Reverse Resources

The Undiscovered Business Potential of Production Leftovers within Global Fashion Supply Chains:

Creating a Digitally Enhanced Circular Economy

Insight from research among fabric and garment factories of China and Bangladesh.

Research conducted by

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Reverse Resources, August 2017

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"The figures presented are of a similar magnitude to WRAP estimates. This report is an important insight into an underexplored area. We hope that it will prove valuable in tackling this issue." **Keith James – WRAP**

"I have been impressed with the innovative and comprehensive approach Reverse Resources is taking to this niche and often overlooked topic, one that is an essential part of moving the sector towards true circularity and which presents many opportunities for the apparel sector, at every stage of the value chain." **Ria Kearney - MADE BY**

"RR certainly lays the critical stepping stone toward Sustainable Manufacturing and Internet of Things, which are two of the main keywords of the Digitalisation: the 4th Industrial Revolution. It is thrilling to watch how RR will help tackling the intractable inefficiency problem of the fashion industry by enabling transparent communication to optimise the material flow globally."
Dr Curie Park - Centre for Industrial Sustainability, UNIVERSITY OF CAMBRIDGE

"It may be possible to argue with some of the figures presented in the Reverse Resources report and the industry may challenge some of the assumptions made by the authors, but it is clear they have unearthed important finding through their research. Circularity for the clothing industry requires a re-thinking of the model and Reverse Resources have started to identify some of the fundamental pillars of the industry that need to be dismantled and re-imagined. The way we view the supply chain and how 'connected' it is requires challenging. The business as usual model needs to be unpicked. And a real attempt at true transparency is a vital part of the jigsaw. Reverse Resources has developed an alternative view of the existing model, and whether this view is right or wrong is immaterial; the model and the work done to date needs to be considered and developed further as we may not truly understand the supply chain as well as we had thought."
Dr Mark Sumner - Sustainability; Retail & Fashion UNIVERSITY OF LEEDS

"This is a valuable contribution to what is very much a hidden industry – the collection and processing of production waste from the textile industry. The report helps to explain why textile producers act in the way that they do, and sets out some practical steps of how matters can be improved. The report illustrates how building trust and sharing the financial benefits of better fabric utilisation between brands and factories is key to making progress towards more materially circular production." **Nick Morley - FAERLING LTD**

Abstract

Reverse Resources, after winning the Global Change Award, has carried out extensive research among major fabric and garment factories in China and Bangladesh. We conclude that the volume of production leftovers is systematically underreported and thus underestimated by the industry. After the capacity of lean manufacturing methods (process optimisation) end, still >25% of resources (for a variety of reasons) are spilled out of original supply chains. Even though these materials get used somewhere, most materials get downcycled, incinerated or dumped. We describe the economic incentives for stakeholder (a "hidden subsidy" embedded in current pricing scheme) to continue along linear patterns, preventing more effective use of resources. We analyse the market situation, and potential for growth within the industry via improved material circulation, in the example of Bangladesh. We suggest a win-win business model of remanufacturing - integrating >20% of the leftovers (bigger fabric pieces) back into the same production. We describe an alternative pricing scheme which could give great economic incentive for suppliers to open up their data digitally. Better data from factories would facilitate virtual traceability of resources and digital interconnections throughout supply chains. This is crucial for building an effective circular economy as well as supporting many digital solutions of industry 4.0 globally (e.g. blockchain-based transparency).

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1. Introduction

Circular economy has undoubtedly become a trend in the fashion industry. It is discussed within the framework of three main topics: (1) gathering and sorting of post-consumer leftovers; (2) better recycling technologies to turn post-consumer leftovers into new yarns and thus close the loop and (3) purchasing alternative materials, especially recycled yarns. But the fashion industry could gain much higher economic value from a more holistic approach to the material circulation throughout global supply chains. The key to that is giving a business incentive for fabric and garment suppliers to make their data accessible to enable virtual traceability of fabrics and fibres throughout circular material flows.

The goal of circular economy is to move towards effective use of resources and decoupling economic growth from environmental impacts. Even if the material loop gets closed, circularity itself requires efficiency to carry that goal. This is why this white paper analyses material circularity from the perspective of resources efficiency in garment production and discusses the means of building new business value from more efficient use of leftovers.

There is another major trend emerging in the industry - entering the information and technology era. We are fast approaching a digital transformation involving an array of technologies that promise to reshape the way things are made - industry 4.0[1]. This transformation is data-driven and much needed. Many of the digital technologies in the fashion industry are usually discussed first in the context of the consumer experience. More than ever, the *production* side of the supply chain must join the digital exchange.

This white paper analyses how better access to information on fabrics and leftovers from garment production could benefit the circular economy goals of major fashion brands. We explain how inconsistent data gathering methods and the current linear pricing schemes are creating inefficiencies, and affecting the knowledge level and actions of the industry. We analyse the current market value of production leftovers in the example of Bangladesh, and estimate the market potential of these leftovers, if different means of remanufacturing and recycling were applied in the future. We also suggest key topics which should be addressed to create an economic incentive in the supply chains, in order to move towards material circulation and waste hierarchy naturally.

We believe that shortening the loops of circular supply chains is a major unexplored business opportunity for growth within the industry sector. Shorter interconnections can unlock the potential for open data sharing and virtual traceability of fabrics and fibers through supply chains. Access to information is key to building effective circular economy in the global fashion industry, but demands cooperation and open discussion.

[1] https://capability-center.mckinsey.com/files/mccn/2017-3/digital_4.0_model_factories_brochure_2.pdf

2. The volumes of garment production leftovers are systematically underestimated

Research by MIT[2] reported in 2015 that 150 billion garments are produced every year worldwide. In Bangladesh 10,2 billion garments were produced in 2014[3], which represents around 5-7% of global garment production. At the same time the volume of by-products was reported as over 351 000 tonnes[4] out of total yarn consumption (production + import) of garment production being 1,394 million tonnes[5]. This means the by-products represent 25% of the total consumption.

However, previous studies estimate that the quantity of pre-consumer textile waste equals only 10-20% of the textiles used in clothing manufacturing[6]. Our experience confirms that the volumes of production leftovers are systematically underreported and thus underestimated by brands and researchers.

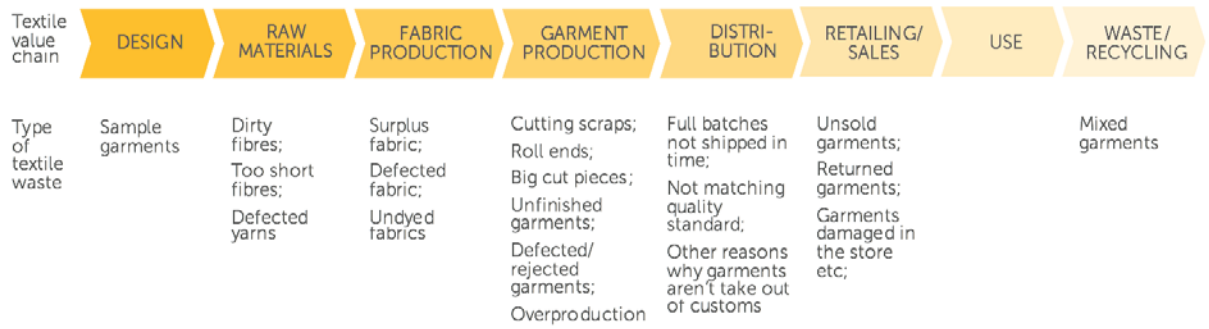

Figure 1. Simplified value chain and examples of spill from each phase.

Commonly the term "pre-consumer leftovers" is used. This refers to any type of leftovers that emerge throughout the value chain (as seen on Figure 1), but do not reach a consumer. However, this white paper focuses only on such leftovers which are considered the responsibility of garment suppliers - leftovers (or spill) from fabric and garment production factories only, which can be referred to as "post-industrial leftovers".

The list of spill types in Figure 1 is not all-inclusive: a single garment factory can report >70 different subcategories of spill based on material composition, piece size and reason for discarding the materials from production, the method of segregation etc.

Reverse Resources (RR) has gathered data from 7 garment factories[7] in China and Bangladesh and carried out >100 interviews since January 2016 (sustainability experts,

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[2] http://msl.mit.edu/publications/SustainableApparelMaterials.pdf

[3] BKMEA, "Apparel export statistics of Bangladesh, Fiscal year 2013-2014," Bangladesh knitwear manufacturers and exporters association (BKMEA), Narayanganj, 2014

[4] http://archive.dhakatribune.com/bangladesh/2014/nov/22/rags-riches-prospects-recycled-rmg-products

[5] https://gain.fas.usda.gov/Recent%20GAIN%20Publications/Cotton%20and%20Products%20Annual_Dhaka_Bangladesh_4-11-2017.pdf

[6] www.ncbi.nlm.nih.gov/pmc/articles/PMC4796196

management of different retail corporations, designers, production office managers, merchandisers, supplier management, recycling companies, etc)

The following graphic illustrates the distribution of different types of leftovers from vertically integrated fabric and garment production factories - a model developed based on the data gathered from 7 major factories producing in total >250 million garments per year.

