vaaayu

Otrium

Methodology

Quantifying Otrium's Avoided Carbon Emissions and Waste

March 2023

Introduction

About Otrium

Otrium is the world's most innovative end-to-end platform for off-price fashion, driven by a visionary mission to eliminate fashion waste and maximize recovery value for unsold items. Founded in 2015 in Amsterdam by Milan Daniels and Max Klijnstra, Otrium seamlessly connects a global community of 5 million members to excess stock from leading brands through its technology-led approach. Otrium partners with 400+ beloved brands, empowering consumers to choose conscious options beyond trends and seasons, while giving fashion brands a lasting presence outside traditional models. The team envisions a future where every garment finds its rightful place and is steadfast in its goal to ensure no new clothing ends up in landfills. In 2023, Otrium was named to Fast Company magazine's annual list of the Most Innovative companies in the world.

About Vaayu

Vaayu is the world's first automated carbon software empowering retailers to calculate and cut emissions in real-time. By leveraging proprietary AI and machine learning technology, Vaayu gathers data from production, sales and logistics to provide retailers with granular science-based insights about their carbon impact. Founded in 2020, Vaayu has onboarded more than 50 global brands, including Klarna, Missoma, Vinted, Lick, Ace & Tate, Bol.com, and Wunderman Thompson Commerce. Vaayu was named one of TIME's 2022 Best Inventions, Fast Company's 2022 Next Big Things in Tech and also won the Europas 2022 Hottest Climate Tech/ Sustainability Startup Award.

About this Research

Until now, there has been limited research on unsold stock practices and related environmental impacts in the fashion industry, due to a lack of representative primary data. Unsold stock exists because brands plan inventory months or years in advance based on past sales performance. This leads to inaccurate stock levels and less flexibility to adapt to unexpected seasonality, changing fashion trends and disrupted supply chains. As a result, products are leftover at the end of each season, which may eventually enter end-of-life pathways such as landfill dumps or incineration.

Otrium partnered with Vaayu to deliver a comprehensive, independent analysis of the avoided carbon emissions[1] and waste of its off-price business model, based on insights from over **45 fashion brands** and data from almost **5 million fashion products**. The research explores the broader role that businesses such as Otrium can play in enabling a circular fashion economy, and represents a new contribution to understanding the end-of-life phase of fashion products based on one of the **largest primary datasets on unsold stock practices**[2]. The results will be used to inform Otrium's sustainability strategy and climate targets, and to communicate with Otrium's customers, brand partners and external stakeholders.

External Review Statement

"I met with the Vaayu team regularly during the development of their methodology, providing suggestions and independent review comments. I did not review the final model or calculations. Determining the consequences of new business models and methods to avoid emissions is a complex and challenging area, as outlined recently by Stephen Russell and the World Resources Institute (Russell, 2019). In following this and other guidance, I have been impressed with the thorough and conscientious approach that Vaayu has taken – they have clearly aimed to provide the most representative estimates of avoided emissions that are possible with currently available data."

Dr. Stephen Allen, Associate Professor of Life Cycle Assessment, University of Bath, March 2023

1. Following common usage, 'carbon' is used here as shorthand to refer to the 100-year global warming potential of a range of greenhouse gases, expressed as a mass of carbon dioxide equivalent (e.g. $kgCO_2e$).
2. See Wijnia 2016, Avery Dennison 2022 and Fashion Transparency Index 2022 for limited data on unsold stock and waste channels.

Methodology

Goal

The main goal of the research was to estimate the **avoided carbon emissions and waste** of Otrium's off-price business model, which connects customers to unsold stock from fashion brands. In addition, Vaayu would provide Otrium with avoided carbon emissions and waste estimates at product and brand level, for the purposes of customer (B2C) and internal brand (B2B) communication.

The research employed elements from consequential life cycle assessment (LCA)[3] to quantify the change in emissions and waste within the broader fashion system. This was done by comparing the 'status quo' to a scenario, in which off-price businesses like Otrium do not exist and fashion brands have to find other channels to clear their unsold/excess stock. As this is still an emerging field with limited real-world examples, a conservative approach was therefore used throughout to avoid over-representing Otrium's emissions and waste-saving potential, following best practice guidance on the calculation of comparative emissions impacts[4] and product carbon footprinting[5].

Scope

The off-price sector primarily operates two business models: **selling excess new stock** (1) from brands at a significant discount versus the original retail price, and **producing new items** (2) directly for off-price or 'outlet' stores. Otrium operates both models, but out-of-season excess stock that was once sold through traditional retail channels accounts for over three-fourths of sales versus the industry average range of excess stock sold which is 25-60%[6]. This ensures Otrium remains in line with its mission to reduce industry waste. It also offers a **'refurbished returns'** (3) service to recondition and resell damaged items that have been returned to new condition. All three models were included in the scope of the analysis[7].

On occasion within the methodology, 'off-price' is used as a proxy for Otrium. To ensure fair and representative results for Otrium, the difference in the percentage share of the two main business models described above was modelled for Otrium versus the broader off-price sector and accounted for within the overall calculations[8].

