

## Future vertical

# Textile Discarded Materials

Enzymatic degradation of PET microfibres at the mill prevents textile effluent from reaching municipal waterways.

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SECTION 5 · VERTICALS

# 1. Customer Description

The textile discard vertical covers post-industrial and post-consumer textile waste that is landfilled, incinerated, downcycled, or exported. Polyester is the dominant synthetic fibre in this stream. It is chemically identical to the PET polymers used in plastic bottles, so PET-degrading enzymes such as PETase can, in principle, break it down.

### 1.1 Textile Recycling Categories

Textile recycling methods fall into four categories (Patti, Cicala, and Acierno 2021):

- **Primary.** Reprocessing industrial scrap back into its original form.
- **Secondary (mechanical).** Shredding and re-spinning fibres, which yields lower-quality material.
- **Tertiary (chemical).** Processes such as hydrolysis that return the polymer to its monomers.
- **Quaternary.** Incineration for energy recovery.

For PET textiles, mechanical recycling collects, sorts, cleans, shreds, melts, and re-extrudes scrap into pellets or filaments (Patti, Cicala, and Acierno 2021). Because PET degrades each melting cycle, mechanical recycling can only be repeated a limited number of times before the material loses its quality. Chemical and enzymatic depolymerisation (tertiary) avoid this by breaking PET down into its monomers, which can be rebuilt into new PET of the same quality as virgin material.

Within the Canadian landscape, iGEM Toronto interviewed Christina Seidel of the Recycling Council of Alberta (pers. comm.), who noted that while reuse markets in Canada are well developed, textile recycling is not. According to Seidel, most discarded textiles flow through donation bins and centres, and anything not reused is generally sent to landfill. She also observed that what is currently called “textile recycling” mostly turns other materials, such as plastic bottles, into textiles, rather than recycling textiles themselves to make new fibre materials.

### 1.2 Target Customer

PetaScale’s primary customer in this vertical is the textile reprocessor, a facility that buys sorted polyester textile waste and converts it into PET pellets or chips, which are later spun into new

fibre. PetaScale would operate within the reprocessor's facility, using its enzymes to break down the polyester into monomers, and would charge a fee per tonne processed as outlined in Section 2. Because this process returns PET to its original chemical building blocks through enzymatic hydrolysis, PetaScale falls within the tertiary recycling category described in Section 1.1.

Two secondary stakeholders do not pay PetaScale directly but are pivotal in determining whether the model succeeds:

- **Collectors and sorters**, who gather and separate textile waste, thereby controlling the supply of polyester feedstock.
- **Apparel brands**, who purchase the recycled polyester as offtakers and, through their circularity commitments, generate the demand that makes reprocessing economically viable.

### 1.3 Why This Customer Would Want PetaScale

The textile reprocessor's central problem is a lack of viable pathways for recycling polyester textiles back into polyester. In a stakeholder interview held by iGEM Toronto, Paul King of Kendor Textiles (pers. comm.) described a clear gap in polyester-to-polyester recycling, noting that existing polyester recyclers predominantly use plastic bottles as feedstock rather than textiles. As a result, textile waste remains an under-used resource, and reprocessors currently have no scalable means of converting it back into spinnable polymer.

Where textile recycling does occur, it is largely mechanical, which produces yarns of lower thermal and mechanical quality than the original material (Patti, Cicala, and Acierno 2021). This downcycling limits the value reprocessors can recover from textile waste. Enzymatic depolymerisation, however, addresses this limitation by breaking PET down into its monomers, yielding material that can compete directly with virgin PET. The process may also operate under comparatively mild conditions. A 2026 study by Graham et al. reported that an engineered PET-degrading enzyme, a cutinase fused to a binding module, sustained activity at 50 °C over extended operation (Graham et al. 2026). While the results have not yet been tested with PetaScale's engineered enzymes, it suggests that enzymatic depolymerisation of PET can be carried out at moderate temperatures. This finding offers a promising direction for future wet lab testing to determine whether similar conditions are achievable with PetaScale's enzymes.

Market demand for textile-derived recycled polyester further strengthens the case for adoption. Apparel brands are increasingly committing to use polyester recycled from post-consumer

garments rather than plastic bottles, yet current production capacity falls short of meeting this demand. Research by Syre and McKinsey estimates that by 2030, demand for textile-to-textile recycled polyester will exceed supply by 10 to 12 million tonnes per year (Syre 2025). By adopting PetaScale's enzymatic process, a reprocessor would gain the ability to accept textile feedstock and supply this growing, under-served market.

