Overview of bio-based plastics

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Grey to Green
Sustainable Solutions

Alternatives to single-use

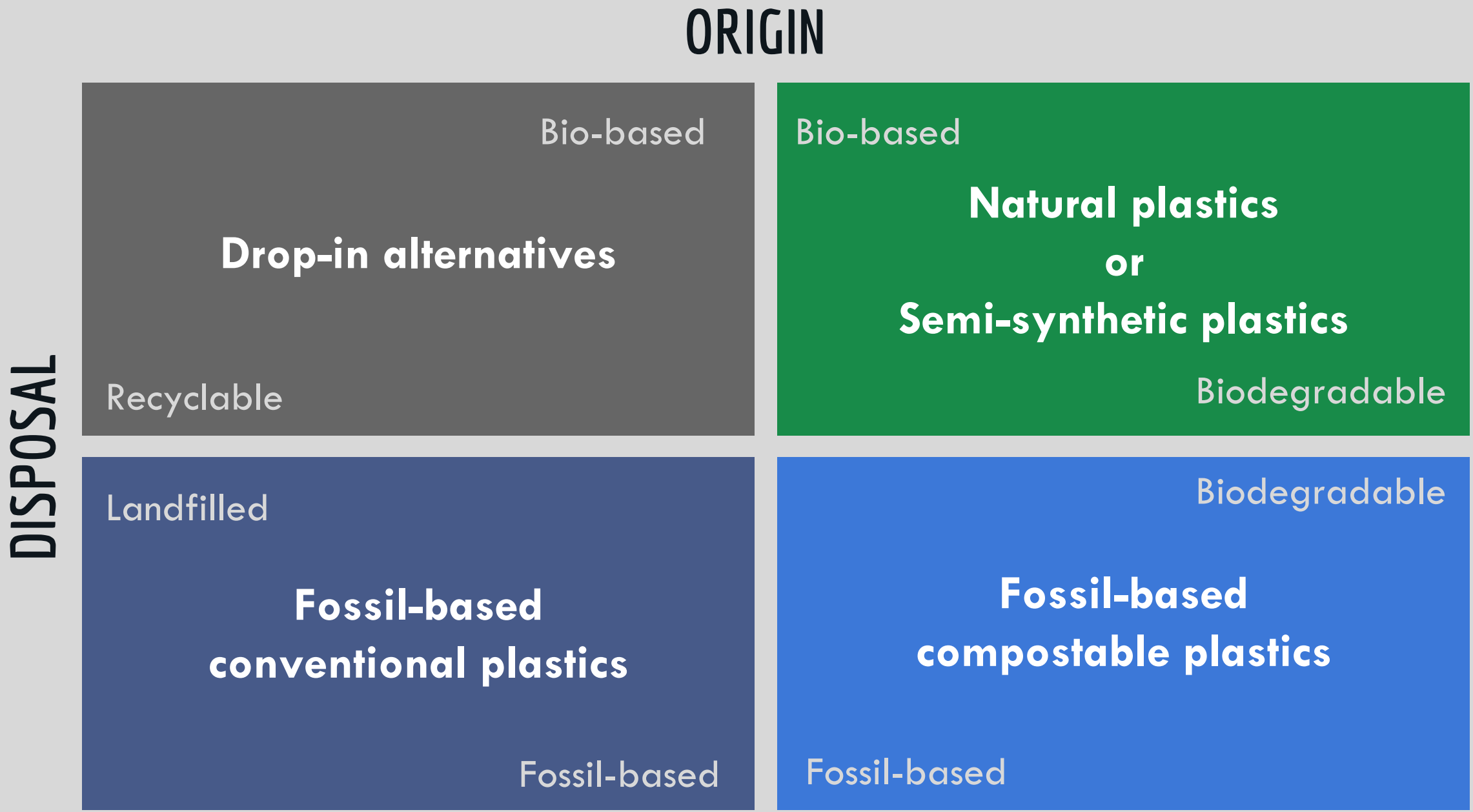
- Avoiding disposable items
- Re-usables are always the more sustainable option

“Bio-based” vs. “Biodegradable”