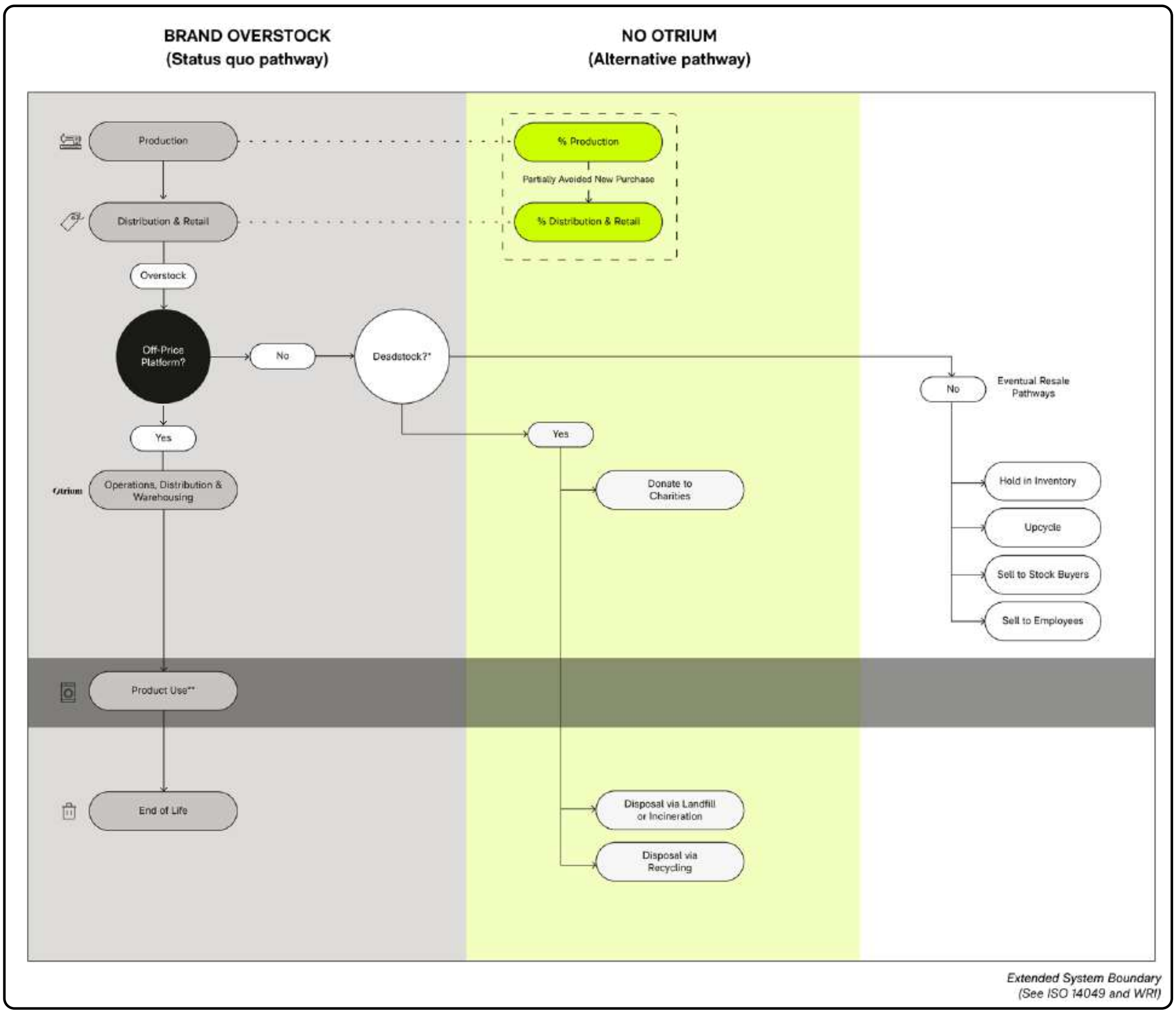
3. A method that estimates comparative impacts (such as carbon emissions) as the total, system-wide change that results from a given decision or intervention.
4. Stephen Russell, World Resource Institute, Estimating and Reporting the Comparative Emissions Impacts of Products, (2019).
5. Draft EU Product Environmental Footprint Category Rules for Apparel and Footwear v1.3, Quantis (March 2022), ISO/TR 14049:2012 (Environmental management - Life cycle assessment).
6. Based on proprietary Otrium sales data, secondary research and anecdotal experience from former off-price buyers.
7. Another model, 'gated sales' (brands selling excess stock directly to their employees) was excluded, as it is only in the testing phase.
8. Per average item and for all Otrium transactions. A range of scenarios were included to account for potential differences in sales versus stock levels and ensure a representative result for off-price businesses.

In line with a consequential LCA approach, broader market rebound effects were also accounted for, such as potential change in consumer demand driven by discounting[9].

Approach

Fashion brands use multiple methods to clear the unsold/excess stock leftover at the end of each season, as illustrated in the diagram below. Some choose to partner with off-price businesses like Otrium, whilst others may use other resale channels, donate to charities, or dispose of the goods directly. The decision depends on a variety of factors, including time, cost, item quality, and existing waste regulations.

System Overview *of* Alternate Pathways



*Deadstock is defined as products that could not be sold at full or sale price, and have either been i) written off from the company's inventory or ii) have remained in stock in a warehouse for more than 3 years[10].
**Product use was excluded from the scope of the analysis

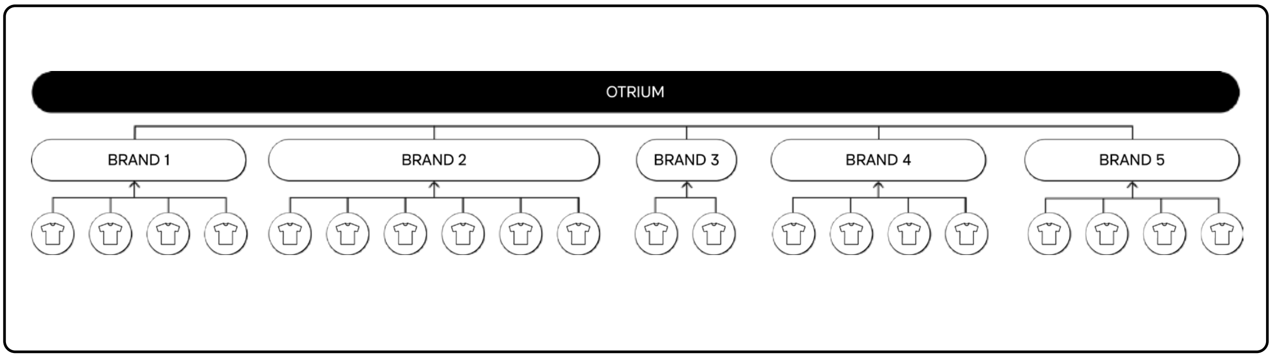
9. See Appendix A for a full list of market effects included or excluded from the research scope.

