PLUG AND PLAY

SILICON VALLEY SUMMIT

TRENDS PRESENTATION

#PNPTCSiliconValley

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PLUG AND PLAY

NEW MATERIALS & PACKAGING

Single-Use Packaging: From Linear to Circular

A Plug and Play Overview

SILICON VALLEY SUMMIT



Plastics Have Been Ruling for 70 Years



Performance

- **Molecular Control.** Designed at a microscopic level to act like a custom shield.
- **Ordered Structure.** Creates an crystalline structure that completely blocks out oxygen and moisture.
- **Decay Prevention.** Stops the natural spoiling process to guarantee sterility and extend shelf-life.



Efficiency

- **Strength-to-weight.** Provides extreme structural protection using ~3.6x less material mass than glass or metal.
- **Resource thrift.** Requires fewer raw natural resources and significantly less water to produce than glass, metal, or paper.

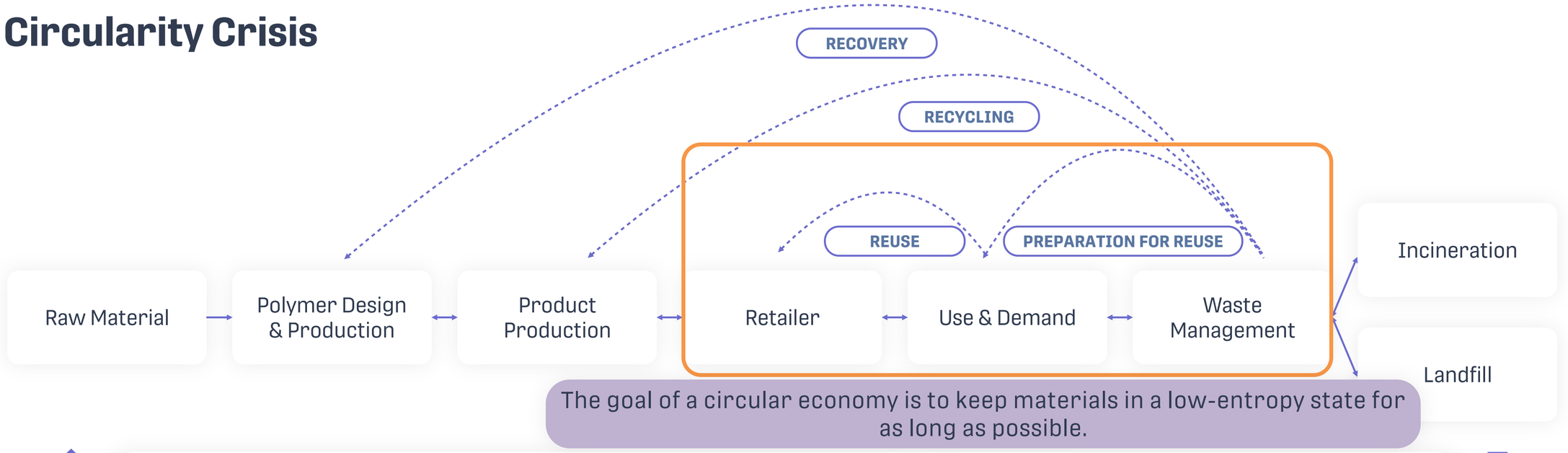


Economics

- **Cost-Effective Scalability.** Inexpensive raw materials and high-speed mass production.
- **Low-Energy Shaping.** Melts at much lower temperatures (150-200 °C) than aluminum (660 °C) or glass (1,500 °C), drastically cutting energy costs.

The exact traits that make plastic so efficient are what turn it into permanent, unmanageable waste.

Circularity Crisis



The goal of a circular economy is to keep materials in a low-entropy state for as long as possible.

Circular Value

Reuse: Using items again for the same purpose without altering their physical or chemical structure.

Recycle: Transforming waste into raw materials to create new products through physical, chemical or biological processing.

Recover: Extracting value from waste that cannot be reused or recycled. This primarily means converting waste into energy.

Entropy Increase

The Polymer Recovery Gap



Polymer Degradation

- **Molecular Weakening.** Melting and recycling tears polymer chains apart, permanently degrading the material.
- **Limited Lifecycle.** Plastic can only be recycled 2 to 3 times before becoming too brittle.
- **Downcycling Inevitable.** Weakened material is ultimately downgraded into low-value items like park benches.