‘**Bio-based**’ = **origin** of the plastic
‘**Biodegradable**’ = **breakdown** of the plastic

A plastic being **fossil- or bio-based**,
does **not** determine if it’s biodegradable

No North American certification standards for bio-based products


ORIGIN
DISPOSAL
Bio-based
Drop-in alternatives
Recyclable
Bio-based
Natural plastics
or
Semi-synthetic plastics
Biodegradable
Landfilled
Fossil-based
conventional plastics
Fossil-based
Biodegradable
Fossil-based
compostable plastics
Fossil-based

Important properties for packaging

Ideal

Ok

Not ideal

End-of-life options

Biodegradation

Recyclability

Barrier properties

CO_2 O_2 H_2O

Impermeable

Permeable

Mechanical properties

Tensile Strength

Elasticity

Cost

Low cost: < $1 per lb

High cost: > $5 per lb

Environment impact

GHG potential

Energy use

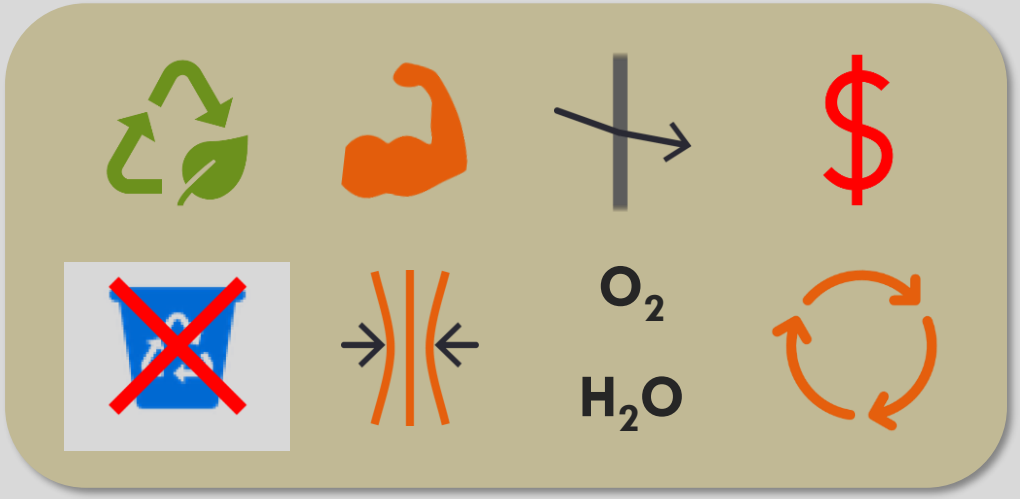
Ease of processing

Natural polymers

Found in nature

Cellulose and its' esters

- Paper packaging
- Cellulose is the most widely spread natural polymer and is derived by a delignification from wood pulp or cotton linters.
- Cellulose esters can be processed by injection molding or extrusion



Used mostly in rigid containers or cellulose esters in films

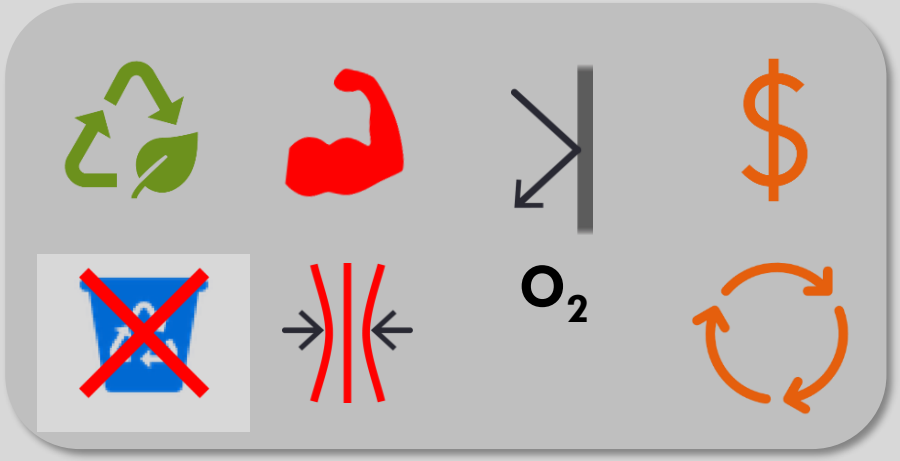
- Paper straw
- Bowls, clamshells, boxes, trays, plates
- Sealable films for packaging vegetables, bakery, cheese