10. Draft EU PEFCR for Apparel and Footwear v1.3, Quantis (March 2022): *"The deadstock definition used in this PEFCR is the French deadstock definition (Décret n°2020- 1610 1724): products that could not be sold in traditional sales channels, or through discount sales or private sales. Items that could not be sold are defined as items that have either been written off from the company's inventory, or have remained in stock in a warehouse for more than 3 years".*

Following a consequential LCA approach, Otrium's overall avoided carbon emissions and waste were estimated by comparing the sale of products via Otrium (the **'Status quo'** baseline) against an alternative scenario, in which off-price businesses like Otrium do not exist and fashion brands have to find other channels to clear their unsold/excess stock.

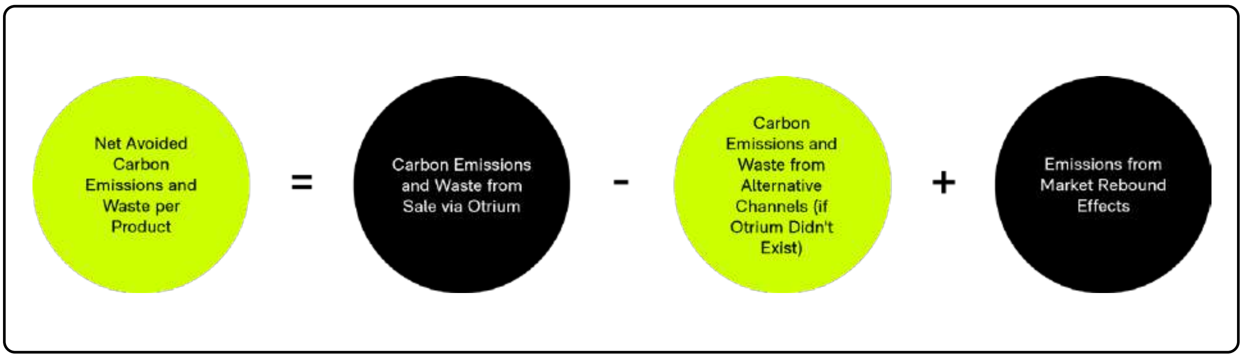
The net results were calculated on a **per-product** level. They were based on the likelihood and resulting carbon emissions and waste of brands using alternative stock clearance pathways in the absence of Otrium, and then expanded to quantify the impact at **brand**[11] (supplier) and total **Otrium** level, as shown below:

Overall Approach



The estimated avoided carbon and waste on a per product/pathway level was calculated as follows[12]:

Overall Calculation



11. Brand-level estimates are modelled using Otrium sales and stock data and representative survey responses from 45 fashion brands including information on size, segment and typical unsold stock practices.

12. See Appendix B for detailed calculations.

1. The carbon emissions and waste from the **'Status quo'** of selling via Otrium was calculated to generate a representative baseline[13].
2. This was compared against the carbon emissions and waste of **alternative stock clearance pathways**[14].
3. Additional carbon emissions and waste generated by indirect **market rebound effects**[15] were included, to account for broader changes within the system, such as additional purchases driven by discounting[16].

Finally, the net carbon emissions and waste was then derived by multiplying the per product/pathway impact by the **likelihood** of brands using other stock clearance pathways in the absence of Otrium (e.g. whether emissions and waste increased or decreased), based on survey responses from fashion brands about their unsold stock practices.

1. Carbon emissions ('footprint') and waste from sale via Otrium

Although Otrium acts as a reseller, the products are new and therefore have a carbon and waste footprint. In order to estimate the impact of selling products via Otrium (the 'Status quo' baseline), the footprint per sold product was calculated based on the draft EU Product Environmental Footprint Category Rules for Apparel and Footwear, data provided by Otrium, and emissions data from Vaayu's proprietary LCA Modelling Engine (product carbon footprinting technology), within the system boundaries outlined below:

System boundaries

- Raw material extraction
- Material manufacturing
- Wet treatments
- Product assembly
- Distribution and warehousing activities at the partner brands
- Warehousing activities at Otrium, including:
  - Electricity required for warehousing
  - Additional transport for some product returns (~30.9% of all outbound)
  - 'Polishing' of items (e.g. steaming, photographing and repacking)
  - Refurbishing activities for damaged returns (~0.75% of all returns)
- Distribution until the final customer
- End of life

13. Based on the draft EU PEFCR for Apparel and Footwear v1.3, Quantis (March 2022), product data provided by Otrium and emissions data from Vaayu's proprietary Carbon Modelling Engine.

14. Using a range of data from secondary literature, listed in Appendix B.

15. Changes in market size that occur over and above any changes in market share, and changes in the market price of inputs. See Maxwell, Owen, McAndrew, Muehmel, & Neubauer, 2011.

16. Based on statistical analysis of primary sales data and additional secondary research.

→ Impacts of product use were not taken into account. This study's focus was the comparative analysis of selling products through Otrium versus an alternative scenario, in which off-price businesses like Otrium do not exist and fashion brands have to find other channels to clear their unsold/excess stock. The impact that comes from laundering during product use is considered equal in both. In a comparative analysis, these equal impacts cancel each other out.

Product data analysed

- Product type
- Product size (weight)
- Material composition
- Fabric construction and type
- Country of origin
- Country of sale

Accounting for 'refurbished returns'

As part of its service offer, Otrium also refurbishes selected products that are damaged upon return and resells them to consumers (off-price model 3). This equates to around ~0.75% of all returned items[17]. Because the damaged items are repaired and resold instead of disposed of, the refurbishing process essentially lowers the carbon and waste footprint per product by lowering the waste generated[18]. The impact of refurbished returns was integrated into the overall calculations by estimating aggregated avoided emissions at the level of Otrium as a whole.

2. Carbon emissions and waste from alternative channels

Following a consequential LCA approach, the carbon emissions and waste of selling products via Otrium (the 'Status quo' baseline) was then compared against that of a set of hypothetical **alternative pathways**, in which off-price businesses like Otrium do not exist and fashion brands have to find other channels to clear their unsold/excess stock.