The Sorting Entropy Difficulty

- **Incompatible Polymers.** Visually identical plastics often have different melting points, causing major structural flaws if they are mixed together.
- **Contamination Risk.** Just 1% contamination from food oils or labels can ruin an entire recycling batch, creating toxic gases or structural defects.

Packaging Innovations to Overcome Entropy

The evolution of the packaging industry constantly brings new technologies and applications to light.

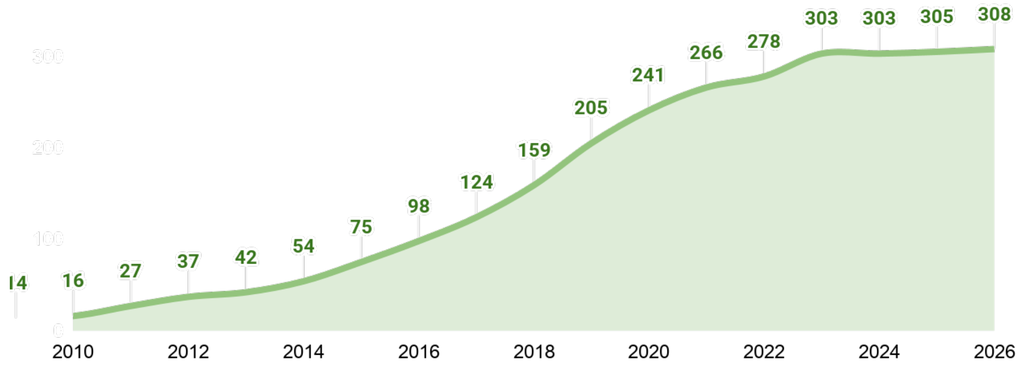
Recent demands for sustainability have lead to advancements in the sourcing, transparency, and disposal of these products.

The following slides will focus on the topics highlighted.



Bio-Based Materials

Cumulative Number of Startups Since 2010



Startup Spotlight

Seaweed/Algae

SWAY

Notpla

OCEANIUM

BLOOM

Mycelium & Fungi

ECOVATIVE DESIGN

Agricultural Waste

grale

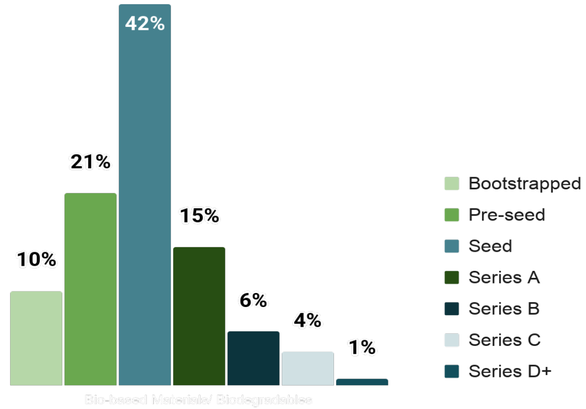
BIOTREM

traceless

KEY INSIGHTS

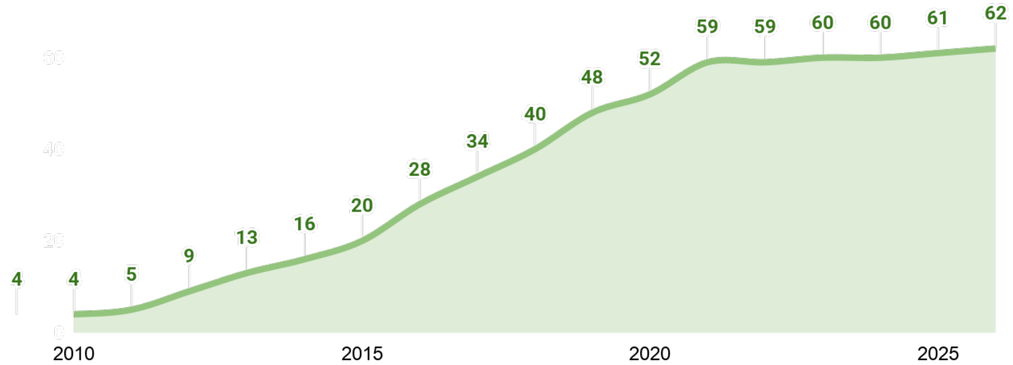
- Bypasses microplastics and toxicity entirely by leaning into biological lifecycles.
- The bio-based materials space is oversaturated
- New materials must match the exact cost and barrier performance of traditional plastics to fully replace them
- Many companies are focusing heavily on additives and coatings to help bio-materials meet plastic standards.
- **$1B+** total amount raised