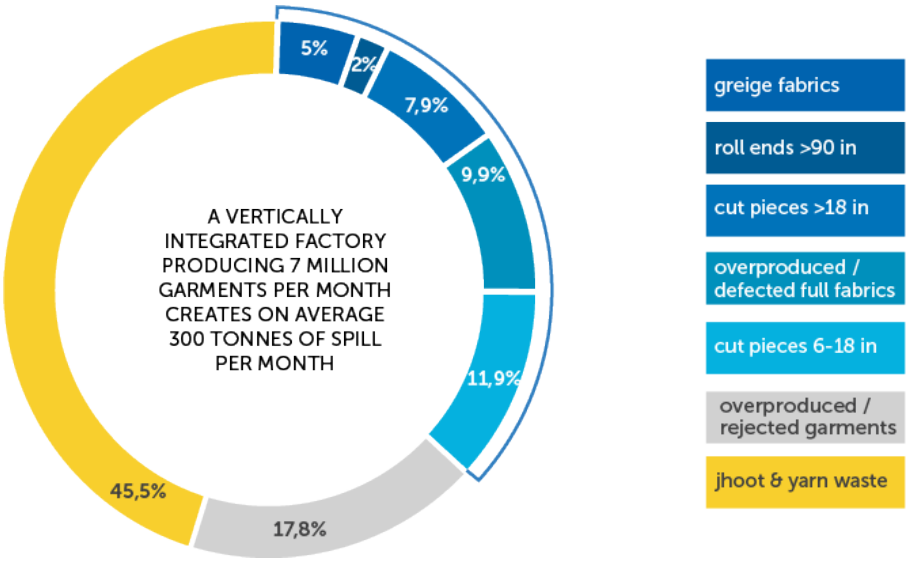

Figure 2. The proportion of different types of leftovers from vertically integrated fabric and garment factory in Bangladesh.

Our research indicates that the volume of textile spill from factories in developing countries is being systematically underestimated. For example, a report by University of Cambridge, EPSRC and IfM (2017) refers to 15-20% of post-production textile waste from factories in Sri Lanka.[8] Comparing different data from the 7 factories in China and Bangladesh, we can estimate that the total volume of different types of leftovers from fabric mills and garment factories (i.e. post-industrial spill, not including several sources of pre-consumer leftovers) is at least 25% of resources used by these factories on average, in some cases even up to 47% of the fibers and fabrics bought by a factory. This includes everything from valuable by-products to waste getting dumped.

But commonly, data from factories about leftovers is inaccurate and not comprehensive enough. Most often, only paper-based documentation or excel sheets are used and inventory is done irregularly or periodically. Even factory management does not often have access to accurate, comparable and live data from production. There is also no systematic categorisation of leftovers across different factories and data, if being gathered by brands, is not easily

[7] Due to a conflict of business interests, several suppliers have not been willing to disclose their name as the source of the data and most suppliers did not share all leftover statistics fully. In total, the suppliers we interviewed produce >25 million garments per month ranging from 0,5 million to 9 million per geographical location.
[8] https://www.ifm.eng.cam.ac.uk/uploads/Resources/TransTextile_Report.pdf

comparable. Thus, it is difficult to make conclusions about the volumes and methods of using the leftovers.

As a result of general unawareness of the situation, the topic of production leftovers is under-represented in the discussion of circular economy in the fashion industry. To demonstrate it, we compared our data with the value chain footprint graph published by Nike (2015), which estimated what proportion of resources throughout value chains becomes waste at which stage[9].

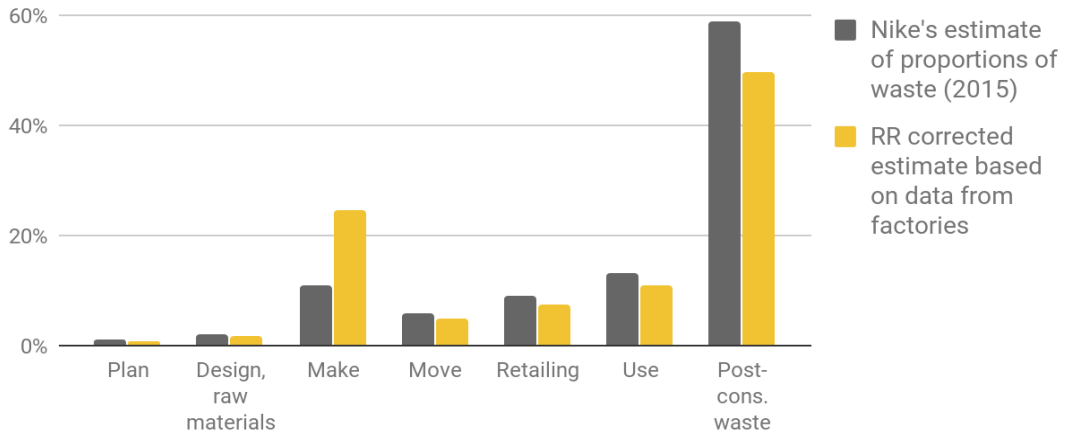

Figure 3. The proportion of waste in different phases of value chain: comparison between Nike's and RR research. Fashion industry has been underestimating the production leftover volumes and thus the potential of reusing these materials.

Lack of transparency has created fertile grounds for the development of an excessive aftermarket for leftovers. Due to the aftermarket almost none of the stakeholders in these "secondary" supply chains now have an incentive to enable transparency.

The leftover fabrics usually move through 3-5 levels of different traders before reaching next production. An extensive number of intermediaries distorts the market in several ways. It **brings up the market prices, lowers lead times for recycled materials, holds back the spread of knowledge on best practices** and limits the percentage of leftovers reaching optimum new life-cycles. Factories are unaware which materials are worth segregating from production. Thus, too much of the leftovers get mixed up in bulk on the production floor losing most of their economic value instantly.

We would argue that the aftermarket amplifies the information deficiency problem, but is not the cause of it. The corrupt and obscure aftermarket can in fact be seen as the results of systemic market failure. **Until it is economically meaningful for factories to sell the leftovers to local traders and earn extra income from it, there is no incentive for the factories (or factory employees) to provide accurate data.**

[9] Nike's approach was to consider all materials reaching consumer as potential post-consumer waste. Thus the columns add up to 100% of resources moving through the life-cycles. The report is not fully available online, but the original graph can be seen here: https://drive.google.com/open?id=0B74aNG0UHrpyXzVoYzhJZEgtNnc

Picture 1. One of the official dumping sites in Dhaka for 14 factories.

Picture 2. Sorting of mixed leftovers by piece size behind a factory.

3. Linear pricing schemes giving an incentive not to gather comprehensive and accurate data

Traditionally, leftover management is considered the responsibility of suppliers in any linear supply chain. Being separate legal entities, buyers cannot interfere directly in waste management methods. However, if we consider the supply chains from the circular economy perspective, each stakeholder in the supply chain plays a certain role in enabling circularity. Global fashion brands (the buyers) play a more significant role in how factories manage their leftovers, than they imagined.

Brands and suppliers work hand in hand to find more advanced methods of optimisation. Lean manufacturing brings great economic benefits for factories. For example, a factory in Dhaka explained: simply by rearranging how fabrics are fixed on the cutting table, they managed to reduce the length of each fabric lay by 3 cm and achieved 22 000 USD savings per month.

However, there are various reasons why factories still have leftovers from all different phases of production (shading and shrinkage differences of fabric rolls, mismatches in purchase orders and production, regular overproduction, fabric defects etc). After production is finished, factories gather data from production and analyse where further improvements could be done for optimisation.

Currently there is a major information gap between factories and brands about the volumes and types of leftovers which could not have been used in main production. **This is because the current dominant method of production costing gives a monetary incentive for garment suppliers to underreport leftover information after production is finished.**

While planning production, brands are often aware of the exact volume and price of the fabrics which are produced or bought. Due to expected production inefficiency, 3 to 10% extra fabric needs to be bought to cover unavoidable cutting scraps. This means that when paying for their purchase orders, brands perceive that they have already paid for the excess fabrics and leftovers that will be created from production. However, as woven fabrics are bought in yardage and knit fabrics in kilograms, but the ready-made garments are measured in number of pieces, the input-output ratio is not actually tracked.