Exploring the alternative pathways

In the 'Status quo' pathway, a customer is looking for a product (e.g. a T-shirt), which they find and buy on Otrium. This T-shirt is typically excess/unsold stock from a brand, which has already been produced. In the alternative pathways, the T-shirt would not be sold via Otrium, but either resold via other channels, donated or disposed of. In total, there are seven possible alternative pathways:

17. Based on a return rate of 39.3% in 2022 (across all markets and categories). 2-2.25% of returned items were damaged, out of which, 0.75% were refurbished and made available for sale. The remaining items that could not be sufficiently repaired were sold to stock buyers.

18. The emission savings equates to the cradle-to-gate and end of life impact of the damaged items, minus those generated by the refurbishing process such as sewing buttons, steaming, and transport.

1. Holding the stock in inventory for eventual resale
2. Upcycling the stock for eventual resale
3. Selling the stock to 'stock buyers'[19]
4. Selling the stock to employees
5. Donating the stock to charities
6. Disposing of the stock via landfill or incineration
7. Disposing of the stock via recycling

In the first four alternative pathways, the T-shirt follows a similar flow to the 'Status quo' of sale via Otrium. It is still used and eventually disposed of, resulting in negligible difference in carbon emissions and waste[20].

In the remaining three alternative pathways, the T-shirt is considered to be 'deadstock' because it no longer has any economic value. It is either directly disposed of via landfill, incineration or recycling, or donated to charity (which also often results in disposal[21]). In these cases, the T-shirt wouldn't be available for a customer to buy, which would result in the purchase of a different (new) T-shirt elsewhere. In these pathways, Otrium can therefore be said to be avoiding the carbon and waste associated with disposal of the original T-shirt, as well as (partly)[22] avoiding the carbon and waste generated by the manufacture and distribution of the additional new T-shirt.

→ For a full overview of assumptions, sources and calculations per alternative pathway, see Appendix B.

3. Carbon and waste generated by additional market rebound effects

To enable a more holistic assessment of Otrium's indirect impacts, the carbon emissions and waste generated by additional market rebound effects[23] were also included. For example, customers may be encouraged to buy more than they need or were originally looking for, because they consider a product to be a good deal with limited availability. More purchases results in more carbon emissions and waste, which 'cancels out' some of the carbon and waste otherwise avoided by Otrium.

19. Actors without branded, consumer-facing retail outlets that resell second-hand stock.

20. For example, from keeping items in storage for longer.

21. See Cobing et al. 2022 and Trzepacz et al, 2022.

22. This is not a 1:1 displacement, because customers might be buying more items on Otrium they don't need, driven by the sense of "missing out on a good deal". This market rebound effect is accounted for in Part 3.

23. The analysis reflects a snapshot in time, based on sales and stock data from 2022. It does not measure future effects, which should be modelled separately based on a specific decision or intervention. Proxies were used in the absence of detailed consumer behaviour data, which could be included in future iterations.

Both of the main off-price models employed by Otrium were accounted for in the analysis. For **excess stock** (Otrium's primary operating model), it was assumed that the existence of Otrium/off-price had no influence on brands' current production of new clothing, since orders are primarily based on future sales volumes and growth targets, overstock is less profitable and therefore not intentionally planned, and emerging technology and business models (e.g. on-demand production) are still in their infancy. For **new production** of bestselling styles[24], it was assumed that better supply and demand matching leads to 0% deadstock. This is in line with current practices at Otrium[25] and a lack of other reliable market data.

Increased sales due to reduced prices (demand-price elasticity) was used as a proxy to estimate the increase in overconsumption driven by discounting (% excess purchased per item) for both models. Regression modelling[26] was used to measure the change in sales (quantity sold) in 2022 for each product at the discounted price, compared to the original Recommended Retail Price. Regression models were differentiated in terms of product type and the country of sale. The latter was used to control for possible country-wise price changes and other geographical effects. Other variables (product style (SKU), brand name and brand type) were not taken into account since the sample became statistically insignificant.

The modelling resulted in demand-price elasticity for different product types, which was further differentiated by the country of sale. For example, a 1% increase in price for T-shirts led to a 0.66% decrease in demand. The results were multiplied by discount on a per transaction level to estimate the increase in consumer demand.

Overall, the results show a relatively low Excess Purchase Rate of 18%. This means that for every six items sold on Otrium, a customer buys one more additional item. On average, 82% of purchases on Otrium therefore displace the need for a new item.

24. Referred to internally by Otrium as 'data-made'.

25. Where any unsold new production is subsequently sold to stock buyers.

26. See Wooldridge, Introductory Econometrics: A Modern Approach, third edition, Chapter 2.

Likelihood of alternative stock clearance pathways

A survey was conducted between November 2022 and February 2023 with support from Otrium to gather representative primary data from fashion brands regarding their unsold/excess stock practices. The survey was sent to Otrium's existing brand partners and also shared with fashion industry groups and other relevant public forums[27] to ensure a representative and statistically relevant sample size. In total, 46 responses were collected, with 30 responses that included insights about brands' unsold stock practices. The responses were used to inform the avoided emissions and waste estimations for each alternative pathway, as well as the brand-level avoided emissions and waste estimations that will be shared with Otrium's brand partners.

The survey asked questions related to the following topics:

- Company type and size
- Segment (luxury, designer, premium, trend-focused, value)
- Brand identity (affordable, conscious[28], trendy, luxurious, timeless)
- Unsold stock practices (stock type, quantity, age, traceability)
- Use of off-price and other alternative channels to clear stock

The likelihood of brands choosing an alternative stock clearance pathway in the absence of Otrium was determined using primary survey responses as well as insights from secondary literature. The brands were asked about their current practices of dealing with the unsold stock and what they would do in the absence of off-price platforms like Otrium. The results were then used to calculate the avoided carbon and waste from the change in likelihood of each pathway ('Status quo' versus 'no Otrium')[29], in order to derive the net carbon and waste impact.

