

Beachfront Market

Wastewater Treatment Plants

Enzymatic removal of PET microplastics in wastewater treatment facilities.

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SECTION 5 · VERTICALS

1. Customer Description

1.1 Technical Feasibility

1.1.1 Proposed Technology and Objectives

PetaScale proposes an enzyme-based approach for the removal of polyethylene terephthalate (PET) microplastics from wastewater treatment plants (WWTPs). At the core of PetaScale is our platform, the PETadex, which integrates large-scale biological datasets to identify promising enzyme candidates. Subsequent rapid experimental testing enables the identification, evaluation, and optimization of hundreds of enzyme variants for specific biodegradation applications. By combining computational enzyme discovery and design with enzyme optimization and deployable hardware, PetaScale aims to develop a full-stack biodegradation solution that can ultimately scale across multiple sectors of the bioeconomy. As an initial application, the technology will focus exclusively on PET, a widely used plastic that is increasingly detected in wastewater and the environment. Rather than modifying the primary treatment process, PetaScale proposes deploying the enzymatic system in a secondary sidestream within WWTPs, an approach recommended by Rasha Maal-Bared (pers. comm.) and that is conceptually aligned with existing sidestream treatment strategies for contaminants such as PFAS and antimicrobial resistance genes. The enzymes will be immobilized onto a suitable medium to prevent enzyme washout and enable their retention within the treatment system. During treatment, the immobilized enzymes will catalyze the depolymerization of PET into its constituent monomers, primarily terephthalic acid (TPA) and ethylene glycol (EG), thereby converting PET microplastics into recoverable molecular products rather than simply fragmenting them into smaller particles or forming harmful toxic substances.

1.1.2 Drivers for Microplastic Reduction: Biosolids Quality

Biosolids, the nutrient-rich solid byproduct of wastewater treatment, are commonly land-applied as fertilizer, which reduces reliance on synthetic fertilizers and their associated upstream emissions (e.g., Haber-Bosch nitrogen production). However, biosolids are also a known reservoir for microplastics: studies report concentrations ranging from roughly 228 to over 500,000 particles per kilogram of dry weight, depending on the source and methodology (Letwin et al. 2023). Importantly, according to Ryan Prosser (pers. comm.), at current environmentally relevant concentrations, there is no strong evidence that these microplastic levels are causing measurable

harm to soil organisms; the case for removal is currently precautionary and reputational rather than ecological damage. Even so, this precaution has real financial weight: in Ontario, landfill disposal (the fallback when biosolids cannot be land-applied) can cost up to 190 CAD per tonne, and rising tipping fees continue to make land application the economically preferable option (City of Toronto 2025). There is currently no Canadian regulation banning microplastics in biosolids, but the Federal Plastics Registry's ongoing reclassification of microplastic risk signals that future regulation is plausible, and operators are already anticipating this shift. Reducing microplastic contamination in biosolids therefore protects a plant's ability to keep land-applying its sludge, preserving both an economically favorable disposal pathway and a defensible position ahead of potential future regulation.

1.1.3 Drivers for Microplastic Reduction: Process Efficiency

Beyond biosolids quality, microplastics also affect the wastewater treatment process itself. Microplastics can affect membrane performance, increasing transmembrane pressure and shortening operational runtimes. According to Rasha Maal-Bared (pers. comm.), any technology that reduces microplastic load in solids or sidestreams could improve membrane longevity. Moreover, microplastics interfere with coagulation and flocculation processes within WWTPs. Because microplastics are lower in density and more buoyant than the natural colloids these processes were built around, they do not settle the same way. The density mismatch between microplastics and the natural colloids these processes were built to handle is also why microplastics can throw off floc settling over time (Sahini and Banyikwa 2026). Instead of settling out evenly, they end up concentrated in specific spots within the system, creating localized buildup that worsens the longer it remains unaddressed.

