DECARBONISING THE FASHION INDUSTRY

through reducing (over)production

Tech Tailors

December 2023

An Introduction to Overproduction

Overproduction has been fashion's constant companion for years. For a long time, overproduction was financially feasible due to (inhumanely) cheap raw materials, labour, and transport. Combined with high mark-ups, fashion found a way to make overproduction profitable, albeit at a great environmental expense.

However, with increasing raw materials, labour, and transport costs, overproduction is becoming more financially painful by the day. Overproduction is estimated to cost retailers 500 billion US$ annually[1], and it's about to get a whole lot worse for them.

U.S. inventory levels are at an all time high[2] and return rates are growing faster than revenue growth rates for 91% of US retailers[3]. When customers return a garment, that garment needs to be checked, cleaned, repacked and reshipped (costing 21%-66% of the order value[4]). For low priced garments, restocking returns just isn't financially viable, which is probably why 50% of returned items are not restocked, but sent straight to landfill. Shockingly, 50% of clothes offered online globally are on sale, with an average discount rate of 33%[5]. Suggesting retailers are actively trying to get rid of their excess inventory.

Unfortunately for them, storing inventory is becoming more expensive; US warehouse rents are up 16% from last year[6]. Concurrently, getting rid of unsold inventory will become more difficult, since EU legislators are working on a ban of the destruction of unsold goods[7]. Moreover, Uganda has just imposed an apparel import ban[8]. Which is not really surprising when you consider that 40% of the clothes that enter for example Ghana, are in such a dire state, that they go straight to landfill[9].

Soon, brands won't be able to afford storing unsold inventory, and they won't be able to burn them, while exporting these clothes could become infinitely more complex. So what will retailers do with all their excess inventory?

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[1] Can Technology Eliminate Fashion's $500B Overproduction Problem?
[2] Retail Inventories: Clothing and Clothing Accessory Stores (MRTSIM448USS) | FRED | St. Louis Fed
[3] How To Reduce E-Commerce Returns After The Holidays With UGC
[4] Pitney Bowes Survey: Returns Cost US Online Retailers 21% of Order Value | Business Wire
[5] Retail Dashboard | EDITED
[6] Why Warehouse Rents Keep Going Up While Demand Is Dropping - WSJ
[7] EU states back ban on destruction of unsold clothing
[8] What Uganda's 'War' on Used Clothing Imports Means for Fashion | BoF
[9] 'It's like a death pit': how Ghana became fast fashion's dumping ground | Global development | The Guardian

As if storing and getting rid of (unsold) inventory isn't complex enough, it's only one part of the overproduction problem. Brands and retailers also have to comply with the Paris Agreement, meaning they have to reduce their production emissions by 45% in 2030. Decarbonisation is no longer merely a nice marketing tool, it's now a legal obligation.

Production emissions can be reduced through two ways:

- more sustainable production
- lower production volumes

For a long time, the focus for making the fashion industry more sustainable has been on better material production. And rightfully so, material production is responsible for circa 45% of a garment's total life cycle emissions. But what is often overlooked in sustainability analyses is the decarbonisation effect of reducing (over)production. The reason so little research has been done into this is because degrowth in production levels is widely associated with degrowth in margins. And that is a blatant misconception.

Tech Tailors will demonstrate that the best way to reduce (over)production is by automated on-demand, made-to-measure production. By only producing what is actually sold, brands would minimise emissions related to overproduction, the over transportation and the over destruction of unsold garments. Thereby potentially decreasing carbon emissions throughout the garment's life cycle by the double digits, while simultaneously maintaining or even increasing margins[10].

Tech Tailors performed an extensive analysis to quantify the decarbonisation effect of reducing overproduction, drawing on data from Statista, the World Bank, the US International Trade Commission, the European Environment Agency, UN Comtrade, the European Commission, as well as annual reports, carbon reports and scholarly articles.

First, we will demonstrate how big of a problem overproduction actually is, by properly defining and quantifying it. Secondly, we'll look into the size of the decarbonisation opportunity associated with reducing overproduction. After which we'll analyse the different methods that could actually reduce overproduction. Finally, we'll recommend which methods are the most effective based on their potential scale, absolute decarbonisation effect and cost effectiveness.

In doing so, we hope to provide the industry with well-founded arguments to make strategic choices regarding why and how to reduce overproduction.

[10] The Unexpected Profitability of Mass Tailoring - The Interline

Content

1. Overproduction Analysis

In order to estimate the size of the decarbonisation opportunity associated with minimising overproduction, it is first necessary to define and quantify the level of overproduction. Overproduction is a widely used term in the fashion industry and while many agree that it is estimated at around 30%[11], no one seems to have a clear cut definition of what overproduction actually entails, which makes the 30% more of a guessing game, and less of a reliable estimate. The reason so little data on overproduction is available, is due to several factors:

1. (Unsold) inventory is hard to keep track of for brands, so most brands don't actually know how much they overproduce. 'Due to factors like counting errors, mistakes in packing and shipping, misplaced items and theft, retailers can have surprisingly poor knowledge of what stock they're holding, with studies finding accuracy levels of around 50 percent or less in some cases'[12].
2. Overproduction and subsequent garment destruction are dirty words in the fashion industry, especially since (amongst others) Burberry was caught destroying unsold goods[13]. Ever since, brands aren't so keen on disclosing:
    a. How much they over produce
    b. What happens with these unsold garments
3. Overproduction also has a seemingly undefined scope. Does it just include garments that haven't been sold by the end of the season? And what about garments that are sold, but returned, restocked and never sold again? Or garments that are sold, returned, and not restocked but immediately sent to landfill? And what about garments that end up in outlets? Or unsold garments that are sold to liquidators or donated? Are any of these garments included in the dead stock analysis? We just don't really know.

1.1 Overproduction Definition

We define overproduction as follows:

$$overproduction\ Y1 = \frac{number\ of\ garments\ unsold\ Y1}{number\ of\ garments\ produced\ Y1} \times 100\%$$

11 https://fashionunited.uk/news/fashion/infographic-the-extent-of-overproduction-in-the-fashion-industry/2018121240500

12 https://www.businessoffashion.com/articles/technology/rfids-quiet-revolution-in-retail/

13 https://www.forbes.com/sites/oliviapinnock/2018/07/20/no-one-in-fashion-is-surprised-burberry-burnt-28-million-of-stock/

1.2 Overproduction Scope

In scope:

- Garment types included:
  The scope of this research is women's, men's and children's apparel. This includes Coats & Jackets, Blazers, Suits & Ensembles, Dresses & Skirts, Trousers, Shirts & Blouses, Jerseys, Sweatshirts & Pullovers, Sports & Swimwear (Performance Apparel, Sports-Inspired Apparel, Swimwear), Night & Underwear, T-Shirts, Tights & Leggings, Socks, Clothing Accessories & Other Clothes).
- Sold garments include:
  - garments sold at full price
  - garments sold at discount
  - garments that are sold, returned, and sold again
- Unsold garments include:
  - initial unsold garments
  - garments sold, returned, and not sold again
  - unsold garments to be sold to liquidators
  - unsold garments to be donated to charity

Out of scope:

- Garments produced for sampling purposes
- Baby clothes
- Failed deliveries that are returned to the warehouse. What happens with these failed deliveries (restocked or not) is fairly unknown, albeit significant. It is estimated that around 7% of ecom deliveries fail (mostly due to address input errors)[14].

1.3 Quantifying Overproduction

In order to quantify overproduction levels, we'll first look into sales- and return levels.

Sales levels

Production levels in the apparel industry are widely estimated anywhere between 50 billion and 150 billion garments per year[15]. However, according to Statista in 2022, 170 billion garments were sold[16] (including women's, men's, and children's apparel). So more garments are sold than supposedly produced, which seems odd at the very minimum.

14 https://info.loqate.com/hubfs/Loqate%202021/Fixing%20Failed%20Deliveries/Fixing%20Failed%20Deliveries%20-%20Final.pdf

15 https://www.bloomberg.com/graphics/2022-fashion-industry-environmental-impact/?in_source=embedded-checkout-banner

16 https://www.statista.com/outlook/cmo/apparel/worldwide

With 170 billion garments sold initially, and assuming an initial overproduction rate of 30%, it is more likely that around 276 billion garments per year are actually produced. Meaning the industry output level estimates (and up until now, also our own) are off by approximately 125 billion garments. Please see methodology section 1 for a more detailed explanation.

Return levels

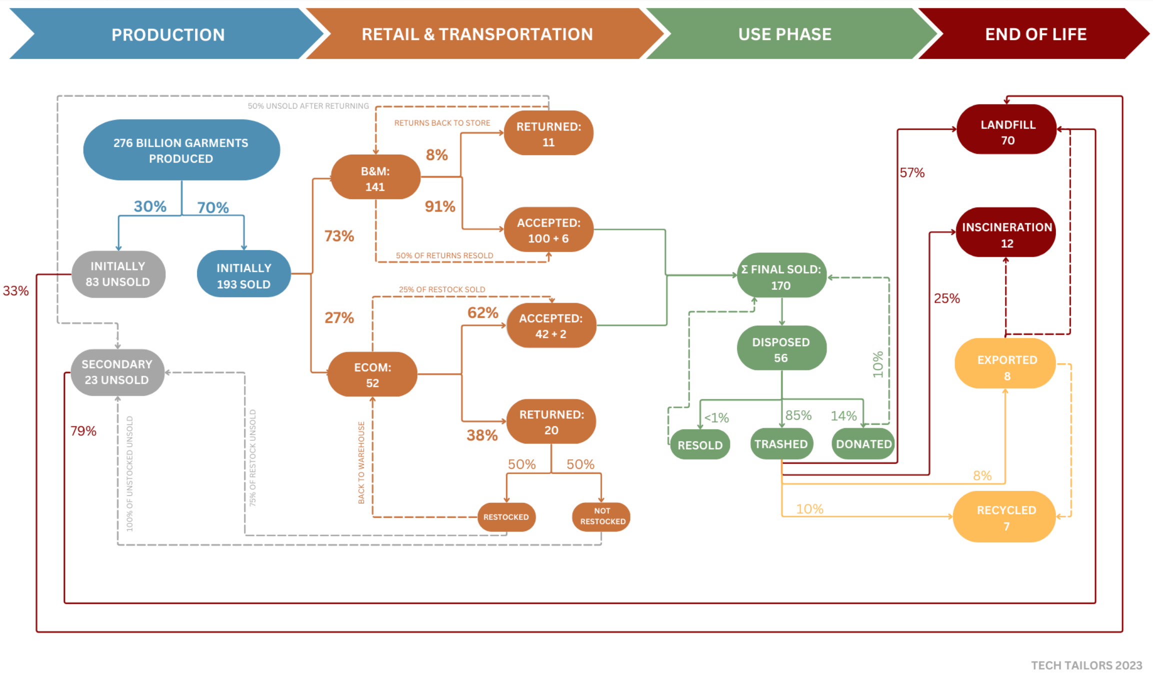
According to Statista, of 170 billion garments sold in 2022, 27% was sold online, whereas 73% was sold through Brick and Mortar (B&M). That means around 52 billion garments were sold online. Of which 38% were returned, that's nearly 20 billion garments, 10 of which go to landfill directly[17]. Are these discarded returns included in the overproduction numbers? The other ±10 billion garments are unaccounted for, are they resold, or just restocked and never sold again? The truth is, we can't tell for sure, not in the least due to the fact that even if returns are mentioned in annual reports, they remain undefined and undisclosed. Are returns defined on an order basis, on an item basis, or on a value basis? Say a customer would order 4 items, and returns 2 of those, is that considered as 1 return (order based) or two returns (item based), or whatever % of the order value is returned? If we account for unsold returns, that's adding a minimum of 10 billion garments to the final unsold inventory number.

Overproduction Quantification

In order to quantify overproduction, we first created a unit flow analysis, to get a sense of what actually happens with these 276 billion produced garments. How many are sold, how are they sold, how are they worn, how are they disposed of and how many end up in landfills each year?

17 https://www.forbes.com/sites/andrewbusby/2019/11/22/returns-an-epidemic-which-the-fashion-industry-is-choosing-to-ignore/?sh=7b1f87007363

Figure 2: *Garment Flow Chart 2022*



all numbers are in units of billions, unless stated otherwise

Assumptions:

- The initial overproduction rate is 30%
- That 170 billion garments sold entail initial sales and are corrected for returns that are not resold
- That for B&M, 50% of returns are resold (own estimate)
- That for Ecom, 25% of restocked returns are resold (own estimate)

In 2022, overproduction amounted to:

$$83\ billion\ garments\ unsold\ initially\ +\ 23\ billion\ returns\ that\ were\ never\ sold\ again$$
$$=106\ billion\ unsold\ garments$$

The final overproduction rate was:

$$106\ billion\ unsold\ garments\ \div\ 276\ produced\ garments\ \times\ 100\%\ =\ \pm 38\%\ total\ overproduction$$

Both the level of overproduction and the subsequent impact of reducing it (as well as the methods of reducing it), are severely understated in current research. Current overproduction rates are estimated at 30%, while current production levels are estimated at 150 billion garments per year. Supposedly resulting in 45 billion unsold garments per year. From our sales- and return analysis, it can be concluded that total overproduction is more likely to be around 38% of 276 billion garments, e.g. 106 billion unsold garments. Per year, that is. Meaning that industry estimates are off by a mere factor of two.

Additionally, it is important to note that not all overproduction is created equally. Apparel is roughly split up in three categories; children's garments, non-upperwear (underwear, socks, ties, tights, etc.), and upperwear (shirts, trousers, dresses, coats etc.). It can be assumed that overproduction occurs more often in upperwear than non-upperwear, due to two factors:

- Lower initial overproduction non-upperwear
  Seasonality, evergreen, never out of stock etc.
- Lower secondary overproduction non-upperwear
  Returns not allowed or less fit critical common

If we assume that $^{2}/_{3}$ of overproduction volume is due to upperwear, overproduction per category will look like this:

Table 1: *Overproduction upperwear per category*

	RTW total	RTW non-upperwear	RTW Upperwear
production	100	57	43
initially unsold	30	10	20
secondary unsold (due to returns)	8	3	6
final sold	62	44	18
overproduction	**38%**	**22%**	**59%**

For every upperwear RTW garment sold, approximately 2.6 garments were produced. According to our analysis, overproduction for non-upperwear is 22%, whereas overproduction for upperwear is 59%.

Since upperwear garments are heavier than non-upperwear garments (+57%), the share of upperwear production weight has been underestimated up until now.

Table 2: *Production Weight Upperwear*

TOTAL APPAREL MARKET 2022				
	children	**women & men**		**Total**
		non-upperwear	upperwear	
Giga units sold	59	62	49	170
Giga units produced	77	80	119	276
Giga kg sold	14	22	28	64
Giga kg produced	19	29	67	115
Unit share (produced)	28%	29%	43%	
Weight share (produced)	16%	25%	59%	

Table 2 demonstrates that upperwear production is responsible for 59% of the weight of all garments produced in the apparel industry. And is thus responsible for 59% of all production associated emissions. In the following sections we'll distinguish between overall overproduction and upperwear overproduction.

2. Potential Impact of Reducing Overproduction

Now that we've quantified the level of overproduction (keep breathing), it's time to look into the potential environmental impact of reducing it. In order to do so, we first studied the Life Cycle Analysis (LCA) for RTW garments. Please note that data on this topic is ill-defined and sometimes missing entirely. We used a triangulation approach to estimate the numbers that were missing. More reliable data is absolutely welcomed for future analysis and we'll update our charts as new - or more reliable data - surfaces.

