to help decrease the outtake of natural resources and to make more money from reused/regenerated fibres. The Sustainable Apparel Coalition has detailed the environmental impact from textile fabrics in relation to the planetary boundaries (Table 2), this will be used to discuss the environmental benefits from the re-textiles project.

Impact category	LCIA method	Unit	Reference
Climate Change	IPCC 2013 GWP 100a v1.02	kg CO eq	Intergovernmental Panel on Climate Change. 2013. IPCC Fifth Assessment Report. The Physical Science Basis. http//www.ipcc.ch/report/ar5/wg1
Eutrophication	CML-IA baseline version v3.03	kg P04-eq	Center of Environmental Science of Leiden Universsity (CML). 2013. CML-IA Baseline. http://cml.leiden.edu/software/data-cmlia.html
Abiotic resource depletion, fossil fuels	CML 2013 v4.2	MJ	Center of Environmental Science of Leiden Universsity (CML). 2013. CML-IA Baseline. http://cml.leiden.edu/software/data-cmlia.html
Water resource depletion/Scarcity	WSI Pfister et al. 2009 v1.01	m3	Pfister S., Koehler A., & Hellweg S,. (2009). Assessing the Environmental Impacts of Freshwater Consumption in LCA *Environmental Science Technology*. 43 (11), pp 4098–4104
Chemistry	N/A - qualitative questions	Points	SAC Chemicals Assessment Team, 2016.

Table 2. Environmental Impact Areas, Higg Index Material Sustainability Index[40]

The project has reduced negative impact in the five areas (Table 2) but depending on the chosen method for incremental design the benefits for the environment will differ. The re-sneaker concept will for example likely be beneficial to the environment in four out of the five impact areas with a question mark on the "Chemistry" impact area. Because even though the dye stuff used is GOTS-certified, the finishing of the product requires heating, which releases fumes that need to be taken care of. In more general contexts conditional design would decrease environmental impact in all areas.

6. Benefits for Sweden as a leading enabler

Sweden is considered a leading enabler in environmental protection and policy, according to OECD[41]. In the referred report it is noted that Sweden is among the most innovative OECD countries, in the field of environment-related technology, and has pioneered several policy instruments, many based on the principle of putting a price on environmentally harmful activities. One recommendation is to use tax instruments to curb environmentally harmful activities, like previously for carbon emission, landfill or congestion, and on the other hand focus

[37] http://msi.higg.org/uploads/msi.higg.org/sac_textpage_section_files/13/file/MSI_Methodology_11-15-16.pdf
[38] http://www.ecologyandsociety.org/vol14/iss2/art32/main.html
[39] http://www.nature.com/nature/journal/v461/n7263/full/461472a.html
[40] Higg Materials Sustainability Index (MSI) Methodology, 15 Nov 2016, product@apparelcoalition.org
[41] OECD Environmental Performance Reviews: Sweden 2014

support to industries that need to develop their environmental innovation activities. It is also recommended to enhance the environmental performance of small and medium-sized enterprises with incentives and decision support. Textiles are not addressed specifically in the report, but for instance the Swedish strategy for a non-toxic environment would pertain to textiles[42]. It is noted that the removal of the incineration tax 2010 increased the demand for waste for incineration to a level where much is imported, which does not promote recycling. There are subsidies that are potentially adverse to environmental objectives, primarily in energy, transport, agriculture and fishing.

There is thus a need for Sweden to further develop technology and innovation in order to meet its environmental objectives and remain a leading player in environmental policy, including the reduction of textile and clothing waste. Legislative measures can of course support this in combination with voluntary initiatives, e.g. regarding producer responsibility.

7. Technology considerations

7.1. Design and manufacturing

The design principles according to Section 1.3 (Figure 4) enable means for development of a "classification system", where the aim is to provide the conditions for design and the ability to enhance the conditions for automatic sorting (for re-purposes). The framework consists of three principal elements, as presented in sections 7.1.1-7.1.3 below.

7.1.1. Design classification

The classification structure enables the creation of a systematic identification system that allows for automatic or semi-automatic sorting.

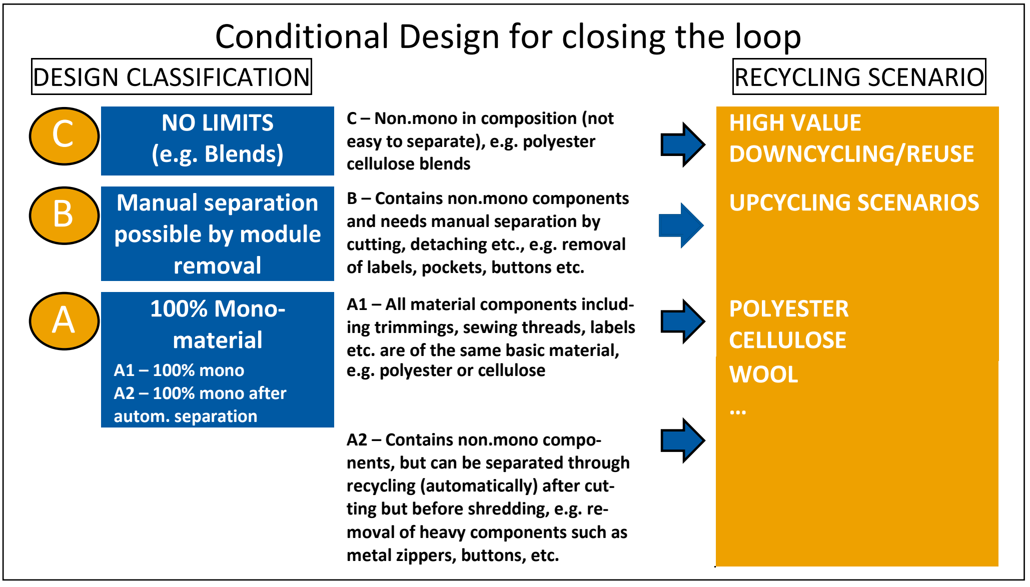


Figure 13. Classification for conditional design.

[42] Prop 2013/14:39

7.1.2. The aspect of ID technology for coding development

A Coding in the production processes (i.e. already from the design phases), using RFID, cryptographic tracking tags, etc.

For example A1a

- No harmful chemical, e.g. OEKOTEX certified
- Polyester
- 100% mono-fibre

B By classification in the sorting process (to the same codes).

	RFDs	Magnetic Tags	Data Matrix / XXXX	Logos	Holograms	Ideal Tag
Visibility	Covert	Covert/overt	Overt	Overt	Overt	Overt
Digital Identity	Yes	Yes	Yes	No	No	Yes
Integration in Textiles	Yes	No	No	Yes	No	Yes
Protection against copy	Weak	Weak	Weak	Weak	Strong	Strong
Mass Manufacturing	Easy	Easy	Very Easy	Easy	Easy	Easy
Unauthorized Reproduction	Easy	Easy	Very Easy	Easy	Fairly Difficult	Difficult/ no reproduction

Blue: Disadvantage Green: Advantage

Figure 14. A comparison of the different possible ID technologies that can be used.

7.1.3. Sorting systematics

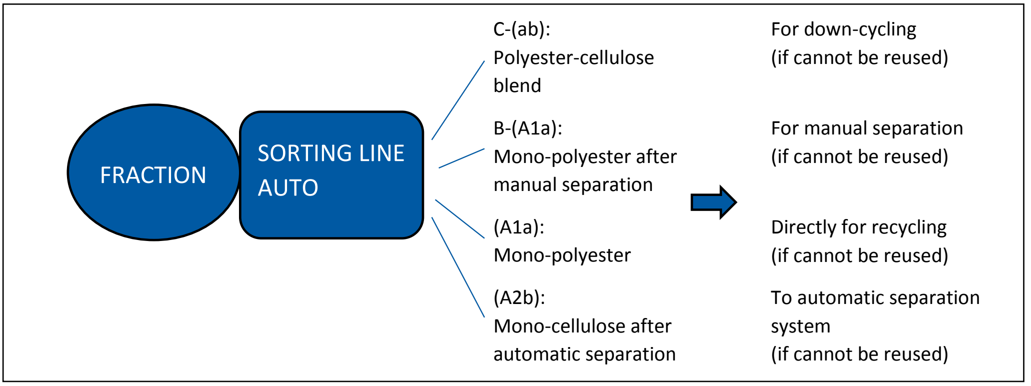


Figure 15. Sorting systematics.

Important technologies, which enable easy separation of modules and thus provide for both redesign, incremental design and separation for mono-material recycling, are critical for cost effective solutions. Such technologies are shown in the enclosed demonstrations and include also, e.g., the "wear to microwave" system for the dissolving of seams.

7.2. Separation and recycling technologies

An important aspect in the recycling process is the removal of e.g. buttons, zippers, metal parts and plastics from the raw material. By the use of a special "U"-shape or nail beat roller, these kinds of waste are broken and shredded. There will be 95% heavy waste, like buttons, zippers, metal and high density plastics, that will drop out during this process. The other 5% will be removed by a strong magnet in the transport pipe. Light waste, like glue and plastics, which have been broken and shredded, will be sucked out from the raw material by wind power of fans. It is worth mentioning that there is wastage during this production process, taking more spare parts is sensible[43].

Progress in chemical separation of especially cotton and polyester has also been made (e.g. Deakin University in Australia), using ionic salt liquid.

Other examples of technology development projects are demonstrated in table 3 below.