Used mostly for more flexible films

- Trash bags, shopping bags

Thermoplastic starch (**TPS**), **starch blends** and **plant-fibre blends**

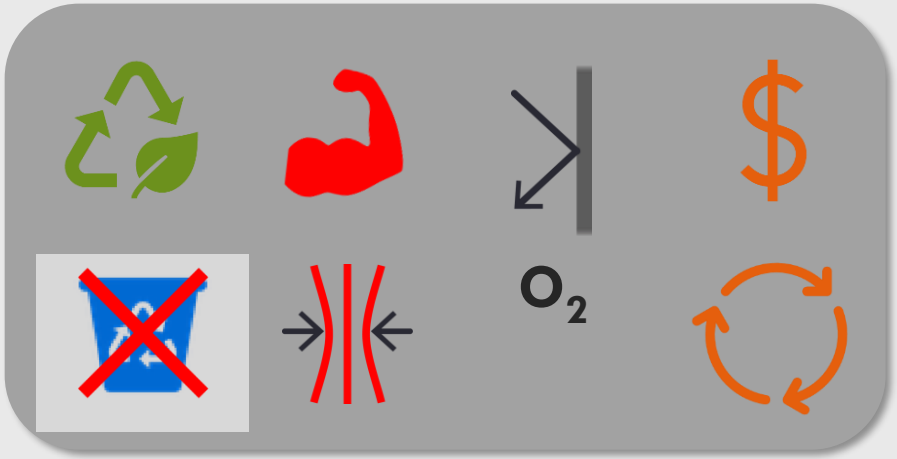
- Starch extracted from potatoes, wheat, corn and rice
- High water content or plasticizers needed to produce a plastic-like film
- Moisture-sensitive and brittle