1.1.4 Technical Plausibility of Enzymatic Degradation

PETase can bind to the surface of PET microplastic particles and hydrolyze the ester bonds within the polymer, breaking the long PET chains into smaller, soluble intermediates, primarily mono(2-hydroxyethyl) terephthalate (MHET) and bis(2-hydroxyethyl) terephthalate (BHET). However, PETase alone does not typically achieve complete depolymerization of PET into its terminal monomers. Further conversion of MHET to terephthalic acid (TPA) and ethylene glycol (EG) requires MHETase activity, which hydrolyzes MHET into these two products. Consequently, a complete enzymatic degradation system would need to provide both PETase and MHETase activity, either through the co-delivery of two enzymes or through the development of an engineered bifunctional enzyme with both catalytic functions. The resulting soluble products no

longer particulate microplastics and may undergo further biological transformation within the wastewater treatment system or remain as dissolved compounds that downstream treatment processes can address. The feasibility of this approach is supported by preliminary enzyme-screening results: in an initial randomized screen of 161 natural enzymes, two candidates already demonstrated activity exceeding that of the current FAST-PETase benchmark. If this performance is representative of the broader PETadex sequence space, the platform could contain approximately three million candidate enzymes with the potential to outperform the existing benchmark, providing a substantial pool from which enzymes with improved activity, stability, and wastewater compatibility could be identified.

1.1.5 Integration into Wastewater Treatment Plants

Because temperature and pH vary considerably between facilities depending on source water and process design, our approach relies on optimizing enzyme candidates for the specific conditions of each individual deployment site rather than pursuing a single universal formulation. This site-specific optimization is made tractable by the scale of the PETadex database, which uncovers sufficient enzymatic diversity to select or engineer candidates suited to a given plant's temperature and pH profile. According to Rasha Maal-Bared (pers. comm.), pH within a given plant tends to remain relatively stable once process conditions are established, which simplifies pH-related optimization for any single deployment site. Temperature, by contrast, is not stable within a plant and varies significantly over the course of the year as seasonal weather conditions fluctuate, meaning candidate enzymes must retain activity across this seasonal range rather than being optimized for a single fixed temperature. In practice, this means enzyme selection is not a one-time optimization but an ongoing process. As seasonal temperature shifts occur, candidates need to be reselected or adjusted up to four times a year to maintain performance. The need for seasonally optimized enzymes turns a one-time purchase into a recurring service and recurring revenue. Beyond temperature and pH, deployed enzymes must also tolerate chemical interferents present in wastewater, including heavy metals, surfactants, and other organic contaminants capable of causing enzyme denaturation or activity loss. A further open question concerns the potential for interaction between deployed enzyme candidates and the native microbial communities that WWTPs rely on within their bioreactors. Aaron Yip (pers. comm.) suggests that such microbiome disruption is likely minor, though this remains a largely unstudied aspect of enzymatic PET degradation in operational settings. These interactions could also be beneficial: native microbes may help by degrading intermediate breakdown products such as MHET or ethylene glycol, maintaining redox balance, or preventing the buildup of inhibitory compounds.

Both possibilities will be directly assessed, along with any toxic chemical-enzyme interaction, as part of our validation process using real sludge matrices in the bioreactor array. Flow rate and retention time also vary between facilities and are an additional factor we are considering as part of site-specific enzyme optimization.

1.1.6 Microplastic Accessibility

Beyond enzyme stability within the sidestream environment, an important question is whether deployed enzymes will have sufficient physical access to microplastic particles to degrade them at all. Microplastics in wastewater treatment systems are frequently colonized by microbial biofilms (Kelly et al. 2021), and the resulting biofilm environment plays a determining role in the efficiency of biological treatment processes, potentially limiting direct enzyme-substrate contact at the particle surface. Additional open variables include the size distribution and concentration of PET microplastics reaching the sidestream. There is significant variation in microplastic concentration in dry sewage sludge from plant to plant (Lofty et al. 2022), which will inform whether particle flux through our system is sufficient for meaningful contact with immobilized enzymes, as well as the flow velocity through the reactor. Collectively, these factors raise fundamental reactor design questions. These variables are not yet characterized for our system and represent a core focus of validation using our bioreactor array, which will test enzyme performance under configurable flow, particle concentration, and substrate conditions that mimic these real-world constraints.