### 1.4 Technical Feasibility

The most relevant evidence for this vertical comes from a 2026 study by Graham et al., which tested whether an engineered enzyme could break down a real polyester textile under conditions similar to those found in industry (Graham et al. 2026). The researchers used a fusion enzyme, where a PET-degrading enzyme was attached to a binding module that helps it stick to the plastic surface. Their findings show both the potential and the current limits of enzymatic textile recycling.

The main challenge is crystallinity. When polyester is spun into fibre at high speed, its polymer chains pack tightly into an ordered structure that enzymes struggle to access. The textile tested in the study was approximately 40% crystalline. When left untreated, neither enzyme was able to degrade it (Graham et al. 2026). However, pretreatment significantly improved results. Grinding the fabric into a fine powder enabled roughly 18 to 19% degradation after 96 hours. When the fabric was first melted and rapidly cooled to loosen its crystalline structure, then ground into powder, the fusion enzyme degraded 82% of the material, more than double the 36% achieved by the enzyme lacking the binding module (Graham et al. 2026). The authors also found that performance depends heavily on how well the enzyme is matched to the specific material, meaning results must be confirmed under real operating conditions rather than assumed from lab tests alone (Graham et al. 2026).

Based on this evidence, PetaScale's working position is that enzymatic recycling of polyester textiles is scientifically feasible, but only when combined with a pretreatment step that makes the fibres easier to break down. Improving the enzyme alone will not be sufficient.

Dyes and finishes present a second consideration. Synthetic fabrics are coloured with a range of dyes, and binders and resins are applied to hold pigments in place (Patti, Cicala, and Acierno 2021). These additives can carry through into the recovered monomers, so a purification step will be a necessary part of PetaScale's process.

### 1.5 Stakeholder Insights

**Table 1.1. Stakeholder interviews and implications**

| Stakeholder | Key Insight | Implication for PetaScale |
|---|---|---|
| **Christina Seidel**<br>Recycling Council of Alberta | Reuse markets are strong, but textile recycling is underdeveloped. Most textiles go to donation bins, and the rest is landfilled. | Feedstock exists but is not aggregated for recycling. Collection partnerships are a prerequisite. |
| **Paul King**<br>Kendor Textiles | There is little polyester-to-polyester recycling, and recyclers prefer bottle feedstock. Recycled polyester is only slightly more expensive than virgin. Fibre blending is the main barrier. Jerseys are a promising 100% polyester source. | This confirms the market gap and identifies a pure, sortable starting feedstock. It also signals thin price margins. |
| **Worn Again Technologies** | Collection and sorting are their biggest barrier, since plastic recycling benefits from government incentives that textiles lack. They can decontaminate and remove dye from polyester, but they recapture PET rather than depolymerising it. | This names the sorting bottleneck and suggests a potential complementary partner for purification upstream of enzymatic depolymerisation. |

### 1.6 SWOT Analysis

**Table 1.2. SWOT analysis for the textile discard vertical**

| Strengths | Weaknesses |
|---|---|
| PetaScale's enzymatic process breaks PET down into its original monomers, which can be rebuilt into polyester of the same quality as virgin material. This avoids the quality loss that occurs each time PET is melted and reshaped in mechanical recycling (Patti, Cicala, and Acierno 2021). The process also operates at comparatively low temperatures, with engineered PET-degrading enzymes shown to remain active at 50 °C over extended periods (Graham et al. 2026), reducing energy demands relative to thermochemical methods. Because PetaScale offers depolymerisation as a service within existing reprocessing facilities, it does not need to fund and build its own recycling plant. Finally, the workflow developed for PetaScale's adjacent verticals applies directly to textiles, allowing progress in one area to benefit the others. | Polyester fibres are highly crystalline, and untreated polyester fabric could not be broken down by enzymes under industrial conditions (Graham et al. 2026). Effective breakdown requires pretreatment steps such as melting and grinding, which add energy and equipment costs to the process. In addition, the effect of dyes, finishing chemicals, and fibre blends on enzyme performance has not yet been tested for PetaScale's enzyme, and these additives may reduce efficiency or contaminate the recovered monomers (Patti, Cicala, and Acierno 2021; Holkar et al. 2016). As PetaScale has not yet completed a pilot, its performance at industrial scale remains unproven. |

| Opportunities | Threats |
| --- | --- |
| Brands currently demand more textile-to-textile recycled polyester than the industry can supply, creating room for new processing capacity. This demand is further reinforced by brand circularity commitments and by EU policy promoting textile recycling (European Commission 2020). Garments made entirely of polyester, such as sports jerseys, offer an accessible starting feedstock that requires no fibre separation. Finally, polyester garments shed microfibres during washing and wear (De Falco et al. 2020; European Environment Agency 2022), which connects this vertical to PetaScale's laundry and wastewater treatment verticals and allows research and partnerships to be shared across them. | Several well-funded competitors are already scaling textile recycling technologies (more information in Section 4). Polyester recycled from plastic bottles is also widely available and inexpensive, and Paul King noted that most polyester recyclers already rely on bottles rather than textiles. Feedstock access poses a further challenge: Worn Again Technologies and Christina Seidel both identified the weak collection and sorting of textile waste as a major barrier. Finally, King observed that recycled polyester costs only slightly more than virgin polyester, limiting how much reprocessors can afford to pay for new processing technology. |