[43] hopermachinery.com

From textile to textile			
Input material	**Process**	**Output**	**Status**
100% polyester garments from Teijin	Chemical recycling (depolymerization)	Polyester fibres/yarn	Teijin produces several tonnes/year
100% cotton fabric	Tearing to fibres	Short fibres; can be blended into virgin material (max 15-20%)	E.g. H&M and G-Star produce several garments/year
Wool and wool blends	Tearing to fibres	'Shoddy' for non-woven, felt etc.	E.g. Oxfam and J Cotton Nonwovens produce at a small scale
100% cotton fabric	Chemical recycling (dissolving cellulose)	Viscose, Lyocell, Ioncell fibres	Re:newcell, Lenzing. Aalto/VTT and Swerea IVF have test and demo facilities
Input material	**Process**	**Output**	**Status**
100% Nylon 6 material, fishing nets, rugs, industrial residues etc	Chemical recycling (depolymerization)	Nylon 6 fibres/yarn	Econyl produces several tonnes/year
100% Nylon 6,6 industrial residues	Remelting	Nylon 6,6 fibres/yarn	Fulgar produces several tonnes/year
100% PET bottles and other food packagings, industrial residues	Remelting	Polyester fibres	Large scale production
From textile to various			
Input material	**Process**	**Output**	**Status**
Mixed textile waste	Tearing to rags	Industrial wipers (disposable)	Large scale production
Mixed textile waste	Tearing to fibres	Insulation, composites, etc.	Large scale production
Mixed textile waste	Energy recovery	Electricity, heating	Large scale production

Table 3[44]. A summary of textile recycling techniques.

8. Markets and marketing (characteristics/conditions)

8.1. Target markets

The branded companies drive the global textile and apparel value chain. They design their products and select materials, while garment manufacturing is normally located in low cost countries. Knitted and woven fabrics, as well as accessories, are produced by material suppliers, which often are separate from garment manufacturing, except for knitwear. The fabric producers present their fabric collections to the brand companies. The larger brands may request that materials are produced according to their specifications, while smaller players purchase from the fabric collection offered to them.

In order to comply with the mono-material requirements, the brand company designing the garment needs to ensure that the shell fabric, lining, ribs, zippers, button, labels, etc. are made of the same material, for example polyester, and select materials accordingly.

Swedish consumers purchase 132 000 ton of new textiles annually, out of which 103 000 tons (78 %) is disposed and at the end incinerated. Almost all of these products are imported, often from outside Europe sources. China is the main source for clothing made both of knitted and woven fabrics imported to Sweden. Out of the separately collected used textiles of 29 000 tons, only 7 500 tons are currently reused in Sweden.[45]

[44] Roos, S., 2016. Livscykelanalys (LCA) och kemikalier i textil, Mistra Future Fashion presentation 8 Nov. 2016, Swerea IVF, Mölndal.
[45] Schmidt, A, et al, Gaining benefits from discarded textiles, Norden 2016

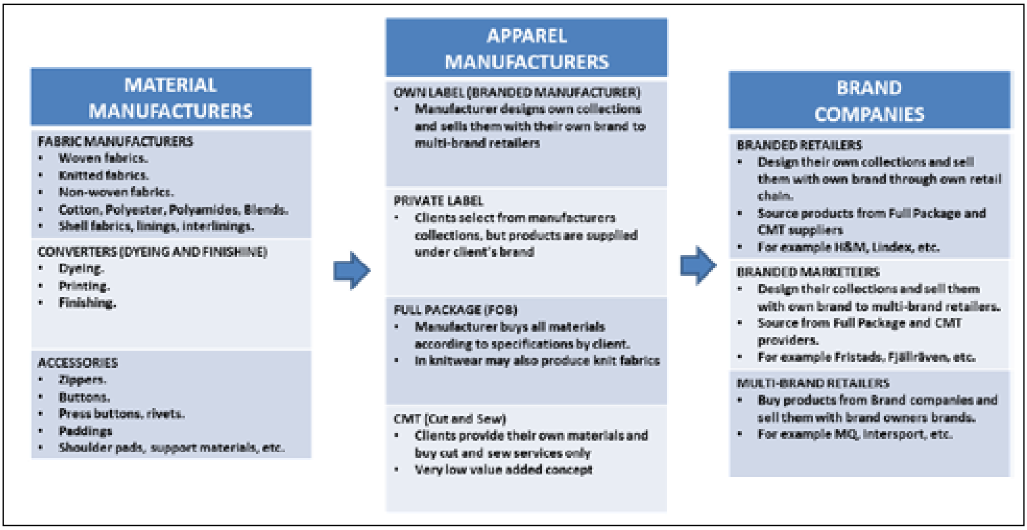


Figure 16. Players in the global fashion supply chain.

The Swedish fashion companies operate globally. The domestic consumption was SEK 98 billion in 2015, while exports was SEK 207 billion. According to interview of main Swedish fashion companies by Volante, the most important export markets today are Norway, Finland, Germany and Denmark[46], i.e. Northern Europe, where consumers in general value sustainability. These would also be the main markets for recycled fashion products.

According to the European Man-Made Fibres Association 22,8 % of global textile fibre consumption was cotton and 69,4 % synthetics in 2015, while Norden's 'Gaining benefits from discarded textiles' report says that 57 % of all fibres used in the Nordic countries are cotton.

8.2. State of the art, competition

All major Swedish fashion brands emphasize sustainability. Many speak about recycling and circular economy, despite the fact that recycling is still such a small part of the total consumption. H&M say in their 2015 annual report that they collected garments for reuse 7 684 tonnes in 2014 and 12 341 tonnes in 2015. In Sustainability report 2015 of IKEA they say that *'rather than saying goodbye to used or waste materials, we are adopting circular economy thinking into the way we work'.* Several of the smaller brands share these statements.

However, very few in-depth scientific studies have been made on the recycling possibilities of textiles. Norden's 'Gaining benefits from discarded textiles'[47] is among the few which seriously map the processes and potential. By using a life cycle assessment approach different scenarios for treating discarded textiles were produced. The report concludes that textile recycling today is mostly mechanical, leading to down-cycling to lower quality products.

[46] Sternö, J. Nielsén T. Modebranschen i Sverige – Statistik och analys 2016, Vonte Research 2016
[47] Schmidt, A., D. Watson, S. Roos, C. Askham and P. B. Poulsen (2016). Gaining benefits from discarded textiles, TemaNord 2016:537, Nordic Council of Ministers, Copenhagen

8.3. Consumer acceptance

Several studies have been made on consumer acceptance of second hand clothing concluding that in the industrialized countries this is a small niche market. Consumers' attitudes on apparel recycling through defibrating within a circular economy have been less studied. Several indicators, however, demonstrate that environmental issues, sustainability and social accountability are growing concerns among apparel companies and the consumers. The business world, in this case apparel companies, are very good in monitoring the preferences and needs of consumers.

The following companies have had success stories and drawn a lot of attention based on the concept of consumer acceptance towards apparel recycling:

- Patagonia Re///Collection: Has gained a lot of attention in media and consumers and positive response[48, 49, 50]
- Houdini Rental Service: Recycled or reused Houdini garments are sold at Houdini brand retailers and have gained sufficient acceptance amongst customers, to the point where some customers do not bother about the new stock.[51]. Houdini recently opened up their rental service online[52].
- Beyond Retro: Well accepted among customers, but struggling with profitability in Sweden.[53, 54]

Perceptions on the life of garments – how long are garments expected to last?

Consumer expectations and market needs differ greatly, but as long as a garment retains its function during use consumers are generally, unconcerned with the product lasting for longer than is required[55]. Simultaneously design decisions can confuse consumers because they confront preconceived ideas about price and brand, where the durability of a garment is seen to correlate with a high price and brand[56]. To complicate the picture further evidence has shown that products considered poor in their design, quality or construction may be in use for long periods of time, but as noted by Laitala et al.[57] this does not provide an "…excuse for producing poor quality clothing." Rather the point here is that while design can play a part in delaying the disposal of garments a greater success is achieved if consumer behaviour is understood and acknowledged. To designers there is then a significant opportunity; to not only extend the physical life of garments but also to change the perceptions and expectations that consumers have towards clothing lifetimes.

48 https://www.wired.com/2016/11/patagonia-recycled/
49 http://www.highsnobiety.com/2016/11/04/patagonia-recollection-made-from-recycled-materials/
50 http://blog.gessato.com/2016/11/04/patagonias-recollection-redefines-the-standards-of-eco-friendly-clothing/
51 http://houdinisportswear.com/en/sustainability/second-hand
52 http://houdinisportswear.com/en/sustainability/houdini-rental
53 http://www.beyondretro.com/sv/
54 http://www.allabolag.se/5566844477/the-fashion-archive-ab
55 Cox, J., Griffith, S., Giorgi, S., & King, G. (2013). Consumer understanding of product lifetimes. *Resources, Conservation and Recycling,* 79, 21-29.
56 Gwilt, A., Leaver, J., Fisher, M., & Young, G. (2015) Understanding the caring practices of users. In PLATE conference proceedings, Nottingham, UK, 17-19 June.
57 Laitala, K., Boks, C., & Klepp, I.G. (2015) Making clothing last: A design approach for reducing the environmental impacts. International Journal of Design, 9 (2), pp. 93-107

8.4. New business models

This study explores the potential of circular textile businesses with special focus on conditional design, as highlighted in Figure 17.