It is common practice to leave leftovers for factories to solve due to large amounts of small scraps and lack of means of recycling. It is in the interest of production efficiency to mix leftovers up in bulk and moving them out of the factories quickly to avoid costs. Although materials are then sold at a low price, it brings good additional revenue for them. Despite the low market price of leftovers, the fact that factories commonly operate with very small profit margins means that the extra margin from leftover sale is significant, compared to their margins from the main production.

This next illustration of the cost structure from a hypothetical pair of trousers is from a factory in Bangladesh to describe how meaningful the extra margin from the aftermarket can be.

Costing of main purchase order		Leftovers	
Total volume of fabric used in a product (yards)	2.00	volume of leftovers (20% from fabric used in production), converted to kg	0.22
Price of the virgin fabric (USD/yard)	2.50	example low price of leftovers (USD/kg)	0.20
Virgin fabric in the product (price, USD)	5.00		
Production cost, taxes, etc.	1.86		
Supplier gross margin per product (2% from total cost)	0.14	Supplier extra gross margin from left-overs (USD per product)	0.04
FOB* paid by the buyer	7.00	Total gross margin of supplier per product	0.18
How much does the factory earn extra from the aftermarket			**24%**

* Free on Board, including export taxes and costs till the moment products are delivered to nearest port

Table 1. Example costing of a product, illustrating the % of additional margin earned by a supplier from selling leftovers from this one product to local aftermarket.

Although only an illustration (the actual average price of leftovers is higher), these numbers explain a clear pattern. Factories earn a relatively high share of the total profit margin from selling leftovers, compared to the margin from the purchase orders from their key buyers. Considering that big factories operate with millions of garments produced per month, these numbers shown here per product can escalate to hundreds of thousands of dollars.

As a growing number of brands are starting to discuss circular economy and closing the loop of leftovers, there is often discussion of reusing dead stock fabrics and roll ends in production. However, knowing that these brands claim to have already paid for the leftover fabrics as part of the main purchase order, garment factories face the risk of losing that second margin.

In conclusion, the current pricing scheme strongly benefits linear economy - **stakeholders in the supply chain benefit more from selling materials on without considering the efficiency of the system both in terms of environment and economy**. However, now that brands are one by one setting goals towards 100% circularity, the pricing issue needs to be discussed as well.

Material circularity of production leftovers is already established, but it is by default inefficient, rather costly for end-users and out of the control of the stakeholders in the core supply chains. With the spread of circular economy, having control over waste material flows is becoming one of the most strategic goals of leading corporations.

4. Unlocking market potential to improve the use of production leftovers and enhance material circularity

4.1. Supporting recycling initiatives with higher visibility of leftover materials

Among the >100 interviews, we talked to several recyclers and research groups developing next-generation recycling solutions[10]. The growing demand for input materials for recycling in the coming years predicts the need for better information about leftovers.

Current recycling practice

Mechanical recycling of cotton is becoming a common practice globally. Over time mechanical cotton recycling has been practised in producing countries to lower the cost of yarn production by mixing new virgin fibers with leftover fibers. Due to improving technologies the quality of recycled yarn is going up, and so the price of recycled yarn is said to be 15-30% lower compared to standard yarns.[11] With growing confidence in demand for recycled yarns, the market for mechanical recycling is clearly growing fast.

But mechanical recycling is limited by composition (100% cotton or in some cases mixed materials with at least 80% cotton content) as well as colour. For example, Recover (www.recovertex.com) is not dyeing the recycled yarns, but mixing different colours of scraps to reach a necessary dye for the yarns and thereby attaining higher quality of recycled yarns.

100% polyester is also gathered for recycling among garment factories, as we have witnessed, but these are not used for making new yarns. *"Although a number of companies worldwide have depolymerization equipment and use post-industrial fabric waste among other PET materials, it is not commercially possible yet to make yarns from textile waste. All rPET (recycled PET) and recycled polyester yarns are currently produced out of PET bottles or containers. Most of this manufacturing is done in Asia."*[12]

But various methods of improved sorting technologies and **chemical recycling** of mixed fibers are emerging fast. A number of initiatives currently in lab phase are estimated to be on the market on industrial and scalable level in 2-5 years' time, in some cases even

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[10] 3 major recyclers (Recover, Pure Waste, Lenzing), 1 major post-consumer sorting centre who is working with recyclers (I:Co/Soex), and 3 organisations who are developing a soon-to-be scalable recycling solution (Ambercycle, Worn Again and Ioncell-F)

[11] https://sourcingjournalonline.com/innovative-bangladesh-manufacturer-makes-low-cost-closed-loop-yarn-td/

[12] Comment by Akshay Sethi, Ambercycle (www.ambercycleinc.com)

sooner.[13] It will soon be technically possible to recycle at least 80% of all textile leftovers of any solid or mixed fiber compositions commonly used in fashion industry.

We can conclude that lack of information on production leftovers is affecting the recycling market in several ways:

- Whilst recycling is a consistently hidden business in developing countries, the already **existing capacity and knowledge of mechanical recycling is underestimated** and could be employed more efficiently amongst developing countries.
- Sorting centres in Europe looking for means of recycling post-consumer leftovers lack information on how to **setup a network of recycling partners** in Asia.
- Project teams working on improved recycling technologies do not have enough information with which to plan where and in what volumes should they **set up new recycling plants**.
- There is significant price difference in what factories earn for their cutting scraps and what recycling centres perceive as "good price" paid for the scraps.

Potential future recycling practice

Recycling market would benefit in various ways from open and transparent marketplace of production leftovers. It would increase the competitive advantage of recycled yarns and fabrics next to conventional materials in following ways:

- Skipping intermediaries from the trade schemes and setting up one-on-one transactions between factories and recyclers would be easier. It would bring down costs for recyclers and increase earnings for suppliers.
- Trustworthy and regular background information about cutting scraps from production (including information on chemicals) means less need for testing the input materials.
- Lowering lead times: with some recycling technologies recyclers have fluctuations in the need for a certain colour or composition at a certain time and they are sensitive to location. Higher transparency enables more efficient planning.
- Increasing the percentage of materials being recycled for new yarns (increased system efficiency).
- Tracking leftovers from factories to recycling would enable **transparency of circular material flows** - it would be possible to measure the % of their production leftovers being upgraded to new yarns in comparison to downcycling or dumping, giving significant insight into progress towards circularity.

As more recycling solutions emerge, the competition will grow over the use of leftovers and having accurate information is going to be of strategical value. Efficiency and low-cost circulation depends on the ability to plan material flow, which is why visibility and virtual traceability of resources will be a hot topic in the future.

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[13] Some references as an example: http://www.lenzing-fibers.com/en/tencel/refibra/; http://wornagain.info; https://www.ambercycleinc.com/; http://www.hkrita.com/newsletter/issue41/making.htm

4.2. Remanufacturing to be established before recycling

Our research indicates that more than a quarter of the production leftovers are fabric pieces bigger than 18 inches (0.5 yards) which could still be usable in the factories, without recycling. Waste hierarchy suggests that recycling (to make new yarns) should only be applied on smaller cutting scraps, yarn waste and such leftovers which cannot be reused as fabrics, products or product details.

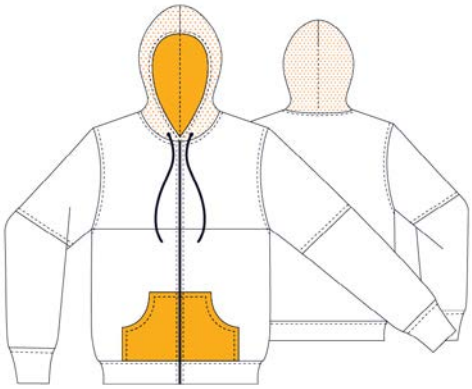
The focus of RR research and trials has been on how to **remanufacture these bigger pieces** of fabrics in mass-production Our goal is setting up **a process that maintains standardisation and efficiency.** We distinguish remanufacturing from recycling because it does not involve heavy investment in recycling technology or significant use of energy or water to have materials prepared for next production. We also distinguish this from process optimisation and lean manufacturing practices - we look into waste created after lean manufacturing principles have been applied.

We have seen that the production leftovers from a supplier (especially a vertically integrated supplier) are often similar in fabric type and specification. By using leftover fabrics of a similar specification on small sections of another style, leftover fabrics could very efficiently be remanufactured into following purchase orders.

Reverse Resources has developed 3 methods of remanufacturing that are applicable in mass-production:

1. **Invisible remanufacturing** – Using production leftovers invisibly on internal sections of a garment (e.g. pocket, cuff and fly facings, collar stands, back yoke). The exterior of the garment remains completely standardised. By only using a small % of leftovers invisibly within a garment, the potential for reuse of fabrics within mass production is created.