2.1 LCA Off-Shored Production

In this part of the LCA, we assumed off-shored RTW production. Suppose brand A produces in China and sells in Europe, has several stores in Europe, and one centralised warehouse in Europe.

***Figure 4**: LCA emissions per RTW garment produced off-shore*

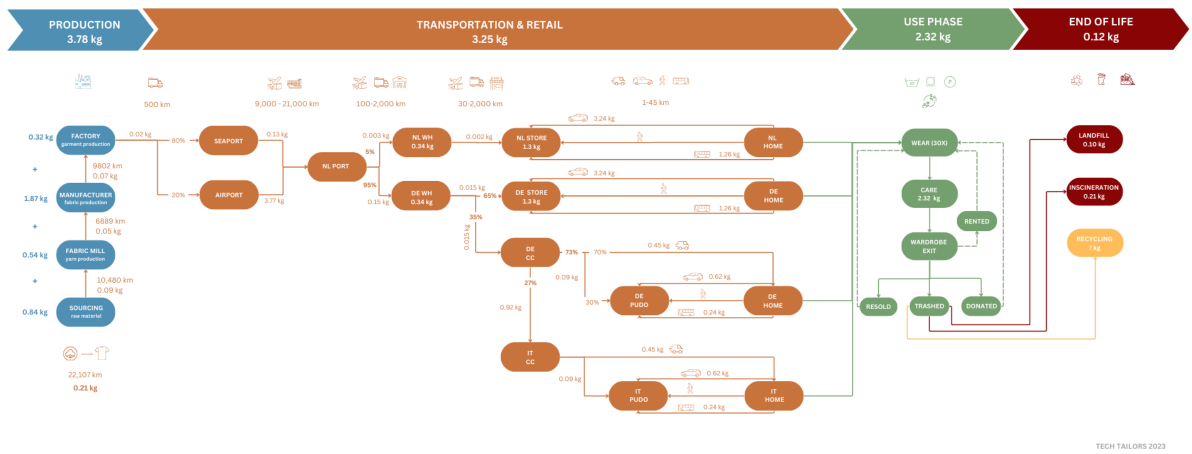


Figure 4 shows the LCA for off-shored RTW production, assuming a 100% sell through rate and 0% initial overproduction. It illustrates a severely simplified RTW garment trajectory. And even severely simplified, it's still an intricate route for just one garment. Using TradeCom data, we established the most common routes garments follow around the world. For this scenario, raw material production takes place in the U.S., after which the yarn is produced in Turkey, the yarn is then shipped to India for fabric production and finally the fabric is shipped to China for garment manufacturing. Meaning that before the garment has left the factory, it has already travelled 27,000 kilometres. Even though quite literally travelling half the world seems intense, per garment, this isn't very emission intensive, because most of this transport is done by sea. The most emission intensive part of the garment's transport journey is widely considered to be the so-called last-mileage. However, we discovered that it is very likely that the transport from the factory to the destination port is severely deflated up until now. It is widely assumed that off-shore garments are mostly shipped to the West by container ship (±92%) and some by aeroplane (±8%). After analysing retailer's different flight routes and export cargo flight data, it seems like this ratio is more likely to be 80%/20%. And since flying is so emission intensive, this strongly affects the emissions relating to the first leg of the transportation phase.

When RTW production is off-shored, the LCA per RTW garment sold looks like this (corrected for overproduction and returns):

Figure 5: LCA per RTW garment sold off-shored

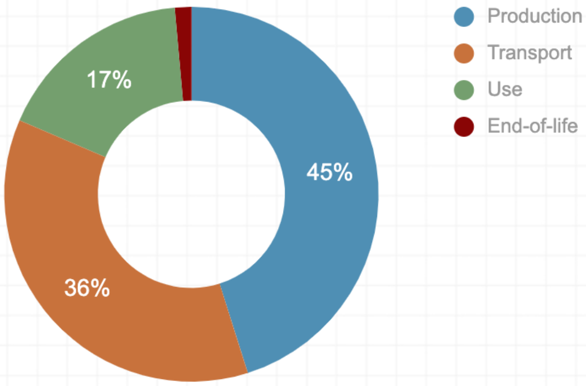


Figure 5 demonstrates that, when corrected for overproduction and returns, production and transport are responsible for roughly 80% of the garment's life cycle emissions.

2.2 LCA Near-Shored Production

In this part of the LCA, we assumed near-shored RTW production. Suppose brand B produces in Europe and sells in Europe, has several stores in Europe, and one centralised warehouse in Europe.

***Figure 6**: LCA emissions per RTW garment produced near-shore*

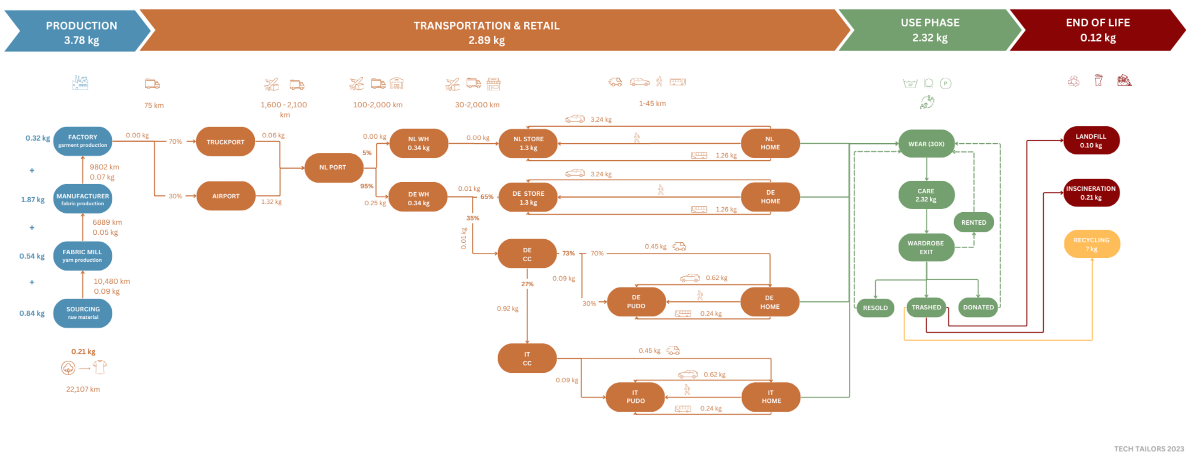


Figure 6 shows the LCA for near-shored RTW production, assuming a 100% sell through rate and 0% initial overproduction. It demonstrates that even when production is near-shored, the distribution phase is still very elaborate, albeit less emission intensive, especially in the first leg of the transportation phase.

Figure 7: *LCA per RTW garment sold near-shored*

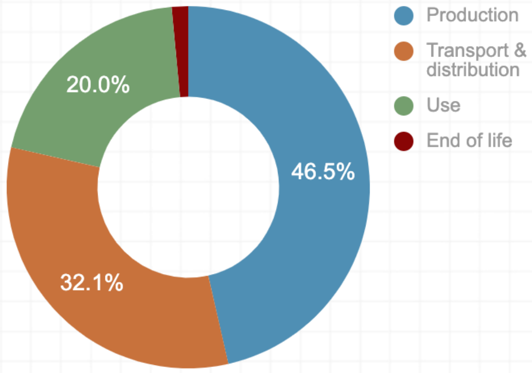


Figure 7 demonstrates that when RTW production is near-shored, production and transport make up just under 80% of the life cycle emissions. This is due to the fact that transport from the factory to the destination port only makes up ±x% of the total transport emissions in this case.

General considerations regarding product lifecycle vs. annual production and sales:

- production is annual
- Sold is annual, but could also include clothes produced in the previous year
- Packaging is out of scope
- Use includes only annual use per garment
- 2nd life includes only annual garments
- End of life includes only annual garments
- Unsold garments also go to outlets and liquidators, this is out of scope
- The industry average return rate is interpreted as 30% of items being returned.

Reduction opportunities per phase:

- Production phase:
    - Better material in terms of
        - Extraction (raw materials, water, land)
        - Emissions (carbon, methane, micro plastics)
        - Toxins & Chemicals
        - Durability of material
    - renewable energy use in plants
- Retail & Transportation phase
    - Nearshoring
    - Move from air to sea freight
    - Improve sea freight quality fuel
    - Renewable energy trucks/vans/cargo
    - Cargo bikes for last milage

        - renewable energy warehousing/stores
        - More sustainable packaging (out of scope)
        - PUDO in stead of home delivery (1.6 times as many emissions)[18]
        - Fewer returns
        - Digital sampling (out of scope)
- Use phase
    - Lower temperature washing
    - Less tumble drying
    - More efficient washers and dryers (steam), especially in under developed countries
    - Extending life (either in terms of material or consumer mindset)
    - Renting clothes (out of scope)
    - Repairing clothes (out of scope)
- End of life phase
    - Better materials to postpone or avoid landfills:
        - Recyclable materials
        - Biodegradable materials
        - Single fibre garments
    - More efficient recycling plants
    - Non plastic materials to avoid microplastics in oceans and drinking water

Please note that this analysis only takes into consideration the carbon reduction opportunities. Many of the above mentioned options may have a relatively low impact on carbon reductions, but would have a massive impact on water-, toxins-, and microplastic reductions. So while we do not go into detail on these opportunities for now, we do acknowledge that they are highly relevant to making the fashion industry more sustainable. And while all of the above mentioned reduction opportunities are significant, almost all of them are affected by reducing overall output levels.

2.3 Decarbonisation Effect of Eliminating Overproduction

Reducing overproduction lowers the overall production emissions (no surprise there), but it also reduces a significant part of the emissions from the transport and distribution of unsold items, and avoids the emissions associated with unsold garments being destroyed. What would happen if we were to eliminate initial overproduction?

18 https://press-center-static.vinted.com/Vaayu_x_Vinted_Full_Climate_Impact_Report_2021_045f9e5c4b.pdf

***Table 3**: CO_2 reduction per RTW garment sold by eliminating initial overproduction off-shore*

Phase	**30% initial overproduction** (kg CO_2)	**0% initial overproduction** (kg CO_2)
Production	5.40	3.78
Transport & distribution	4.26	3.25
Use	2.32	2.32
End of life	0.17	0.12
Total	**12.15**	**9.48**
CO_2 reduction due to lower overproduction		22%

Clearly, eliminating initial overproduction would result in a nearly 22% reduction in *overall* carbon emissions.

If we look solely at the overproduction due to upperwear, the carbon reduction due to overproduction elimination looks as follows:

Table 4: *CO_2 reduction per RTW garment sold by eliminating initial upperwear overproduction off-shore*

Phase	**46% initial overproduction** (kg CO_2)	**0% initial overproduction** (kg CO_2)
Production	9.66	5.19
Transport & distribution	6.94	4.17
Use	3.16	3.16
End of life	0.33	0.18
Total	**20.09**	**12.70**
CO_2 reduction due to lower overproduction		**37%**

Table 4 demonstrates that when we look strictly at upperwear, eliminating its overproduction would result in a staggering 37% lower carbon footprint, for the entire life cycle of the garment.

While this is all very nice in theory, realising such significant reductions is an entirely different ball game. The next section will assess which of the different methods for reducing (upperwear) overproduction has the most potential.

3. Most Effective Methods for Reducing Overproduction

Overproduction is not a new problem, it has been fashion's constant companion for years. Overproduction was financially feasible due to (inhumanely) cheap raw materials, labour, and transport. Combined with high mark-ups, fashion found a way to make overproduction profitable. But now the industry is losing about $500 billion per year due to overproduction[19]. And it's about to get a whole lot worse. With increasing raw materials, labour, and transport costs, overproduction is becoming more financially painful by the day. Add to that increasing legislatory pressure and incoming import bans, and it becomes clear that brands can no longer afford to ignore overproduction. But how can they tackle overproduction? Up until now, the most commonly heard solutions include: better sales forecasting and on-demand production. This section will dive into the effectiveness of these methods, as well as exploring a more novel approach to reduce overproduction: mass tailoring.

3.1 Better Sales Forecasting

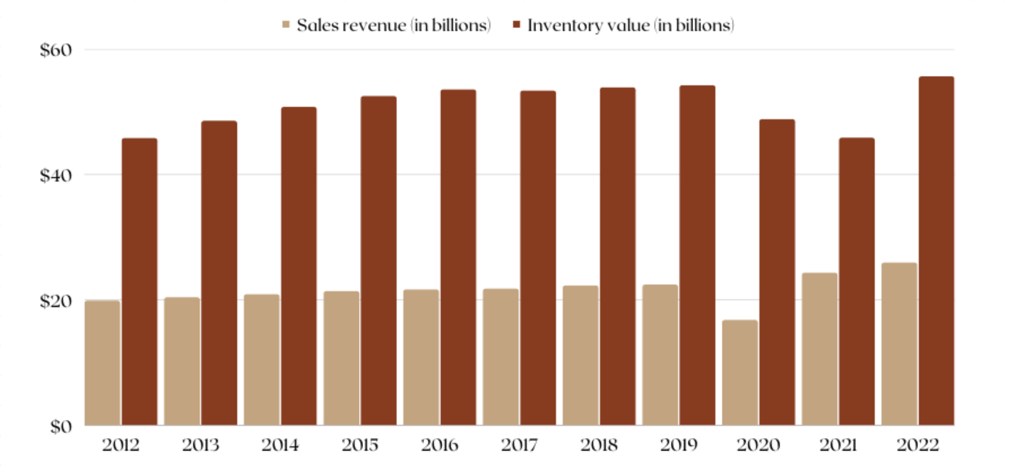
The most common solution for excess inventory: better forecasting combined with shorter lead times. A good example of this is Zara, they produce ±25% of their collection in advance, and ±75% is produced based on what's selling well, with an impressive lead time of approximately four weeks[20]. However, Zara is unwilling to share any information on sell-through rates or overproduction, so the efficacy of this model in terms of overproduction is anyone's guess. What is clear is that brands are sitting on - on average - 27% more unsold inventory than last year[21]. Inventory levels and inventory to sales ratios over the past decade confirm this trend, so while some retailers might be doing well in terms of inventory management, the majority are clearly struggling.

19 https://www.mannpublications.com/fashionmannuscript/2020/11/06/can-technology-eliminate-fashions-500b-overproduction-problem/#:~:text=The%20industry%20loses%20about%20%24500,the%20lengthy%20apparel%20development%20process.

20 https://quickbooks.intuit.com/r/supply-chain/zara-supply-chain-its-secret-to-retail-success/

21 https://www.businessoffashion.com/articles/retail/retail-inventory-glut-markdowns/

Figure 8[22]*: US inventory & sales US apparel retailer stores 2012-2022*



The peak and dips in 2020 are due to the pandemic and global lockdowns. At first retailers were left with huge amounts of unsold inventory, and the subsequent reduction in revenue limited their spending capacity for 2021 orders, where there was an inventory shortage for the first time in years.

Figure 8 shows that U.S. retailers, for the past decade, have held more than twice the amount of inventory than what was being sold.