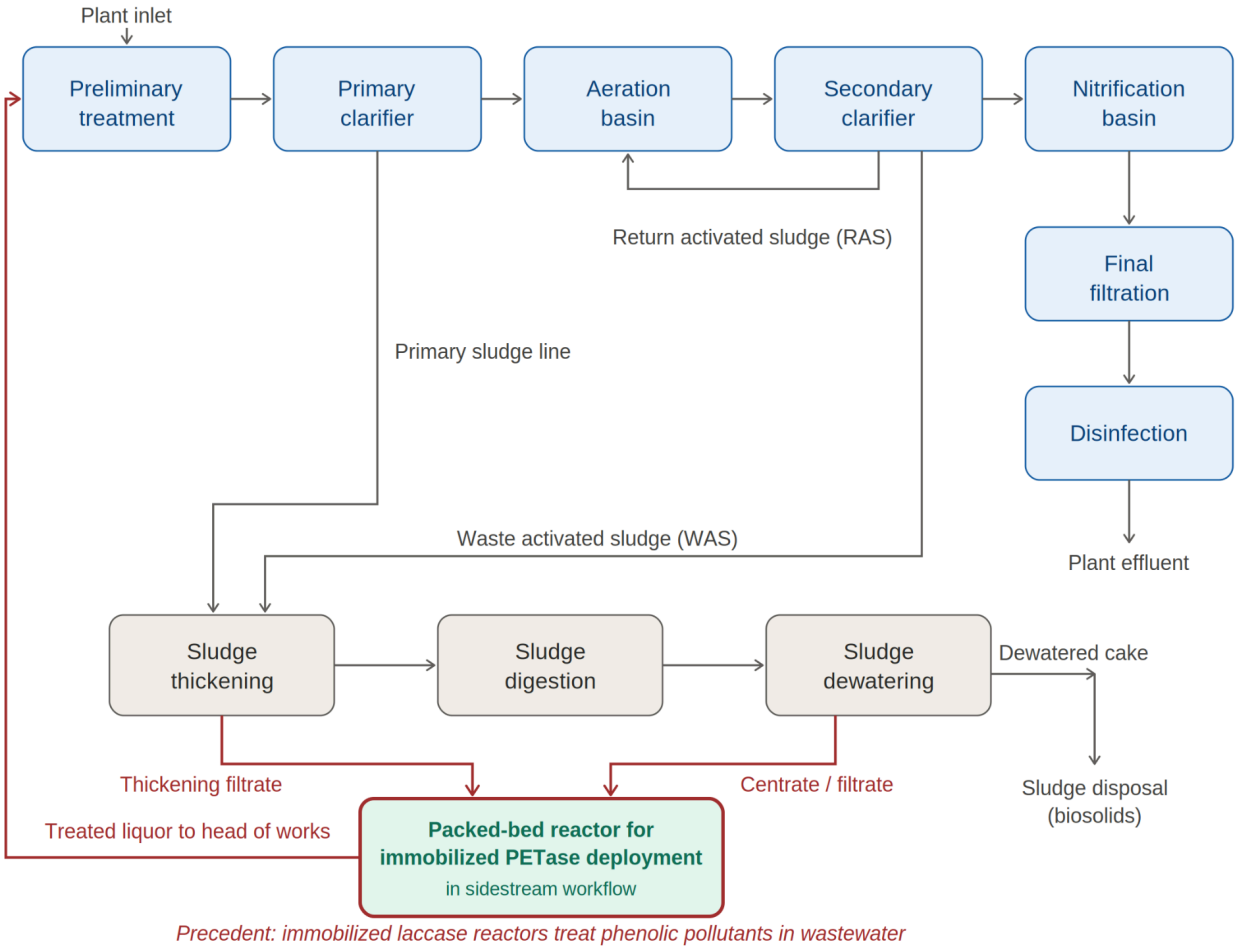
1.1.7 Measuring Success

Success for this vertical will be defined by quantifiable degradation performance within the operating envelope defined above. Specifically, candidate enzymes will be evaluated against the following criteria: (1) degradation efficiency, measured as the percentage of PET microplastic mass or particle count converted to soluble intermediates within the plant's operational hydraulic retention time, (2) activity retention in situ, measured as the enzyme's residual catalytic activity after exposure to real sludge matrix relative to its activity in clean buffer, and (3) operational durability, measured as the number of treatment cycles an immobilized enzyme preparation can sustain before activity drops below a functional threshold. At every deployment site, enzymes will be benchmarked against FAST-PETase and related engineered variants under matched, site-specific conditions. Notably, published performance data for benchmark enzymes such as FAST-PETase have, to date, been generated almost exclusively under idealized laboratory conditions. To address this, our bioreactor array will be configured to replicate

wastewater-relevant conditions specific to this vertical, enabling direct, side-by-side evaluation of both benchmark enzymes and novel candidates under identical, matched conditions.