Pathway	Weighted share, Status quo	Weighted share, No Otrium	% Change (D_{path})	Probability by pathway, Otrium Stock	Avoided carbon (t CO_2e)	Avoided waste (t)
1. Holding in inventory	37%	36%	-1%	-2%	-3.48	10
2. Upcycling	2%	11%	9%	28%	288	-145
3. Selling to 'stock buyers'	8%	15%	7%	23%	-540	-70
4. Selling to employees	8%	11%	3%	9%	-307	-47
5. Donating to charities	8%	12%	4%	12%	1264	74
6. Disposing via landfill or incineration	1%	5%	4%	14%	2744	193
7. Disposing via recycling	5%	10%	5%	16%	3034	221
[Sale to Otrium /off-price]	31%	-	-	-	-	-

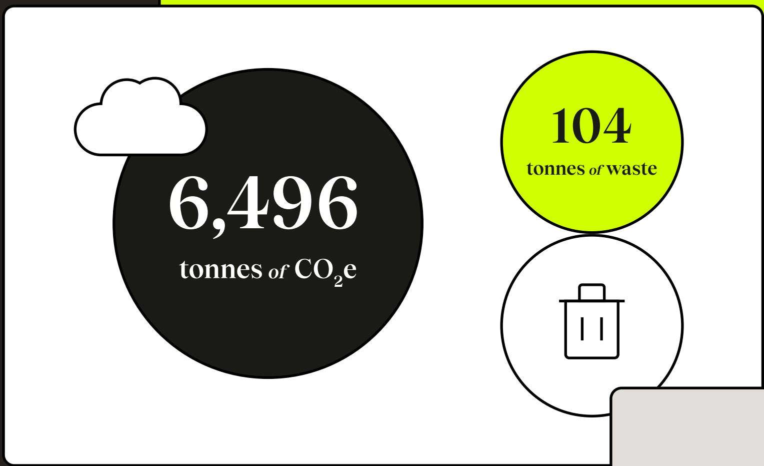
27. Shared by Vaayu and Otrium on Linkedin and with relevant Linkedin groups related to sustainability in fashion.

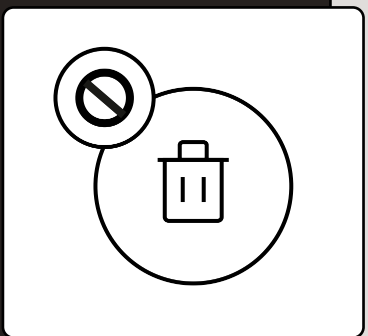
28. Based on Otrium's own internal definition.

29. Referencing the most likely scenario, taking into account the uncertainties in the model.

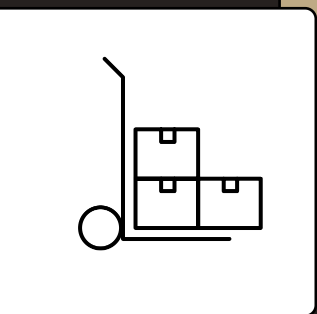
Results

In 2022, Otrium avoided 6,496 tonnes of carbon emissions (CO_2e) and 104 tonnes of waste by providing brands with a profitable route to dispose of their unsold stock. This equates to 2.13 kg CO_2e and 30g of waste per average purchase[30].





The largest carbon and waste savings come from avoiding disposal. According to the survey results, brands are 30% more likely to directly dispose of the stock that is otherwise sold through Otrium. By providing a route to market for these products, Otrium avoids the carbon and waste impacts of disposal as well as the (partial) manufacture of a replacement new item.



Another driver of Otrium's net impact is their strong focus on excess stock, compared to the broader off-price sector which manufactures a significant amount of new products directly for their outlet stores.

30. By selling 5,411,574 items, compared to a hypothetical scenario in which Otrium and other off-price players do not exist.

Appendix

Appendix A: Research Scope

Table 1: Business models accounted for in the scope of the analysis

Model	Description	In scope?	Rationale
‘Excess’ stock	Selling existing excess or ‘close-out’ stock from brands at a significant discount versus the original RRP.	**Yes**	Represents the majority of Otrium’s sales.
‘Data-made’ stock	Producing new items specifically for the off-price market based on bestselling styles, sold at a lower price.	**Yes**	Represents a significant part of Otrium’s sales.
Refurbished returns	Refurbishing and reselling damaged returns (~2.5% of ~39% returned items).	**Yes**	Modelled as part of the existing product system flow.
Gated Sales	Selling existing excess stock exclusively to employees at a discount.	**No**	Included in alternative scenarios for excess stock but not calculated separately. Not part of original research scope but can be included in future research.

Table 2: System effects accounted for in the scope of the analysis

Effect	In scope?	Comment
Otrium's comparative impact versus the broader off-price sector	Yes	Modelled using a sensitivity analysis, based on business model scenarios of excess stock and new items.
Otrium offering greater value and transparency (to sell excess stock)	Yes, indirectly	This may lead to brands preferentially choosing Otrium over other channels/off-price businesses, and customers paying a higher final sale price (with lower discount rate). A higher sale price and lower discount rate results in fewer excess purchases, meaning a higher replacement rate and therefore more avoided emissions for Otrium. This effect is only partially modelled for Otrium, which took into account different stock types but not the final sale pricing at other off-price businesses. Another consequence could be that Otrium has a higher share of excess stock in its sales than for newly produced items. This is modelled through sensitivity analysis of different stock type scenarios (see above).
Change in amount of waste for 'excess stock'	Yes	Modelled through alternative scenarios, see Approach, Part 2.
Change in consumer demand driven by off-price (discounted) model	Yes	Modelled for both excess stock and new production, see Approach, Part 3.