The system parts in the model facilitate a recovery of fibres from used textiles and in turn reduce the need of new fibres, as follows:

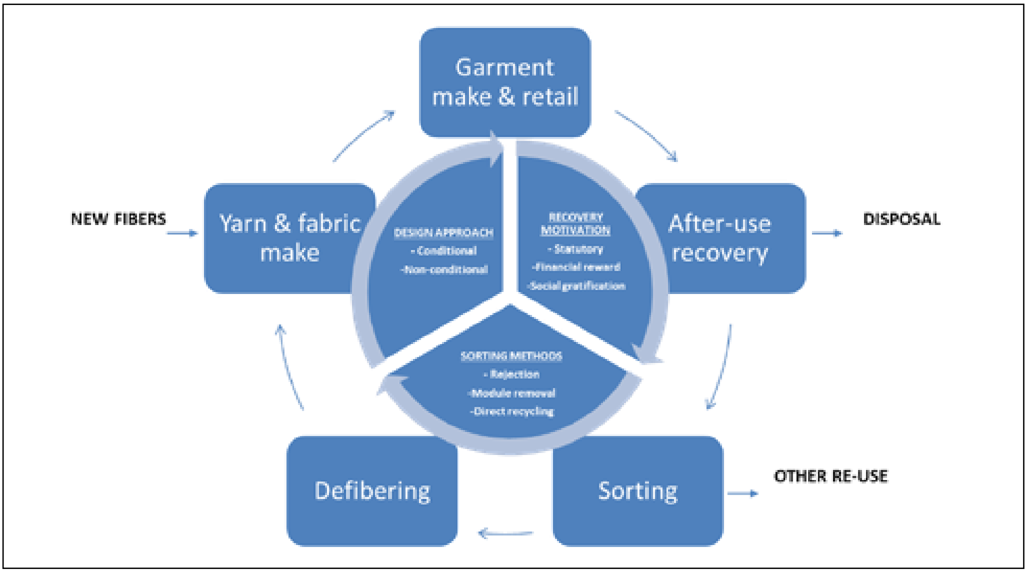


Figure 17. Model for circular textile business with special focus on conditional design

8.4.1. Garment design

The aim of conditional design is to use recyclable materials, preferably mono-materials, complying with the global recycling standards. For example, if polyester is chosen, 100 % polyester yarns are used for producing cell fabric, lining, interlining, pocket materials, zipper tapes, labels and any other knitted or woven parts. Furthermore, zipper teeth need to be polyester as well as any other accessories. Zipper slider and perhaps press buttons can still be metal, as they can be easily removed in the sorting process. Modular garment design in terms of recyclable materials may also be used, as long as easily removable components are made of one material only. The modules can then be separated after the use of the garment and sorted by material groups in the sorting process.

Within this model fabrics and other textile materials are made of a mixture of new and recycled fibres. Any waste from garment making, such as cutting remnants and roll ends, can be forwarded to recycling and defibrated after sorting. Material blends can also be used, provided that the recycling technology facilitates their separation. In this case, it will influence the classification system.

8.4.2. Recovery

Collecting of garments and perhaps household textiles is carried out by charity organizations, municipalities, sorting companies and retailers. As discussed earlier, there is an interest among retailers to add this sustainability attribute, in order to enhance the brand value and support their image. After-use recovery can be motivated by statutory means (a law that requests every retailer to do so), a deposit to be paid to the consumer for returning a used garment, and by creating a social feeling among the consumers that this is the right thing to do.

Despite the very international value chain of fashion, after-use recovery of garments may have to be organized on national level (country by country).

8.4.3. Sorting

Conditional design ensures that garments arriving to sorting and defibrating are homogeneous in terms of materials. Products made of blended materials and accessories may have to be rejected and reused or disposed in another way. Defibrating breaks the textile parts and garments to fibres that can be further used in yarn spinning.

Sorting and defibrating could be located in Sweden, to minimize the transports of recovered garments. The customers, i.e. spinning mills, are located mainly outside of Europe, closer to fabric and garment production. As result, the global journey of textile fibres continues.

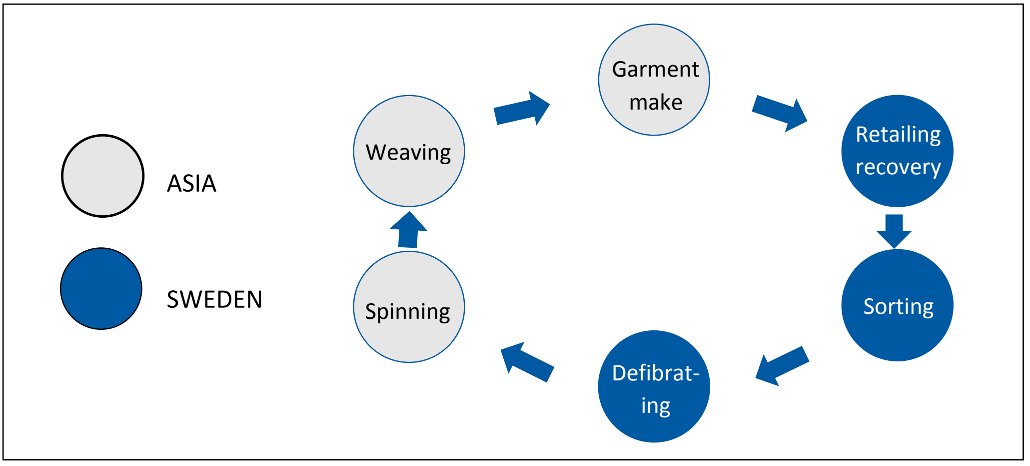


Figure 18. The global journey of recovered textile fibres.

There is a new business opportunity in sorting and defibrating. Once the collecting of used garments is in place, the company would receive the products, and after sorting and defibrating, recycled fibres could be sold to the global spinning industry. Conditional design provides incitements to change the intermediate steps of the global supply chain (as in Figure 18) by bringing some of the outsourced processes back home.

9. Economic feasibility, a projection

9.1. Introduction for projecting economic feasibility

The economic feasibility of the circular textile value chain depends on the price of recycled fibres and yields in various process steps. The spinning industry will be interested in mixing recycled fibres with new ones only, if the cost is similar or lower. Besides price, quality is another issue as recycled fibres may not have the same properties as virgin fibres. This chapter attempts to outline the cost drivers and likely costs and prices of recycled fibres, once the volumes achieve industrially economical levels.

9.2. Financial model for apparel recycling

Mechanical recycling of garments and textiles is currently in use by a number of companies. The end products are often insulations materials, office screen fillings etc. Some companies defibrate left-over fabrics and remnants from the production process and make new garments out of them, like the Finnish company Pure Waste, which concentrates on recycling of pre-consumer waste.

Chemical recycling of cotton and polyester fibres are not commercially exploited yet. Several laboratory scale set-ups are, however, in use for research and development purposes.

An economic model was developed for understanding the interlinking of various process parts and for defining the cost-build-up throughout the value chain, as presented in Figure 19. The share of polyester, cotton and other textile fibres in global consumption are reflected in products for recycling. As of today, a large majority of fabrics used for both apparel are blends, primarily of polyester and cotton, creating problems in recycling.

The first step in recycling is Collecting and the 1st Phase Sorting, where prime products and products for second-hand sales are separated. At the 2nd Phase Sorting products of 100% cotton and 100% polyester are separated from the rest. A part of the outcome (fraction) is trash for energy and blended garments for mechanical recycling. For the financial model presented below, prices for purchasing textile products to be recycled after collecting and the first phase sorting and selling residual products with blended composition were taken from a previous study[58].

Before chemical and mechanical recycling, non-textile components need to be removed. The products are cut into small pieces and those parts containing a rivet, press button or metal zipper part are removed. The rest, about 75%, can be recycled. The chemical recycling of cotton parts will produce dissolving pulp, which can be used for producing viscose fibres.

The chemical recycling process for polyester parts will result in fleece, to be used for producing e.g. quilted clothing, and new polyester raw materials. The mechanical recycling process starts with defibrating of the small parts. After carding, felts, insulants and similar products are produced by needle bunching and similar techniques.

Some companies defibrate left-over fabrics and remnants from the production process and make new garments out of them, like the Finnish company Pure Waste.

[58] Carlsson, J., H. Torstensson, R. Pal and M.K. Paras, Re:Textile – Planning a Swedish Collection and Sorting Plant for Used Textiles – Feasibility Study, University of Borås, 2015. Available as http://media.retextile.se /2015/10/Feasability-study-Swedish-collecting-and-sorting-center.pdf

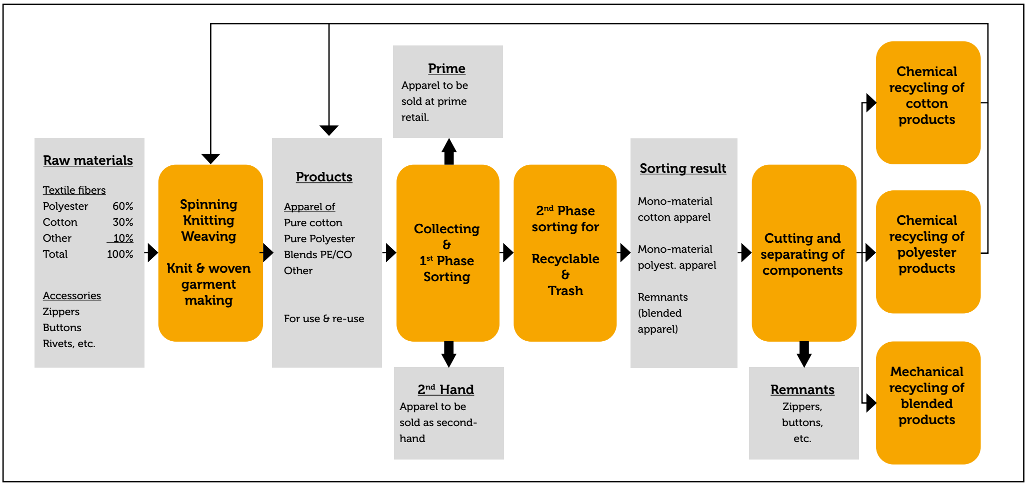


Figure 19. Textile and apparel value chain from virgin fibres to recycling

The critical success factors for recycling in the textile and apparel value chain are as follows:

– Conditional design with classified products as presented in Figure 4 should be maintained in spinning, knitting, weaving and garment making.
– Volume, yield and costs of the 1st collecting and sorting.
– Fractions in the 2nd sorting.
– Yield in cutting and separating of components.
– Process cost, yields and value of remnants in chemical recycling.
– Process cost through-out the value chain

A financial model for testing the impact of conditional design on the cost of chemical recycling of cotton and polyester garments was developed as presented in Box 1. The aim is to define the leeway for process costs after collecting and the 1st sorting, by considering fractions and yields in various processes, in comparison to current market prices of virgin dissolving pulp and polyester chips.