Natural plastics

Zein = corn protein:
Brittle, edible

Chitosan = made from chitin (shellfish):
Water sensitive, potential allergen

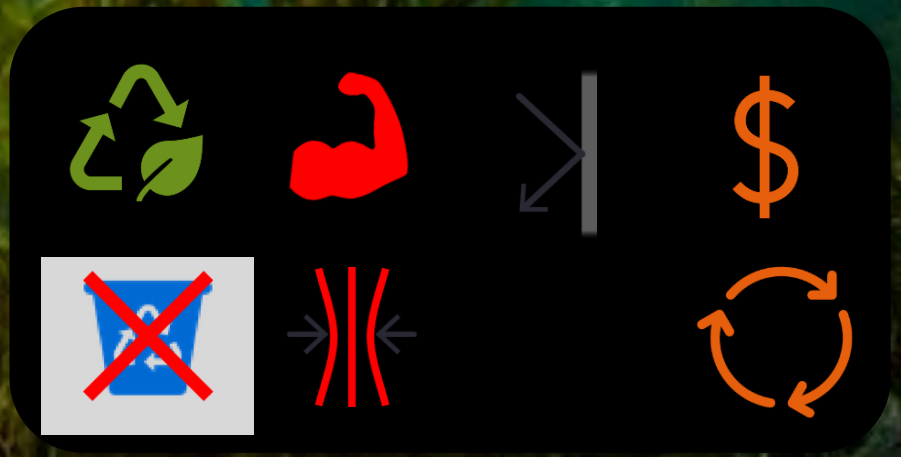


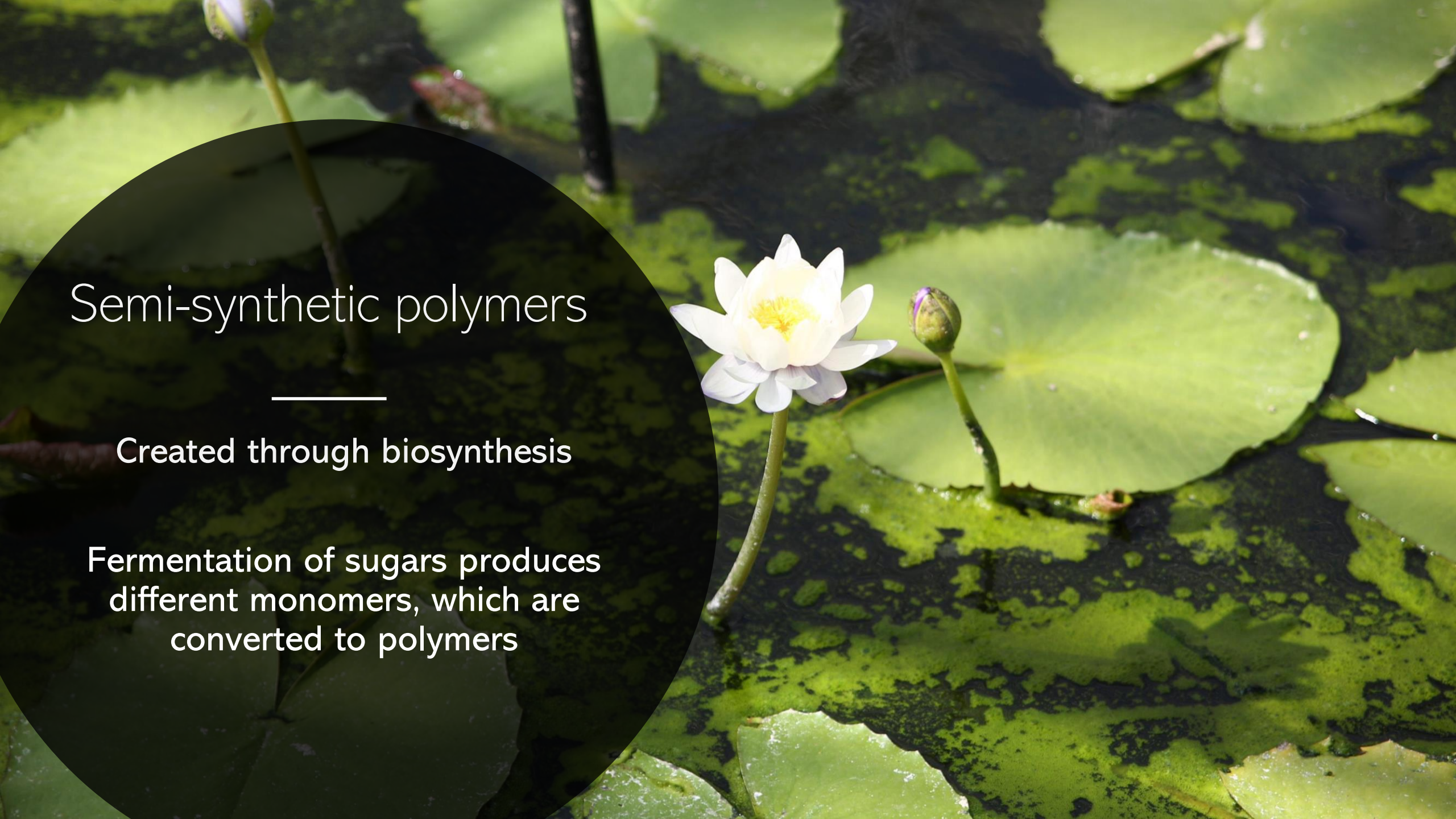
Alginate

Made from brown algae

Specific species farmed in ponds

Moisture sensitive and brittle





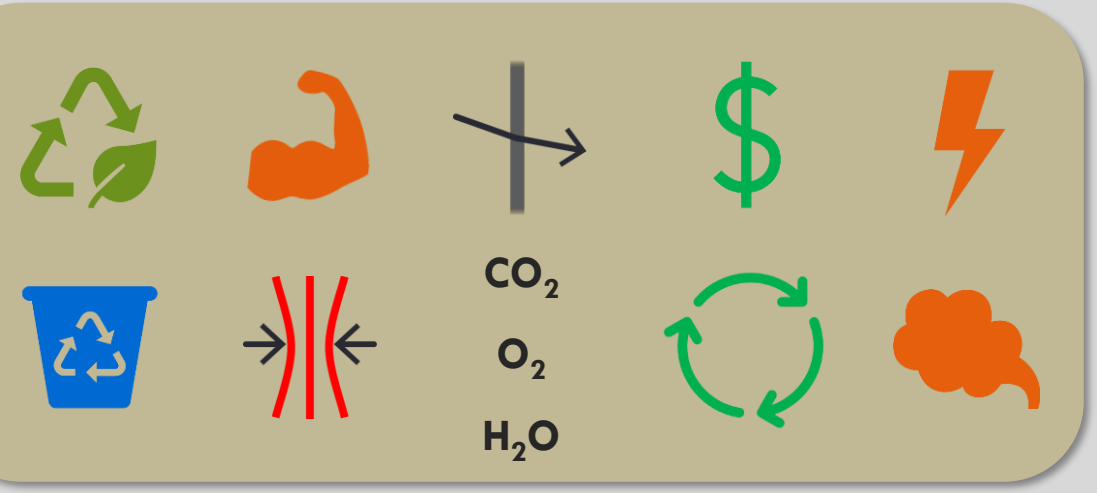
Semi-synthetic polymers

Created through biosynthesis

Fermentation of sugars produces different monomers, which are converted to polymers

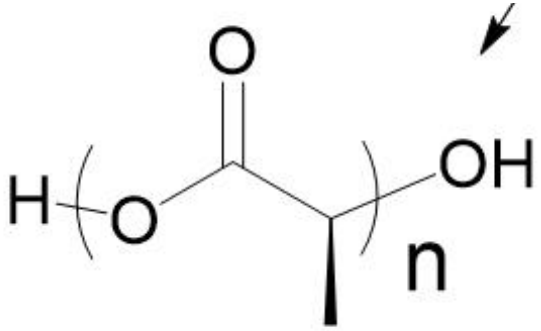
PLA = Poly(lactic acid)

- Most well known compostable plastic
- Promising substitute for PE, PS and PET
- Can be shaped using injection molding, extrusion, blow molding & thermoforming
- Can be transparent