Figure 9*: Inventory and sales growth with respect to 2012*

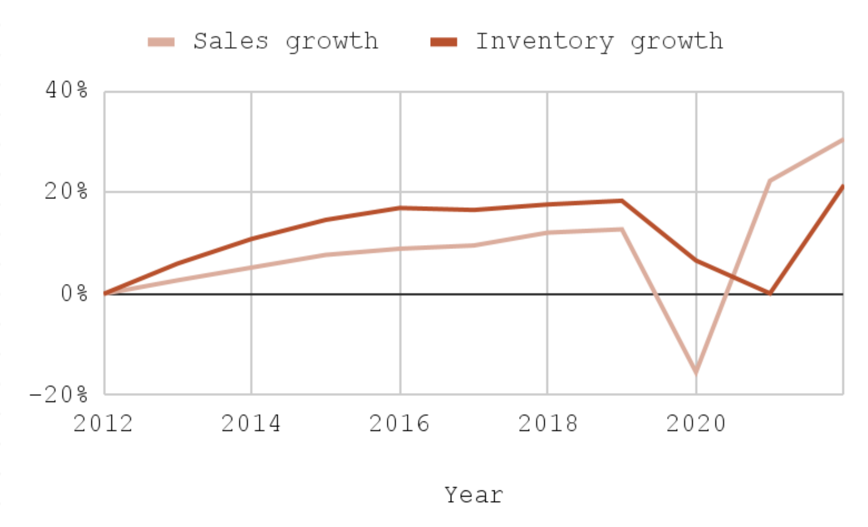


Figure 9 demonstrates that Up until the pandemic, inventory has outgrown sales, and inventory growth is catching up to post pandemic sales growth. .

While sell through rates remain elusive, we can look into the share of garments that are on sale at any given point in time. After all, if brands wouldn't have any excessive inventory, they wouldn't have to sell their garments at a discounted price.

22 https://alfred.stlouisfed.org/series?seid=MRTSIR448USN&utm_source=series_page&utm_medium=related_content&utm_term=related_resources&utm_campaign=alfred

Figure 10[23]*: Global share of garments on sale online 2021-2023*

Figure 11*: Global average product online discount rate 2012-2023*

[23] https://edited.com/retail-dashboard/

Figure 10 and 11 demonstrates that, for the past three years, at any given moment, around 50% of retailers' online assortment has been on sale for a discounted rate of on average 33%. And both the share of assortment that's offered at a discounted price and the average discount rate seem to be soaring, not declining. The harsh reality is, forecasting models have supposedly gotten more advanced and accurate over time, whereas the inventory problem has only gotten worse. So maybe the solution to overproduction is not in sales forecasting models.

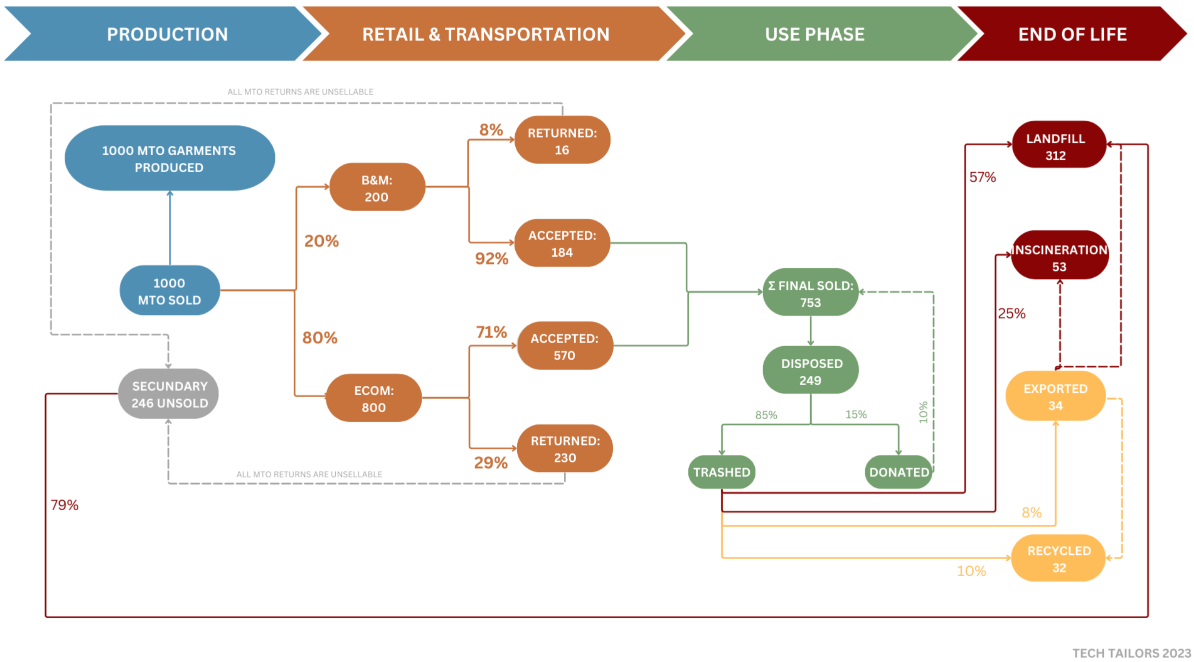
3.2 MTO: On-demand production in standard sizes

Now, on-demand production (MTO) is actually a very promising solution. If brands only produce what is actually sold, overproduction becomes obsolete. It's important to note that not all garments are eligible for on-demand production. On-demand production is fairly uncommon with children's garments. The same goes for men's and women's underwear. On-demand production is already being used for women's and men's upperwear (trousers, shirts, coats etc.) and sportswear. It's used mostly for non-critical fit items, since MTO is still produced in standard sizes.

The Decarbonisation Opportunity of MTO

***Figure 12**: MTO Garment Flow Chart 2022*

This flow chart assumes that 1 billion MTO garments are sold per year.



Assumptions:

- MTO returns are allowed:
  - Possible return reasons:
    - Unhappy with fit
    - appears different than in photo
    - Change of heart
    - Need for extra cash due to change in customers' liquidity
    - Fraud
  - Returns are not eligible for resale

Figure 12 illustrates the potential MTO garment flow. To estimate the size of the MTO decarbonisation opportunity, it is important to differentiate between emission per garment sold and emissions per garment produced. The two are used interchangeably in many publications, adding to the already confusing maze of decarbonisation opportunities. Presumably, producing a MTO garment or a RTW garment in identical materials, will result in identical carbon footprints. However, the same does not go for the carbon footprint per garment *sold*. Because for every RTW garment sold, 28% extra garments are produced and not sold. The distribution process (and associated CO_2e emissions) are also different for sold RTW garments and MTO garments, further affecting the carbon footprint per garment sold.

Figure 13: LCA emissions off-shored per MTO garment produced

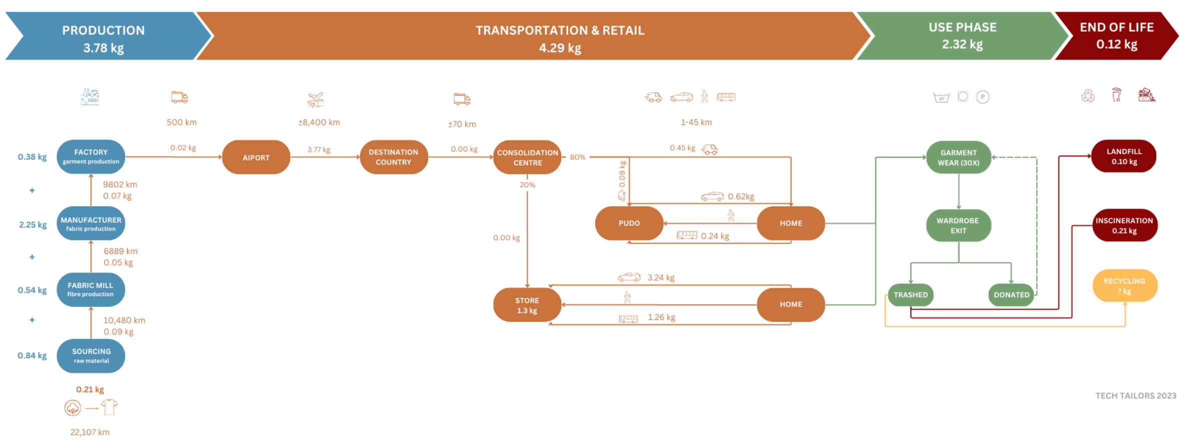


Figure 13 shows the LCA for off-shored MTO production, assuming a 100% sell through rate and 0% initial overproduction. As compared to RTW, MTO garments follow a much more efficient route. This is due to the fact MTO garments are only made once an order is placed. Now, let's look at where MTO will most likely be used: upperwear garments.

***Table 5**: Emissions per phase per MTO upperwear garment sold offshored, accounting for initial upperwear overproduction and secondary overproduction due to returns and return emissions themselves.*

Phase	RTW (kg CO_2)	MTO (kg CO_2)	MTO savings
Production	12.67	6.88	46%
Transport & Distribution	9.19	8.89	3%
Use	3.16	3.16	0%
End of life	0.39	0.21	46%
Total	**25.41**	**19.15**	**25%**

For this analysis, it was presumed that returns are allowed (for both RTW and MTO). As it turns out, MTO saves significantly on production and end-of-life emissions. But when off-shored, it costs an abhorrent amount of carbon on the transport side of things, because as it stands, off-shored MTO garments are flown to their destination countries, to ensure quick delivery. Since overproduction with RTW upperwear garments is so severe, the MTO emissions increase from transport are offset by the MTO emission reductions in production, resulting in a 25% lower overall carbon footprint per MTO garment sold.

Figure 14: LCA emissions near-shored per MTO garment produced

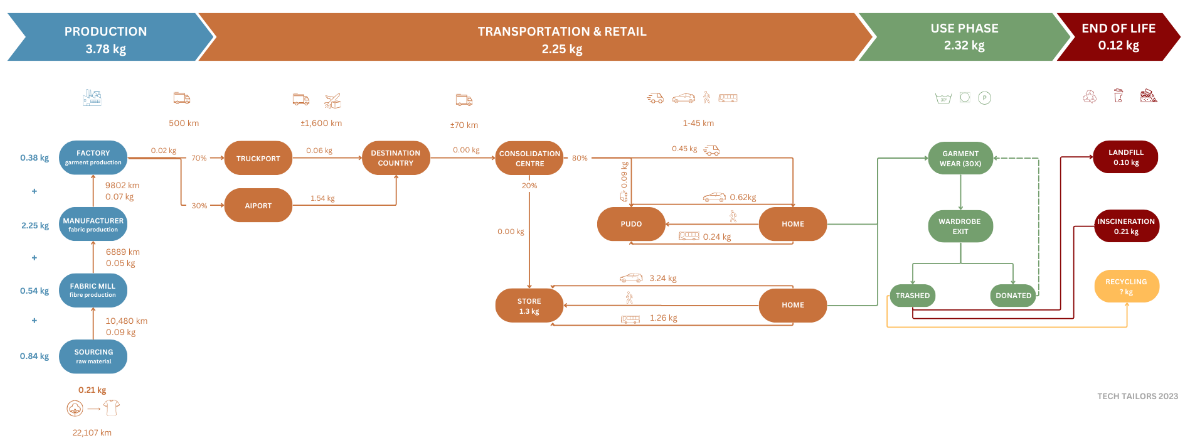


Figure 14 shows the LCA for near-shored MTO production, assuming a 100% sell through rate and 0% initial overproduction. What becomes clear is that near-shored MTO production results in an extremely efficient transport phase, and subsequently in significantly lower transport emissions. Now, let's look at where MTO will most likely be used: upperwear garments.

Table 6*: Emissions per phase per upperwear MTO garment sold near-shored, accounting for initial upperwear overproduction and secondary overproduction due to returns and return emissions themselves.*

Phase	RTW (kg CO_2)	MTO (kg CO_2)	MTO savings
Production	12.67	6.88	46%
Transport & Distribution	7.95	4.80	40%
Use	3.16	3.16	0%
End of life	0.39	0.21	46%
Total	**24.18**	**15.07**	**38%**

Table 6 demonstrates that when near-shored, MTO actually saves on transport emissions, since the garment follows a much more efficient route as compared to RTW, resulting in a nearly 40% lower transportation emissions. MTO has the potential to reduce emissions by 38%, for the entire life cycle of the garment.

Practical Limitations of MTO:

- On-demand production doesn't solve the sizing problem. 70% of returns are returned due to fit issues. So either:
  - returns are allowed, and 38% will likely be returned (and subsequently unsellable), especially for critical fit garments (±49% of garments sold, good for ±70% of all garment revenue, according to Statista).
  - or returns aren't allowed and customers are too hesitant to order
  - or customers do order and are unhappy with the fit and won't order again
- The question remains, will MTO in standard sizes be able to scale, in order to reach absolute reductions?
- Some on-demand facilities serve as a smoke screen for bulk production. Custom orders, if broadly defined, also include pre-made orders, with, for example, initials embroidered on them. This makes brands and/or production facilities appear like they only produce what they sell, when in reality, they have warehouses full of stock that's ready to be personalised for the customer.

3.3 MTM: On-demand production made-to-measure

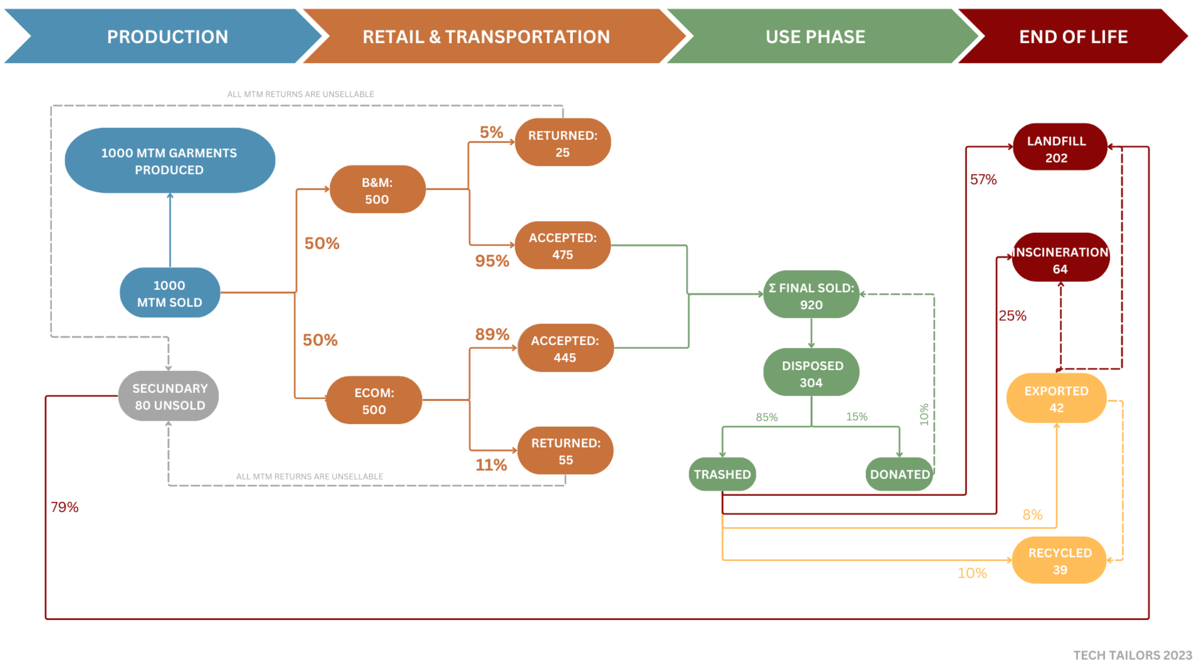
The most effective way of tackling overproduction is automated on-demand, made-to-measure (MTM) production, also known as mass tailoring. Mass tailoring solves the biggest pain point in the on-demand model: sizing. Until now, tailoring is mostly used for high-end traditional formal wear. But with new technologies, it's possible to produce

MTM for fast fashion and luxury fashion alike. MTM returns are likely to be around 8% (as opposed to 38% for MTO). Mass tailoring would mean that brands lower emissions by producing on demand, thus avoiding emissions associated with overproduction, but it would also mean that brands lower emissions associated with returns. After all, 70% of returns are due to sizing issues. It is important to note that MTM will mostly be used for critical fit garments like jackets, shirts, dresses, pants etc. 49 billion upperwear garments per year are sold. That's ±29% of all garments sold annually, so clearly mass tailoring won't solve the overproduction problem for the industry at large. But it will make a significant dent in the carbon emissions, as we will demonstrate below.