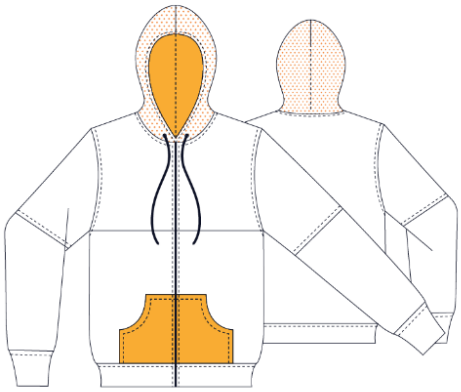
2. **Visible remanufacturing** - Using leftover fabrics for small details on the outside of a garment. This could be done in the same or contrast colour. The leftover fabric is visible, but does not significantly affect the design. (The product planning follows the usual design-buying-purchasing pattern).



3. **Design-led remanufacturing** - Designing a garment with a specific wastestream in mind. It is similar to the concept of upcycling fashion design, except that it does not demand producing a full garment out of 100% leftovers. Mixing a small % of leftover fabrics with new fabrics increases the application of remanufacturing in mass production and reduces design limitations.

The main goal of remanufacturing, in addition to reducing production spill and closing the loop of materials, is to reduce the volume of new fabrics needed in production. As illustrated in the next graphic, if the pieces marked with yellow were taken out of the marker (lay plan), the blue section demonstrates how much virgin fabrics could be saved from the cutting of one garment. If 10 000 hoodies were produced like that, the total purchase of virgin fabrics would be reduced by 17%.

Visible remanufacturing – using leftover fabrics on external sections of a garment

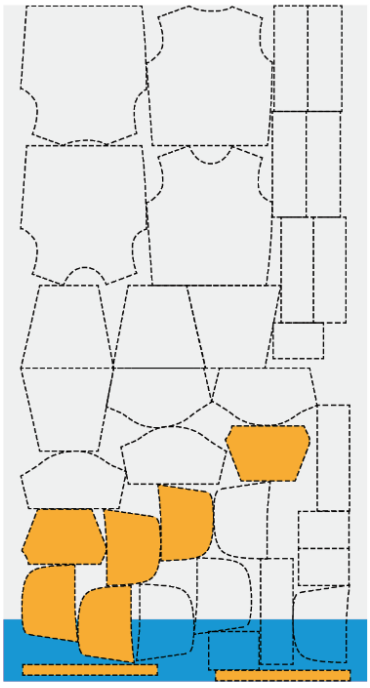


PRODUCTION OF 10 000 OF THESE HOODIES WOULD:

- Save 2843 yards (17%) of virgin fabrics
- Avoid 0.88 tonnes of fabrics from being spilled
- Save 7827 kg CO2

HOODIE SPECIFICATION DRAWING & MARKER PLAN ▶

VISIBLE REMANUFACTURED FABRIC PIECES
INVISIBLE REMANUFACTURED FABRIC PIECES
VIRGIN FABRIC
AMOUNT OF SAVED VIRGIN FABRIC



Potential impact of remanufacturing

We have also analysed and done trials on the applicability of remanufacturing in production (see appendix 2) and can make the following conclusions about the potential impacts of remanufacturing:

- It could **reduce >20% of production spill** if materials were used more efficiently by original buyers within their next purchase orders.

- If remanufacturing was practiced with only the invisible or visible methods, it would have **the potential to save in total ~3% of virgin fabrics from conventional production**.

- By using a small 5-20% of leftover fabrics in production instead of using 100% as is often the current approach we can maintain a high level of standardisation and efficiency without scale restriction.

- Remanufacturing **does not imply significant investments in technology**, it only implies adapting processes slightly, improving segregation and storage systems in factories and creating fast and accurate communication and data exchange from factory to designer.

The environmental impact from remanufacturing can be calculated in ratio to the volume of virgin fabrics saved from production. If a brand has set up their environmental footprint calculation methods for their conventional production, the impact of remanufacturing would be easy to calculate.

However, if remanufacturing was set up as regular practice, it is debatable whether such simplified approach can be applied. The real impact actually emerges from the amount of leftovers that are saved from dumping, energy recovery or downcycling. It also emerges from the lower amount of energy invested in recycling of leftovers as well as the extended life-cycle of the fabrics through their next life-cycles.

The full impact of remanufacturing can only be time-tested on full production and via proper measurement methods. Our trials and interviews so far indicate that the concept could benefit best use of resources in the fashion industry. If each different type of leftover found its next best use, the waste hierarchy could be applied properly and dumping leftovers could eventually be phased out.

Remanufacturing **is particularly interesting because it could be the key to creating the economic incentive for transparency.** As explained above, the current pricing scheme creates a strong barrier for brands and factories to even start a meaningful discussion around transparency of information. But making data on leftovers accessible and creating transparency is the critical key to unlock effective circularity of material flows. Thus, we should consider adapting the pricing schemes when remanufacturing to create an incentive for both sides - buyers and suppliers - to work together towards material circularity.

4.3. Suggestions how to incentivise circularity and open information sharing in production

To create an incentive for factories to work towards material circulation and to develop solutions for maximum resource integration in production, three elements are essential:

1. preserving the current margins for both brands and factories;
2. giving an additional means to earn extra or cut costs from transparent material circularity
3. considering the conflicting interests of buyers and suppliers, the new agreement between them needs to be measurable, controllable and transparent.

The double pricing of leftovers is a barrier to efficient material circulation. In some ways, it is comparable to the public subsidies of fossil fuels as a barrier to the competitive advantage and spread of green energy solutions. "There is no one-size-fits-all strategy for subsidy reform - but there are a set of planning stages that are generic, along with many common issues, challenges and potential solutions," explains the Guidebook to Fossil-Fuel Subsidy Reform by Global Subsidies Initiative.[14]

Similarly to fossil-fuel subsidy reform, a step-by-step action plan should be developed for the fashion industry to move from linear to circular. Monetary, regulatory and supportive measures need to be considered in balance and impact analysis carried out.

As the first step, we suggest a discussion of the following means of change to create a win-win business case and enable adequate transparency on both sides.

Adapting the pricing scheme

Develop a pricing scheme for leftovers which is linked with the prices of virgin fabrics, instead of the current market prices of leftovers. For example, the following graphic illustrates the possible win-win business case for buyers and suppliers if leftover fabric pieces were worked into production at 70% of virgin fabric price.

Such pricing would increase earnings from leftovers for factories by 3 times and at the same time reduce the FOB price of partially remanufactured garments. The impact from such a pricing scheme on factories and brands should be validated case by case, but we have provided some hypothetical calculations on the impact on FOB prices in appendix 3.

[14] https://www.iisd.org/gsi/fossil-fuel-subsidies/guidebook

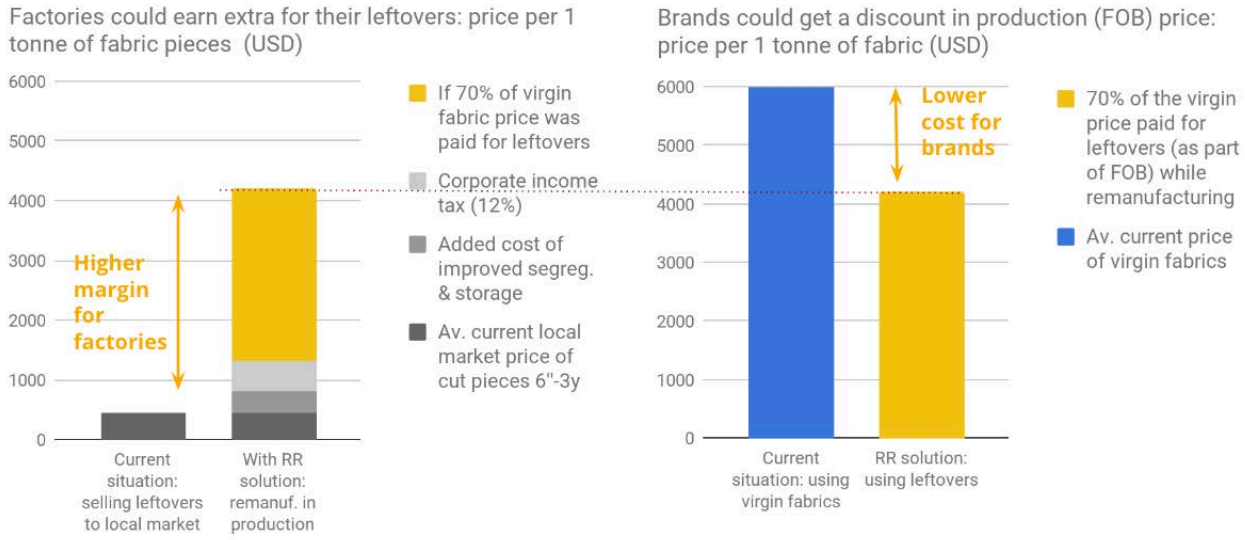


Figure 4. Suggested new pricing scheme of leftovers in case of remanufacturing and closing the loop for original buyer.

