

Cheaper Protons: Rocket Engineering Methods for World-Scale Chemical Textile Recycling

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Gap: Textiles remain one of the least circular high-volume material streams in Europe: roughly 1,350 kt of textile waste arise annually in Germany and 7,200 kt across the EU [1]. The obstacle is not chemistry. Glycolysis, methanolysis and hydrolysis of Polyethylene terephthalate (PET) are well described [2] and can, in principle, address the blended fabrics that defeat mechanical recycling. The unsolved problem is cost structure. Glycolysis and methanolysis depend on organic solvents whose make-up losses scale with throughput. Alkaline hydrolysis avoids this by using water but consumes stoichiometric base to cleave the ester bond and stoichiometric acid to precipitate terephthalic acid (TPA), producing a salt stream of the same order of magnitude as the product. The binding constraint on textile circularity is the cost of the protons. ReSolution was founded to remove that constraint. The company develops a water-based electrochemical process for recovering polyester monomers from mixed-fiber textiles. It received theACHEMA Start-up Award 2024 and the Innovation Award of the Dornbirn Global Fiber Congress 2025, and is a finalist for the WirtschaftsWoche Best of Technology Award 2026.

Objective and approach: This work shows an example of ReSolution's engineering philosophy inspired by launch-vehicle engineering: **design-to-cost from first principles**, coupled to a short, hardware-rich iteration cycle which we applied to chemical textile recycling. Rather than optimizing a chemistry chosen in advance, we began with a resolved cost model of the plant and let the dominant cost drivers select the process. Three requirements emerged: tolerance of mixed-fibre feedstock, because a robust process chemistry allows us to maintain a feedstock cost advantage compared to fossil-based PET.

Methods: The cost model is a bottom-up techno-economic formulation resolving CAPEX by equipment item and OPEX by feedstock, reagent, utility and labor, with sensitivities over feedstock purity and specific energy demand. Three proton-supply routes were assessed against purchased mineral acid and caustic on a common basis: chlor-alkali with brine recycling, bipolar-membrane electrodialysis, and EIC. Reference CAPEX for the chlor-alkali case was benchmarked against a published greenfield plant project [4]. Equipment and materials costing follow established chlor-alkali practice [5],

with alloy selection considering the corrosive nature of concentrated chloride solutions. The pH-swing comparison follows the framework established for electrochemical pH cycling in carbon capture [3].

Results: Reagent consumption is the dominant variable-cost line in conventional alkaline hydrolysis. Supplying the pH swing electrochemically rather than by purchased chemicals reduces this line by 50–80 % in OPEX. The range reflects electricity price, plant size and location. For a PET hydrolysis plant equipped with chlor-alkali-based acid and base recycling, the additional brine purification and concentration duty raises capital cost by 44–56 % over the base process, against ≈ 10 % for EIC. Materials of construction compound the difference: chloride-bearing streams require corrosion-resistant alloys, and substituting 1.4539 for 1.4571 raises material cost by a factor of 1.8, translating into a 37 % increase in CAPEX for the core recycling process and adding CAPEX for the recycling section. EIC operates in a chloride-free electrolyte at roughly four-fold lower concentration, permitting standard austenitic grades, and requires no HCl production, storage or handling train at all. Operating mini-plant and semi-industrial units in parallel with real mixed waste yields what we believe is the **shortest and least expensive learning cycle for chemical textile recycling**: a design hypothesis can be formulated, tested on representative feedstock and closed out within one week.

Significance and outlook: We can execute rapid recycling: a one-week iteration on real feedstock is not only a development advantage but a data-generating engine. Each cycle contributes to an operational database that no laboratory campaign can produce, and that database is the substrate for machine knowledge. This sets on which we intend to build AI agents for autonomous process operation, capable of handling the chemical complexity that end-of-life feedstock presents. The barrier to textile circularity is a cost-structure problem with an engineering solution. And that solution is now running.

References

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