The Decarbonisation Opportunity of Mass Tailoring

Figure 15: *MTM Garment Flow Chart 2022*

This flow chart assumes that 1 billion MTM garments are sold per year.



Numbers are in millions, unless stated otherwise.

Assumptions:

- MTM returns are allowed:
    - Possible reason for returns:
        - Unhappy with fit
        - appears different than in photo
        - Change of heart
        - Need for extra cash due to change in customers' liquidity
        - Fraud
    - Returns are not eligible for resale

Figure 16: *LCA emissions off-shored per MTM garment produced*

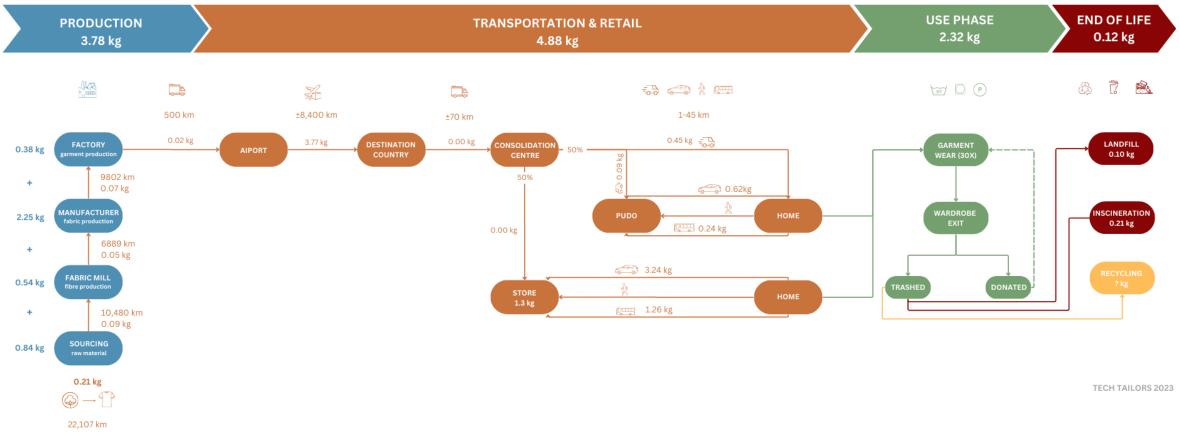


Figure 16 shows the LCA for off-shored MTM production, assuming a 100% sell through rate and 0% initial overproduction. As compared to RTW, MTM garments follow a much more efficient route. This is due to the fact MTM garments are only made once an order is placed. Now, let's look at where MTM will most likely be used: upperwear garments.

Table 7: *Emissions per phase per MTM upperwear garment sold offshore, accounting for initial overproduction and secondary overproduction due to returns and return emissions themselves.*

Phase	RTW (kg CO_2)	MTM (kg CO_2)	MTM savings
Production	12.67	5.64	55%
Transport & Distribution	9.19	7.77	15%
Use	3.16	3.16	0%
End of life	0.39	0.18	55%
Total	**25.41**	**16.75**	**34%**

Table 7 demonstrates that MTM production saves a staggering 55% on production and EOL emissions, per garment. MTM only saves 15% on the transport side of things, since most off-shored MTM garments are flown to their destination country, whereas most RTW garments are shipped by sea. When off-shored, MTM can save 34% of LCA emissions as compared to RTW.

***Figure 17**: LCA emissions near-shored per MTM produced*

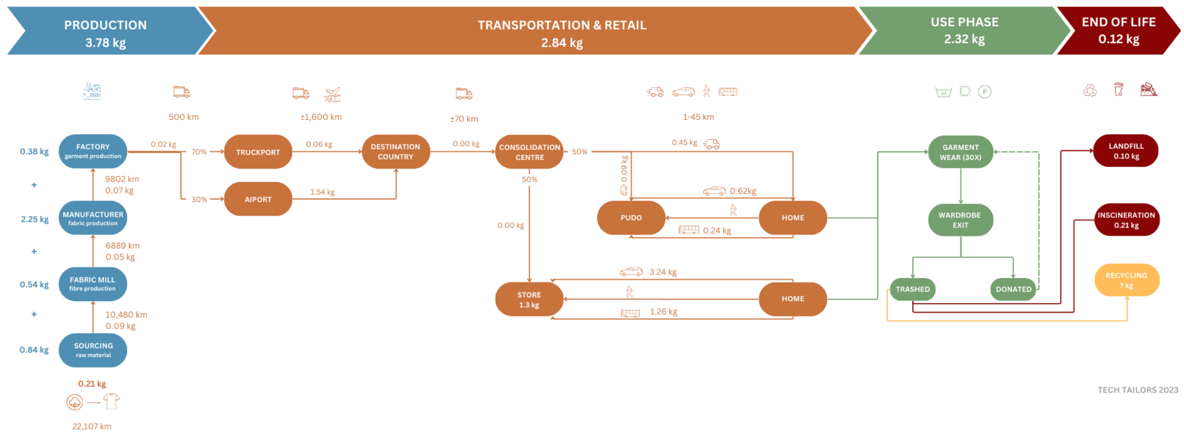


Figure 17 shows the LCA for near-shored MTM production, assuming a 100% sell through rate and 0% initial overproduction. What becomes clear is that near-shored MTM production results in an extremely efficient transport phase, and subsequently in significantly lower transport emissions. Now, let's look at where MTM will most likely be used: upperwear garments.

***Table 8**: Emissions per phase per MTM upperwear garment sold nearshored, accounting for initial overproduction and secondary overproduction due to returns and return emissions themselves.*

Phase	RTW (kg CO_2)	MTM (kg CO_2)	MTM savings
Production	12.67	5.64	55%
Transport & Distribution	7.95	4.42	44%
Use	3.16	3.16	0%
End of life	0.39	0.18	55%
Total	**24.18**	**13.40**	**45%**

Table 8 demonstrates that when near-shored, mass tailoring could be 45% less polluting than RTW, for the whole life cycle of the garment. That is a massive reduction. Here, MTM actually saves significantly on transportation emissions, since the garments follow a much more efficient route as compared to RTW.

Please note that the aforementioned MTO and MTM savings are potential CO_2e savings, not realised CO_2e savings (yet). We used data from our own clients and (very established) suppliers, as well as scholarly research and publications to estimate the potential decarbonisation effect of mass tailoring. The MTO and MTM analyses rely on an array of assumptions (as detailed in the Methodology section), and contain a large margin of error. These numbers should thus be interpreted as rough estimates, not as definitive values.

While it is plausible that mass tailoring will reduce production-, distribution- and end-of-life emissions, it's unsure how it will affect the use phase. This analysis did not take the replacement rate of garments into account, nor the emissions associated with reselling and renting a part of the customer's wardrobe. It could be argued that (especially initially) brands that sell MTM have a higher price point, and therefore produce garments of higher quality, with a longer life, postponing the replacement moment. It could also be argued that MTM aren't eligible for resell, thus increasing the use footprint, as compared to RTW. The net effect of mass tailoring on the use phase is still unknown.

Practical Limitations to Mass Tailoring

Now, we have to be realistic about the scale and timeline of implementing mass tailoring. Even if industry leaders would be forward thinking enough and willing enough to switch from RTW to MTM tomorrow, there are practical limitations to implementing MTM at scale. It won't be an overnight success.

Production Capacity

MTM garments can only be produced cost effectively and at scale in highly automated on-demand facilities. Initially, we thought this would have to be near-shored to ensure quick lead times (<2 weeks), but we've recently discovered that drop shipping from a on-demand facility in Asia to a EU or US customer is as quick, albeit obviously less sustainable from a transportation perspective. On-demand facilities can produce around one million garments per year. We don't know how many on-demand facilities are able to produce one-off MTM garments (please feel free to get in touch with us if you do), but it's presumably less than a hundred facilities globally. Meaning right now, global capacity is ±100,000,000 MTM garments per year. That's a mere 0.04% of all apparel sold in 2022 worldwide. However, several well known RTW facilities are now expanding to on-demand sites as well. Even though the projected growth rate of on-demand facilities is (at least to us) unknown, these trends do seem hopeful for a more on-demand, MTM driven future.

Body Measurement Apps

One of the many challenging aspects of implementing mass tailoring is getting accurate customer body data. There are roughly three methods for getting measurements:

1. *Manual measurements*
   Manual measurements taken by tailors in shops. Very accurate, but not only feasible for high-end brands, and not very scalable.
2. *Physical 3D body scanners*

Digital measurements taken by physical scanners in stores or malls. Very accurate, but requires customers to go to a physical location. If enough locations have a physical scanner, and these scanners are connected to the cloud, it could become a scalable solution.

3. *Mobile 3D body scanning apps*

   Mobile 3D body scanning apps require the customer to either:
   - Take photos of themselves (which is a bit of hassle, but doable)
   - Fill in a questionnaire (which is very easy)

   While both are scalable, neither are highly accurate yet, especially where outliers are concerned (presumably the people most inclined to order MTM).

Supply Chain Puzzle

As briefly mentioned before, the fashion industry has built a monsterouses supply chain. Contrary to popular belief, the supply chain is not actually all that trendy. It's riddled with legacy software, hardware and workflows. Operation flexibility is limited due to investment intensive machinery. Adding to this already complex system is the fact that most hardware and software providers are protective when it comes to interoperability. This makes connecting the dots more time consuming and difficult than it needs to be. Thankfully more and more platforms are connecting the dots for brands, customers and manufacturers, to ensure a hyper efficient MTO and MTM process. But there's still a long way to go.

4. Impact Assessment

This research has demonstrated the decarbonisation effect of reducing (over)production volume through MTO and MTM. For a long time, the focus for making the fashion industry more sustainable has been on better (material) production. And rightfully so, (material) production is responsible for circa 45% of the total life cycle emissions. But in order to reach the industry's net-zero goals, brands need to look into the most (cost) effective combination of both relative *and* absolute carbon reduction practices. Which is easier said than done.

Tech Tailors has compared the decarbonisation effect of MTO and MTM, with the most popular current decarbonisation method: sustainable material production (SMP).

1. **SMP:** Sustainable Material Production (SMP) includes carbon reductions from the entire production cycle:
   a. raw material (t4) production
   b. yarn (t3) production
   c. fabric (t2) production
   d. garment (t1) production

   Preemptively, we want to emphasise that more sustainable materials are most definitely instrumental to move the fashion industry forward and to make it more sustainable. Not only when it comes to decarbonisation, but maybe even more importantly so when it comes to the reduction of the use of chemicals, toxins, water, and the subsequent threat to biodiversity and overall habitability of our planet. We merely aim to demonstrate that the industry's focus on more sustainable materials is not sufficient to achieve net-zero goals. There's only so much you can optimise for when it comes to decarbonising raw materials. To source cotton, you'll always have to use fertile land, water the seeds, transport the flowers to the mill, transport the yarn to the fabric manufacturer and finally transport the fabric to the garment manufacturer. At the end of the day; you can't redesign cotton. For these calculations, we estimated that SMP would reduce the total production (so in all four tiers) carbon emissions by 30%. This is highly optimistic.
2. **MTO:** Made-to-Order production (MTO) includes carbon reductions from lower (over) production levels. For these calculations, we assumed near-shored production.
3. **MTM:** Made-to-Measure (MTM) production includes carbon reductions from lower (over) production levels and lower returns. For these calculations, we assumed near-shored production.

We established three criteria for assessing the decarbonisation effectiveness of these methods:

1. **Market Scale:** Where could the solution be applied? What is the maximum theoretical reach of the solution in terms of market- value, volume, weight and emissions?
2. **Absolute Effect:** What is the total effect of the solution, how big of a decarbonisation dent can it make?
3. **Cost Effectiveness:** How much will the solution cost to implement? Are customers willing to pay a premium for this solution? What's the ROI of the solution?

4.1 Market Scale

What is the theoretical reach of the solution in terms of market- value, volume-, weight- and market emissions?

It is assumed that initially, MTO will be used only for non-critical fit garments, and that MTM will be used for both non-critical and critical fit garments, and that SMP will be used for all types of garments. While it's true that all garments that are produced with SMP, have a lower carbon footprint, it's not true that any SMP solution can be applied to all garments. If manufacturers find a way to make the production of cotton less carbon intensive, that only benefits garments that have cotton in their fibre composition, not all the garments on the market. But for the sake of simplicity, we assumed that SMP could potentially affect the carbon footprint of all garment types.

Table 9: *Total Apparel market revenue, volume and weight*

TOTAL APPAREL MARKET 2022					
	children	women & men			Total
		non-upper wear	upper wear		
			non-critical fit upperwear	critical fit upperwear	
Apparel Revenue	249	408	276	639	1,573
Revenue Share	16%	26%	18%	41%	
Unit of garments sold	59	62	25	24	170
Unit share	35%	36%	15%	14%	
Total weight	14	225	8	20	64
Weight share	22%	35%	13%	30%	

Table 9 summarises the makeup of the apparel market. SMP could theoretically affect 100% of revenue, volume and weight. Whereas MTO could only affect ±15% of all three. MTM could affect 59% of the market value, 29% of its volume and 43% of its total weight.

Figure 18: *Life Cycle Emissions per garment sold RTW*

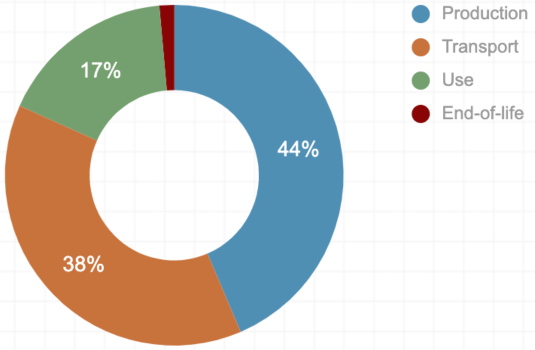
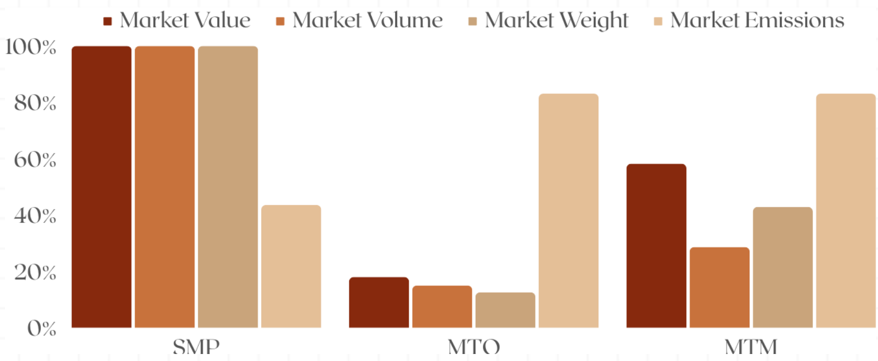


Figure 18 shows the life cycle for a RTW garment, corrected for overproduction and returns. SMP affects the production phase (44% of the emissions throughout the garment's life cycle). Whereas MTO and MTM lower the number of garments produced, the number of garments distributed and the number of garments incinerated or landfilled, thereby affecting 83% of the garment's life cycle emissions.