On the left, the dark grey section refers to how much factories currently earn from leftovers on average per tonne - this margin needs to be preserved for them. The middle grey section takes into consideration the added tax obligations for suppliers once the informal trading of leftover materials has been officially formalised. The light grey section estimates the extra cost suppliers might gain from better segregation and storage systems - a cost that needs to be covered. The yellow section indicates the new earnings for factories if leftover fabrics were priced at 70% of the new fabric price while remanufacturing. On the right side, the blue column shows the average new (virgin) fabric price, and the potential cost savings for brands if one tonne of new fabrics were switched with leftovers in their next purchase orders.

Further research is needed into using the pricing scheme as a fair incentive to always favor the waste hierarchy for each type of leftover; the lower the solution found for each leftover in the hierarchy, the less suppliers will earn, and the more cost-efficient it should be for buyers.

Implementing measurement systems

A measurement and data gathering system should be set up per each purchase order as well as in total per factory, supplier and buyer. Double checking data from different checkpoints and stakeholders allows for data accuracy and identification of systematic errors in reporting. Although the categorisation of leftovers varies significantly from factory to factory, it is possible to suggest similar methods of data gathering across factories to enable regular daily statistics and data analysis. In appendix 4 we have developed a simplified structure for data gathering, for both planning of circular material flows and double checking data.

Enforcing circularity and demanding transparency

Closing the loop via circular practice can only be applied if there exists a regular demand for remanufacturing and recycled materials. Thus, buyers are carrying the role of enforcement via their purchase orders. But unless the pricing issue is solved first, transparency remains a challenge. The remanufacturing concept could provide the necessary business case for suppliers, mitigating the risks related to transparency. In return of offering a good new price deal for leftovers, buyers have the chance to demand higher transparency and data accuracy.

Dealing with the "hidden subsidies"

Phasing out double pricing should not be done until remanufacturing processes and information sharing systems are properly set up. For example, at the moment there is clearly a mismatch between volumes of leftovers that are already covered in the FOB price of initial order and the actual volume of leftovers. When FOB price includes 3-10% of extra fabric bought for production and 2% overproduction planned then this does not match with >25% of leftovers from production in total. Without proper information sharing systems, it is not possible to capture the ownership and responsibility issues.

However, it is necessary to give a clear signal that the double pricing issue needs to be addressed to avoid new unwanted impacts and new hidden incentives. Common interests between buyers and suppliers must be considered while negotiating a new pricing scheme for the long-term. Involving research partners to analyse the possible impacts of different measures is important.

One possible option here is renaming and restructuring the initial payment for the excess fabrics, currently included in the original purchase order. It could eventually be phased out for those factories who are not following the new best practice examples of material circularity and data sharing. This way, instead of negative impacts on supplier margins, it could act as a means of positive change.

Setting up support mechanisms

Developing this new circular scheme should be a joint effort between several different buyers and suppliers. Suppliers produce for several major buyers and negotiating new pricing scheme separately in each case would be time-consuming.

OECD has analysed the general needs of different industries when dealing with eco-innovation. They claimed that overcoming specific market failures associated with green innovation are often linked to the dominance of existing technologies, systems and incumbent firms. They suggested that support for general-purpose services and technologies, fostering the growth of new entrepreneurial firms and facilitating the transition to green growth with the help of SMEs to deal with market failures.[15]

Therefore, we also suggest finding a neutral bystanding party or parties and an external general-purpose solution to cope with this market failure. Neutral support would help building trust and transparency between buyers and suppliers without compromising business interests. Neutral parties could also help spread best practices of material circulation by waste hierarchy in factories.

[15] http://www.oecd.org/australia/fosteringinnovationforgreengrowth.htm

4.4. Estimating the potential growth within the fashion industry by closing the loop of production spill

We have done market analysis to compare the current and potential market value of leftovers in the example of Bangladesh. The following graphic illustrates how remanufacturing and recycling, if practiced transparently on an open market, could increase earnings for factories over 3 times.

According to the Bangladesh Garment Manufacturers and Exporters Association (BGMEA), in 2014 there were some 4,500 active RMG (ready-made garments) units producing >351 000 tonnes of by-products[16] Considering that not all leftovers get sold as by-products, and there is lack of comprehensive data, we could assume that the real volume of all kinds of leftovers could exceed 500 000 tonnes per year. One vertically integrated factory producing 7 million garments per month creates on average ~300 tonnes of leftovers. 500 000 tonnes per year then would refer to 150 factories of that size in Dhaka (2% of all factories). For further analysis, **we assume the total volume of leftovers in Bangladesh is around 400 000 tonnes per year**.

If these leftovers could be turned into new yarns and garments (considering also more advanced technologies coming available over 5-10 years), this is equivalent to 1.6 billion new garments potentially **worth >4 billion USD (from Bangladesh alone)**. In comparison, a report by Global Fashion Agenda and The Boston Consulting Group (2017) suggests: "*Currently the opportunity to the world economy from waste reduction* (incl. post-consumer waste) *along a linear value chain is modest at around €4 billion per year in 2030. But under a circular model of production and consumption, this value would be manifold higher."*[17]

Using different types of spill requires different investments, and processes. Therefore, to describes the market potential better, we further analyse the value that the factories are earning from the market when selling their leftovers forward. The following graphic illustrates the current market value of different leftovers and compares it with the potential value factories could get in future perspective (5-10 years ahead).

Although we still must rely on many assumptions (and this should be considered illustrative), the graphic expresses all information that was accessible to us (e.g. price comparison from several factories).

In addition to earnings for factories, the following benefits of remanufacturing over recycling should be considered:

- Remanufacturing does not expect heavy investments in technology which means that it is relatively cheaper
- The many traders and intermediary partners in the supply chains currently make the price of circulating materials relatively expensive.
- The environmental aspects should be considered: recycling is energy-demanding and has little environmental benefit vs. reuse of leftover fabrics.[18]

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[16] http://archive.dhakatribune.com/bangladesh/2014/nov/22/rags-riches-prospects-recycled-rmg-products
[17] https://www.copenhagenfashionsummit.com/wp-content/uploads/2017/05/Pulse-of-the-Fashion-Industry_2017.pdf
[18] http://onlinelibrary.wiley.com/doi/10.1111/jiec.12208/full

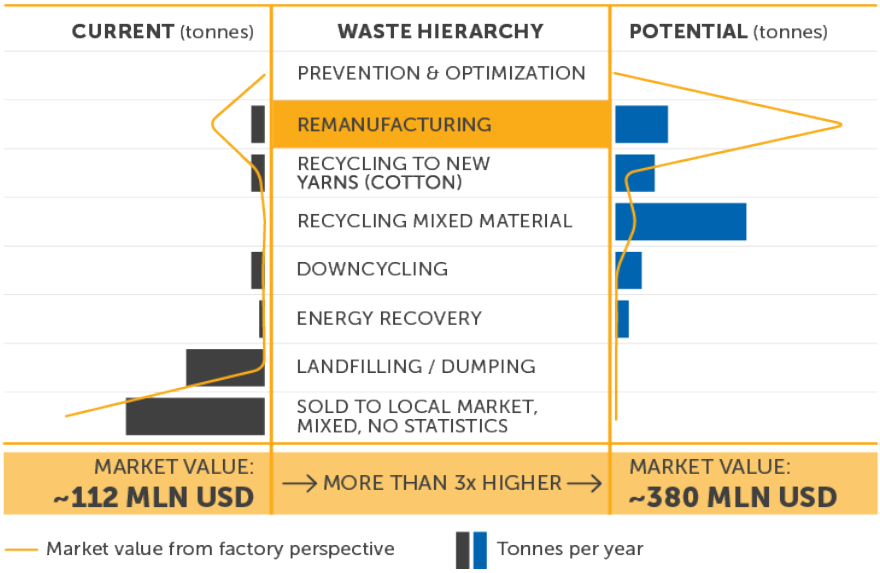


Figure 5. Estimation of the current situation compared to potential use of leftovers from garment production in Bangladesh

Getting the pricing right and setting up a supportive system for material circularity in shorter loops can incentivise the fashion industry to start following the waste hierarchy naturally. The market value of leftovers could increase for the key stakeholders by 3 times at least, while also saving costs for buyers and consumers. Although this analysis follows the market situation in Bangladesh, our experience shows that the situation is similar in most other countries which have high concentration of fabric and garment production.