Financial Stage Breakdown



Alternative Synthesis Sources and Additives

Cumulative Number of Startups Since 2010



Changing the Source

- Exact same molecules from plants: Bio-PE and Bio-PET.
- These processes using alternative sources can capture ~2 tons of CO2 for every ton produced.
- 100% recyclable in the standard streams.

Challenges

- Lacks the massive production scale needed to compete with global petroleum supply chains.
- Risks pulling vital land and water resources away from the global food supply to grow crops for plastic.
- Requires massive capital for biorefineries, resulting in significantly higher prices for brands compared to fossil fuels.

Startup Spotlight

NatureWorks

ORIGIN

RWDC INDUSTRIES

danimer scientific

NEWLIGHT

PAQUES biomaterials

Alternative Synthesis Sources and Additives

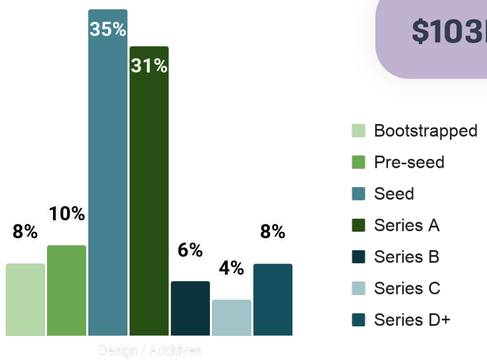
Performance Additives & Coatings

- New dispersion water-based coatings
  - Effective barriers against oil, grease, and oxygen
  - No use of aluminum foil or PFAS.
- Chain extenders
  - Molecular glue to reconnect broken polymer chains
  - Restoring the plastic's original strength.
- Compatibilizers
  - Allow different plastics (PE and PP) to mix and bond together during melting.

Challenges

- Introduces chemical additives that can accidentally pollute standard recycling processes.
- Demands complex, high-energy recovery methods that risk releasing hazardous chemical byproducts.

Financial Stage Breakdown



$103M+ total amount raised

Startup Spotlight

Melodea
RECYCLABLE PACKAGING SOLUTIONS

INTERFACE POLYMERS

KEBOTIX

GRAFT POLYMER
COMBINE INCOMPATIBLE

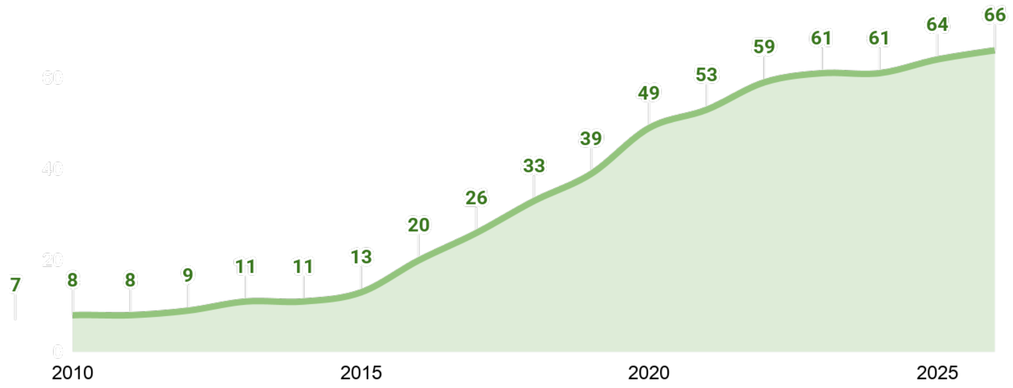
Calyxia

aqdot

BERKM

Advanced Waste Sorting

Cumulative Number of Startups Since 2010



Key Insights

- Uses advanced AI-enhanced robotics to automate sorting of chaotic waste streams.
- Identifies and isolates different plastic types with molecular precision.
- Reaches a 99% purity goal needed to create virgin-quality material.
- Serves as the primary tool to fight and manage stream chaos.
- Drives a hyper-competitive market with startups chasing industry leadership.
- **$230M+** total amount raised.