Figure 19: *Share of market that could theoretically be impacted*



SMP, MTO, and MTM could potentially affect different shares of the apparel market's value, volume, weight, and emissions. Which helps explain why assessing decarbonisation methods is so complex. Which combination of methods yields the highest absolute emission reduction?

4.2 Absolute Decarbonisation Effect Comparison

One of the many challenging aspects of decarbonisation analysis is the constant shift between relative effectiveness (carbon reductions per unit) and absolute effectiveness (total carbon reductions). Per garment, more sustainable container ships aren't going to make a huge difference. But for the industry as a whole, it sure will. More sustainable organic cotton might hugely affect the carbon footprint of that garment, but it only represents ±0.95%[24] of the total cotton fibre market, which represents ±22%[25] of the total fibre market, thus the absolute reductions will be negligible.

We'll look into the absolute effect of reducing upperwear overproduction through MTO and MTM for three of the four life cycle phases:

1. Production
2. Transportation
3. End-of-life

4.2.1. Production Phase Emissions

Brands and retailers also have to comply with the Paris Agreement, meaning they have to reduce their production emissions by 45% in 2030.

Production emissions can be reduced through two ways:

- more sustainable (material) production
- lower production volumes

According to the Apparel Impact Institute, if brands find a way to simultaneously:

- ➔ maximise material efficiency,
- ➔ invest and scale in sustainable material processes,
- ➔ maximise energy efficiency,
- ➔ eliminate coal in fabric mills and manufacturing facilities,
- ➔ and shift to 100% renewable energy in manufacturing,

projected apparel production emissions for 2030 will amount to 932 billion kg of carbon. Unfortunately, the emission target for 2030 is 564 billion kg of carbon, meaning we still need to remove a minimum of 368 billion kg in 2030. In just the production phase. The only way to remove the remaining 368 billion kg of carbon is by reducing overall production volume.

Let's see what happens if we (for argument's sake) produce 100% of upperwear in 2030 either MTM or MTO.

24 https://ota.com/advocacy/organic-standards/fiber-and-textiles/get-facts-about-organic-cotton#:~:text=Organic%20cotton%20currently%20makes%20up%20approximately%200.95%25%20of%20global%20cotton

25 https://textileexchange.org/app/uploads/2022/10/Textile-Exchange_PFMR_2022.pdf

Table 10: *Upperwear production emissions in 2030*

	MTM	MTO	RTW
% units sold realised with solution	100%	100%	100%
Total CO2 emissions garments produced with SMP	252	308	566
Reduction w.r.t. RTW	313	258	

If all (projected) upperwear garments in 2030 are produced with MTM, 85% of the *total* apparel reduction goal (368 billion kg) could be achieved. This, of course, is a long way from becoming reality. Let's look into a (slightly) more realistic scenario.

If 20% of all (projected) upperwear garments in 2030 are produced with SMP and MTM and MTO, the effect would be the following:

Table 11: *Upperwear production emissions in 2030 units in billions*

	MTM	MTO	RTW	TOTAL
% units sold realised with solution	10%	10%	80%	100%
Unit of garments sold with solution	8	8	65	81
Unit of garments produced to realise sales	9	11	158	177
Total weight of produced garments	5	6	90	101
Total CO2 emissions garments produced with SMP	25	31	453	509

Table 11 demonstrates that if 10% of upperwear is produced MTM in SMP and 10% of upperwear is produced MTO in SMP, 57 billion kg of carbon can be saved. Which is 15% of the *total* apparel reduction goal.

The bleak reality is that in order to have a fighting chance of meeting 2030 production emission goals, the industry needs to find a way to ramp up *both* SMP *and* MTM & MTO production. And as much as the industry has scorned carbon offset schemes, it now seems that they will be instrumental in achieving 2030 goals.

4.2.2. Transport Phase Emissions

As stated before, SMP does not affect the number of garments distributed and transported. MTO and MTM, on the other hand, do affect transport emissions (albeit indirectly). Strictly looking into upperwear (and assuming a higher sub-overproduction rate) transport phase emissions for RTW, MTO and MTM in 2030 would look like this:

Table 12: *Transport emissions upperwear 2030*

	MTM	MTO	RTW
% units sold realised with solution	100%	100%	100%
Unit of garments sold with solution	80,747,863,415	80,747,863,415	80,747,863,415
Transport emissions per garment sold (taking into account unnecessary transport overproduction and return emissions)	3.77	4.06	8.26
Total transport emissions	304,382,981,933	328,224,001,276	666,812,405,773
Savings w.r.t 100% RTW	**362,429,423,840**	**338,588,404,497**	
	54%	**51%**	

Table 12 demonstrates that if 100% of upperwear would be produced MTM in 2030, theoretically, 54% of transport emissions would be saved with respect to 100% RTW.

Table 13: *Transport emissions upperwear 2030*

	MTM	MTO	RTW	TOTAL
% units sold realised with solution	10%	10%	80%	100%
Unit of garments sold with solution	8,074,786,341	8,074,786,341	64,598,290,732	80,747,863,415
Transport emissions per garment sold (taking into account unnecessary transport overproduction and return emissions)	3.77	4.06	8.26	
Total transport emissions	30,438,298,193	32,822,400,128	533,449,924,618	596,710,622,939
Savings w.r.t 100% RTW				**70,101,782,834**
				11%

More realistically, if 10% of upperwear is produced MTM and 10% is produced MTO, transport emissions could be 11% lower as compared to 100% RTW.

However, we are hopeful that by 2030, transport emissions will be significantly lower due to the ongoing transition from fossil fuel to renewable energy transport. If this trend continues to evolve, MTO and MTM savings regarding transport could become negligible.

4.2.3. End-of-life Phase Emissions

End-of-Life (EOL) emissions are 'only' 1% of the total life cycle emissions. But if you consider that 82 billion garments per year are being landfilled and incinerated, the net effect from reducing overproduction is far from negligible for this phase.

For this part of the analysis, we looked into the destruction of unsold goods by suppliers. The destruction of unsold goods by customers is not taken into account. We also didn't take into account the emissions from transport in this life cycle phase. Because so little is known about the destruction of unsold goods, we also don't know how they're moved around. If transport would be taken into account, EOL emissions would probably be higher.

Table 14: *2030 EOL emissions upperwear units in billions*

	MTM	MTO	RTW
% units sold realised with solution	100%	100%	100%
Unit of garments sold with solution	81	81	81
Unit of garments produced to realise sales	88	107	197
Unsold units	7	26	116
Weight of unsold units	4	9	66
Emissions disposal unsold units	1	2	7
Savings wrt 100% RTW	**7**	**6**	
	92%	**75%**	

Table 14 demonstrates that if 100% of upperwear would be MTO or MTM, theoretically, 75% to 92% of EOL carbon could be saved respectively.

Table 15: *EOL 2030 upperwear units in billions*

	MTM	MTO	RTW	TOTAL
% units sold realised with solution	10%	10%	80%	100%
Unit of garments sold with solution	8	8	65	81
Unit of garments produced to realise sales	9	12	158	177
Unsold units	1	3	93	96
Weight of unsold units	0,4	1	53	54
Emissions disposal unsold units	0,1	0,2	6	6
Savings wrt 100% RTW				**1**
				17%

Table 15 demonstrates that if 20% of upperwear would be MTO and MTM, 17% of carbon could be saved. It is important to note that emissions from landfilling and incinerating clothes aren't limited to carbon. A whole bunch of toxins are released into the atmosphere in the disposal process, hugely impacting the air quality of the surrounding area. So any reduction at all will greatly improve the air quality of the surrounding areas.

The EU is already working on a ban of the destruction of unsold goods, which will hopefully have a positive impact on the air quality in the EU. But make no mistake, without an export ban, these unsold goods will be shipped to the global South, where the air quality will deteriorate further. That's moving the problem, not solving the problem.

4.2.4 Total Life Cycle Upperwear Decarbonisation Comparison

Let's look into the net effect of both SMP, MTO and MTM for upperwear, for the three life cycles combined.

Table 16: *Total Carbon savings in billions of kg with respect to 100% RTW in 2030*

	10% MTM, 10% MTO, 80% RTW	100% MTM	100% MTO
Production emissions with SMP	57	313	258
Transport emissions	70	362	339
EOL emissions	1	7	5
Total savings	**128**	**683**	**602**

Table 16 demonstrates that producing 20% of upperwear MTM and MTO and 80% of upperwear RTW, all with SMP in 2030, that 128 billion kg lower carbon emissions, throughout the garments' entire lifecycle, can be saved.

Table 17: *Total Carbon savings in % with respect to 100% RTW in 2030*

	10% MTM, 10% MTO, 80% RTW	100% MTM	100% MTO
Production emissions with SMP	10%	55%	46%
Transport emissions	11%	54%	51%
EOL emissions	17%	92%	75%
Total carbon savings	**10%**	**55%**	**49%**

Table 17 demonstrates that producing 20% of upperwear MTM and MTO and 80% RTW all with SMP, would result in 10% lower emissions in 2030, for the garments' entire lifecycle. Theoretically, producing 100% of upperwear MTM in 2030, would cut carbon emissions in half, for the entire life cycle of the garment. Even though this is not realistic yet, it is worth looking into the extraordinary potential of MTO and MTM in more detail.

4.3 Cost Effectiveness of Decarbonisation Method

As important as the potential scale and the absolute effect of the decarbonisation solution is, brands also need to consider its financial ROI. Tech Tailors has published an article on the economics of MTO and MTM in 2022[26]. We performed the same analysis, this time for upperwear. We have also updated our set of assumptions:

- online upperwear sales
- identical price points MTO, MTM and SMP
- 30% higher unit production costs MTO & MTM
- 20% higher unit production costs SMP
- Returns are allowed across the board
- Customers pay a $5 fee per return

Table 18: *Margin comparison for MTO, MTM and SMP at identical price points*

Change with respect to RTW at identical price points			
	MTO	**MTM**	**SMP**
Total production cost	-79%	-79%	+20%
Total revenue	-45%	-45%	0%
Gross profit	+128%	+135%	-40%
Gross profit margin	**+152%**	**+163%**	**-40%**

It is assumed that MTO and MTM only produce what would have been sold at full price under RTW (for the full calculations, please see the spreadsheet linked in the methodology section). Even though the cost per garment produced is 30% higher for MTO and MTM, the cost increase is offset by the output decrease, resulting in 79% lower total production costs. At the same time, revenue for MTO and MTM is 45% lower (because MTO and MTM only sell what would have been sold at full price RTW). However, the losses in revenue are offset by lower production (and return) costs, resulting in 152% higher profit margins for MTO and 163% higher profit margins for MTM. This analysis also demonstrates that the 20% higher production costs for SMP with RTW results in significantly 40% lower margins than RTW produced in a regular material. At identical price points, MTM is clearly the most profitable production method.

Now, let's look into the cost effectiveness of these methods, assuming brands can charge a premium of 30% for MTO and MTM, and a 15% premium for SMP (customers are often willing to pay more for customisations/tailoring than they do for a standard garment in a more sustainable material).

[26] The Unexpected Profitability of Mass Tailoring - The Interline

Table 19: *Margin comparison for MTO, MTM and SMP at premium price points*

Change with respect to RTW at premium price points			
	MTO	**MTM**	**SMP**
Total production cost	-79%	-79%	+20%
Total revenue	-29%	-29%	+15%
Gross profit	+148%	+158%	+18%
Gross profit margin	**+168%**	**+181%**	**+3%**

If brands were to charge a premium for customisations, tailoring and more sustainable materials, the cost effectiveness changes. Compared to RTW, MTO & MTM revenue is now 29% lower, whereas SMP revenue is 15% higher. The gains in revenue for SMP are not offset by the higher production costs, resulting in 18% higher gross margins for SMP. Coincidentally, at a premium price point, MTO and MTM increase profit margins by 168% and 181% respectively.

What becomes clear is that even though SMP is much needed in the fashion industry, it's not financially viable (yet). MTO and MTM on the other hand, already offer great returns on investment. And are thus the more financially attractive decarbonisation method for brands (and their profit hungry shareholders).

Please note that these are simplified margin calculations, these numbers should be interpreted as rough estimates, and will vary greatly per brand.

5. Conclusion

This research aimed to demystify overproduction. Although tangible data remains elusive, Statista's numbers paint a dreary picture. Up until now, it was estimated that global production volume was somewhere between 50-150 billion garments per year. Tech Tailor's research has demonstrated that production volume is more likely to be around 276 billion garments per year. And that overproduction is not 30%, but more likely to be around 38%. Furthermore, Tech Tailor's analysis has demonstrated that not all overproduction is created equally. Overproduction for upperwear is most likely even higher, around 59%.

Reducing overproduction doesn't just affect the emissions from the garments that were unnecessarily produced, it also affects the transportation emissions of garments that were unnecessarily shipped and the end-of-life emissions from garments that were unnecessarily destroyed. Eliminating upperwear overproduction would theoretically decrease emissions for the total life cycle per upperwear garment sold by 37%.

Admittingly, eliminating overproduction in its totality is somewhat impossible. However, brands *can* significantly reduce overproduction. Tech Tailors looked into three overproduction reduction methods: better sales forecasting, made-to-order (MTO) and made-to-measure (MTM).

1. Better sales forecasting is the most popular overproduction reduction method, but unfortunately also the least effective one. Over the past three years around 50% of retailer's online offerings have been on sale for an average discount rate of 33%. At the same time, retailer's inventory has been outgrowing sales. So while sales forecasting has supposedly gotten more advanced, overproduction has gotten worse.
2. MTO produces on-demand, in standard sizes. While made-to-order solves for inventory, it doesn't solve for online returns. MTO provides customisation, but still produces in standard sizes. 70% of online returns are due to incorrect fit. So either brands have to deal with custom returns that can't be resold, or customers can't return their order, making them more hesitant to order in the first place. Both put pressure on this method.
3. MTM produces on demand, tailored to the customer. MTM solves the biggest pain point in the on-demand model: sizing. Until now, tailoring is mostly used for high-end traditional formal wear. But with new technologies, it's possible to produce MTM for fast fashion and luxury fashion alike. But this new production method is in its infancy and production capacity is not nearly sufficient to make a significant impact yet.

Which of these overproduction reduction methods can help reach the industry's 2050 net-zero goals? In order to comply with net-zero regulations, brands need to look into the most (cost) effective combination of relative (per unit) and absolute (overall output) carbon reduction practices.

Tech Tailors has compared the decarbonisation effect of MTO and MTM, with the most popular current decarbonisation method: sustainable material production (SMP). Tech Tailors established three criteria for assessing decarbonisation effectiveness:

1. Potential Scale

What is the theoretical reach of the solution in terms of market- value, volume-, weight- and market emissions? SMP theoretically affects 100% of revenue, volume and weight. Whereas MTO only affects ±15% of all three. MTM affects 59% of the market value, 29% of its volume and 33% of its total weight. SMP affects the production phase (44% of the emissions throughout the garment's life cycle). Whereas MTO and MTM lower the number of garments produced, the number of garments distributed and the number of garments incinerated or landfilled, thereby affecting 83% of the garment's life cycle emissions.

2. Absolute Effectiveness

2.1 Production Emissions

Production emissions can be reduced through two ways:

- more sustainable (material) production
- lower production volumes

According to the Apparel Impact Institute, if brands find a way to make (material) production as sustainable as possible, projected apparel production emissions for 2030 amount to 932 billion kg of carbon. Unfortunately, the emission target for 2030 is 564 billion kg of carbon, meaning we still need to remove an additional 368 billion kg of carbon in 2030. In just the production phase. The only way to remove the remaining 368 billion kg of carbon is by reducing overall production volume. MTO and MTM can save 46%-55% of production emissions respectively per upperwear garment sold (as compared to RTW).