4.5. Virtual traceability of fabrics and leftovers as the next step forward

Unofficial material circulation is already happening in producing countries. It is inefficient, has major environmental impacts and is hidden from the global discussion of circular economy. In the meantime another major trend is happening more openly in the industry, which could help overcome the challenges of circular economy.

The Internet of Things, or Industry 4.0 as it is called when referring to manufacturing production, describes some powerful emerging currents with strong potential to change the way factories work. It is a new wave of technological changes which decentralize production control and trigger a paradigm shift in manufacturing.[19]

McKinsey explains: "While proven principles of lean manufacturing will remain fundamental, new sensors, more data, and advanced analytics can boost the ability to solve problems and identify sophisticated improvement measures, resulting in smarter solutions and new productivity gains. These advances can be complemented with digitally enabled

[19] http://www.mckinsey.com/business-functions/operations/our-insights/manufacturings-next-act

transparency"[20] e.g. via blockchain technologies.

To help industry embrace the first best use mindset of industry 4.0, McKinsey has mapped out various promising opportunities arising from this. **Productivity increase** (3 - 5% by their compass), the **increase in forecasting accuracy** (85+%), **decrease in cost of quality** (10-20%) and **decrease in cost for inventory holding** (20 - 50%)[21] are just a few of the possible impacts depending on where the digitalization is focused. Even though their compass is rather generic, it helps to explain that the value of digital solutions also for the fashion industry.

The data inefficiencies and opposition to transparency which we have described are a major block to industry 4.0 practices. But if remanufacturing as a business case pushed factories to make their data accessible, then industry 4.0 framework would explain how this data could be put to even better use. **Open data from factories would help to improve interconnections and transparency through supply chains and create further significant value for the whole industry.**

By applying remanufacturing as a business case for better data, it would significantly reduce the effort and investment to deliver information in regards to transparency for consumers.

Within one factory, the possible gains of digitalization are clear. Quoting an experience from Beximco, one of the biggest vertically integrated fabric and garment producer in Bangladesh: by integrating their inventory information from locally maintained excel sheet into the Enterprise Resource Planning (ERP) system, they managed to increase the weekly revenue by almost 100k USD.

Much more can be achieved with digitalisation if interconnections and data synchronization is applied beyond single legal entities in the supply chains. **Decentralising and standardising information exchange through supply chains with blockchain technologies could to trigger disruptive changes for the industry.** This can be put in practice to facilitate circular economy significantly.

Here are a few concepts where fabric and leftover information from factories can create new business cases in the value chains, (in addition to enabling more efficient remanufacturing and recycling as discussed earlier):

- "Rent a closet" and "Live Long Fashion" and "Connected clothes" were three of the five megatrends of circular economy described by Accenture[22] representing more than half of the 2634 applications for the Global Change Award in 2016. All these projects are strongly data-driven and digital. Having enough accurate data available on the garments and fabrics from factories on a daily basis would significantly accelerate the scalability of such ideas from niche to mass-market level.

[20] http://www.mckinsey.com/business-functions/operations/our-insights/industry-4-0-demystified-leans-next-level
[21] https://capability-center.mckinsey.com/files/mccn/2017-03/digital_4.0_model_factories_brochure_2.pdf
[22] http://www.accenture.com/t20170410T044051Z__w__/us-en/_acnmedia/Accenture/Conversion-Assets/DotCom/Documents/Global/PDF/Consulting/Accenture-HM-Global-Change-Award-Report.pdf

- Tracking fabrics or garments from production to post-consumer sorting would help increase efficiency of sorting, enabling greater value recovery, because different grades of material can be better separated. Even a simple QR attached to a garment would help sorting centres have better knowledge of the exact fibre composition of a garment and increase the percentage of garments that can be take to recycling. In addition, in recycling, having accurate composition and chemical information available would significantly reduce the need for lab testing of the input materials.
- For factories, one standardised method of data management would simplify implementation of best tracking technologies from factory to post-consumer recycling (example: Eon-ID[23])

The ownership of waste resources is an important strategical value for which recycling companies traditionally compete. The traceability of garments through their life-cycles would give an opportunity for the industry to establish virtual ownership of resources throughout supply chains.

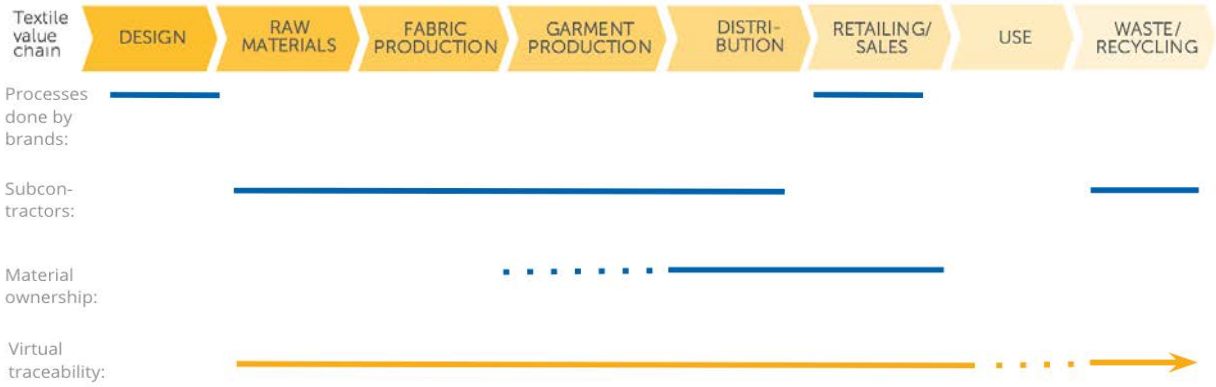


Figure 6. Distribution of responsibilities and ownership through global supply chains.

The figure above illustrates the current fragmentation of the responsibilities and "problem" ownership through the industry. **Creating a digital layer for the industry** to manage ownership issues collectively throughout supply chains (e.g. with blockchain tokens) with proper data coverage would give an opportunity to create a full perspective of the material flows and efficiency of resources. **This would give proper tools for the industry to analyse how to shorten the loops, move towards resource effectiveness and thereby reach profound circular economy**. Accurate data available from factories is a crucial element to make this possible.

[23] http://eonid.co/

5. Conclusion

This white paper gave an overview of the research by Reverse Resources among major garment factories in China and Bangladesh over 1,5 years. We conclude that the volumes of leftovers from fashion production are systematically underestimated. More than 25% of resources are spilled out of fabric and garment factories. Instead of seeing this as a problem, this white paper discussed various undiscovered business opportunities from better use of leftovers and improved transparency.

Lack of proper data available about leftovers is caused by the economic incentive arising from the current dominant pricing schemes of garment sourcing. 3-10% extra fabric is initially paid for by design-led brands to cover the production losses, signaling that they have already paid for their leftovers in advance. Over time it has become common practice for factories to sell on leftovers to the local aftermarket. Compared to the rather low margin from main production, factories are earning a significant proportion (we estimate around one quarter) of their profit margins from that aftermarket. When brands express their interest in reuse or recycling their "own" leftovers, factories sense the risk of losing that income. Thus, the fashion industry is unknowingly fueling the linear industry.

Material circularity is already happening extensively in developing countries like Bangladesh locally, but the loops of circularity are long and contain too many levels of traders. Factories often do not know which materials are worth segregating better in the cutting room and thus mix materials up in bulk, reducing the value of the resources instantly. After sorting and 4 levels of traders, the next users of the leftovers pay a rather high price for the leftovers.

Poor transparency in the aftermarket raises the market prices of secondary materials and recycling, lowers lead times of recycled materials, and holds back the spread of knowledge on best practices. Even though material circularity is already taking place in some ways, this does not meet the goals of circular economy - to decouple economic growth from environmental impacts by resource effectiveness. Material circulation needs efficiency - shorter loops, proper planning and a helicopter view of the supply chains.

This white paper described a potential new win-win business case to incentivise fashion brands and their suppliers to cooperate on closing their own loop of production spill and improved data exchange. In addition to emerging technologies of recycling we discussed the potential of re-manufacturing - using bigger fabric pieces (~25% of the spill are pieces bigger than 18 inches) in next purchase orders by the same buyers. However, to enable remanufacturing it is necessary to adapt the pricing scheme, setting up proper measurement and data gathering methods to map leftovers, enforce circularity and demand transparency, deal with hidden subsidies and set up a support mechanism for stakeholders to build trust and cooperation.