Box 1. Financial model for chemical recycling of cotton apparel

Assumptions for current processes:

- Price after Collecting & First sorting………………………………………………… 3,00 SEK/kg
- Fractions for recycling…………………………cotton 20%, polyester 30%, blends 50%
- Selling price for the remnants……………………………………………………… 0,50 SEK/kg
- Yield from cutting and separating components……………………………………… 75 %
- Market price of dissolving pulp in December, 2016 ………………………..9,46 SEK/kg
- Market price for polyester chips, December 2016 ………………………10,00 SEK/kg[59]

From Collecting & First Sorting

1.00 kg
3.00 SEK/kg

Fraction for recycling	CO	PE	BLENDS
Fraction	20%	30%	50%
Remnant price SEK/kg			0.50

Yield from cut + separate components	
Yield	75%
Remnant price SEK/kg	0.00

Yield from chemical recycling	
Yield	95%
Remnant price SEK/kg	0.00

Output	Dissolving Pulp	Polyester Chips
	0.14 kg	0.21 kg

Leeway for processing costs (SEK/kg)	Dissolving Pulp	Polyester Chips
Market price	9.46	10.00
Material costs	21.05	14.04
Income from remnant sales	0.40	0.35
Leeway for processing cost	-11.19	-3.69

Outcome of model:

- Yield of dissolving pulp from 1 kg of ingoing material ……………………………0,14 kg
- Yield of polyester chips from 1 kg of ingoing material ……………………………0,21 kg
- Cost of materials for recycled pulp ……………………………………………………21,05 SEK/kg
- Cost of materials for recycled polyester chips ………………………………..14,04 SEK/kg
- Income from remnant sales …………………………………………………….0,40/0,35 SEK/kg
- Leeway for processing costs of recycled dissolving pulp………………… -11,19 SEK/kg
- Leeway for processing costs of recycled polyester chips…………………..-3,69 SEK/kg

[59] Source: Textile and clothing trade information, www.emergingtextiles.com

The outcome of the model demonstrates that with the current fraction, process yields and collecting costs recycling of apparel is not feasible. In order to improve the feasibility, the following scenarios could be considered:

1. Conditional design of cotton garments (Scenario 1)
   Mono-material design is possible in simple knitwear, like T-shirts, sweat shirts and similar, while more complex garments will contain other materials as well (such as metal, plastics etc. in zippers and buttons). With modular material design, components made of other material than cotton can be easily detached by the consumer before returning the product to collection and 1st sorting. With conditional design the yield from cutting and separating is estimated to improve to 95%, while the fraction for recycling at 2nd sorting would stay the same.

2. Process improvement of recycled cotton garments (Scenario 2)
   Mono-material garments and modular garments, after detaching of components, are returned to separate collection bins by the consumer. This will simplify the 1st sorting process, lowering the price after collecting and 1st sorting to 2.50 SEK/kg. Furthermore, the fraction for recycling at the 2nd sorting is forecast to be 30%.

3. Enhanced process of recycled cotton garments (Scenario 3)
   The price after collecting and 1st sorting is brought down to 1,00 SEK/kg by financial support of the society or by more automatic systems. The price for selling remnants is increased to 1.00 SEK/kg by improved sorting process. These changes would radically improve the leeway for processing costs.

4. Conditional design of polyester garments (Scenario 4)
   Mono-material design is easier with polyester garments, as several accessories, such as zippers, buttons, etc. could be made of polyester as well. With conditional design the yield from cutting and separating is estimated to improve to 95%, while the fraction for recycling at 2nd sorting would stay the same.

5. Process improvement of recycled polyester garments (Scenario 5)
   Mono-material garments and modular garments, after detaching of components, are returned to separate collection bins by the consumer. This will simplify the 1st sorting process, lowering the price after collecting and 1st sorting to 2.50 SEK/kg. Furthermore, the fraction for recycling at the 2nd sorting is forecast to be 40%.

6. Enhanced process of recycled polyester garments (Scenario 6)
   The price after collecting and 1st sorting is brought down to 1,00 SEK/kg by financial support of the society or by more automatic systems. The price for selling remnants is increased to 1,00 SEK/kg by improved sorting process. These changes would radically improve the leeway for processing costs for polyester garments as well, as demonstrated in Table 4.

	COTTON				POLYESTER			
	CURRENT	SCENARIO 1	SCENARIO 2	SCENARIO 3	CURRENT	SCENARIO 4	SCENARIO 5	SCENARIO 6
Price after collecting & 1st sorting	3,00 SEK/kg	3,00 SEK/kg	2,50 SEK/kg	1,00 SEK/kg	3,00 SEK/kg	3,00 SEK/kg	2,50 SEK/kg	1,00 SEK/kg
Fraction for recycling at 2nd sorting	20%	20%	30%	30%	30%	30%	40%	40%
Selling price of remnants	0,50 SEK/kg	0,50 SEK/kg	0,50 SEK/kg	1,00 SEK/kg	0,50 SEK/kg	0,50 SEK/kg	0,50 SEK/kg	1,00 SEK/kg
Yield from cutting and separating	75%	95%	95%	95%	75%	95%	95%	95%
Selling price of cutting remnants	0,00 SEK/kg	0,00 SEK/kg	0,00 SEK/kg	0,00 SEK/kg	0,00 SEK/kg	0,00 SEK/kg	0,00 SEK/kg	0,00 SEK/kg
Process output	0,14 kg	0,18 kg	0,27 kg	0,27 kg	0,21 kg	0,27 kg	0,36 kg	0,36 kg
Total cost of materials (pulp)	21,05 SEK/kg	16,62 SEK/kg	9,23 SEK/kg	3,69 SEK/kg	14,04 SEK/kg	11,08 SEK/kg	6,93 SEK/kg	2,77 SEK/kg
Market price	9,46 SEK/kg	9,46 SEK/kg	9,46 SEK/kg	9,46 SEK/kg	10,00 SEK/kg	10,00 SEK/kg	10,00 SEK/kg	10,00 SEK/kg
Leeway for processing costs	-11,19 SEK/kg	-6,67 SEK/kg	+ 0,58 SEK/kg	+6,47 SEK/kg	-3,79 SEK/kg	-0,83 SEK/kg	+ 3,27 SEK/kg	+7,83 SEK/kg

Table 4. Financial results for the six scenarios of recycling.

Mechanical recycling of apparel disintegrates the collected garments back to fibres for producing felts and similar products. The end use may vary from building insulation to paddings for furniture and other products. Several companies are already involved in this kind of manufacturing, many of them quite successfully. Only in a few cases, such as Pure Waste, mechanical recycling is used for apparel production. However, Pure Waste uses textile waste from weaving and garment-making processes rather than used garments.

Figure 20. Mechanical recycling used by Pure Waste[60]

[60] Pure Waste Company. www.purewaste.org

10. Economic feasibility for design for longevity, a projection

10.1. Introduction for projecting economic feasibility

Design for longevity is often reported to increase garment costs by up to 5% for some products and add up to 2 weeks to garment lead times, thus confirming suggestions that improving garment construction to last for longer could increase costs[61].

Given this lack of financial incentive for design for longevity, this chapter attempts to redefine economic feasibility for design for longevity in terms of the power of the garment design process based upon certain radical product design conditions (mentioned earlier in Figure 4) to synthesize not only a longer lifespan of the garment by also financial viability through it.

Based upon this consideration, an economic model was developed for understanding the interlinking of various reverse logistics processes and for defining the cost build-up throughout the reuse value chain, aimed at understanding the effects of design for longevity in generating higher redesign (ReD) potential of the garments. By reflecting upon the margin or window within which the redesign activities can operate (leeway) enables us to calibrate the effects of various cost drivers on economic feasibility of ReD against the market price of the products.

The results are interesting for a large number of actors engaged with the apparel reverse value chain, such as retail brands, smaller design brands, and even charities. The study can serve as a motivation for the retail brands to engage and invest more for design for longevity, experiment with innovative garment design and construction principles, and also try out new business models and pricing strategies to appropriate the value generated through sales of redesigned used garments. Such a strong economic feasibility, added to already proven positive environmental effects of design for longevity[62].

10.2. Financial model for apparel redesigning

Given the purpose of this economic feasibility projection of such ReD processes, understanding the overall reuse-based apparel value chain is vital. The value chain starts with the collection process, as the material is collected from the consumers via multiple channels or through donation. Charities are by far the largest collectors of used clothes via various collection points (e.g. kerbside bins, partnerships with retailers, own second-hand stores)[63]. As explained above in section 9.2, this is followed by 1st sorting (mostly carried out by the charities), where the prime products are separated. These prime products account for about 10-15% of the total collected volume (fraction) and are of “very good quality, hardly worn and fashionable” – sometimes also classified as *Quality Extra or Europe quality*[40]. Following 1st

[61] WRAP, 2013, Clothing Longevity – Measuring Active Use. Available at http://www.wrap.org.uk/content/clothing-longevitymeasuring-active-use
Oxborrow, L., Claxton, S., Cooper, T., and Hill, H. (2015), Product development and supply: help or hindrance to clothing longevity?, In PLATE conference proceedings, Nottingham, UK, 17-19 June.
[62] Claxton, S., Cooper, T., Hill, H. & Holbrook, K. (2015), Opportunities and challenges of new product development and testing for longevity in clothing, In PLATE conference proceedings, Nottingham, UK, 17-19 June.
[63] Carlsson, J., H. Torstensson, R. Pal and M.K. Paras, Re:Textile – Planning a Swedish Collection and Sorting Plant for Used Textiles – Feasibility Study, University of Borås, 2015. Available as http://media.retextile.se /2015/10/Feasability-study-Swedish-collecting-and-sorting-center.pdf

sorting the remnants that includes garments of export quality (to developing countries), and further inferior qualities (suitable for rag manufacturing, or for recycling, or simply waste) are sold to global sorting firms. This accounts for nearly 85-90% of the total volume (fraction). Both sorted and unsorted products are exported to various markets, which determine the price per Kgs. Incomes and cost estimates of these diverse fractions made suggest: Actual wholesale price/kg of unsorted items (including prime) = ~8-10 SEK, Actual wholesale price/kg of unsorted items (excluding prime) = ~4-5 SEK, Average wholesale price/kg obtained by the sorter for prime = ~40 SEK.[40]

Currently, only a very small fraction is redesigned either by charities themselves (e.g. Stockholm Stadsmissionen Remake[64]) or are send to small redesign brands (e.g. Studio Re:design[65]). In the above context, redesign means designing a product so that it changes into a new useful product (here referred only as garments). Various redesign process and activities are required to recreate this value and typically include refurbishing activities such as washing, repairing etc. after the garments are collected and 1st sorted. Re-labelling is the simplest of the redesign options, requiring lower ReD processing costs related to e.g. sewing of additional parts or components. Such relabelled or refurbished garments can have a market price of 20-25 SEK/garment. Additional value adding processes, such as cutting, adding, washing, stitching, and printing, generally require higher process costs and reflect higher incremental design potential of the garments – thus resulting in achieving a market price between 50 and 90 SEK/garment. Finally, higher degrees of de/reconstruction and assembling processes could result in fetching a market price of 400-500 SEK/garment. See Carlsson et al. (2014)[66] for detailed analysis. The yield in such ReD processes can be considered as:

[100% - loss of material/component/parts, such as trims, accessories, etc.]