2.2 Transport Emissions

While near-shored MTO and MTM production also save hugely on the transport and distribution side of things (40%-44% per garment sold respectively), it is our hope that by 2030, the majority of transport will be done in renewable energy. This would mean that MTO and MTM would still reduce the number of garments that need to be shipped, but with zero emission shipping, their carbon reduction effect will be negligible.

2.3 End-of-Life Emissions

The final phase of a garment's life cycle up until recently has been overlooked. But pictures from landfills in Ghana and Chile are printed on our collective minds. Brands need to take more responsibility and decrease overproduction and the subsequent over-destruction of unsold goods. MTO and MTM can save 46%-55% per garment sold respectively in this phase.

3. Cost Effectiveness

Although necessary, SMP is unfortunately not always financially viable (yet). The harsh reality is that consumers are not always willing to pay a premium for a more sustainable product, while they are willing to pay a premium for a custom or tailored product. But even if we assume that SMP, MTO and MTM garments are all sold at identical price points, MTO and MTM still yield 152% and 163% higher gross margins respectively.

Tech Tailor's research has demonstrated the immense decarbonisation potential of reducing overproduction. And the only way to effectively reduce volume, without sacrificing margins, is MTO & MTM.

Right now, the most efficient MTO and MTM production is done off-shore (from a Western perspective). Global production scale is estimated at 100 million units per year. But as demonstrated in the previous section, that won't cut it - not by a landslide. We need to scale up on-demand production capacity to *billions* of garments per year. And we need to move it closer to home.

We can no longer afford to ignore output reduction as an instrumental part of decarbonising the fashion industry. If we want a fighting chance of meeting 2030 targets, let alone 2050 targets, the industry needs to invest in SMP *and* MTM facilities, right now.

Further Considerations

Acknowledgement of Complexity

Firstly, we need to acknowledge that decarbonising the fashion industry is an immensely complex undertaking. While malpractices, injustices and grievances absolutely need to be addressed, it's too easy for us to point to the fashion industry and say 'just change'. Because how should the industry effectuate that change? The fashion industry has one of the most complex supply chains in the world. Even if brands and retailers would want to change into Mother Theresa tomorrow, they simply couldn't from a practical standpoint. So let's keep the industry accountable, but let's also collaborate and innovate to actually implement the change we all want to see.

Shifting the Onus from Consumers to Brands

Secondly, it's time to shift the onus from consumers, to brands. Just as pointing the finger to the industry is an oversimplification, pointing the finger to just the consumers is as nescient. An often heard argument is 'people just need to buy less, buy from more sustainable brands and buy more second-hand clothes'. And while all of this is true, not all of this is feasible. Sure, overconsumption is a very real issue, but brands have also made it very difficult for shoppers to avoid overconsumption. By continuously offering clothes for an inhumane low price, everyone is tempted to buy more. Returns are actually involuntarily encouraged by having the most inconsistent sizing charts known to mankind. Shoppers often order multiple sizes, also known as bracketing, because they know the odds of a garment fitting them at the first try are slim to none. Plus, not everyone can afford to buy from more sustainable brands. And while shopping second-hand has become infinitely more accessible due to the likes of Vinted and Vestiaire Collective, it's still not as convenient as shopping for new clothes.

Appeal for Improved Legislation

Legislation could prove to be very effective in at the very minimum illustrating the size of the overproduction problem, but it could also incentivize brands to minimise it. If brands are required by law to disclose (over)production levels, they will have to a) invest in inventory tracking solutions and b) invest in overproduction reduction solutions. Because disclosing that you've overproduced one billion garments is just, well, bad PR. New EU legislation will force brands to actually do something with their unsold goods, rather than burning them. Which, might, in turn, make them want to avoid it in the first place. A girl can dream.

Disclaimer

In the spirit of full disclosure: we're a software company dedicated to minimising overproduction by enabling mass tailoring. We have skin in the game. In trying to estimate the environmental impact of mass tailoring (again, for our own business case), we hit so many walls. Existing publications fall short in consistent data use, clear cut definitions, scope inclusion, annual vs. historic emissions, etc.. Comparing apples and oranges seems to be the rule, not the exception. That's why we aimed to make our research as transparent as possible. We've disclosed all our sources, assumptions, definitions, considerations and calculations to ensure full transparency. Since we didn't have full access to retailers' databases, we used data from our own clients and (very established) suppliers, as well as scholarly research, retail- and carbon reports, and news publications to estimate the potential decarbonisation opportunities. Most of our estimates are on the conservative side, as to not inflate mass tailorings' decarbonisation potential. This research could be hugely improved by real life databases, such as Vaayu's analysis (with over half a billion transactions) for Vinted[27]. Furthermore, the focus of this research has been on decarbonisation. We are aware that resource extraction, as well as other GHG emissions are relevant in making the fashion industry more sustainable. Please note that this research has not been peer reviewed yet - we're working on it.

27 https://press-center-static.vinted.com/Vaayu_x_Vinted_Full_Climate_Impact_Report_2021_045f9e5c4b.pdf

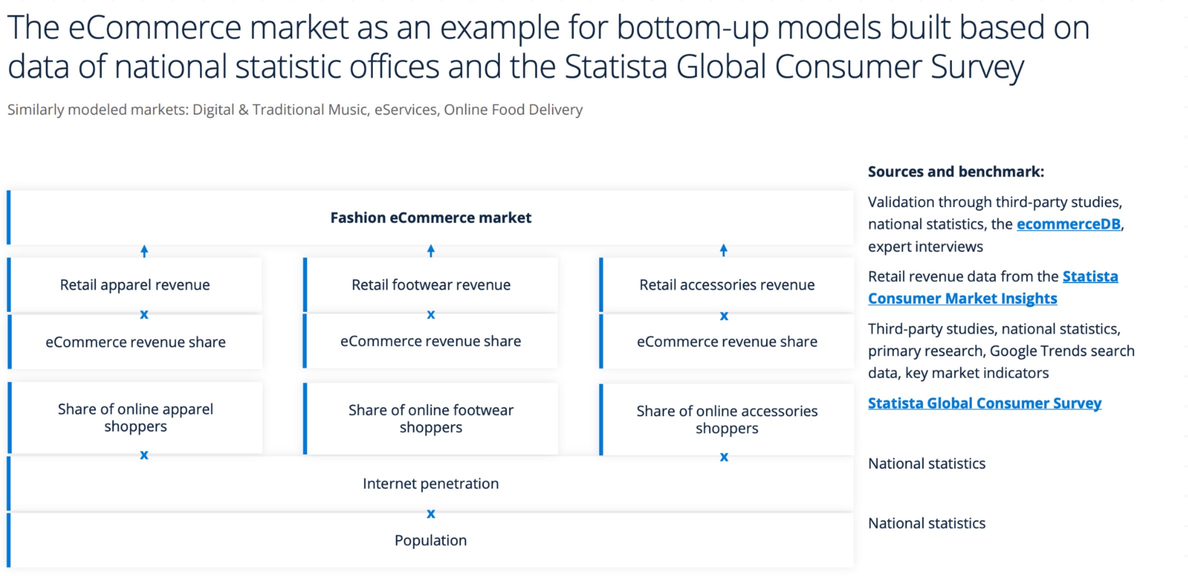
6. Methodology

This section will elaborate on the definitions and assumptions made to reach our conclusions.

1. Production level estimates

According to Statista, the number of garments sold in 2022 amounted to 170 billion[28]. While Statista clearly defines the scope in terms of garment types included, it is unclear to what extent these numbers include second hand apparel, if they account for returned garments that are not resold etc. Presumably, the sales level also includes garments that were produced to be sold in year t-1, which would explain why the sales volume is higher than the presumed production volume. However, sales volume has steadily outperformed presumed production volume for years on end. Please see figure 1 for a more detailed description on Statista's methodology. We interpreted the sales volume as initially sold 'new' garments. It is likely that this is a misinterpretation. Our guess would be that the Statista sales volume also accounts for second hand sales through recommerce platforms, but most likely not sales through second hand shops. It could therefore be that our estimated overproduction volume is slightly inflated.

Figure 1: Methodology Statista Apparel Data



[29]

[28] https://www.statista.com/outlook/cmo/apparel/worldwide#volume
[29] https://cdn.statcdn.com/static/img/outlook/methodology/methodology-en.pdf

2. Carbon emissions estimates

In order to estimate the carbon emissions per garment produced and sold, the following was assumed:

In scope:

Average garment weight	0.571 kg	Fishwick, 2012. Please note that this is not a weighted average.	https://www.researchgate.net/profile/Matt-Fishwick/publication/306145659_A_Carbon_Footprint_for_UK_Clothing_and_Opportunities_for_Savings/links/57b3117808aeaf239baf0297/A-Carbon-Footprint-for-UK-Clothing-and-Opportunities-for-Savings.pdf
Distance covered by sea		Ports.com	http://ports.com/sea-route/port-of-shanghai,china/port-of-amsterdam,netherlands/#/?a=0&b=3037&c=Port%20of%20Shanghai&d=Port%20of%20Rotterdam,%20Netherlands
Emissions per tonne-km sea freight	0.01469 kg CO2e	Conversion factors UK Government Guidelines	https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2022
Emissions per tonne-km land freight, heavy truck (100% laden)	0.07384 kg CO2e		
Emission per tonne-km air freight (international flight)	1.0189 kg CO2e		
Raw material	China, India, US		https://www.statist

producers			a.com/statistics/263055/cotton-production-worldwide-by-top-countries/
Main yarn producers	China, India Vietnam		https://www.statista.com/statistics/1044170/textile-yarn-leader-importers-worldwide/
Main fabric producers	China, EU, India		https://www.statista.com/statistics/236417/share-of-the-leading-global-textile-exporters-by-country/
Main garment manufacturers	China, EU, India		https://www.statista.com/statistics/236397/value-of-the-leading-global-textile-exporters-by-country/
Main Importers of readymade garments (RGM)	EU, US, Japan		https://www.statista.com/statistics/1198349/apparel-leading-importers-worldwide-by-value/
Garment Trade Flows	From fibre to yarn to fabric to garment to destination port.	Common Objective, UN Comtrade	See
Average distance factory to export port	500 km	S. Moazzem, E. Crossin, F. Daver et al. 2021	https://www.researchgate.net/publication/355336081_Environmental_impact_of_apparel_supply_chain_and_textile_products
Loss in raw material for each production phase			
From raw material	9.27%	S. Moazzem, E.	https://www.resear

to yarn		Crossin, F. Daver et al. 2021	chgate.net/publication/352504043_Assessing_Environmental_Impact_Reduction_Opportunities_Through_Life_Cycle_Assessment_of_Apparel_Products Also see tab 'Production Phase CO2'
From yarn to fabric	8.40%		
From fabric to garment	12.65%		
Total average material waste per garment	27.79%		
Total emissions apparel industry	1024 million metric ton CO2e	Apparel Impact Institute	https://apparelimpact.org/wp-content/uploads/2022/02/roadmap-net-zero-delivering-science-based-targets-apparel-sector.pdf
Emissions T-1	91 million metric ton CO2e		
Emissions T-2	536 million metric ton CO2e		
Emissions T-3	156 million metric ton CO2e		
Emissions T-4	241 million metric ton CO2e		
Total garments produced 2022	276 billion garments	Tech Tailor's estimate: based on Statista sales volume and 30% initial overproduction	https://www.statista.com/outlook/cmo/apparel/worldwide Also see tab 'Garment Flow RTW'
Average emissions per garment produced	4.30 kg CO2e	Aii & Tech Tailors	See tab 'Production Phase CO2'
Split transport air vs sea from exporting country to destination country	80% sea freight, 20% land freight	Tech Tailor's estimate	See '3. Garment Trade Flows'
EU customers			
Split domestic vs.	73%/27%		

International warehouse			
Split air vs land freight to domestic warehouse	0%/100%		
Split air vs land freight to international warehouse	80%/20%		
Split air vs land to domestic consolidation centre	0%/100%		
Split air vs land to international consolidation centre	80%/20%		
Split domestic vs international consolidation centre	73%/27%		
Split e-commerce and B&M	35% of sales are from e-commerce, 65% from B&M	Statista Apparel Worldwide	https://www.statista.com/outlook/cmo/apparel/worldwide
Average number of garments per ecom order	2.61	Dynamic Yield, 300 million transactions	https://marketing.dynamicyield.com/benchmarks/units-per-transaction/
Average number of garments per B&M order	1.69	Vend HQ, 13,000 retailers	https://www.vendhq.com/blog/retail-metrics-and-kpis/
Average apparel return rate e-commerce	38%	The actual ecommerce return rate varies greatly across garment categories and brands. Ecommerce returns are also ill-defined.	https://www.retaildive.com/spons/reducing-the-cost-of-reverse-logistics-present-and-future/638146/ Also see '6. Returns'

Average apparel return rate B&M	8.5%		
Average delivery failure rate per e-commerce delivery	7%	Loqate research, >300.000 transactions analysed, pg. 7	https://info.loqate.com/hubfs/Loqate%202021/Fixing%20Failed%20Deliveries/Fixing%20Failed%20Deliveries%20-%20Final.pdf
Average distance consolidation centre-home	43 km	Vaayu report for Vinted, 200 million transactions analysed pg. 149	https://press-center-static.vinted.com/Vaayu_x_Vinted_Full_Climate_Impact_Report_2021_045f9e5c4b.pdf
Average emissions CS-home per garment	0.68 kg CO2	Vaayu report for Vinted, 200 million transactions analysed pg. 84. Home delivery (1.3 garments) is estimated at 0.68 kg/delivery, but we corrected for a single garment delivery.	
Average distance store-home	12 km	Oliver Wyman, pg. 65	https://www.oliverwyman.com/content/dam/oliver-wyman/v2/publications/2021/apr/is-ecommerce-good-for-europe.pdf
Emissions per transport type			
Car (this is for the average car, not the newest cars, where emissions are around 0.108 kg/km[30])	0.270 kg/km	Since the route to the store/PUDO will most likely be urban, 50% higher emissions are assumed.	https://www.statista.com/statistics/1185559/carbon-footprint-of-travel-per-kilometer-by-mode-of-transport/
Train	0.105 kg/km		

[30] https://www.eea.europa.eu/ims/co2-performance-of-new-passenger

Bus	0.041 kg/km		
Average distance CS- PUDO	43 km	Vaayu report for Vinted, 2 million transactions analysed pg. 149	https://press-center-static.vinted.com/Vaayu_x_Vinted_Full_Climate_Impact_Report_2021_045f9e5c4b.pdf
Average emissions/garment CS-PUDO	0.14 kg Co2e	Vaayu report for Vinted, 2 million transactions analysed pg. 84. PUDO delivery (1.3 garments) is estimated at 0.18 kg/delivery, but we corrected for a single garment delivery.	https://press-center-static.vinted.com/Vaayu_x_Vinted_Full_Climate_Impact_Report_2021_045f9e5c4b.pdf
Transportation mode home-PUDO	While it is observed that the majority of buyers (55%) and sellers (58%) used their personal cars to travel to and from PUDOs, a considerable proportion (>30%) did so by foot, which is correlated to the area's PUDO density.	Vaayu report for Vinted, 2 million transactions analysed pg. 70	
Average distance PUDO-home (round trip)	2.3 km	Vaayu report for Vinted, 2 million transactions analysed Pg. 83	
Average amount of CO2 for warehousing a garment	0. 341 kg CO2/garment	Oliver Wyman, pg. 72	https://www.oliverwyman.com/content/dam/oliver-wyman/v2/publications/2021/apr/is-ecommerce-good-for-europe.pdf
Average amount of CO2 for keeping a garment in the	1.299 kg CO2/garment	Oliver Wyman, pg. 72	