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## 2. Market Size and Opportunity

### 2.1 Total Addressable Market (TAM): ~47.9 Billion USD

Built top-down from the global plastics recycling market, which BCC Research valued at 42.4 billion USD in 2024 and projects to reach 57.9 billion USD by 2029 at a 6.4% CAGR (BCC Research 2026). Interpolating that growth rate gives a 2026 market of approximately 47.9 billion USD. This market represents the theoretical ceiling, as enzymatic depolymerization enables recovery of virgin-grade material, making the entire segment technically addressable. The figure covers plastics recycling across all polymer types, so the PET-addressable portion is a subset of

this ceiling. PetaScale's potential lies in delivering end-to-end depolymerization and vertical integration, selling clean PET directly to suppliers. As the platform matures, the ceiling extends toward the broader virgin PET market, since depolymerized output competes wherever virgin PET is used.

### 2.2 Serviceable Addressable Market (SAM): ~60 Million CAD

A bottom-up build based on Canadian synthetic textile volumes, filtered for PET. According to Statistics Canada's Physical Flow Account for Plastic Material (Statistics Canada 2024), roughly 280 kt of synthetic textiles were discarded in 2020. Assuming polyester dominates synthetic materials, ≈70% (200 kt) is treated as PET. At ~2,300 CAD/t for recycled PET (rPET) clear flakes, grade-dependent between 1,200 and 2,600 CAD, the gross recoverable material value yields an absolute ceiling of ≈460 million CAD. The price benchmark is drawn from a Western European post-consumer polymer price series (Statista 2022) and is applied as a proxy for Canadian pricing, since no equivalent Canadian series is published. Realistically, the flake value would not be fully realized directly; instead, depolymerization as a service represents the initial value-add. Applying a processing value of ≈300 CAD/t results in a SAM of ≈60 million CAD.

### 2.3 Serviceable Obtainable Market (SOM): ~1.2 Million CAD

Following a three-pilot, two-conversion pipeline with an annual contract value (ACV) of 600,000 CAD per facility, PetaScale's projected annual revenue from this vertical reaches ≈1.2 million CAD within three years. Each pilot facility processes ~2,000 t/yr at 300 CAD/t. Though modest in absolute terms, the scalability and strategic positioning are significant; this initial SOM serves as a beachhead into the broader PET circular economy, establishing early credibility and infrastructure for long-term growth.

**Table 2.1. Pilot-to-contract pipeline, Years 1 to 3**

| Year | Pilots | New conversions | Contracts | Revenue (CAD) |
|---|---|---|---|---|
| 1 | 2 | 0 | 0 | 0 |
| 2 | 1 | 1 | 1 | 600,000 |
| 3 | 0 | 1 | 2 | 1,200,000 |
| **Total** | **3** | **2** | **2** | **1,200,000** |

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## 3. Barriers to Entry

### 3.1 Feedstock Collection and Sorting

Textile waste is not collected or sorted for recycling at scale. In an interview with iGEM Toronto, Worn Again Technologies (pers. comm.) identified this as the primary barrier to its own technology, noting that plastic recycling is more advanced because of government incentives. Christina Seidel's account of donation-driven textile flows reinforces this.

**Mitigation.** PetaScale will begin with pre-consumer and post-industrial polyester scrap, such as fabric offcuts and rejected material, rather than used clothing, which is cleaner and more consistent in composition than post-consumer waste. It will also target materials made entirely of polyester, such as sports jerseys, which Paul King identified as a promising source. By partnering with existing sorters and recycling organisations, PetaScale can secure early feedstock without building its own collection infrastructure.

### 3.2 Fibre Blends

Paul King identified blending, such as poly-cotton and elastane blends, as the main barrier to fibre-to-fibre recycling. PETase acts only on the PET fraction, so blended feedstock leaves non-PET residue that must be separated.

**Mitigation.** In the initial phase, PetaScale's working position is to process only high-polyester-content feedstock. Blended textiles are a later expansion, possibly paired with fibre-separation partners.

### 3.3 Crystallinity and Pretreatment Cost

Polyester fibres have a tightly packed structure that enzymes struggle to break down. In the study by Graham et al., untreated polyester fabric could not be broken down at all under industrial conditions (Graham et al. 2026). High breakdown was only achieved after the fabric was melted, rapidly cooled to loosen its structure, and ground into a fine powder (Graham et al. 2026). These pretreatment steps add energy and equipment costs to the overall process.