This may be due to cutting out from the garment to either augment redesignability (modularity) or to produce new designs. Considering the lack of previous research and a consensus among various ReD activities in terms of material loss we have in this study estimated the yield to be 75%, which may eventually increase with more conditional design options (e.g. modular design). ReD process cost is another factor that determines the feasibility of its leeway. Previous study (Carlsson et al. (2014)) has presented a calculation example of processing costs for refurbished garment (re:labelling) and a heat transferred printed pattern (re:coupling), which has estimated that the ReD process costs can be ~15-20 SEK/garment and ~20-60 SEK/garment for refurbishing and recoupling activities, respectively. In this feasibility study we have multiplied by a commonly used factor of 2.5 to convert SEK/garment to SEK/Kgs.

[64] https://www.stadsmissionen.se/vad-vi-gor/remake-hallbart-mode-och-design (February 2017)
[65] http://epi.vgregion.se/studioredesign/ (June 2015)
[66] Carlsson, J., Pal, R., Mouwitz, P. and Lidström, A., 2014. ReDesign kläder: Förstudie [ReDesign Clothes: Prestudy], under Support for regional development within Västra Götaland 2020 - the strategy for growth and development 2014-2020, The Swedish School of Textiles, Borås, Sweden

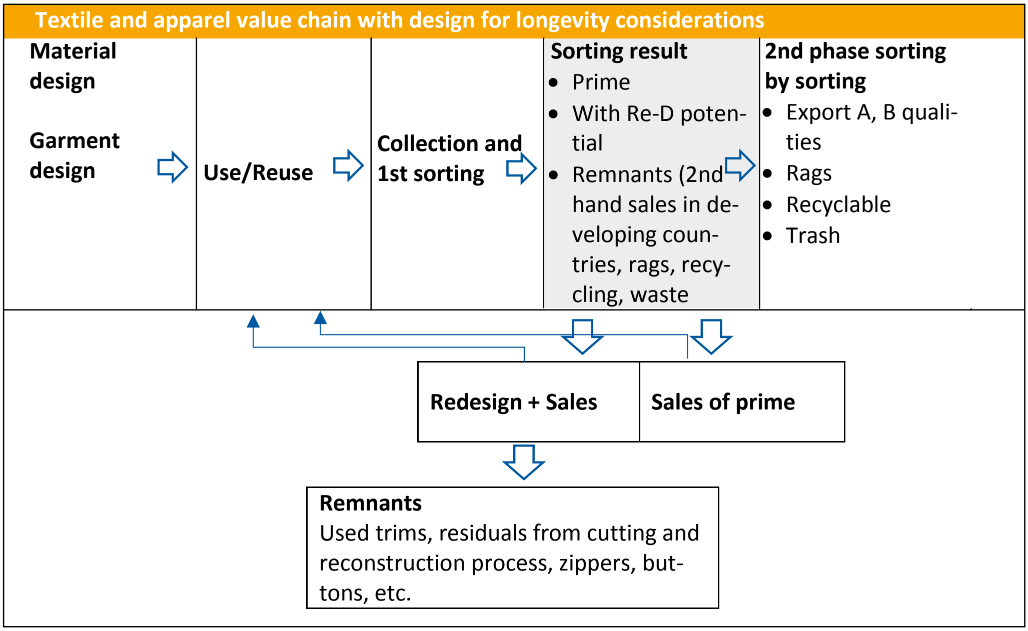


Figure 21. Mapping of apparel reuse value chain.

The Figure 22 below provides a summary of the ReD categories classified as A to C based on Carlsson et al. (2014), as used in this study.

The critical success factors for ReD in the reuse-based apparel value chain are as follows:

- Conditional design with classified products as presented in Figure 4 (modular and incremental garment design potential) should be maintained during garment making.
- Volume, fractions and material costs of the 1st sorting.
- Market price of the various sorted fractions (prime, 2nd sorting products).
- Yield and price of remnants in ReD.
- Process costs through-out the value chain.

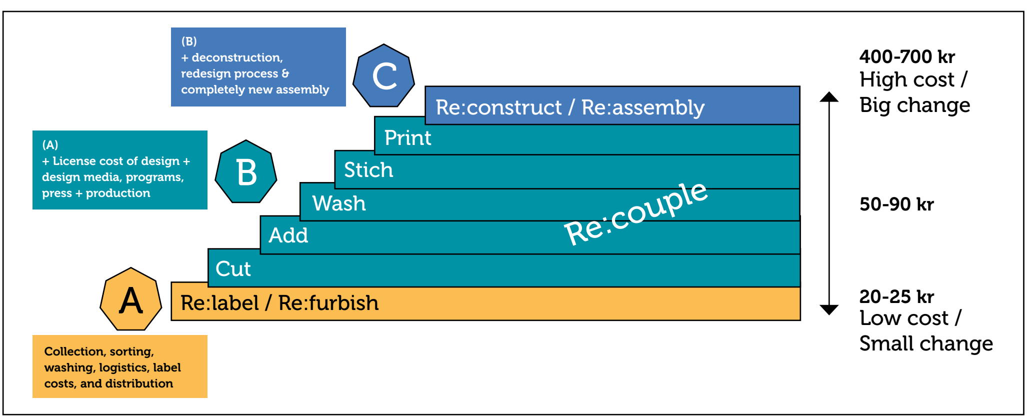


Figure 22. Re:D categories, activities, and pricing

Based upon the above mentioned factors, a financial model for testing the impact of conditional design on the cost of ReD of garments was developed, as presented below. In Box 1, the realistic considerations made in describing the current processes are highlighted. It is to be noted that the financial calculations made below are reflective of a certain set of parameters, considered realistically to test the model. For the financial model presented below, all parameters (market prices, process and material costs, and fractions) were taken from previous studies (Carlsson et al. 2014, 2015). The aim is to define the leeway for ReD process costs after collecting and 1st sorting, by considering fractions and yields in various processes, in comparison to current market prices of redesigned garments.

BOX 1. Financial model for redesign of garments for longevity

Realistic considerations for current processes:

- Wholesale price of unsorted items (including prime) .... 8,00 SEK/kg[1]
- Fractions from 1st sorting .... Prime 10%, To Sorting company 88%, For Redesign maximum 2%[1]
- 1st sorting process cost .... 4 SEK/kg[1]
- Market price for the prime items .... 40 SEK/kg[1]
- Market price for the 2nd sorting items .... 4 SEK/kg[1]
- Yield from Redesign stage 75%
- Market price for Redesigned items .... Category A 25 SEK/garment, Category B 70 SEK/garment, Category C 400 SEK/garment[2]
- Garments/kg .... 2.5[2]

1. Data available from Carlsson et al. (2015)[67]; 2. Data available from Carlsson et al. (2014)[68]

As such the model is flexible, meaning that it can accommodate different parameters and also reverse value chain structures. Here we consider two structures: (i) without an intermediary ReD brand (charity does all ReD), (ii) with intermediary ReD brand (when the charity sells @ 25 SEK/Kgs).

[67] Carlsson, J., Torstensson, H., Pal, R. and Paras, M.K., 2015. Re:Textile – Planning a Swedish Collection and Sorting Plant for Used Textiles (Feasibility Study), under Support for regional development within Västra Götaland 2020 - the strategy for growth and development 2014-20, The Swedish School of Textiles, Borås, Sweden

[68] Carlsson, J., Pal, R., Mouwitz, P. and Lidström, A., 2014. ReDesign kläder: Förstudie [ReDesign Clothes: Prestudy], under Support for regional development within Västra Götaland 2020 - the strategy for growth and development 2014-2020, The Swedish School of Textiles, Borås, Sweden

Collecting & First Sorting

1,00 kg
8,00 SEK/kg

Fraction from 1st sorting

	Prime	For ReD	To Sorting
Fraction	10%	2%	88%
Remnant price SEK/kg	40,00		4,00

Yield for ReD

Yield	75%
Remnant price SEK/kg	0,00

Output
ReD

0,0150 kg

Leeway for ReD costs (SEK/kg)

	without intermediary ReD brand			with intermediate ReD brand		
	A	B	C	A	B	C
Market price	62,50	175,00	1000,00	62,50	62,50	62,50
Material costs	533,33	533,33	533,33	533,33	533,33	533,33
Income from remnant sales	7,52	7,52	7,52	7,52	7,52	7,52
1st sorting cost	4	4	4	4	4	4
Leeway for ReD processing cost	-467,31	-354,81	470,19	-467,31	-467,31	-467,31

The financial outcome of the model is presented below in Box 2.