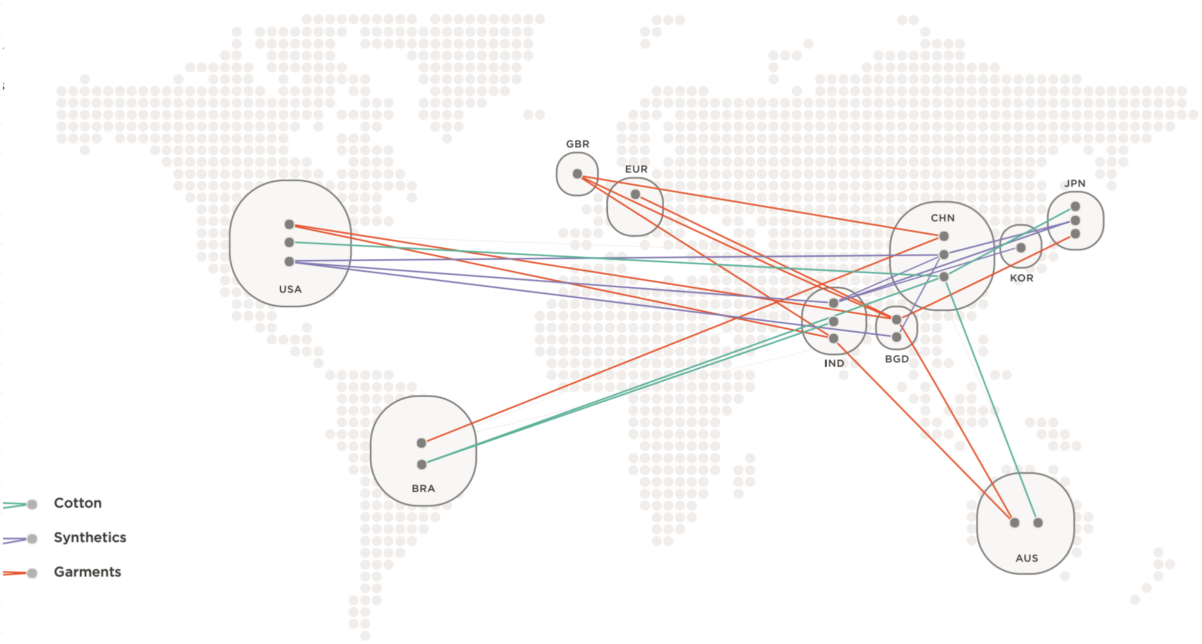
store			
Average distance WH-store	30 km	S. Moazzem, E. Crossin, F. Daver et al. 2021	https://www.researchgate.net/publication/355336081_Environmental_impact_of_apparel_supply_chain_and_textile_products

Out of scope:

- truck transport for transporting raw material to sea port, from sea port to fabric mill etc.
- Sample production and distribution
- end of life transportation (customer to second hand shop or waste facility etc.)

3. Garment Trade Flows

Garment flow trade by Common Objective, with UN Comtrade data from 2016:



For the nominal case, the following was assumed (based on Statista import and export data):

Raw material production	US
Export port:	New York
Yarn production	Turkey

Export port:	Mersin
Fabric production	India
Export port:	Mumbai
Garment production	China
Export port:	Shanghai

Route	Km by sea	Kg CO2/garment	Km by air	Kg CO2/garment
US → Turkey	10,480	0.088		
Turkey → India	6,889	0.058		
India → China	9,802	0.082		
China → Netherlands	22,222	0.186	8,920	5.19

Split air vs. sea export

Currently, a split of 92% through sea and 8% by air is assumed for apparel exports[31]. This split, however, is based on average freight export logistics, for all types of trade. While exact export transport mode data is not in our possession, it seems likely that this split is vastly different for apparel. Research by Yeonkyeong Park 2019[32], paints a different picture from what is currently assumed:

31 https://www.researchgate.net/publication/355336081_Environmental_impact_of_apparel_supply_chain_and_textile_products

32 https://www.researchgate.net/publication/344980541_Port_Infrastructure_and_Supply_Chain_Integration_under_the_Belt_and_Road_Initiative_Role_of_Colombo_Port_in_the_Apparel_Industry_in_South_Asia

Table 1. Transport modes by major states in apparel industry trade.

Transport Modes	Export			Import		
Share, %	Sea	Air	Others	Sea	Air	Others
Turkey (2015)	9.5	76.9	13.1	46.8	47.6	5.0
Cambodia (2014)	53.0	31.0	14.3	44.3	36.8	16.5
Myanmar (2014)	69.3	30.0	…	98.4	1.5	…
Bangladesh (2014)	40.9	58.2	0.9	88.0	9.4	2.6
India (2015, 2014)	68.2	30.1	1.7	82.2	17.5	0.3
Sri Lanka (2015, 2014)	47.4	52.6	0.0	22.5	23.0	…
Pakistan (2014)	20.4	79.3	0.3	66.1	32.9	1.0
European Union 28 (2014)	53.0	31.0	14.3	44.3	36.8	16.5
United States (2015)	22.0	72.9	5.1	38.5	57.3	4.1

* Missing data.
Source: World Trade Organization Country Profiles (2014, 2015)

This data is based on 2015, and while the freight landscape is continually evolving, a 92% sea and 8% air seems like a stretch for apparel. Recent publications support this view:

- India exports Mumbai Airport has reported a near 30% increase in overall cargo volumes this year, with international freight up 26% and domestic shipments up 40%[33]:
- 22% of apparel imports in the US came in through air freight[34]
- Since 2020, Amazon is expanding their air freight by 120%[35]

Furthermore, brands now carry 52 micro seasons per year[36]. Sea cargo takes up to a month to arrive from China to the EU. In order to deliver to stores and warehouses on time, it seems unlikely that only 8% is transported by sea.

First transit port	Rotterdam
Destination WH	Germany
Destination stores	Germany and EU (land)
Destination customer	Germany and EU (land and air)
Split domestic vs international WH	10%/90%
Split road vs air	28%/20%
Domestic WH to dom CS vs int CS split	95%/5%
Split road vs air dom	100% road
Split road vs air int	20%/80%
Domestic WH to int CS	

33 https://theloadstar.com/first-shipper-uses-new-land-air-corridor-to-india-for-bangladesh-exports/
34 https://www.usitc.gov/research_and_analysis/tradeshifts/2020/special_topic.html#_ftn68
35 https://las.depaul.edu/centers-and-institutes/chaddick-institute-for-metropolitan-development/research-and-publications/Documents/Total%20Package%20Amazon%20Air's%20Changing%20Network%20and%20Strategic%20Orientation.pdf
36 https://www.thegoodtrade.com/features/what-is-fast-fashion/

Rotterdam is the gateway to Europe and often considered a transit port. From here, garments are transported throughout Europe by sea, air and land freight. We don't have access to data regarding these garment trade flows yet, so we assumed a nominal case, rather than a weighted average. In the nominal case, a brand is operating internationally, both one centralised warehouse in Germany and stores across Europe.

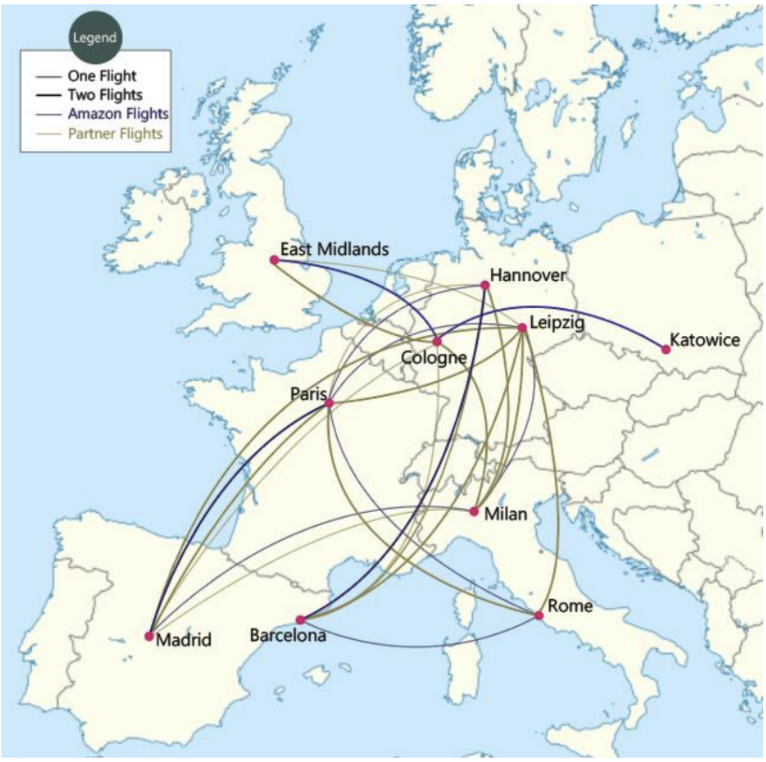
27% of ecommerce was cross border in Europe in 2022[37]. Exact numbers for apparel are not in our possession, but in this ranking, German retailer Zalando takes third place, followed directly by Swedish brand H&M. Spanish brand Zara (Inditex) is ranked sixth, just behind Danish company Lego. This top three mirrors the recent ranking of the top European cross-border fashion e-commerce sites.

Amazon's EU and US flight routes also show that distances that theoretically could be covered by trucks, are indeed being covered by flights[38]:

37
https://www.cbcommerce.eu/blog/2023/03/27/5th-edition-of-the-top-500-cross-border-retail-europe-an-annual-ranking-of-the-top-500-european-cross-border-online-shops/

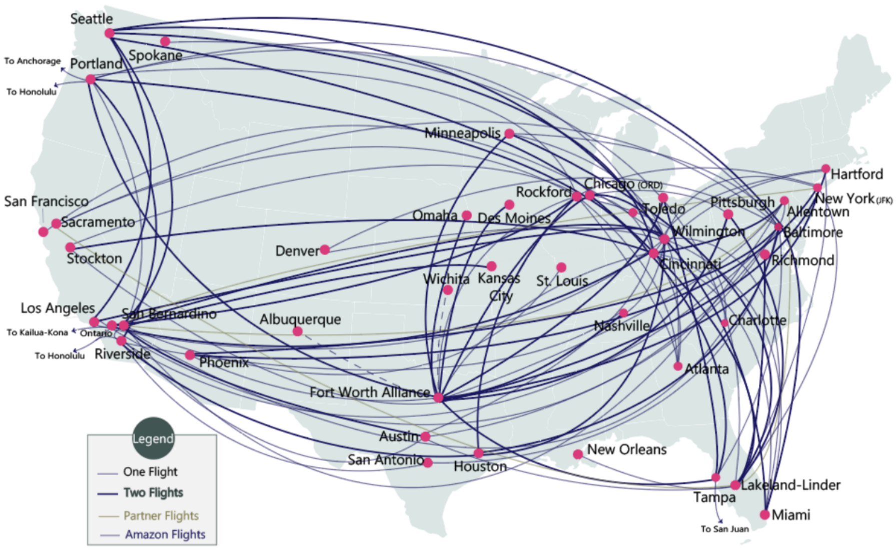
38
https://las.depaul.edu/centers-and-institutes/chaddick-institute-for-metropolitan-development/research-and-publications/Documents/Total%20Package%20Amazon%20Air's%20Changing%20Network%20and%20Strategic%20Orientation.pdf

FIGURE 1: Amazon's European Network, including partner flights



Amazon's intra-Europe network, March 3, 2022. Probable partner flights ("shadow flights") on ASL Airlines freighters not reported as being operated for Amazon Air are in brown.

FIGURE 3: Amazon Air's Growing Domestic U.S. Flight Network, March 3, 2022



While it is not entirely clear is these routes reflect ecommerce deliveries, or larger shipments for warehouses, it is clear that air freight is highly relevant to Amazon.

We assume that for EU international deliveries, 80% is done by air freight and 20% by land[39].This is due to the fact that most retailers offer quick delivery (<1 week), which can only be realised through air freight. For international shipments, an average of 1200 air freight km is assumed. For deliveries to stores, it is assumed that 100% is done by land

4. Mid leg

The mid leg part of the transportation phase has been simplified in this research. The interhub journey is complex and varies greatly across deliveries. Emissions associated with the mid leg could be underestimated in this research.

5. Last mileage

Last mileage is defined as the final leg of the transport, from the consolidation centre to the customer's home, or pick-up/drop-off (PUDO) point. This is often the most polluting part of the journey due to:

- Limited load capacity vans
- Stop and start
- Engine running continuously
- Unsuccessful deliveries
- Inefficient routes

This research did not take into account that some urban areas now have bike deliveries and electric vans to deliver parcels. This would significantly lower the emissions associated with the last milage.

6. Returns

Returns is a tricky subject, for a multitude of reasons:

1. **Definition**
   Firstly, the definition of returns is ambiguous. Are returns defined as initial returns, or corrected returns? Industry data shows that ecom apparel returns are around 30%, whereas B&M apparel returns are around 8%. But how are these return estimates calculated? If we take ecom, when 30% is returned, is that at the end of the season? Meaning initially 30%+X% was returned, but part of those returns were resold, so corrected returns were 30%? And what about one order that contains 6 garments, of which 3 get returned. Is that considered one return? Or three returns?

[39] https://www.aircargonews.net/iata-wcs/e-commerce-ready-for-renewed-lift-off/

2. **Number of resells**
   Secondly, what is the share of returns that get resold? Data on this is limited, but estimates for ecom apparel returns that are restocked are just 50%. But how often are returns resold on average? We assumed that a return can only be resold once, but in reality, it could be two or three times.
3. **Final destination**
   Finally, what happens with these unsold returns? Data on this is, again, scarce, and therefore not taking into consideration for the carbon emissions associated with returns. We know unsold goods are often bought up by liquidators, or sent to landfill. Presumably they are first shipped to a warehouse, before they reach their final destination. This route is fairly unknown, and thus not accounted for in the return emission estimate. Meaning this estimate is probably underestimated.

Average Order Size

This analysis does not account for multiple garments per (B&M or ecom) order, for several reasons. Multiple garments per order (on average 2.02 for RTW) affect the last milage of the consumer going to the PUDO or the store. Where delivery emissions are based on the weight of the garment(s), the last milage of the customer is based on passenger kilometres. One could argue that if you buy 2 garments, the passenger emissions are cut in half. However, for an accurate estimate of the passenger last milage emissions, one would also have to take into account trip dedication (did the customer make the trip specifically to buy the two garments, or was it just to browse etc.). We therefore did not take average order size into account for the last milage of the customer. Assuming fully loaded vans, average order size does not affect the last milage of the order going from the consolidation centre to the customer's home (two garments per order means twice the weight, and thus twice the emissions). We therefore also didn't account for average order size in the home delivery segment of the analysis.

7. Use phase

The use phase is complex and ill-researched, and we did not contribute greatly to current research, there is a lot of room for improvement in terms of accuracy. The purpose of our overall research was to demonstrate the decarbonisation effect of reducing overproduction through mass tailoring. The use phase is fairly similar for both RTW and MTM, with the exception of the resell possibilities for MTM, these are more limited. It can also be assumed that MTM garments would remain in a customer's closet for longer, but we did not account for this.