Startup Spotlight

AMP ROBOTICS

greyparrot

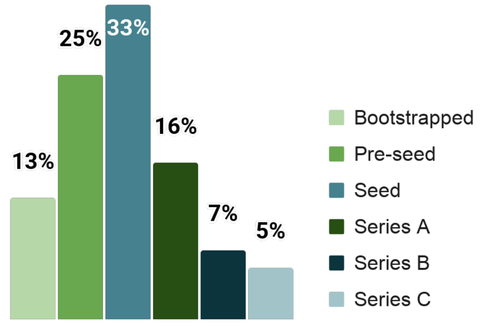
WASTE ROBOTICS

RECYCLEYE

SADAKO TECHNOLOGIES

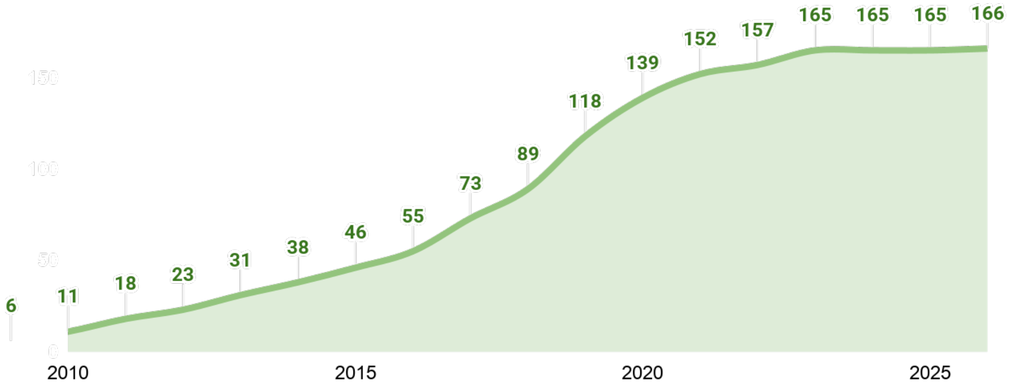
GLACIER

Financial Stage Breakdown



Recycling: Mechanical Recycling Technologies

Cumulative Number of Startups Since 2010



Key Insights

- Transforms plastic waste physically through grinding, washing, separating, drying, thermal processing, and compounding.
- Upcycles recovered resins and granules into materials for the construction and fashion industries.
- Relies on advanced waste sorting as a key driver to unlock better downstream market opportunities.

Challenges

- Degrades in material quality with every single recycling cycle.
- Requires eventual downcycling into lower-value industrial items.
- Exhibits high sensitivity to even minor plastic contamination.
- Risks ruining an entire batch of recycled resin with one wrong plastic type.