1.1.8 Integration Feasibility

Deployment feasibility is supported by established precedent for immobilized-enzyme systems in wastewater treatment using non-plastic solid supports. For example, immobilized laccase has been shown to degrade bisphenol A, a toxic phenolic pollutant, in wastewater when supported on fumed silica nanoparticles (Gasser et al. 2014). In addition, enzymes immobilized on alginate-based beads have been operated continuously in packed-bed reactor systems treating real industrial wastewater, sustaining high removal efficiencies over extended operating periods (Rezvani et al. 2015). Laccase immobilized on granular activated carbon has also been shown to retain high activity across a broad range of pH and temperature conditions in a packed-bed system (Nguyen et al. 2016). Although these systems target pollutants other than plastics, they demonstrate that immobilized enzymes can operate in wastewater-treatment processes and retain activity under relevant operating conditions. This precedent supports the technical feasibility of our proposed approach, in which candidate plastic-degrading enzymes will be immobilized onto a non-plastic solid support and deployed within the plant's sidestream. Consistent with feedback from our industry partners, this deployment is designed to avoid the need for new infrastructure by integrating with existing sidestream flows rather than requiring major civil works. The specific physical format of the immobilized enzyme system, along with the operational protocol for enzyme replacement or regeneration and the approach to ongoing performance monitoring, remain active areas of development and will be informed by results from our bioreactor validation testing.



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2. Market Size and Opportunity

PetaScale sells enzymatic PET removal at 15.75 CAD per megalitre (ML) of plant influent treated, or 1.6 cents per cubic metre. That price sits at 34.8% of what Region of Peel already spends on process chemicals (45.26 CAD per ML across G.E. Booth and Clarkson in 2023), so the service fits inside existing treatment budgets without requiring a new line item. Authorities purchase for every plant they operate under a single decision, which means one successful pilot converts an entire portfolio.

2.1 Total Addressable Market (TAM): 1.37 Billion CAD per Year

Treatment plants in the United States, Canada and Western Europe treat 87.3 billion cubic metres of wastewater each year: 46,977 million cubic metres in the United States, 6,031 million in Canada and an estimated 34,290 million in Western Europe. At 15.75 CAD per ML, that volume represents 1.37 billion CAD a year. This figure measures the water our enzyme could treat, not

money anyone spends on PET-degrading enzymes today, since no commercial market for this service currently exists.

2.2 Serviceable Addressable Market (SAM): 69.1 Million CAD per Year

Our serviceable market is Canadian wastewater that passes through secondary or tertiary treatment, because only those plants produce the thickened sludge our service doses. In 2023, secondary and tertiary treatment handled 4,384 million cubic metres across the 11 reporting provinces and territories (Environment and Climate Change Canada 2023), giving a SAM of 69.1 million CAD a year. Ontario, Quebec, Alberta and British Columbia account for 89.6% of that volume, which concentrates our sales effort in four jurisdictions. The Northwest Territories and Nunavut do not appear in the source data.

2.3 Serviceable Obtainable Market (SOM): 15.8 Million CAD ARR by Year 4

We target regional authorities that operate several plants under one purchasing decision. Pilots begin in Year 1 at Region of Peel, Metro Vancouver and the City of Calgary. OCWA operates both Peel plants, so Peel converts first in Year 2. Metro Vancouver and Calgary follow in Year 3. In Year 4, York-Durham signs, OCWA brings in 10 client plants, and Winnipeg and Quebec City convert after Series A-funded pilots.

By the end of Year 4, PetaScale serves 24 plants across seven authorities: 13 in Ontario, 3 in British Columbia, 3 in Alberta, 3 in Manitoba and 2 in Quebec. Those plants treat 1,003,333 ML a year under contract, which is 22.9% of our Canadian serviceable market and 15.80 million CAD in annual recurring revenue.

2.4 Scope and Assumptions

These figures cover the WWTP vertical only. They exclude bioremediation, detergents, textile effluent, landfill leachate and any revenue from combining verticals. All amounts are in Canadian dollars and remain provisional. Enzyme dose and cost values draw on published benchmarks for LCC-ICCG (Tournier et al. 2020) and the stated assumptions below, and PetaBite's Wet Lab, bioreactor and pilot data will replace them in the same model. The forecast holds prices and costs flat and does not adjust for inflation.

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3. Barriers to Entry

3.1 Procurement Cycles

Adoption will be shaped by the procurement processes typical of municipally operated WWTPs. Because most facilities are municipally funded, purchasing decisions are tied to annual municipal budget cycles rather than being made independently by plant operators (City of Toronto 2017); if our solution falls outside a given year's approved budget, adoption may need to wait for the next cycle. Our product is expected to be classified as an operational expense, since enzymes will require periodic repurchasing. As a novel biological solution, we also anticipate needing to navigate competitive bidding requirements, including vendor registration, qualification, and approval processes. Specific requirements for the supply of enzyme-based treatment technology to wastewater treatment facilities are under investigation and remain to be confirmed. Finally, most facilities are likely to require evidence of a successful pilot deployment before committing to full adoption, which will shape our go-to-market sequencing toward securing an initial reference site.