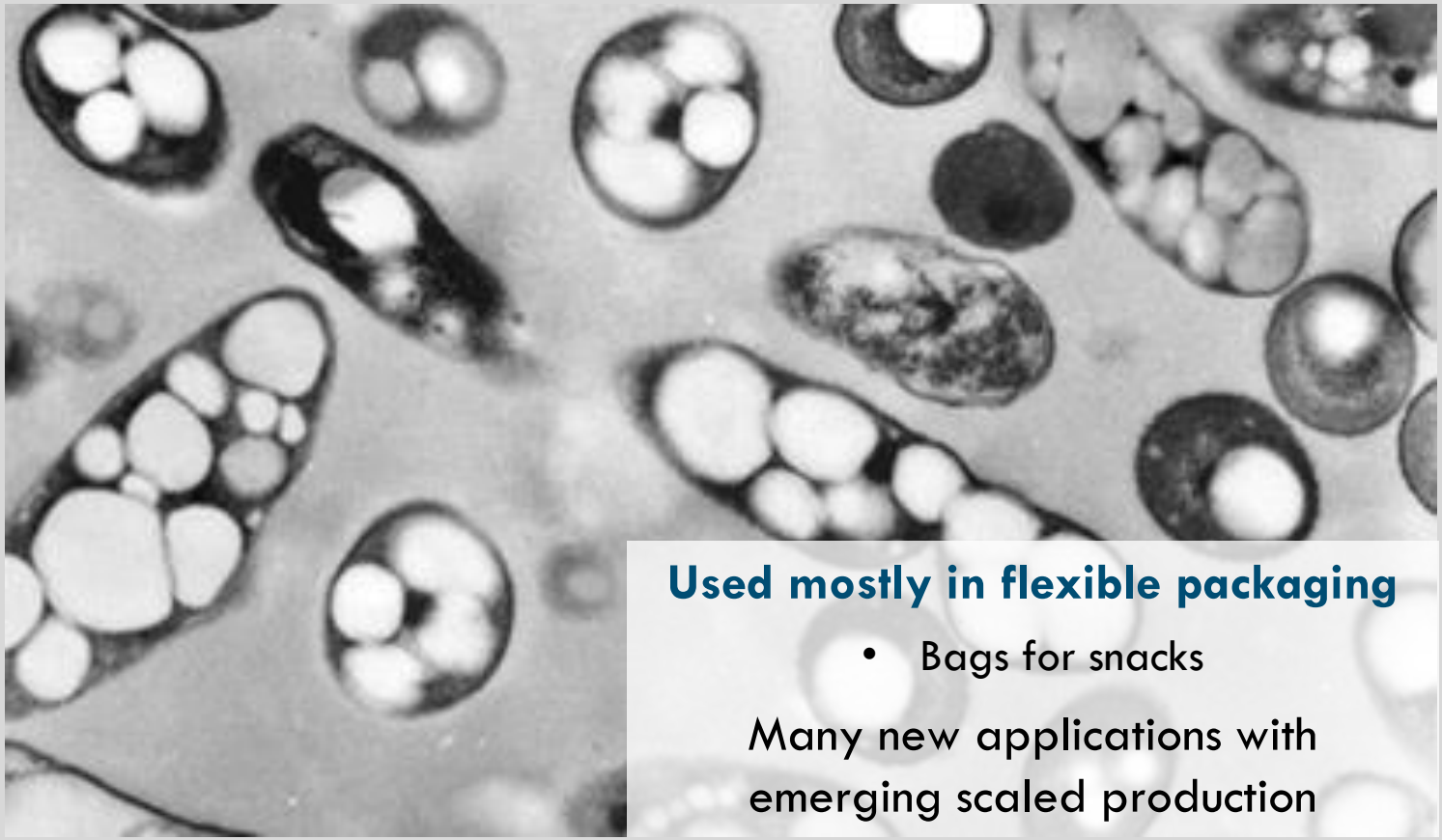


Used mostly in rigid containers for more durable packaging

- Salad bowl, deli container, clamshell, cup, sushi tray, herb tray, berry box
- Lining in cups for hot drinks
- Rigid film for thermoforming, flexible film for packaging
- Compostable utensils (high heat)



poly(lactide)



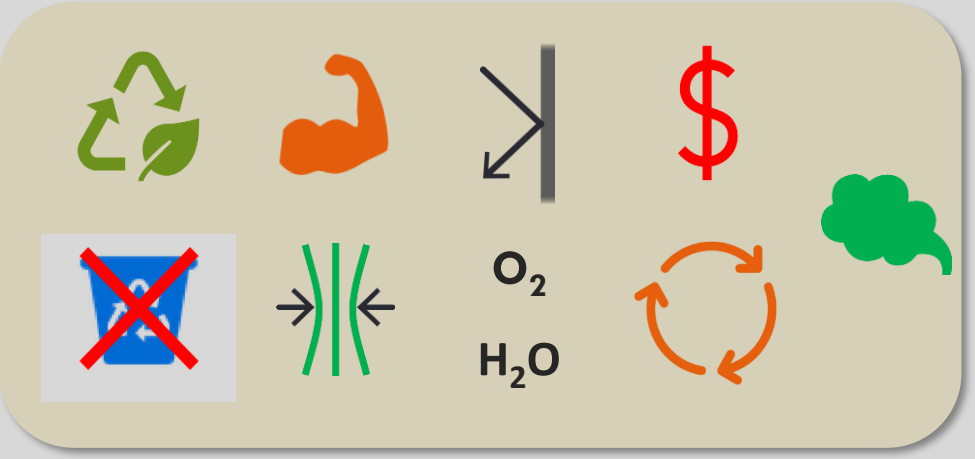
Used mostly in flexible packaging

- Bags for snacks

Many new applications with emerging scaled production

- Thermoplastic bacterial polyesters
- Polymer is produced in the microbial cells through fermentation then harvested
- Waste streams such as used frying oil, discarded food, agricultural wastes, domestic wastewater, glycerol from biodiesel production and landfill gas have been used as free or low-cost fermentation substrates to produce PHA's
- Over 100 different varieties have been developed