Useful life	1.5 years	1-3 years depending on the garment, pg. 3	Moazzem 2021: https://www.sciencedirect.com/science/article/abs/pii/S2352550921001810
Number of washes	30	20-50 washes	
Number of drying machine sessions	7		
Emissions per tumble dry per kg of laundry	0.34 kg CO2		https://www.theguardian.com/environment/green-living-blog/2010/nov/25/carbon-footprint-load-laundry
Emissions per wash per kg of laundry	0.14 kg CO2		
Number of dry cleaning sessions	0.5	Own estimate	
Emissions per drycleaning session per garment	0.84		https://www.researchgate.net/publication/274573852_Estimation_of_the_CO2_Emission_for_the_Clothing_Cleaning_Process

* Renting, clothing swaps are out of scope for this analysis
** Ironing is out of scope for this analysis
*** Use of detergent is out of scope for this analysis

Use phase emissions are dependent on three things:

1. Garment care
2. Donations
3. Resell

In scope:

Garment care

Most current research into garment LCA claims that the use phase is one of the most polluting phases of any garment. The actual footprint of the use phase is highly dependent on:

- The number of wears
- The washing frequency

Current research sometimes assumes 20-50 washing cycles for a garment's lifetime. Which is in stark contrast to the average number of wears of a garment, e.g. seven. While seven wears per garment is cited by The Ellen McArthur Foundation[40], Bloomberg[41] and the WSJ[42], they all refer to the same research done by Barnardo's[43] in 2015. This research surveyed 2000 women and asked them about their shopping habits.

So while 20-50 washes seem excessive, 7 washes (assuming a garment is washed after every wear), seems very little. We assumed a total of 15 wears per garment on average. Now, for the emissions per load of laundry, all roads lead to this 13 year old Guardian article[44]. To estimate the emissions associated with the use phase, one needs to take into consideration the amount of washes per garment and the associated weight of that garment. While some garments are washed after every use (such as underwear, with a very light unit weight), other garments are almost never washed (coats, with a very high unit weight). We tried to find more recent data on average washing- and drying machine emissions, but at this point, we're tired. Feel free to get in touch with us if you have more recent data on this topic.

In order to improve the use phase emissions estimates, the replacement rate of garments should also be taken into account. The replacement rate is dependent on three factors:

- The quality of the garment
- The trendiness of the garment
- The consumer's weight variance

Out of scope:

Donations

Donations can take two forms:

- Donate garments to recycling bins
- Donate garments to second hand shops/goodwill

One could argue that donating a garment extends its useful life and therefore lowers its overall carbon footprint. While this seems very true, it was not taken into account in this analysis. The actual carbon footprint for all the phases could therefore be lower.

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40 https://ellenmacarthurfoundation.org/fashion-and-the-circular-economy-deep-dive#:~:text=Globally%2C%20customers%20miss%20out%20on,just%20seven%20to%20ten%20wears.

41 https://www.bloomberg.com/graphics/2022-fashion-industry-environmental-impact/#xj4y7vzkg

42 https://www.wsj.com/articles/the-high-price-of-fast-fashion-11567096637

43 https://www.barnardos.org.uk/news

44 https://www.theguardian.com/environment/green-living-blog/2010/nov/25/carbon-footprint-load-laundry

Resell

Resell can take several forms:

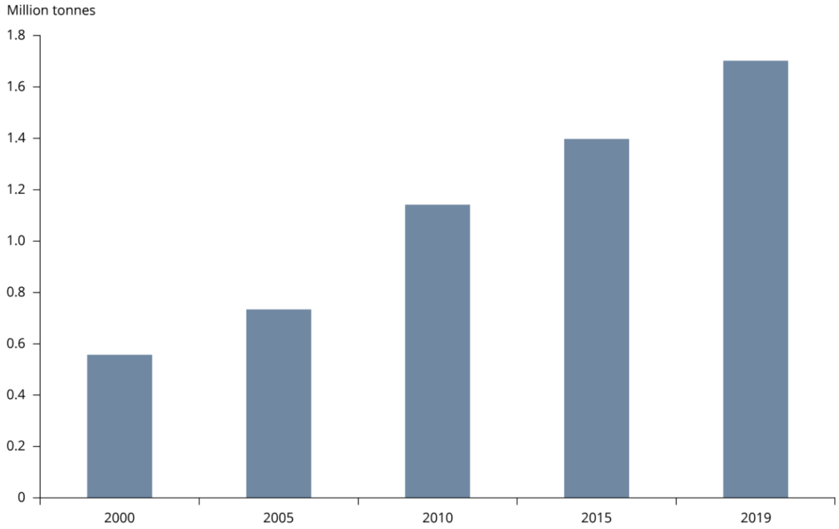
- Consumer to Consumer through online platforms (Vinted, Depop etc.), often one garment per transaction, and mostly womens' and mens' garments.
- Consumer to Consumer through marketplaces like Facebook, Craigslist. Often multiple garments per transaction, also includes childrens' garments.
- Vintage/thrift stores
- Goodwill

The global resell market is worth 177 billion dollars[45]. In the U.S., consumer-to-consumer online platforms sold 15.5 billion dollars worth of second hand apparel. The market is projected to grow significantly. Reselling a garment extends its useful life and therefore lowers the garments' overall carbon footprint. This was not taken into consideration for this analysis. However, Vaayu has done extensive research on this subject, to demonstrate the environmental impact of reselling.

8. End of life

- Disposed
- Donated

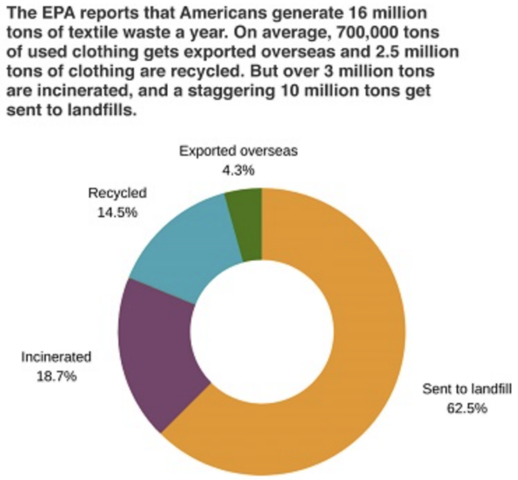
Figure 1 Exports of used textiles from the EU (EU-27 and the UK) to the rest of the world, 2000–2019, by weight (million tonnes)



Note: Combined numbers for nomenclature categories 6309 and 6310.
Source: UN Comtrade (accessed 02 October 2022).
[46]

[45] https://www.statista.com/statistics/826162/apparel-resale-market-value-worldwide/

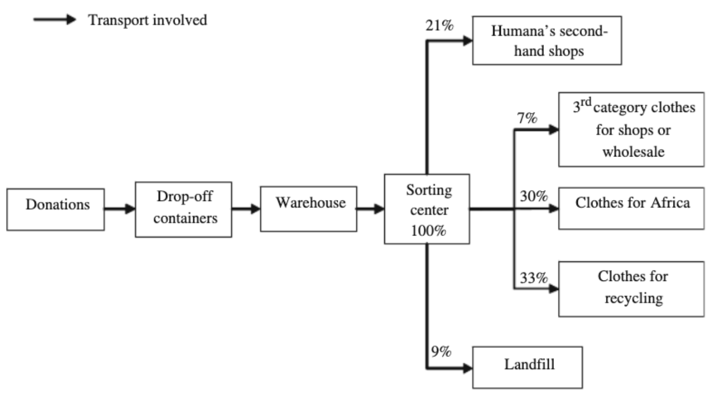
[46] https://www.eionet.europa.eu/etcs/etc-ce/products/etc-ce-report-2023-4-eu-exports-of-used-textiles-in-europe2019s-circular-economy



Fate of Waste	Proportion to this Route
Reuse (UK)	13.9%
Reuse (abroad)	33.7%
Recycling (closed loop)	0.0%
Recycled (open loop)	14.5%
Incineration (with energy recovery)	7.2%
Incineration (without energy recovery)	0.0%
Landfill	30.7%

Table 15: Fate of clothing waste in the UK [47]

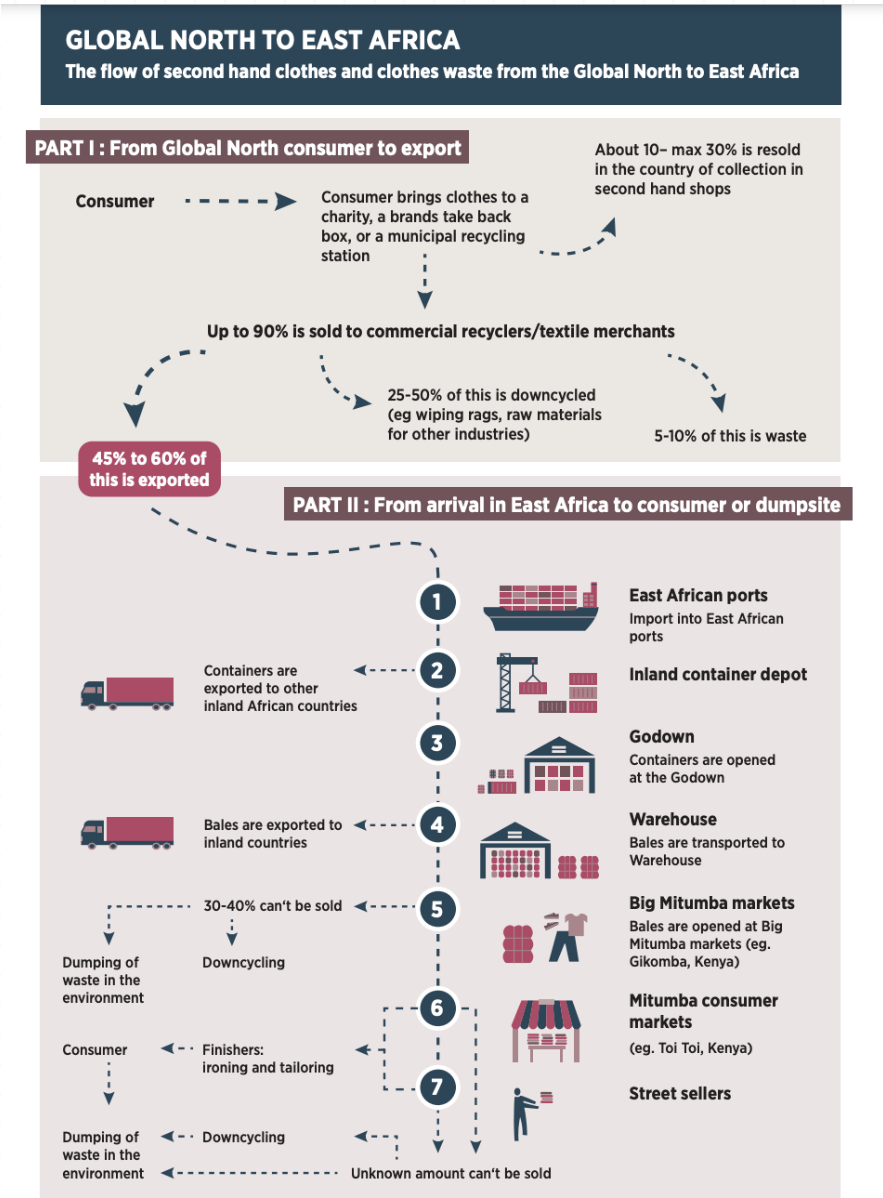
Fig. 2 Clothes collection and sorting activities at Humana Sweden and Estonia (Year 2007) (Pille Piibeleht, personal communication 2008)



[48]

47 https://www.researchgate.net/profile/Matt-Fishwick/publication/306145659_A_Carbon_Footprint_for_UK_Clothing_and_Opportunities_for_Savings/links/57b3117808aeaf239baf0297/A-Carbon-Footprint-for-UK-Clothing-and-Opportunities-for-Savings.pdf

48 https://www.researchgate.net/publication/226848184_Environmental_benefits_from_reusing_clothes



49

49 https://www.greenpeace.org/static/planet4-international-stateless/2022/04/9f50d3de-greenpeace-germany-poisoned-fast-fashion-briefing-factsheet-april-2022.pdf

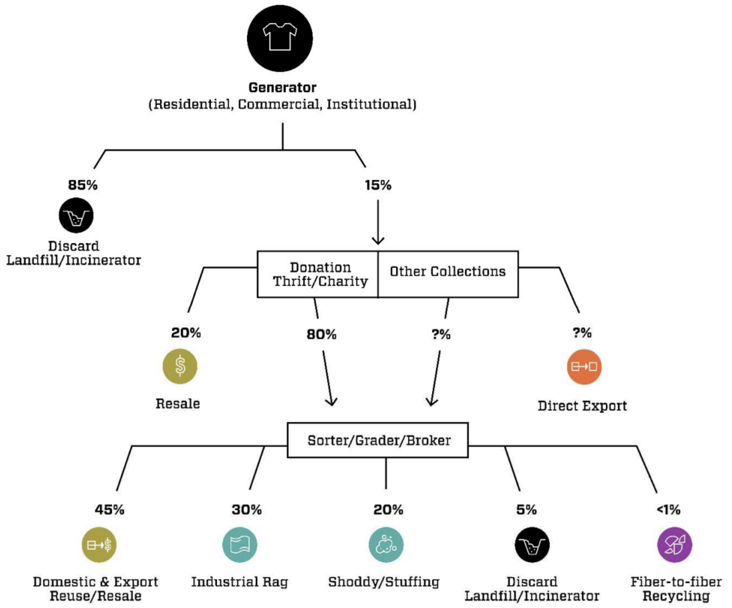


Figure 5: Current fate of used textiles in the United States. Question marks indicate flows for which reliable data are unavailable. Shoddy is made from shredded fibers and used for insulation and stuffing. Based on data from [17, 20, 21]. [50]

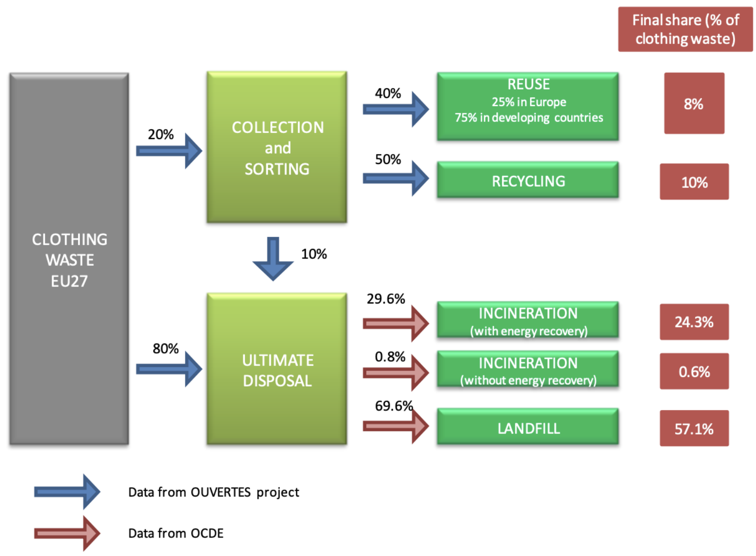


Figure 22: End-of-life routes of textile waste in EU27 [51]

[50] https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.1500-207.pdf
[51] https://publications.jrc.ec.europa.eu/repository/handle/JRC85895

Carbon emissions per garment for end-of-life:

Method	Kg CO2e/garment	Notes	Source
Incinerated	0.286	Munasinghe et al 2021, pg. 15	https://www.sciencedirect.com/science/article/pii/S0959652621030481 Also see tab 'end-of-life'
Landfilled	0.143		