BOX 2. Outcome of model

- Yield for Redesignable items (excluding prime) .... 0,0150 kg
- Cost of material for redesign (considering no additional material used) .... 533,33 SEK/kg
- Income from remnant sales (from 1st sorting) .... 7,52 SEK/kg
- Income from remnant sales (from ReD) .... 0,00 SEK/kg
- Leeway for ReD, Cat A (w/o intermediary) ....-467,31 SEK/kg
- Leeway for ReD, Cat B (w/o intermediary) .... -354,81SEK/kg
- Leeway for ReD, Cat C (w/o intermediary) 470,19SEK/kg
- Leeway for ReD, Cat A-B (w intermediary) .... -467,31 SEK/kg

Equations in footnote[69]

The outcome of the model demonstrates that with the current fraction, process yields and material and process costs, low or intermediate value adding ReD activities (Cat A and B) for garments are not feasible. This is because, the leeway for ReD, for categories A and B, i.e. -467,31 and -354,81 SEK/kg, is lesser than calculated ReD process costs (cf. "ReDesign Clothes: Prestudy" mentioned above). In order to improve the feasibility through design for longevity, the following scenario, based upon a what-if could be considered:

69 Output = Cost of collected & 1st sorted material/kg *Fraction of ReD *Yield for ReD
Material cost = (Volume of collection & 1st sorting * Cost/kg)/Output
Income from remnant sales = Volume of collection & 1st sorting * (Weighted price of Prime + Weighted price of material to 2nd sorting + Fraction of ReD* (100% - Yield for ReD) * Remnant price from ReD)

Scenario/What-if 1: Conditional design of garments (Modular or incremental design).

With modular garment design, it is possible to make garment parts detachable which can be easily done by the consumer before returning them in separate bins. This will simplify the 1st sorting process (lowering the 1st sorting cost to 2 SEK/kg). Further this will increase the fraction of redesignable garments rather than being sold "as it is". Incremental design potential will provide higher possibilities for value addition along the ReD category B (cut, add, wash, stitch, or print). So the redesignable fraction is forecasted to be 10% with 90% yield. Basic requirement however is high design for durability (pilling resistance, colour fastness and dimensional stability of the garment).

These changes would improve the leeway for ReD processing costs for garments, as demonstrated in Table 5.

	CURRENT			SCENARIO 1		
	CAT A	CAT B	CAT C	CAT A	CAT B	CAT C
Price before 1st sorting	8,00 SEK/kg	8,00 SEK/kg	8,00 SEK/kg	8,00 SEK/kg	8,00 SEK/kg	8,00 SEK/kg
Fraction for ReD after 1st sorting	2%	2%	2%	10%	10%	10%
Average Selling price of remnants (from 1st sorting)	7,52 SEK/kg	7,52 SEK/kg	7,52 SEK/kg	7,20 SEK/kg	7,20 SEK/kg	7,20 SEK/kg
Yield for ReD	75%	75%	75%	90%	90%	90%
Selling price of ReD remnants	0,00 SEK/kg	0,00 SEK/kg	0,00 SEK/kg	0,00 SEK/kg	0,00 SEK/kg	0,00 SEK/kg
ReD process output	0,0150 kg	0,0150 kg	0,0150 kg	0,09 kg	0,09 kg	0,09 kg
Total cost of materials	533,33 SEK/kg	533,33 SEK/kg	533,33 SEK/kg	88,88 SEK/kg	88,88 SEK/kg	88,88 SEK/kg
Market price	62,5 SEK/kg	175 SEK/kg	1000 SEK/kg	62,5 SEK/kg	175 SEK/kg	1000 SEK/kg
1st sorting cost	4 SEK/kg	4 SEK/kg	4 SEK/kg	2 SEK/kg	2 SEK/kg	2 SEK/kg
Leeway for ReD processing costs	-467,31	-354,81	470,19	-21,19	91,31	916,31
	Not feasible	**Not feasible**	**Feasible**	**Not feasible**	**Partly Feasible**	**Feasible**
	ReD Process cost	ReD Process cost	ReD Process cost	ReD Process cost	ReD Process cost	ReD Process cos
	35-50 SEK/kg	50-150 SEK/kg		35-50 SEK/kg	50-150 SEK/kg	

Table 5. Financial results for current vs. future scenario of redesigning

11. Organisation and human resources

Redesign and reuse of clothes is an industry that can provide jobs throughout the whole supply chain, in collecting, sorting, designing and redesigning, tailoring, sewing, cobbling, dyeing, logistics, transporting, retail, etc. In Germany the used clothing sector is estimated to sustain 11,000 jobs, many of which are suitable for people with low or moderate qualifications.[70] Generally workers in this sector are semi-skilled or are marginally employable otherwise, which provides an opportunity for meaningful jobs for those categories. Some functions obviously need educated and trained professionals, notably for the design/re-design stage, for tailoring and sewing, for logistics operations and for marketing and retail. One proposal to bring forward is that elements of the Re-... process are emphasized in education

[70] Bavarian Red Cross, https://brk.de/was-wir-tun/kleidersammlung, accessed 21 Nov 2016

and training programmes, i.e. re-design, reverse logistics, etc. There is along this line a proposal as part of an extended producer responsibility about financial assistance and demands for inclusion of sustainable design courses in design schools.[71]

There are however different conclusions regarding the ability of this sector to absorb a large workforce. Several sources support the prospect of employment opportunities, sometimes really over-optimistically,

‘The number of additional jobs would exceed 75,000 in Finland, 100,000 in Sweden, 200,000 in the Netherlands, 400,000 in Spain and half a million in France. This means that unemployment rates could be cut by a third in Sweden and the Netherlands, and possibly more - maybe even cutting unemployment in half…’ (addressing circular economy as such).[72]

On the other hand, a recent study claims that the circular economy will not generate such effects[73]. Several factors are discussed, leading to the general conclusion that a significantly large number of additional jobs will not materialize.

Provided upcycling by conditional design can take place, there will however be opportunities, related to technology adaption, production of semi-finished products, re-design and logistics.

[71] Watson, D. and N. Kiørboe (2015), EPR systems and new business models - reuse and recycling of textiles in the Nordic region, Nordic Council of Ministers
[72] Wijkman, A. and K. Skånberg (2015), The Circular Economy and Benefits for Society, Club of Rome
[73] Miljö, ekonomi och politik 2016, Konjunkturinstitutet, Stockholm

12. SWOT analysis

This section presents an analysis of strengths, weaknesses, opportunities and threats (SWOT), related to a textile (reverse) supply chain, driven by conditional design, and the associated financial model.

STRENGTHS (+)	WEAKNESSES (-)
Design for recyclability – Recovery will be in even higher demand, due to limited resources and thus inflated price – Conditional design concept facilitates mono-material use **Design for longevity** – Power to synthesize a change towards design for textile circularity – Region's textile background, ensuring Swedish and regional lead in textile and clothing (re)design	**Design for recyclability** – Income-cost ratio not favourable, making the concept currently less feasible – Presently no established recycling facilities in the region – Consumer acceptance for recovered textiles and clothing weak **Design for longevity** – Consumer acceptance for redesigned garments is weak resulting in low market prices – High redesign process costs, low fraction available for redesign and low yield – Does not present much financial incentive for brands to invest
OPPORTUNITIES (+)	**THREATS (-)**
Design for recyclability – Technology development can raise the feasibility of recovery – Job opportunities may emerge for both qualified and unqualified persons – Novel design solutions can support recovery and demand by redesign and conditional design – Encouragement from government and NGO – Support from a growing number of commercial stakeholders **Design for longevity** – New business models to support servitized conditional design – Technology development for novel modular garment construction (e.g. Wear 2) and incremental design technologies (e.g. adaptive garments) – Job opportunities for redesign facilities	**Design for recyclability** – Market prices of pulp, synthetic fibres, oil etc. may make the concept unfavourable – Physical risks, such as fire risk in collection and storage, toxic additives or contamination in the material, may influence process, workforce and the final outcome **Design for longevity** – Lack of alternative garment design thinking in mainstream fashion industry – The redesignability potential may suffer if "Design for X" is more economically viable

Table 6. SWOT matrix for conditional design, current state.

13. Results and discussion

The study clearly demonstrates that the "design process" is instrumental for improving the condition for both longevity and recyclability. By implementing "conditional design rules" it is also possible to provide means for improved (automatic) sorting systems as well as achieving considerably *improved yield* in fractions aimed for recycling. As demonstrated in the economic models, this is a prerequisite for achieving feasibility in recycling processes.

There is currently much interest in chemical recycling, and a lot of research projects are going on, but the technologies are not yet commercially viable at this point. This can be positively affected by achieving higher volumes with higher yield at preferably lower cost by applying the proposed design principles.

By implementing those principles it is possible to address the serious challenge of handling

a) the complexity of the products (garments), which are often composed of different fabrics with the assembling materials (stitching and trims) made of different materials,
b) the increasing use of fibre mixes in fabrics, such as cotton/polyester etc.

Often fibre mixes, including elasthane etc., pose even more challenges.

Another challenge is the use of dyeing and finishing chemicals used to create colours and prints and to improve properties. This limits the development of recycled end products in areas such as colouring etc. Removing such ingredients in the process is costly and limits feasibility.

All those aspects can be addressed in applying *conditional design principles,* but obviously it may affect and limit the design ingredients that aim for maximized aesthetic and functional products.

On the other hand, "conditional design rules", aimed at addressing longevity, are crucial for improving the incremental design or redesignability of the garment during the use/reuse phase, which serves as a prerequisite for redesign feasibility. In this context, even though several fashion brands and research institutes have provided increased attention towards design for longevity, these mainly focus either on improving material durability, design aesthetics, or on new business models. Less attention is rendered towards the technical garment design requirements, which can considerably improve the value addition possibility at different stages of the garment's active use life.

By implementing these principles it is possible to address

a) the longevity of the products (garments), which are often reduced due to low design and static aesthetics determined at one stage of the garment lifecycle,
b the increasing redesign potential of the garments.