Startup Spotlight

BYFUSION

ARQLITESPC

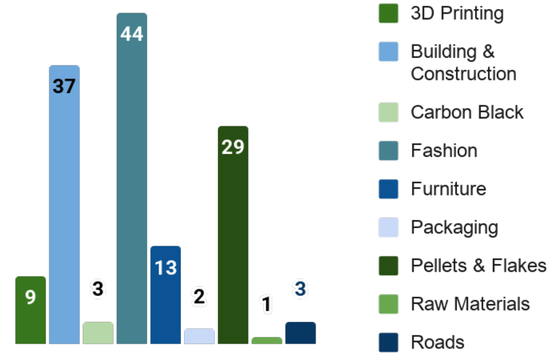
ubq

Fych Technologies

OTHALO

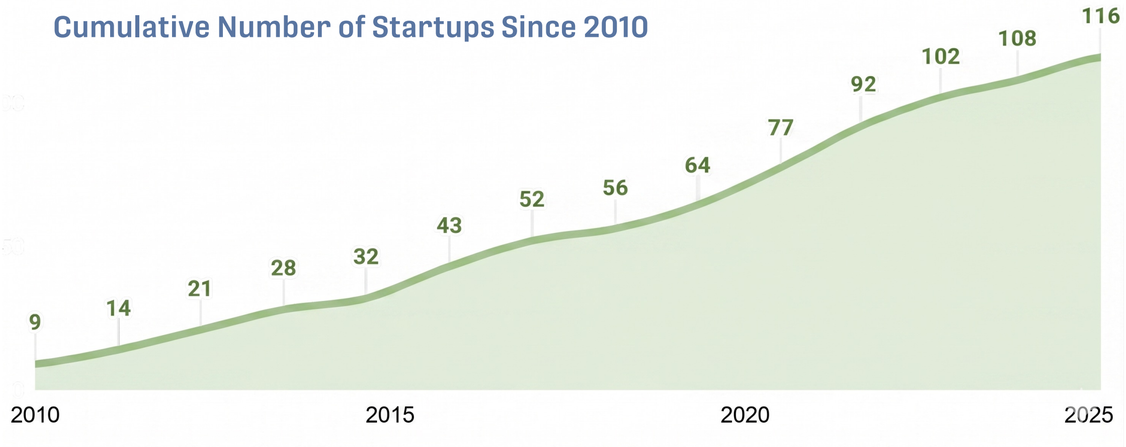
CRDC MATERIALS

End Use Market Breakdown



Recycling: Chemical Recycling Technologies

Cumulative Number of Startups Since 2010



Startup Spotlight

loop INDUSTRIES · PLASTIC ENERGY · agilyx · GR3N · DePoly · PYROWAVE · Resynergi

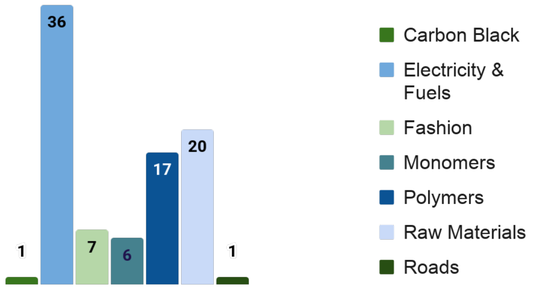
Key Insights

- Breaks plastic waste down to its original chemical components using pyrolysis or solvolysis.
- Converts these components back into raw materials to be repolymerized.
- Erases molecular memory completely to create virgin-quality plastic.
- Relies heavily on advanced waste sorting to succeed.

Challenges

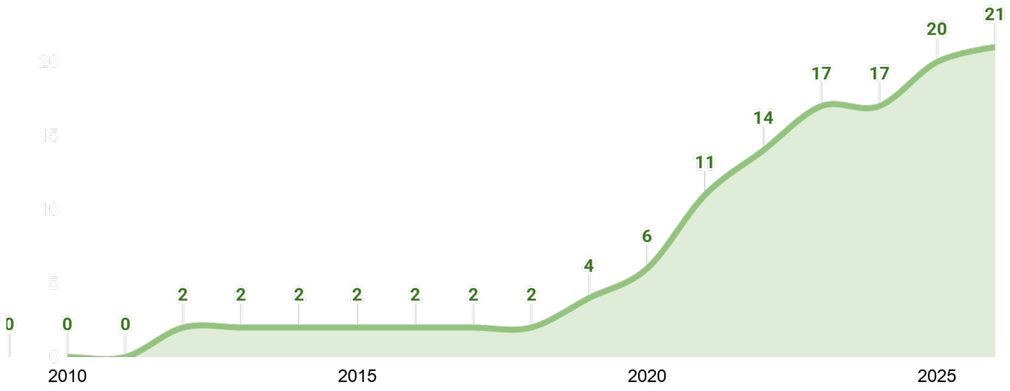
- Requires massive upfront capital costs for both sorting and processing facilities.
- Operates as an inherently energy-intensive recovery process.
- Risks emitting hazardous chemicals during the molecular breakdown phase.