We estimate that such an approach could help increase the market value earned from leftovers by the factories by 3-4 times while simultaneously lowering FOB prices for buyers. It would also reduce the use of new fabrics in production by >3% by switching to leftover fabrics. Along with the first tangible data-driven business case, it provides access to information which is crucial to facilitate various other digital solutions about to come along with industry 4.0 and disrupt the industry (e.g virtual traceability of fabrics through supply chains with blockchain technologies).

Glossary

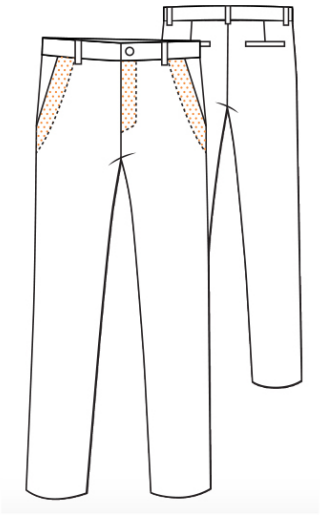
Blockchain techno-lolgy	Blockchain is a digital solution that facilitates secure online transactions. A blockchain is a decentralized and distributed digital ledger that is used to record transactions across many computers so that the record cannot be altered. Blockhain technologies are, for example, used for financial solutions as well as improved transparency through supply chains (e.g. in food industry), but has endless possible applications.
FOB	"Free on Board" price, which is most commonly used when fixing the price of a garment which buyer needs to pay for the supplier. It includes all export taxes and costs till the moment products are delivered to nearest port.
Jhoot	Small cutting scraps and waste yarn mixture from garment factories. All different fibre content is mixed together from production. Jhoot is commonly referred to the mixed scraps that are sold from factories to be used for filling material in furniture, matresses, car seats or similar.
Leftovers	Any fabric, fibre, accessory (zipper, button, etc) or other material that is left out of the main product after production is finished and sent out to the main buyer. Leftovers can also refer to those goods that are sold out of factories as by-products (e.g. ready-made garments without defects, full fabric rolls, cotton lint, etc.), which a supplier does not consider the main source of income.
Spill	The term *spill* is used in the same meaning as *leftovers* in this document.
Post-consumer	Anything that is related to the stages in the supply chain after the use by a consumer, e.g. goods that are returned by consumers.
Post-industrial	Materials which are the direct outcome of production phase in the supply chain. Usually this means that the responsibility to deal with the leftovers is left on the factories (*de facto*), even if the owner of the materials (*de jure*) is the brand.
Pre-consumer	Anything that is related with any of the stages in the supply chain prior to reaching the consumer, including post-industrial leftovers.
Waste	This white paper does not refer to waste because we consider waste as something that cannot be used again either in terms of reuse or recycling, and thus needs to be incinerated or landfilled. Although for chemical composition not all materials are easy to reuse and recycle, we can assume that all materials circulating in the industry will eventually have secondary use cases available.
Waste hierarchy	Environmentally best way to use leftovers: prevention should be considered first, reuse should be considered before recycling. Energy recovery and landfilling should be considered as the last options.

Appendix

A1: The applicability of remanufacturing in mass-production

To further demonstrate the potential of remanufacturing in production, the image below gives a conclusion of cutting trial carried out on a production of chinos.

TRIAL CHINO **Invisible Remanufacturing** switching 14.4% of virgin fabrics with leftovers



Original purchase order:	43 104 pairs of Chino's
Fabric:	54 300 yards of twill
Volume of fabrics usable for remanufacturing:	19.75 yards of bigger fabric pieces in total measured from one cut / estimated **347 yards** from full order
Suggested method of remanufacturing:	small lay (18 inches long) would create enough pocket and fly facings for **another 3 940 trousers**

We investigated the current leftover segregation, storage and production processes and analysed the need for new processes to enable remanufacturing in large garment factories. We did trials to measure the potential savings of virgin fabrics in different basic products. And we measured the exact volumes of leftovers from one purchase order to switch details in the next similar one. We can conclude that **remanufacturing as a concept carries a significant potential for factories to create new added value for their buyers**, if the pricing issue was properly addressed.

Turns out, remanufacturing is not a new concept for factories - it is rather similar to some lean manufacturing techniques already practiced widely. It is only once the first production is finished and fabrics moved out of the cutting room when it becomes economically more beneficial to sell them forward, instead of storage and reuse in the factory.

Also, getting lowest price possible for brands who also accept designs by factories refers to reusing dead stock fabrics extensively. Smaller fabric pieces are used in smaller production to make kidswear.

Our analysis indicates that:

→ Organising and measuring the volumes of larger cut pieces would mean **setting up new processes in some factories**. But time spent on these processes with a data system in place would be insignificant compared to the total current sorting processes, and could be integrated into the cutting and storage rooms without compromising production efficiency.

Picture 3. Cutting of details of a garment, a small side-lay in regular production in a factory in Bangladesh

- **Some additional storage space and an improved storage system would be necessary** in most factories, but starting the remanufacturing process through a system of alerts so only fabrics that were going to be used are kept would mean storage problems would be a minimal. Factories are already commonly storing their leftovers from 2 weeks up to 1 year depending on the materials.

- Using roll ends to make small side-lays in production is a common practice in lean manufacturing. But taking bigger fabric pieces to storage and later back into the cutting room is not commonly done. However, it would not require a significant change in process, often the same warehouses are used for new fabrics and leftover fabrics.
- Without regular segregation, storage and a remanufacturing approach, using leftovers in mass production means significant increase in time and effort. Finding suitable materials from among leftovers which are mixed up and not tracked properly is not feasible and demands significantly more manual work - planning (personal visits by designers to the warehouse), segregation (manually sorting out suitable materials from a pile), storage (keeping the materials for 2-6 months until design and production planning is done). If regular processes were set up for remanufacturing, then **the cost and extra time of such processes compared to regular process setup would be insignificant**.

We have found no evidence of significant loss of efficiency when introducing remanufacturing process into mass production among the 7 factories. However, until remanufacturing is tested out on a large scale, the exact effects can not be confirmed.

A2: The potential impact of the suggested pricing scheme on FOB prices and value for buyers and suppliers

The following table gives a calculation of the total monetary gain for both a hypothetical factory and a buyer if remanufacturing was applied with said pricing scheme.

Av. amount of bigger pieces of fabrics (6 in - 3 yards) from a factory producing ~3,5 million garments / month:	10 tonnes / month
Av. local market price of leftover fabric pieces	0,45 USD / kg
Current total value of the bigger pieces for the supplier, USD per month	**4 500 USD**
Random share of how much leftovers could get remanufactured by one buyer	25%
New cost for factory to segregate and store leftovers better (estimate)	20% of current value = 900 USD
New factory gain if 70% of the virgin fabric cost (6 USD/kg) was covered by brand for remanufacturing (switching virgin with leftovers)	6 USD x 70% x 10 tonnes x 25% - 4500 USD x 25% - 900 USD = 8 475 USD/month = **101 700 USD /year**
Brand saving from lower FOB price (per one factory)	10 tonnes x 25% x 6 USD x 30% = 4 500 USD/month = **54 000 USD / year**
If 100g of leftovers were used in a product, it means this is equivalent to FOB reduction per product by	10 tonnes * 25% / 0.1 kg = **25 000 products** 4 500 USD / 25 000 psc = **0.18 USD per product** saved from FOB price

As seen from the scheme and the table, paying for leftovers with 70% virgin fabric price when remanufacturing would give an extra margin and incentive for factories to use leftovers again instead of selling them on. If hypothetically the average FOB price of such a factory was 5 USD per product while making 3,5 million garments per month, this would mean **2,42% higher gross margin for the factory by remanufacturing only one type of their leftovers**.

It also provides slightly lower costs for buyers - if 25% of the production in that hypothetical factory was usually done **for one key buyer then this pricing scheme would mean 0,1% lowered production costs in total**. It can be small, but considering the added value - strong push towards material circularity and access to open data from factories - this mechanism works in contrast to usual schemes where brands need to make investments into sustainable solutions.

Furthermore, the following calculation illustrates the impact of this pricing scheme on product FOB price in the example of a hypothetical pair of trousers.