But at the same time it is essential not to compromise with the recyclability of the garment in the long run, hence strike an optimal balance between longevity and recyclability. Concerning consumer approval of this change of direction, it is not properly tested.

13.1. Final conclusions

Many of the proposed actions can be carried through within a relatively short time frame. Those include applying the design principles of mono-material choices and modular design and redirecting the design of garments as a process that goes on during the life of the product (i.e. incremental design).

It is however clear that it will take considerable time to form the conditional design processes into a mainstream principle for large volumes. The development and implementation of those principles will nevertheless have the impact of creating new innovation products and create new interesting business models, resulting in a growing small and local industry sector.

For Borås and the VGR region there are numerous areas, where the region can be instrumental in the movement towards circularity:

– An educational centre for Sweden and N. Europe for the implementation of design actions for synthesizing in value chains (all educational bodies, such as HB, Proteko, Nordisk Designskola and independent educational providers).
– Development of media and communication addressing design for circularity in consumers' minds. Taking advantage of the time factor.
– The establishment of a "DO TANK" for realizing new ideas within the area. Service as an inspirational and realigning body. Cross-disciplinary action: textile – fashion – interior and architecture.
– New blood into local companies; design concepts enabling new products and new business areas.
– Ultimately creating a new progressive "design for synthesizing" environment that draws attention to VGR and its infrastructure.
– Spin offs in local companies in more businesses.

14. Recommendations for further actions

Critical success factors for design in relation to circularity:

1. Education of designers in all issues concerning the implications of design in achieving longevity and circularity. Further, design managers are also beneficiaries of such courses, which can be valuable for textile management education:
   a. Integration in design education at design schools of all levels.
   b. Short courses aiming to provide education for designers already in their careers.
   c. Writing a "designers bible" for this purpose.
2. Development of a classification system referring to design conditions for circularity. This enables the identification of the products, already from the design phase. An additional ID system for recognizing the products in sorting phases enables automatic sorting for specific recycling processes. Applicability of the ID system during the design phases aimed for longevity without compromising recyclability.
3. Further development of sorting (automatic) systems.
4. Further R&D activities in *all aspects of recycling processes.*
5. Further development of incremental design approaches and associated business models aiming at longevity.
6. Development of a "DO TANK" with the aim to inspire and educate designers to really demonstrate DESIGN'S POWER TO SYNTHESIZE, i.e. identify problems – come up with ideas – test the ideas – realize the ideas.

Appendix

1. Terms and definitions

For the purpose of this report the following terms and definitions apply.

Allocative efficiency - a state of the economy in which production represents consumer preferences; in particular, every good or service is produced up to the point where the last unit provides a marginal benefit to consumers equal to the marginal cost of producing.

Business model - the plan implemented by a company to generate revenue and make a profit from operations.

Circular economy - an economic model based i.a. on sharing, leasing, reuse, repair, refurbishment and recycling, in an (almost) closed loop, which aims to retain the highest utility and value of products, components and materials at all times.

Closed loop recycling - a strategy where the recycled materials keep their original material properties, providing the same material performance through many recycling loops, ideally endlessly, as part of a circular economy process.

Conditional design – design parameters depend on conditional factors, such as longevity of a garment or its recycling properties. Conditional design relies on the power to synthesize a change of the supply chain toward textile circularity.

Cooperation - an activity in which two or more participants work together for at least one common end.

Defibrate - to separate materials (as textiles, paper, fibreboard) into their fibrous constituents.

Design for circular economy - DfCE is closely linked to design for sustainability (DfS), i.e. the philosophy of designing physical objects, the built environment, and services to comply with the principles of social, economic, and ecological sustainability.

Disposal - destruction or transformation of garbage.

Disruptive innovation - an innovation that creates a new market and value network and eventually disrupts an existing market and value network, displacing established market leaders and alliances.

Down-cycling - a recycling process, where the value and properties of a material are degraded.

Extended producer responsibility (EPR) - an environmental policy approach whereby producers take over the financial and/or organisational responsibility for collecting or taking back used goods, as well as sorting and treatment for their recycling.

Feasibility – the capability of something being done or carried out. In this investigation feasibility presumes a sufficient leeway for process cost.

Fibre - An elongated, tapering, thick-walled cellular unit that is the structural component of woody plants.

Incremental design - A concept to add design elements during the life of a garment, aiming for longevity of the garment.

Landfill - a system of trash and garbage disposal in which the waste is buried between layers of earth to build up low-lying land.

Leeway - an allowable margin of variation, specifically in this report the available margin for processing costs.

Longevity - a long duration of life, for example of a garment.

Modular design - design of a garment made up of recyclable modules.

Mono-material - a pure material, not mixed with other materials or forming a composite or an alloy.

New product development - the transformation of a market opportunity into a product available for sale.

Open loop recycling - a strategy to extend material utilisation for more than one product lifecycle, where the recycled material properties degrade with every recycling loop to finally end up as waste.

Recycling - the process of converting waste materials into reusable objects to prevent waste of potentially useful materials.

Resilience - the ability of a system to withstand disturbances and crises.

Reverse logistics - the process of moving goods from their typical final destination for the purpose of capturing value, or proper disposal. Remanufacturing and refurbishing activities also may be included in the definition of reverse logistics.

Servitization - the delivery of a service component as an added value, when providing products.

Sustainability - using methods and resources so that those resources are not depleted or permanently damaged. Sustainability in this sense covers three domains, ecological, social and economic sustainability.

SWOT analysis – a compilation of identified strengths, weaknesses, opportunities and threats for a system or process.

Textile - a flexible material consisting of a network of natural or artificial fibres (yarn or thread).

Up-cycling - a recycling process, where the original value and properties of a material are maintained or enhanced.

Value chain - a representation of the various processes involved in producing goods (and services), starting with raw materials and ending with the delivered product, which may also apply to the recycled or otherwise recovered product.

Willingness to pay - the maximum price at or below which a consumer will definitely buy one unit of the product.

2. Higg Index indicators

Module	Indicators
EOU-B-1: End of Use (EOU) Program	EOU-B-1.1: Brand has a program to track, measure, and document the environmental impacts from the End of Life of its products. The program includes identification of which EOU stream(s) are being utilized (e.g., re-use, re-purpose, and/or close-/open-loop fiber recycling)
	EOU-B-1.2: The program includes the setting of targets and goals to reduce those environmental impacts associated with the End of Use of products.
	EOU-B-1.3: The program has demonstrated evidence of reducing environmental impacts associated with the End of Use of products
EOU-B-2: Design Policies for End of Use (EOU)	EOU-B-2.1.1: Products are designed to include identification of each individual material type so that material types can be separated for EOU recycling.
	EOU-B-2.1.2: Products are designed with material types that are compatible with existing material EOU recycling streams
	EOU-B-2.1.3: Products are designed so that material types can be separated for EOU recycling
EOU-B-3: End of Use (EOU) Collection/Processing Infrastructure	EOU-B-3.1: Brand adopts, promotes, or develops the collection and processing infrastructure (public or private) required for the End of Use stream(s) utilized in its EOU program to function. These efforts should consider cultural nuances and avoid disrupting existing, well-functioning systems that may be in place locally, regionally, or nationally.
EOU-B-4: End of Use (EOU) Communication to Consumers	EOU-B-4.1: Brand publicly communicates instructions on 1 or more EOU streams for its products via one or more of the following channels
	- EOU-B-4.1.1: Websites
	- EOU-B-4.1.2: In-store communications (written materials and/or staff training)
	- EOU-B-4.1.3: Marketing materials
	- EOU-B-4.1.4: Product packaging—excludes on-product permanent labels

Table 1. List of relevant modules and indicators for End of Use[74]

[74] www.higg.org

Module	Indicators
USE-B-1: Product Care & Repair Service Program	USE-B-1.1: Brand has a program to track, measure, and document the environmental impacts from the Product Care & Repair Service of its products
	USE-B-1.2: The program includes the setting of targets and goals to reduce those environmental impacts associated with the Product Care & Repair Service of products
	USE-B-1.3: The program has demonstrated evidence of reducing environmental impacts associated with the Product Care & Repair Service of products
USE-B-2: Repairability Design Standards	USE-B-2.1: Brand has design standards in place to provide guidance/incentives for design considerations to maximize product features that are repairable and upgradable (e.g., replacement buckles, zipper pulls, components, and accessories)
USE-B-3: Design for Durability and Longevity	USE-B-3.1: Brand has a Quality Assurance Program aimed at understanding and enhancing the durability and longevity of its products. The program must bring durability and longevity information back to the product creation team (i.e., create a feedback loop).
	- USE-B-3.1.1: Developing both product- and material-level durability criteria to ensure longevity in the product's intended use
	- USE-B-3.1.2: Establishing a correlation between durability lab testing and the product's intended end-use
	- USE-B-3.1.3: Establishing a correlation between durability field testing and the product's intended end-use
	- USE-B-3.1.4: Maintaining an active system of feedback to continuously assess worn products (including returns) and upgrade durability criteria accordingly. For example, this may include documenting and reporting product return rates with reason codes that reference "failure due to materials, assembly, etc"
	- USE-B-3.2: At least annually, the Quality Assurance Program sets, tracks, and reviews specific goals, targets, and timelines that demonstrate program efficacy and impact
USE-B-4: "Product Care" Communication to Consumers	USE-B-4.1: Brand makes apparel "Product Care" information (such as alternative, low impact care instructions beyond what is required by regulations) publicly available and easily accessible for consumers (e.g., through website, phone customer service, in-store printed materials, and/or trained staff) – excluding on-product permanent labeling
USE-B-5: "Repair Service" Communication to Consumers	USE-B-5.1: Brand makes apparel product "Repair Service" information (such as repair vs. replace guidance and disclosure on how brand is properly disposing of products) publicly available and easily accessible for consumers (e.g., through website, phone customer service, in-store printed materials, trained staff, and/or warranties or similar policies) – excluding on-product permanent labeling

Table 2. List of relevant indicators from the Care and Repair module[75]

[75] www.higg.org

3. Conditional design examples

Conditional design

The garments in this report are examples of how conditional and incremental design can be applied or already have been applied within the apparel industry in Sweden. A more detailed presentation of conditional design examples, including also a description of wear-2's techniques for disassembly of garment seams, can be found at the following web address: media.retextile.se/2017/03/Conditional-design-additional-examples-1.pdf

Page 44-46 summarize Anna Lindström's collection of scarves, which have been combined and can be combined in different systems to create various kinds of garments and expressions. The calculations in these examples are estimations of production costs in Sweden (SEK 7 per minute) and a mark-up factor of 4.5 for the potential price tag.