Change in amount of waste for new production from bestsellers ('data-made')	Yes, partially	This estimation is only made for the excess purchases caused due to discounts. The deadstock or overstock rate is assumed to zero for data made items. These rates are not compared with the current market numbers.
Change in amount of waste produced/saved by market	Yes	Net amount of waste generated/saved is calculated for each pathway. See Approach.
Change in amount of waste produced/saved due to Extended Producer Responsibility regulations	Yes, indirectly	It is assumed that survey responses will reflect brands' practices based on existing regulation. Future developments are out of scope for this type of analysis.
Change in emissions from transport/ warehousing	Yes	Additional warehousing at Otrium is included in the product carbon emission estimations. Wherever relevant, transport and warehousing is also taken into account for each alternative pathway in the hypothetical scenario that Otrium doesn't exist.
Change in recycling of excess inventory	Yes	Included in the alternative scenarios, modelled using survey data and secondary literature on recycling rates.
Change in higher price items replacing cheaper (lower-quality) items	No	Not observed in academic literature. Could be included in future research.
Impact of sustainably-minded consumer	No	Could be included in future research.
Change in level of future inventory (either reduction through better demand matching or increase due to off-price encouraging excess stock)	No	It is not possible to accurately measure future effects with the approach shown above. Currently, it is assumed that Otrium does not influence brands' order volume of new clothing, as i) new orders are planned based on the previous year's sales and company growth targets (not excess stock) ii) brands' forecasting abilities are poor, and iii) emerging business models such as on-demand production are still negligible.

Appendix B: Calculations

Overall calculation

Net avoided carbon and waste for Otrium

The net avoided carbon emissions and waste for Otrium is calculated as an aggregate of emissions and waste calculated for each brand. There are ~400 brand partners who sell their items through the Otrium platform.

$$I_{net,\ Otrium} = \sum I_{net,\ brand} \quad (1)$$

Net avoided carbon and waste per brand

The net avoided carbon emissions and waste for each Brand is in turn calculated as an aggregate of all its sales. For example, brand 'A' sells 10 T-shirts and 5 trousers. The net avoided emissions of brand 'A' is thus the aggregated net avoided carbon emissions and waste from 10 T-shirts and 5 trousers.

$$I_{net,\ brand} = \sum I_{net,\ product} \quad (2)$$

Net avoided carbon and waste per product

The net avoided carbon and waste per product ($I_{net,\ product}$) is calculated as follows, for each item:

$$I_{net,\ product} = \sum I_{net,\ product} \times D_{path} \quad (3)$$

Where,

- $I_{net,\ path}$ is the net carbon emissions and waste of off-price for each product per pathway. This takes into account the carbon and waste generated by the 'Status quo' off-price pathway, the carbon and waste avoided by new purchases where the item is 'deadstock', and carbon and waste generated by additional market effects such as overconsumption.
- D_{path} is the estimated change in each alternative pathway due to absence of off-price, calculated based on survey responses from fashion brands. The change in the clothing flows to each alternative pathway are not differentiated as a function of the item type. E.g. T-shirt and jackets are assumed to follow the same alternative pathway in the absence of off-price, as per the survey responses.

$I_{net,\ path}$ for each pathway, per item is calculated using the following:

$$I_{net,\ path} = I_{offprice} - I_{new} * y - I_{alt.path} \quad (4)$$

Where,

- $I_{offprice}$ is the carbon emissions and waste of an item sold through the off-price pathway. This includes all life cycle stages typically involved in the production, distribution, and end-of-life of a product, plus the additional carbon and waste generated by Otrium's own operations (e.g. offices and warehouses) calculated using data supplied by Otrium.
- I_{new} is the carbon emissions and waste of a similar new item sold. It is **not applicable** to eventual resale pathways. This includes all life cycle stages involved in the production, distribution, and end-of-life of a new item.
- *y* signifies the displacement of new clothing items happening due to purchases through Otrium, which takes into account the potential increase in additional new purchases due to discounting: $y=(1-x)$. Where, x is the additional purchase rate calculated using demand-price elasticity. For example, if there are 30% *(x)* more sales at a lowered price, $y=(1-x)=$ 0.7. Compared to a baseline of no. of sales at the original retail price.
- $I_{alt.\ path}$ is the carbon emissions and waste of an item following an alternative pathway. For example, items produced, warehoused, and then sent for disposal via recycling.

$I_{offprice}$ can thus be disaggregated as:

$$I_{offprice} = I_{manf.} + I_{dist.} + I_{dist.,\ offprice} + I_{EOL} \qquad (5)$$

Where,

- $I_{manf.}$ is carbon emissions and waste of manufacturing a new item, from raw material extraction until product assembly
- $I_{dist.}$ is carbon emissions and waste during distribution and warehousing a new item
- $I_{dist,\ offprice}$ is carbon emissions and waste during distribution and warehousing due to off-price
- I_{EOL} is the carbon emissions and waste at the end of life

$$I_{new} = I_{manf.} + I_{dist.} + I_{EOL} \qquad (6)$$

<u>Extra note on warehousing</u>:
Based on survey responses from brands (N=29), items that are not sold are held in the warehouse for an average of 18 months before being disposed of through different methods. For both scenarios ('Status quo, Otrium' and 'alternative, no Otrium'), the average warehousing time per item is therefore assumed to be 18 months, plus any additional warehousing time related to the different pathways listed below.

1. Holding in inventory

Assumptions: The product is held in inventory for 6 months on average (min 1-max 12 months) and eventually resold, leading to no avoided purchase of new clothing and therefore no avoided carbon and waste (I_{new} = 0). However, a small amount of carbon emissions and waste are generated by the additional warehousing, which is otherwise avoided by sale through Otrium.

Sources: Impacts of warehousing were calculated using Fichtinger et. al. 2015 & Bottani et. al. 2019. The inventory holding duration was calculated as a distribution between 1-12 months.

Calculation:

Equation (4) for this scenario becomes:

$$I_{net,\ warehouse} = I_{offprice} - I_{new} * y - I_{warehouse}$$

$$I_{net,\ warehouse} = I_{manf.} + I_{dist.} + I_{dist,\ offprice} + I_{EOL} - (I_{manf.} + I_{dist.} + I_{a\text{-}warehouse} + I_{EOL})$$

$$I_{net,\ a\text{-}warehouse} = I_{dist,\ offprice} - I_{a\text{-}warehouse}$$

Where $I_{a\text{-}warehouse}$ is the carbon and waste footprint from additional warehousing.

2. Upcycling

Assumptions: Upcycling processes include cutting and sewing and overdyeing. The product is eventually resold, leading to no avoided purchase of new clothing and therefore no avoided carbon emissions and waste (I_{new} = 0). However, negligible carbon and waste is generated by the upcycling process, which is otherwise avoided by sale through Otrium.