3.2 Technical Validation Requirements

Beyond meeting the performance thresholds for degradation efficiency, chemical and biological compatibility, and operational resilience previously established, commercial adoption requires demonstrating that deployed enzymes pose no unintended risk to the environment or human health. Unlike conventional chemical or mechanical treatment technologies, our platform introduces a novel biological catalyst into a regulated wastewater stream, for which no established regulatory precedent yet exists specifically for PET-degrading enzymes at deployment scale. The validation pathway is time and resource-intensive and largely outside our direct control, therefore representing a meaningful barrier to speed of market entry, independent of the technology's underlying performance.

3.3 Pilot Requirement

Before commercial deployment at scale, PetaScale requires a pilot phase to demonstrate feasibility under real WWTP conditions. Because plants cannot risk disruption to their live treatment process, pilots are run within a closed-loop pipe system. According to York WWTP operators (pers. comm.), pilots at this scale are typically conducted in collaboration with the Drinking Water Research Group (DWRG), who specialize in running this kind of pilot, which is why

DWRG is our intended partner for the first Ontario pilot. This containment-first design also helps qualify the pilot for a lower tier of regulatory review, reducing delays from notification requirements that would otherwise apply at commercial scale (detailed further in Section 6, Regulatory Landscape).

We aim to launch at least two WWTP pilots between September and December 2027, with the first targeted in Ontario alongside DWRG. Each pilot is offered at no cost to the WWTP: PetaScale installs the dosing equipment and runs a 90-day trial, with microplastic reduction measured and independently verified. Successful pilots are then converted into pay-per-performance contracts, and the verified performance data is used to approach the next 10 to 20 Ontario WWTPs, before expanding to provinces where feasibility discussions have already taken place.

The pilot requirement itself represents a meaningful barrier to entry: municipal WWTPs are risk-averse, publicly accountable, and unlikely to adopt a new technology without third-party verified performance data, but that data can only be generated through a pilot in the first place. This creates a credibility barrier that new entrants must actively overcome, typically through no-cost pilot offers and credible research partnerships, before any commercial traction becomes possible.

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4. Competitor Matrix

Currently, no companies are selling enzyme-based microplastic solutions to wastewater treatment plants (WWTPs) at commercial scale. Enzyme-based technologies are still being researched and piloted. Instead, WWTPs rely mostly on physical methods (settling tanks, sand filtration, microfiltration, etc.) for microplastic removal (Kurt et al. 2022).

On the filtration side, two notable players are emerging.

Veolia Water Technologies is a large French transnational company that offers a Hydrotech Cloth Filter: Confidence Series that is designed to capture microplastics with a mechanical disc-filter platform lined with pile cloth media. Veolia’s technology traps microplastics and other suspended solids down to 5 micrometres, and is targeted to WWTPs as their primary customer (Veolia Water Technologies n.d.). Designed on their proven disc-filter technology, Veolia’s solution is a mature commercial offering within the market. However, the Hydrotech filter traps microplastics alongside

organic sludge, generating a concentrated waste stream that still requires processing, disposal, or incineration.

PolyGone is an up and coming company based in the US that is developing the Polypod, a filtration system that uses a proprietary silicon-based “Polypod” medium to bind microplastics in water. Their system advertises high capture efficiency, filtering out 98% of sub-millimeter microplastics via specialized binding mechanisms. While PolyGone is advancing towards commercial deployments in 2026, their filter itself simply traps solid debris that requires ongoing monitoring, removal, and secondary processing (PolyGone Systems 2019). As such, PolyGone is actively exploring partnerships to handle the waste post-capture, which poses an opportunity for collaboration instead of competition.

In the enzyme-based space, the competitive landscape is thin and early-stage.

Enzycle ran a research pilot initiative in 2021 that uses microbial enzymes to treat non-recycled plastic fractions, targeting both WWTPs and waste/recycling facilities. Their project initiative ended in 2024, and no update on the continuation of the project has been announced (Ramos 2020).

Zymatic is a Swedish-based company that offers enzyme-based industrial and wastewater treatment solutions using its proprietary Nexus platform, which immobilizes naturally derived enzymes onto a silica bead substrate known as Zymatic sand. While the company displays an impressive customer base and proven technology, its current focus is limited to the removal of harmful organic compounds instead of plastics. Additionally, the platform relies on natural or customer-selected enzymes rather than engineered variants, limiting their focus in microplastic removal (Zymatic 2024).