Page 47-50 illustrate examples of existing garments that already, or with some small alternations, respond to the ideas of conditional design and incremental design. The calculations in the examples are based on estimates of production costs, put in relation to the original price tag, using the generally accepted mark-up model. The production cost is approximately 20% of the original price tag. The garments in the examples are manufactured in the Baltic countries, so a minute price of SEK 2 per minute is used.

The wear-2 process[76], which is referred to in these examples, is a process that allows for dissolving sewing thread using microwaves. The sewing thread is a polyester/copper sulphur blend that dissolves, when introduced to the right wave length of microwaves, allowing for separation of different materials into recycle streams. Wear-2's own cost-benefit analysis[77] introduces the idea that the system can close the loop at a higher level, compared to conventional recycling processes. The process is beneficial for the user company and generates approximately SEK 6300 per tonne treated products, due to the high recycling value.

The garments are classified according to the table below:

Future design strategy	**Circular strategien valu chains**		**Examples, page**
	Reuse for longevity (slowing the loop)	Recycling (closing the loop)	
Monotipematerial, A	Maintain design classification if redesigned	Best	1-3, 5-7
Modular, B	Maintain design classification if redesigned	Good	1-3, 8
Incremental (blends), C	Optimal	Combine with A&B	8

[76] http://www.wear-2.com
[77] Report: De-labelling Branded Corporate-wear for Re-use, [www.wrap.org.uk/de-labelling] December 2013

**Accessories become garments,
a garment becomes another garment,
parts of garment become again accessories.**

Modular design, or modular construction, is a design strategy that subdivides a system into smaller parts, modules that are created independently and then can be used in different systems. In this way, reusable modules can be used in different systems - a kind of qualitative semi-manufacture, enabling re-contextualisation and a long and varied product life.

This is an example of a modular fashion - clothing parts that can be added to and subtracted to create various kinds of garments, such as dresses, tops, skirts, with sleeves, without sleeves etc.

The collection is based on interconnected modules, flexible in design, fit and construction. The modules are 18 scarves, designed into 5 different types of garments. It is a mono-material collection, 100% polyester, including stitching and thus possible to recycle at fibre level.

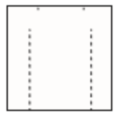
Design: Anna Lidström, photograph: Jan Berg, model: Katarina Johnson

18 SCARFS **= 5** GARMENTS

TOP
2 scarfs
4 seams

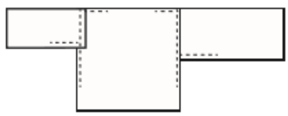
Cost & Price	SEK
Direct material	36,5
Direct production costs	32
Potential pricetag	308

SKIRT
2 scarfs
2 seams
2 hooks & eyes



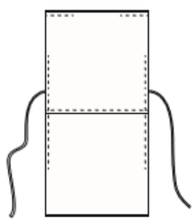
Cost & Price	SEK
Direct material	55
Direct production costs	37,5
Potential pricetag	416

DRESS
4 scarfs
6 seams



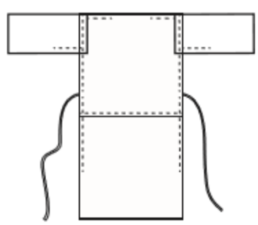
Cost & Price	SEK
Direct material	89,7
Direct production costs	60,6
Potential pricetag	677

DRESS
4 scarfs
6 seams
1 belt



Cost & Price	SEK
Direct material	94,7
Direct production costs	68,6
Potential pricetag	735

DRESS
6 scarfs
8 seams
1 belt



Cost & Price	SEK
Direct material	148,9
Direct production costs	67,7
Potential pricetag	758

ANNA LIDSTRÖM

Conditional design is a design strategy which prepares garments for circular flows, such as re-use, service, remanufacturing or recycling.

These are examples of garments from Houdini Sportswear, Klättermusen, and Icebreaker that have been designed with circularity in mind or that have potential for circular flows, if the garments are altered.

The examples are based on mono-materiality, modularity, and incremental design with a discussion on how to achieve full circularity.

Houdini C9 Jacket - Padded midlayer.

Circular properties

The garment is made of 100% polyester and with current recycling technologies almost 100% recyclable. Teijin eco circle materials have great potential, but recycling has to be done locally, and currently the recycling plants are only located in Japan. Transportation used and collected garments there for recycling limit the benefits of recycling.

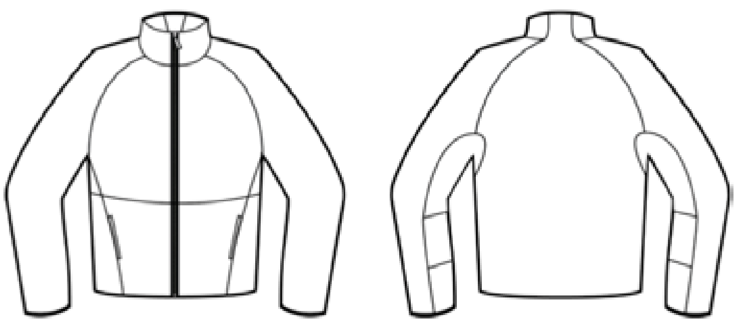
Classification

The garment would, in the coding scheme, achieve the highest possible classification, A1.

Considerations

Synthetic materials release micro-plastics, which is considered hazardous to primarily marine life.

Photo: Jan Berg. Model: Jonas Larsson



CALCULATIONS

Item	Information	Cost		Pricetag	Classification (With current recycling technologies)	Highest possible classification
		Material	Labour			
Insulation fabic	Polartec® Alpha Insulation, 100% polyester, Bluesign® certifierat, Vikt: 100 g/m2	80 SEK /m2	47 min, 94 SEK. Total Production cost ca 400 SEK	2000 SEK	A1	A1
Shell fabric	Teijin C9 ripstop, 100% recycled polyester, Diffusion Stretch 100% recycled 65g/m2	40 SEK /m2				
Sewing thread	Polyester	50 SEK/kg				
Lining fabric	Polyester	30 SEK/ m2				
Zipper	Metal co	100 SEK				

*http://wear-2.com/

Houdini Wooler Houdi - Wool jacket

Circular properties

The garment is made of wool with pocket linings made of polyester. It has high circular properties.

Classification

The garment would, in the coding scheme, achieve the classification A2. If technologies such as wear2 thread technology are used, it might be able to achieve classification A1.

Considerations

Wool fabric also allows for high bio-degradability, but processes such as dyeing and finishing of the garment may limit these positive effects.

CALCULATIONS

Item	Information	Cost		Pricetag	Classification (With current recycling technologies)	Highest possible classification
		Material	Labour			
Shell fabric	100% mulesing free merino wool, Wooler GridMerino 17,5 microns, Biodegradable	200 SEK /kg	27 min, 60 SEK. Total Production cost ca 400 SEK	2000 SEK	B	A2 Wear2 technology is used in assembly*
Lining fabric	Polyester	30 SEK/kg				
Swing thread	Polyester	50 SEK/kg				
Zipper	Polyester & Steel	100 SEK				

*http://wear-2.com/

Houdini Commute Pant

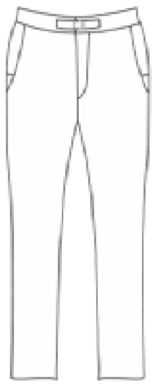
The garment is made of 100% polyester and with current recycling technologies almost 100% recyclable.

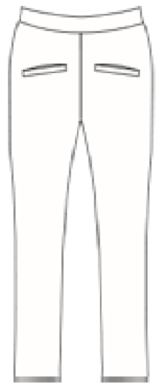
Classification

The garment would, in the coding scheme, achieve the highest possible classification, A1.

Considerations

Synthetic materials release micro-plastics, which is considered hazardous to primarily marine life.





CALCULATIONS

Item	Information	Cost		Pricetag	Classification (With current recycling technologies)	Highest possible classification
		Material	Labour			
Shell fabric	Commute Cordoroy, 100% Polyester, Bluesign Certified, 282 g/m2	80 SEK/ m2	47 min cost 94 SEK. Total Production cost 260 SEK	1300 SEK	A2	A1 if wear2 assembly technology is applied*.
Lining fabric	Polyester	30 SEK/ m2				
Swing thread	Polyester	50 SEK/kg				
Zipper	Steel, Polyester	30 SEK				

*http://wear-2.com/

Klättermusen Mithril Pants

The garment is made of a blend of polyester, polyamide and aramid fibres. It has therefore very limited circular properties. The interesting part of this pant is its modularity. By changing pockets, several different functions can be added or removed as the user may wish.

Classification

The garment would, in the coding scheme, achieve classification C.

Considerations

Very difficult to recycle.

CALCULATIONS

Item	Information	Cost		Pricetag	Classification (With current recycling technologies)	Highest possible classification
		Material	Labour			
Shell fabric	Windstretch 180g/m2-70% Polyamid, 20% Polyester, 10% Elastan Bluesign approved, Reinforcement 100% Kevlar, Shoe cleaning area, 100% Polyester	80 kr/m2	90 min cost 180 SEK. Total production cost 460 SEK	2300 SEK	C	C, as this is an example on modularity, the ambition is not to have as high classification as possible but to showcase modularity.
Sewing thread	Polyester	50 SEK/kg				
Zipper	Polyester & Metal	30 SEK/kg				

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