Sources: Based on typical upcycling process from fashion experts expected. 33% chance is assumed for each of cut & sew, dyeing or bleaching happening. All three can also happen in one case, hence all are entered as probabilities. Bleaching & Dyeing scale with the garment weight but the cut & sew does not. For cut & sew, light repairs are assumed, thus data from T-shirt assembly is used (Sandin et al. 2019, Cotton Inc. 2017, Zhang et al, 2015). For bleaching & dyeing, an average of Cotton & Polyester processes are used (Sandin et al. 2019, BAT 2019, Cotton Inc. 2017).

Calculation:

$$I_{net,\ upcycle} = I_{dist,\ offprice} - I_{new} * y - I_{upcycle}$$

$$I_{net,\ upcycle} = I_{manf.} + I_{dist.} + I_{dist,\ offprice} + I_{EOL} - (I_{manf.} + I_{dist.} + I_{a\text{-}upcycle} + I_{EOL})$$

$$I_{net,\ a\text{-}upcycle} = I_{dist,\ offprice} - I_{a\text{-}upcycle}$$

Where $I_{a\text{-}upcycle}$ is the carbon emissions and waste from upcycling.

3. Selling to 'stock buyers'

Assumptions: The product is eventually resold, leading to no avoided purchase of new clothing and therefore no avoided carbon emissions and waste (I_{new} = 0). Additional carbon and waste is generated by the transportation from point of collection to point of sale, which is otherwise avoided by sale through Otrium. This is assumed to be between 300-1150 km (the same as for sale via charities), following a conservative approach to avoid overestimation of avoided emissions.

Sources: Based on anecdotal evidence from industry professionals. Transportation distance based on distance travelled by a clothing item for a local reuse (Trzepacz et al, 2022 & Schmidt et al. 2016).

Calculation:

$$I_{net,\ stock\text{-}buyers} = I_{dist,\ offprice} - I_{new} * y - I_{stock\text{-}buyers}$$

$$I_{net,\ stock\text{-}buyers} = I_{manf.} + I_{dist.} + I_{dist,\ offprice} + I_{EOL} - (I_{manf.} + I_{dist.} + I_{a\text{-}stock\text{-}buyers} + I_{EOL})$$

$$I_{net,\ a\text{-}stock\text{-}buyers} = I_{dist,\ offprice} - I_{a\text{-}stock\text{-}buyers}$$

Where $I_{a\text{-}stock\text{-}buyers}$ is the carbon emissions and waste from transportation of the item to stock buyers.

4. Selling to employees

Assumptions: The product is eventually resold, leading to no avoided purchase of new clothing and therefore no avoided carbon emissions and waste (Inew = 0). No additional carbon and waste is generated by sales to employees, which typically take place in the office without transportation to another sale location.

Sources: Based on anecdotal evidence from Otrium and other industry professionals.

Calculation:

$$I_{net,\ employee} = I_{dist,\ offprice} - I_{new} * y - I_{employee}$$

$$I_{net,\ employee} = I_{manf.} + I_{dist.} + I_{dist,\ offprice} + I_{EOL} - (I_{manf.} + I_{dist.} + I_{a\text{-}employee} + I_{EOL})$$

$$I_{net,\ a\text{-}employee} = I_{dist,\ offprice}$$

Where $I_{a\text{-}employee}$ is the carbon emissions and waste from sale to employees (= zero)

5. Donating to charities

Assumptions: Products donated to charities by fashion brands are considered to be 'deadstock' since they have zero economic value. Of all donated items to charities, ~10-30% is typically sorted as 'A-Grade' and resold in local charity shops, thrift or vintage stores, which is the most likely case for excess stock items. Thus a local sale is assumed for donated items. For context, the items not sorted as 'A-Grade' are sold to textile merchants or recyclers. Out of these, the majority of items (~45-60%) are exported abroad, where a substantial proportion is disposed of without being used. Of the remaining donations which aren't exported, ~5-10% ends up as waste and ~25-50% is downcycled into wipes or insulation fillers[31]. Donation to charities therefore results in **partial** avoided purchase (or replacement) of a new item, and associated partial avoided carbon emissions and waste. The proportion of avoided emissions and waste is informed by the difference between two replacement rates: via charities (r) and via Otrium (y). Additional carbon and waste is also generated by the transportation from point of collection to point of sale (assumed to be between 300-1150 km), which is otherwise avoided by sale via Otrium.

Sources: Clothing flows from charities operating in Western Europe are described in Trzepacz et al, 2022 & Cobing et al. 2022. Transportation distance based on distance travelled by a clothing item for a local reuse (Trzepacz et al, 2022 & Schidt et al. 2016). The replacement rate (~33%) for sales through charity or vintage stores obtained for European geographies (Farrant et al. 2010 recalculated in Norup et al. 2019; Stevenson et al. 2013)

Calculation:

$$I_{net,\ charities} = I_{offprice} - I_{new} * y - I_{charities}$$

$$I_{net,\ charities} = I_{manf.} + I_{dist.} + I_{dist,\ offprice} + I_{EOL} - I_{new} * y - (\ I_{manf.} + I_{dist.} + I_{c\text{-}trans} - I_{new} * r\ )$$

$$I_{net,\ charities} = I_{dist,\ offprice} - I_{new} * y - I_{c\text{-}trans} + I_{new} * r\ )$$

$$I_{net,\ charities} = I_{dist,\ offprice} - I_{new} * y - (I_{c\text{-}trans} - I_{new} * r\ )$$

Where,

- *r* is the replacement rate for sales through charities or vintage stores;
- $I_{c\text{-}trans.}$ is the impact of additional transport in the charities pathway; and

31. See Figure 1 in Cobing et. al 2022

6. Disposing via landfill or incineration

Assumptions: The product is directly disposed of via landfill or incineration without being used by consumers, resulting in an unfulfilled consumer demand. This leads to the production, distribution and sale of a new clothing item (and associated carbon emissions and waste) which is otherwise avoided by sale via Otrium. However, this benefit may be partly 'offset' by an increase in purchases of new items driven by discounting *(y)*, as outlined in Part 3. Disposal via landfill or incineration therefore only results in a **partial** avoided purchase of a new item.