	Example of costing of 2 hypothetical woven products	
a	Virgin fabric price in product A	2.5 USD/yard
b	% which brand is ready to pay for leftover fabrics while remanufacturing	70%
c	Price of leftover fabric if that % was applied	1.75 USD/ yard
d	Market price of leftover fabric pieces (1-3 yards in size) earned by the supplier	1.2 USD/kg
e	FOB price of product A (a big production volume)	7 USD
f	Gross margin of supplier from product A	0.14 USD
g	Total volume of fabric used in product A	2 yards
h	If 12% of fabrics were replaced with virgin fabrics of product B (small production volume), the volume of leftover fabrics (GSM 320) used from product A in product B would be	0.24 yards -> 0.06 kg
i	Value for brand: savings per product B: (a-c)*h	**0.18 USD**
j	FOB price of product B: e-i	6.82 USD
k	Cost reduction for the brand from product B: i/e	**2.57%**
l	Price that the factory would have earned for this leftover from the market: d*h	0.08 USD
m	New price earned for the leftover fabrics: c*h	0.42 USD
n	Net new earning for the factory per remanufactured product	**0.34 USD**
o	Growth in earnings from the leftovers for the factory: m/l	**540%**

On a single product level, the price increase for the factory is misleading compared to how this scheme influences the total gross margins of the supplier, thus both need to be considered simultaneously. Also, we believe it necessary that the benefit to the supplier seem bigger on product level because the main goal needs to be incentivising suppliers to work towards finding better means of circularity. But a fair balance needs to be found because the solution needs to also give a good incentive for brands to continue as the active party driving the demand for circularity. It is noteworthy that buyers have the chance to scale this solution in cooperation with their hundreds or thousands of suppliers while factories often have limited capability to only work with 10+ buyers.

A3: RR software solution

Based on the research we have done and the analysis in this document, Reverse Resources is developing the first software solution for fabric and garment factories and their key buyers to cooperate on closing the loop of production leftovers and turn this business opportunity into practice. Our long-term goal is to create an interactive database from factories to be applied throughout the supply chain to support the industry in building digitally enhanced circular economy.

RR software functionality:

- map/measure leftovers type by type
- compare numbers from different checkpoints to double check data
- help sharing selected data online with buyers
- provide fast feedback to suppliers as to which leftovers could be segregated better for a potential buyer
- enable setting up the transparent processes of remanufacturing
- enable recycling partners to get background information they need and lowering sourcing costs by increasing efficiency of sourcing scraps.

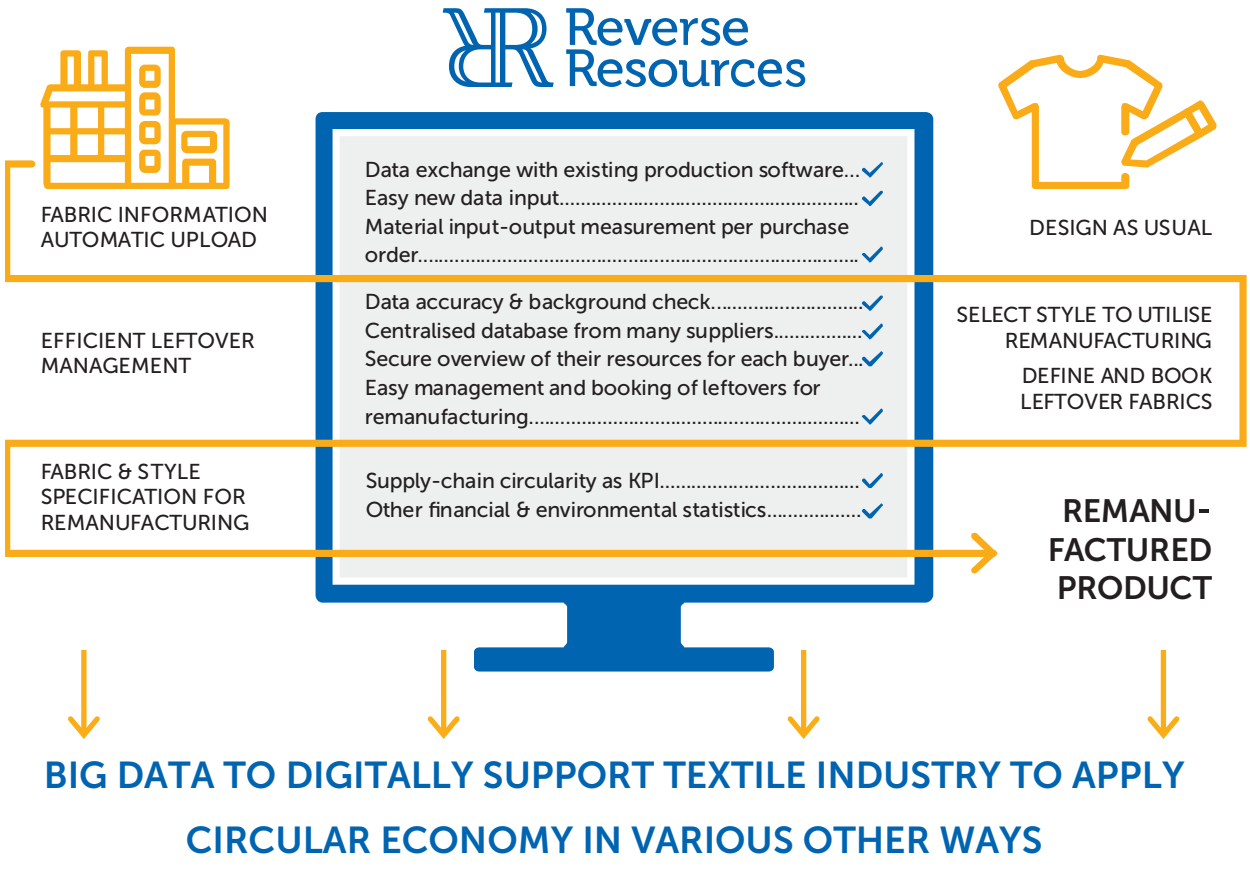


Figure 7. Illustration of the software by Reverse Resources

We are focusing on (1) gathering information from production processes of factories (data creation) into one database for easy access by different buyers, (2) data analytics to support remanufacturing and recycling, and (3) advanced data sharing and communication between suppliers and buyers. The main value proposition is increasing transparency and building trust between suppliers and buyers. However, we also understand the need for factories not to share sensitive information. We see our role in helping factories deliver consolidated data or statistical overviews and providing a kind of digital certification to the buyers instead of giving full access to all production details. We look for the best balance between open data sharing along with data security and confidentiality via distributed ledger system.

Here we have described the initial concept of the data model to double check data from factories as the first step towards a trustworthy database. Connecting information with databases from other stakeholders in the supply chain enables building trust in the data from factories, which makes it crucial to build this as an open platform to enable traceability of leftovers as well as fabrics and garments.

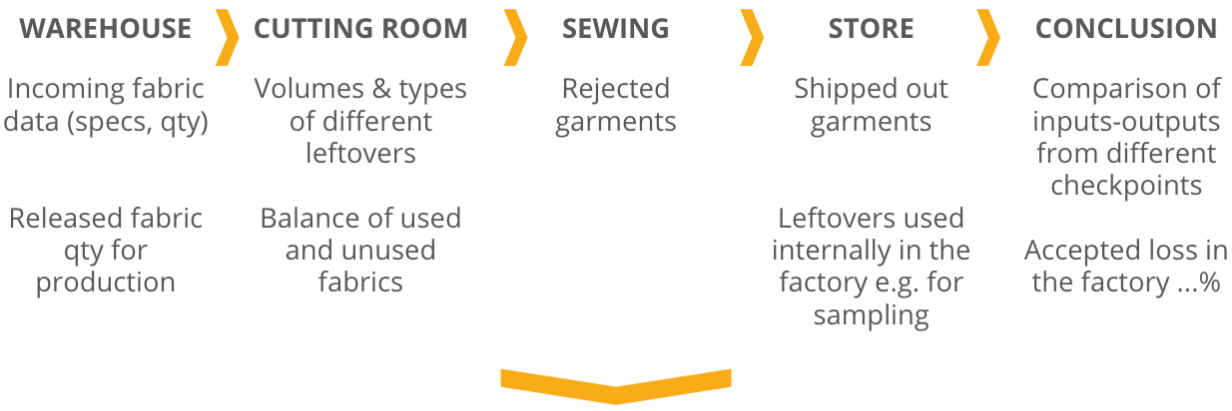


Figure 8. Simplified model of several checkpoint system in garment factories to double-check data from production processes

Thus, our goal is integrating our solution with other platforms which aim for enhanced digital experience throughout supply chains of fashion in various ways. Taking the positive example of the concept of Estonian X-Road[24], the backbone of the country's e-services, we similarly see great value in interconnections between many solutions.

[24] https://e-estonia.com/solutions/interoperability-services/x-road/

Reverse Resources

In parallel to software development and implementation, we provide consultation services and continue with research to support the industry towards effective circular economy.

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