End Use Market Breakdown



Recycling: Biological Recycling Technologies

Cumulative Number of Startups Since 2010



Startup Spotlight

CARBIOS

samsara eco

EPOCH BIODESIGN

enzymity

BIRCH BIOSCIENCES

SCINDO

norbite

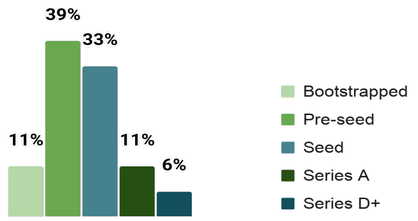
Key Insights

- Uses enzymes to break down plastics with 100% molecular selectivity.
- Turns polymers back into pure monomers, erasing molecular history without extreme heat.
- Attacks only the surface of solid plastic, limiting direct chemical access.
- Requires energy-intensive mechanical pulverization to maximize enzyme contact.

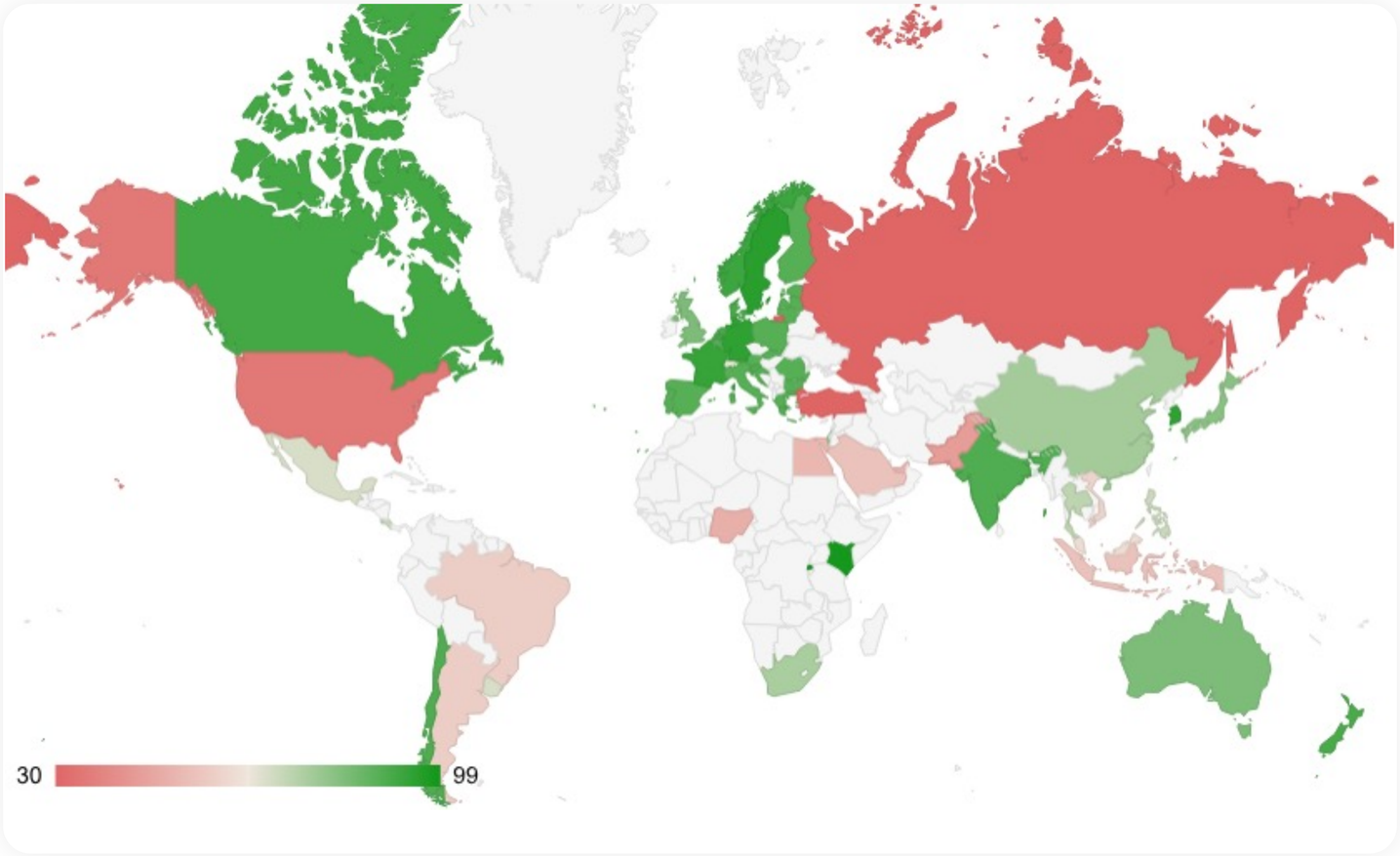
Challenges

- High substrate specificity required.
- Extremely slow reaction times.
- Fragile enzyme stability issues.
- Sensitive to chemical contaminants.
- Expensive enzyme production costs.
- Poor crystalline plastic breakdown.