Other bio-solution-focused WWTP companies include EnviroZyme, BioGlobe, and Infinita Biotech. EnviroZyme is a US-based company that provides specialized biological, microbial, and enzymatic formulations to optimize performance, reduce chemical demands, and accelerate organic breakdown in municipal and industrial wastewater systems. While EnviroZyme excels at processing naturally occurring organic matter, lipids, and standard industrial chemical oxygen demand (COD), their current product and service catalogue lack solutions for synthetic polymers and microplastics (EnviroZyme 2026). BioGlobe Ltd (UK) develops enzyme-based formulations for environmental remediation, specializing mainly in organic sewage treatment, oil spills, and soil restoration. Publicly, they discussed integrating PETase enzymes to break down microplastics in

WWTPs, but noted it remains conceptual and is in their research monitoring stage. Because BioGlobe does not offer a market-ready enzymatic plastic degradation product for WWTPs, they are not yet a direct product competitor (BioGlobe 2025). Infinita Biotech is an industrial biotechnology manufacturer based in India that specializes in bioremediation and customized enzyme formulations for industrial processing and municipal wastewater treatment. Similar to EnviroZyme, they offer WWTP solutions for biochemical oxygen demand and chemical oxygen demand reduction, biogas optimization, desulphurisation, and ammoniacal nitrogen removal. Despite their broad solutions for WWTPs, Infinita Biotech does not offer solutions for enzymatic degradation of microplastics (Infinita Biotech n.d.; Infinita Biotech 2024).

This landscape presents a clear gap: no competitor is yet offering a scalable, enzyme-driven solution purpose-built for plastic degradation across varied conditions. And this is precisely the gap that PetaScale is aiming to fill.

Appendix A. Dose and Cost Model

The enzyme dose begins in the thickened sludge stream where it is applied. Wastewater treatment plants produce approximately 231 g of dry solids per cubic metre of incoming water, based on the average of U.S. and German data. When thickened to 5% solids, this sludge represents 0.46% of total plant flow, or 4,620 L per million litres (ML) of influent. At an assumed working concentration of 1.0 mg/L, the sludge therefore requires 4.62 g of enzyme per ML.

For comparison, the benchmark enzyme LCC-ICCG degrades 90% of PET at a ratio of 3 mg of enzyme per g of PET at 72 °C (Tournier et al. 2020). Applied to the roughly 18 g of PET captured in the sludge from each ML, that ratio would require only 0.054 g of enzyme. The model therefore doses about 85 times the published enzyme-to-plastic ratio. This margin accounts for the highly dilute nature of plastics in sludge, enzyme loss during mixing and settling, and reduced activity at ambient wastewater-plant temperatures.

Production output assumes a 10,000 L fermenter yielding 1.0 g of enzyme per litre over six-day batches. This results in 60 batches per year and a total of 600 kg of enzyme annually, enough to treat 129,870 ML at 4.62 g per ML. Growth media, utilities, and purification cost 210,000 CAD per line per year, or 350 CAD per kg of enzyme, which places the enzyme cost at 1.62 CAD per ML.

Cold-chain logistics (0.40 CAD), dosing and sampling (0.60 CAD), and verification testing (0.40 CAD) bring the total variable cost to 3.02 CAD per ML.

Each production line also carries 582,857 CAD per year in fixed costs, including three operators (270,000 CAD), facility rent (60,000 CAD), equipment depreciation (142,857 CAD) for the line's 1 million CAD cost spread over seven years, and allocated overhead (110,000 CAD). Spread over 129,870 ML, these fixed costs add 4.49 CAD per ML, resulting in a total cost of 7.51 CAD per ML.

The proposed 15.75 CAD per ML price balances margin against buyer expectations. It provides a 110% markup at the base cost and still yields 83% if production-line costs double. The price also remains below 35% of the Region of Peel's authority-wide chemical spending. The 8.25 CAD break-even price covers Year 4 production and operating costs at full contract volume.

The largest assumptions in this model are the 1.0 mg/L working concentration, the 1.0 g/L fermentation yield, and the 1 million CAD line cost. These parameters will be refined using PetaBite's dose-response data, fermentation results, and contract-manufacturer quotes. See the PetaScale Financial Projections for complete calculations, sources, and year-by-year results.

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