Sources: End of life models take into account the transportation and breakdown of clothes landfilled or incinerated at the end of their use as per Kohler et al, 2021. Landfill and incineration models are adjusted according to the expected split of fossil:biogenic content in textile waste as per ratio between synthetic & natural/animal based fibres in global fibre production.

Calculation:

$$I_{net,\ disp} = I_{offprice} - I_{new} * y - I_{disp}$$

$$I_{net,\ disp} = I_{manf.} + I_{dist.} + I_{dist,\ offprice} + I_{EOL} - (I_{manf.} + I_{dist.} + I_{EOL}) * y - (I_{manf.} + I_{dist.} + I_{EOL})$$

$$I_{net,\ disp} = I_{dist,\ offprice} - y * (I_{manf.} + I_{dist.} + I_{EOL})$$

7. Disposal via recycling

Assumptions: The product is directly disposed of via recycling without being used by consumers, resulting in an unfulfilled consumer demand. This leads to the production, distribution and sale of a new clothing item (and associated carbon emissions and waste) which is otherwise avoided by sale via Otrium. However, this benefit may be partly ‘offset’ by an increase in purchases of new items driven by discounting *(y)*, as explained in Part 3. Disposal via recycling therefore only results in a partial avoided purchase of a new item. Garments are typically recycled into rags for insulation, cotton wipes or fibres. The carbon and waste generated or credited from the recycling process and resulting substituted virgin products is also accounted for.

Sources: Recycling distances input as a distribution from multiple sources (PEFCR[32], Trzepacz et al, 2022, Schmidt et al. 2016 & Bianco et al. 2022). Split of recycling processes of textiles into fibre, wipes & rags estimated from various sources (PEFCR, Refashion 2021, Fashion for Good 2022). Recycling impacts for textile to fibre recycling modelled using Duhoux et. al. 2022, Zamani et. al. 2011, Moazemma et al 2022, Bianco et al. 2022 & Schmidt et al. 2016. Recycling impacts for textile to wipes or rags recycling modelled using Schmidt et al. 2016. Recycling processes are assumed to have an efficiency between 80-90%. Recycled fibres avoid an average of polyester fibres & cotton lint, since these two are the most common fibres in the market (internal database). Recycled wipes avoid an average of tissue and cotton greige fabric. Recycled rags avoid production of stone wool and vermiculite insulation.

Calculation:

From Equation (3), avoided emissions and waste per product for recycling pathway = $I_{net,\ recycle} \times D_{recycle} \times I_{net,\ recycle} \times D_{recycle}$ can thus be disaggregated into:

$$D_{recycle} \times (I_{net,\ recycle\text{-}fibre} \times D_{recycle\text{-}fibre} + I_{net,\ recycle\text{-}wipes} \times D_{recycle\text{-}wipes} + I_{net,\ recycle\text{-}rags} \times D_{recycle\text{-}rags})$$

Where, $D_{recycle\text{-}fibre}$, $D_{recycle\text{-}wipes}$ & $D_{recycle\text{-}rags}$ are the % recycled into fibres, wipes and rags respectively out of the total sent to recyclers. Whereas, $D_{recycle}$ is obtained from survey responses.

Net impact from recycling items into fibres can be calculated as:

$$I_{net,\ recycle\text{-}fibre} = I_{offprice} - I_{new} * y - I_{recycle\text{-}fibre}$$

$I_{net,\ recycle\text{-}fibre}$ is then disaggregated as:

$$I_{manf.} + I_{dist.} + I_{dist,\ offprice} + I_{EOL} - (I_{manf.} + I_{dist.} + I_{EOL}) * y - (I_{manf.} + I_{dist.} + I_{fibre\text{-}recycling})$$
$$= I_{dist,\ offprice} + I_{EOL} - (I_{manf.} + I_{dist.} + I_{EOL}) * y - I_{fibre\text{-}recycling}$$

$I_{fibre\text{-}recycling}$ can be further decomposed using the circular footprint formula from PEFCR. Equation (8) thus becomes:

$$I_{net,\ recycle\text{-}fibre} = I_{dist,\ offprice} + I_{EOL} - (I_{manf.} + I_{dist.} + I_{EOL}) * y - (I_{fibre\text{-}rec} - I_{fibre\text{-}virgin} * \frac{Q_{sout}}{Q_p})$$

Where,

- $I_{fibre\text{-}rec}$ is the carbon emissions or waste of the fibre recycling process including collection & transport;
- $I_{fibre\text{-}virgin}$ is the carbon emissions or waste arising from the manufacturing and

32. Draft EU PEFCR for Apparel and Footwear v1.3, Quantis (March 2022), p83.

distribution of virgin material assumed to be substituted by recycled materials; and

- $\frac{Q_{Sout}}{Q_p}$ is the ratio of quality of the outgoing secondary material to the quality of the primary virgin material.

Please note that the allocation factor A is neglected from the CFF equation since the scope of the analysis is system level. The factor A allocates the burdens and credits between the supplier and user of recycled materials. This would thus be irrelevant if the scope of the analysis quantifies overall change in the recycling impacts due to changing deadstock flows.

Similarly, the net impact of off-price from recycling items into rags or wipes can be calculated as:

$$I_{net,\ recycle\text{-}wipes} = I_{dist,\ offprice} + I_{EOL} - (I_{manf.} + I_{dist.} + I_{EOL}) * y - (I_{wipes\text{-}rec} - I_{wipes\text{-}virgin} * \frac{Q_{sout}}{Q_p})$$

$$I_{net,\ recycle\text{-}rags} = I_{dist,\ offprice} + I_{EOL} - (I_{manf.} + I_{dist.} + I_{EOL}) * y - (I_{rags\text{-}rec} - I_{rags\text{-}virgin} * \frac{Q_{sout}}{Q_p})$$

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Methodology

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