**Mitigation.** PetaScale will include pretreatment as part of its service and account for its energy cost when planning pilot projects. Enzyme development will focus on designs that perform best on pretreated fabric. PetaScale will also prioritise partnerships with reprocessors that already own shredding and melting equipment, reducing the need for new investment.

### 3.4 Dyes, Finishes, and Contaminants

Textile dyes and finishing chemicals persist through processing (Patti, Cicala, and Acierno 2021; Holkar et al. 2016). Their effect on enzyme activity and monomer purity is not yet characterised for PetaScale's enzyme.

**Mitigation.** Early pilots will run on undyed or lightly dyed scrap, followed by staged testing on coloured feedstock. Established decolourisation methods, such as those Worn Again Technologies described, could be integrated upstream.

### 3.5 Cost Competitiveness

Paul King noted that recycled polyester costs only slightly more than virgin polyester. As a result, reprocessors earn little extra from selling recycled material and have limited budgets to pay for new processing technology. Polyester recycled from textiles must also compete with polyester recycled from plastic bottles, which is cheaper and already widely available.

**Mitigation.** PetaScale addresses this in two ways. First, it charges a fixed fee per tonne processed (approximately 300 CAD/t, as outlined in Section 2) rather than requiring reprocessors to invest in new equipment, keeping costs manageable for businesses with limited margins. Second, PetaScale does not rely on competing with bottle-derived polyester on price. Instead of competing with bottle-derived polyester in an already crowded market, reprocessors using PetaScale gain the ability to convert textile waste into high-quality polyester, a capability few competitors currently possess. This gives them a distinct competitive advantage: early access to an untapped feedstock and to the growing, under-supplied brand demand for textile-to-textile recycled polyester described in Section 1.3.

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## 4. Competitor Matrix

### 4.1 Company Summary

Carbios has partnered with brands such as Puma to test their plastic degrading enzymes on textile waste. They have successfully scaled up their enzymes to a demonstration scale (Carbios 2022). They are currently looking to create a circular economy with the use of their enzymes taking the enzyme degraded plastics' building blocks and using them to develop new textiles (Carbios 2023).

Samsara Eco is collaborating with Lululemon to create new clothing garments from recycled nylon 6,6 and polyester, creating a circular fashion movement (Samsara Eco 2025). They sort and pre-process garments, trimming and shredding them to ensure the utmost effectiveness of the enzymes (Samsara Eco 2025). The broken down polymers are used to create new ones which can be reused for retail-ready polyesters.

Unifi (REPREVE) focuses on post-industrial textile and yarn waste which can also be reused, creating a circular environment (Unifi 2024).

Syre collects post-consumer and industrial waste which works to create a circular environment, manufacturing products from the waste that is collected. They specify that their textile-to-textile recycling offers better quality products than bottle-to-fiber polymers using rPET. Their solution claims to enable a quick adoption with no switching costs (Syre 2024).

Worn Again is currently scaling a closed-loop chemical recycling technology which breaks down textiles and spins them into new fibers which can be used for new garments using a fiber-to-fiber value chain. They note that recycling all used textiles may significantly reduce the environmental energy, minimizing water and energy use, and decreasing greenhouse gas emissions which are associated with the production of raw materials and waste disposal (Worn Again Technologies 2026).

The competitors above all claim to be scaling closed-loop chemical technologies using plastic-degrading enzymes, however, Loop Industries takes this one step further and does what other companies are not considering. They take the pellet discardants, which are contaminated PET plastic and polyester fiber, that is normally rejected from normal disposal methods, and rebuild them from their molecular level back into the virgin-quality materials. They also claim that their plastic-degrading enzyme technology purifies PET from complex materials which would otherwise be discarded. Similar to the other companies, they also take worn garments, which would otherwise end up incinerated or in landfill, and break down the fibers into their molecular building blocks while also removing dyes, coatings and finishes (Loop Industries 2018).

### 4.2 Competitive Positioning

Where PetaScale stands apart is in deploying real-world plastic-degrading enzymes across diverse environmental conditions, rather than relying on a one-size-fits-all PETase. Enzymes discovered through PetaScale's platform have demonstrated superior speed and efficiency compared to the two leading benchmarks, FAST-PETase and IS-PETase. Our high-throughput assays and bioreactor testing replicate the conditions enzymes encounter during deployment, enabling condition-specific optimization. This approach, unlike that of other companies, positions PetaScale to address current challenges such as textile pollution and pellet runoff, while advancing future closed-loop textile recycling efforts.

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