Financial Stage Breakdown



Single-Use Plastic Regulation: World Landscape



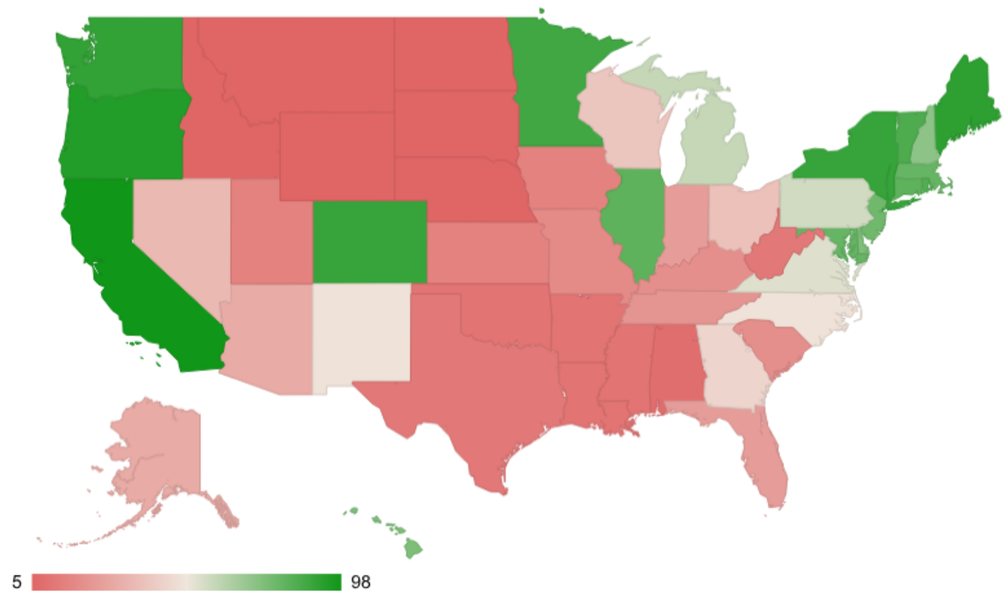
European Union (PPWR 2026):
August mandates harmonize labelling and ban PFAS in packaging.

Asia-Pacific (China & SE Asia):
Mandatory reporting and phased bans on non-degradable delivery plastics.

South America (Chile & Colombia):
Phasing out thirteen specific single-use categories by year-end 2026.

African Strictness (Rwanda & Kenya):
Exceptional enforcement includes confiscations at borders and potential jail time.

Single-Use Plastic Regulation: US Landscape



- CA, OR, ME, CO, MN, MD, and WA have enacted Extended Producer Responsibility (EPR) laws, forcing manufacturers to fund the entire lifecycle of their packaging.
- CA's Landmark Mandates: Effective January 1, 2026, SB 1053 eliminates grocery checkout loopholes; SB 343 prohibits the recycling symbol on non-recyclable items.
- States like IL and ME enforced 2026 bans on PFAS in food packaging, while states like FL and TX legally block local municipalities from passing plastic bans.

Key Takeaways

The original linear model of plastic production was revolutionary for its time, but its exponential growth has created a global entropy crisis. Future industry dominance belongs to materials that maintain low-entropy states (reuse) or technologies capable of a total molecular reset.

Emerging technologies in bio-based feedstocks and performance additives are actively working to transition these alternatives from niche innovations to industry standards.

Technical and financial limitations often cause promising startups to stall at the seed stage, as the capital required for industrial scaling remains a significant barrier to long-term success.

Future breakthroughs will rely on the strategic integration of advanced mechanical sorting, chemical depolymerization, and biological recycling to manage increasingly complex packaging waste streams. These processes bypass the degradation limits.

As of 2026, global regulations like the EU's PPWR and expanded producer responsibility laws have moved sustainability from a voluntary brand goal to a mandatory legal and operational requirement.