Polyhydroxyalkanoates = PHA's



Used in same applications as fossil-based products

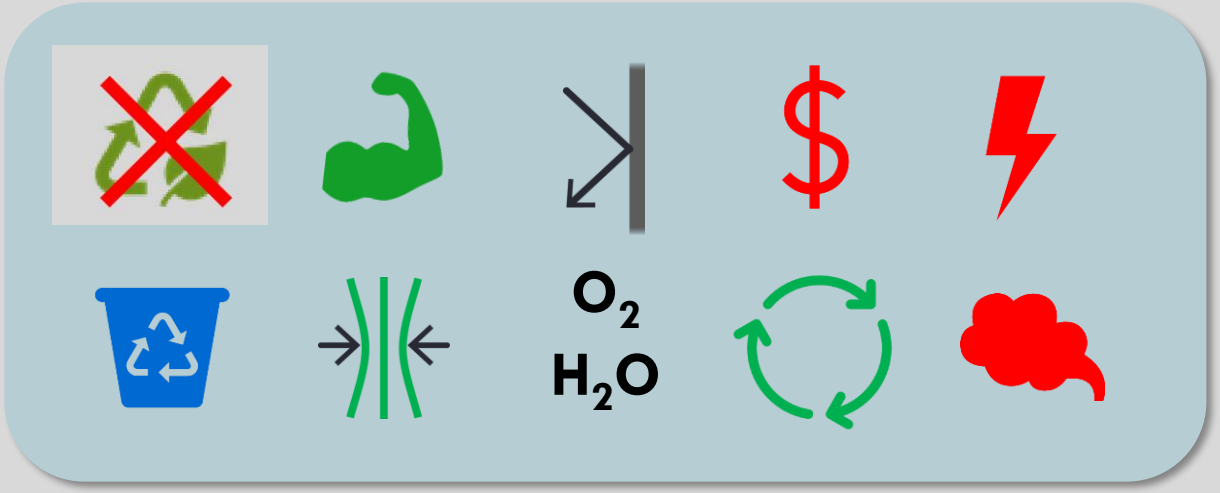
- Beverage, condiment bottles
- Film, bottles, coated paper, zipper bags

Bio-based "drop-in" plastics

Glucose → Ethanol → Ethylene → Ethylene glycol

- Ethylene → **Bio-PE**
- Ethylene glycol → **Bio-PET**

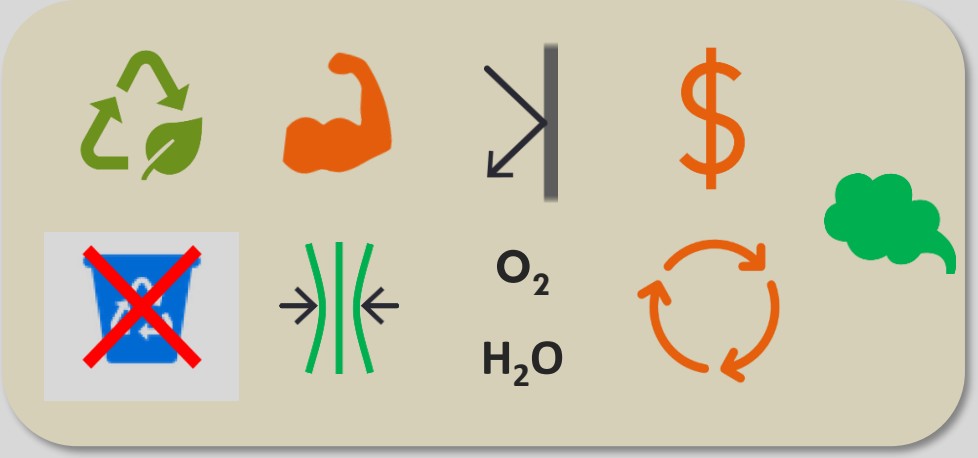
- Same chemical and physical properties as fossil-based plastic



Fossil-based, compostable plastics

PBS = polybutylene succinate
Fossil based w/ high strength

PBAT = polybutylene adipate terephthalate
Industrially compostable w/ high strength

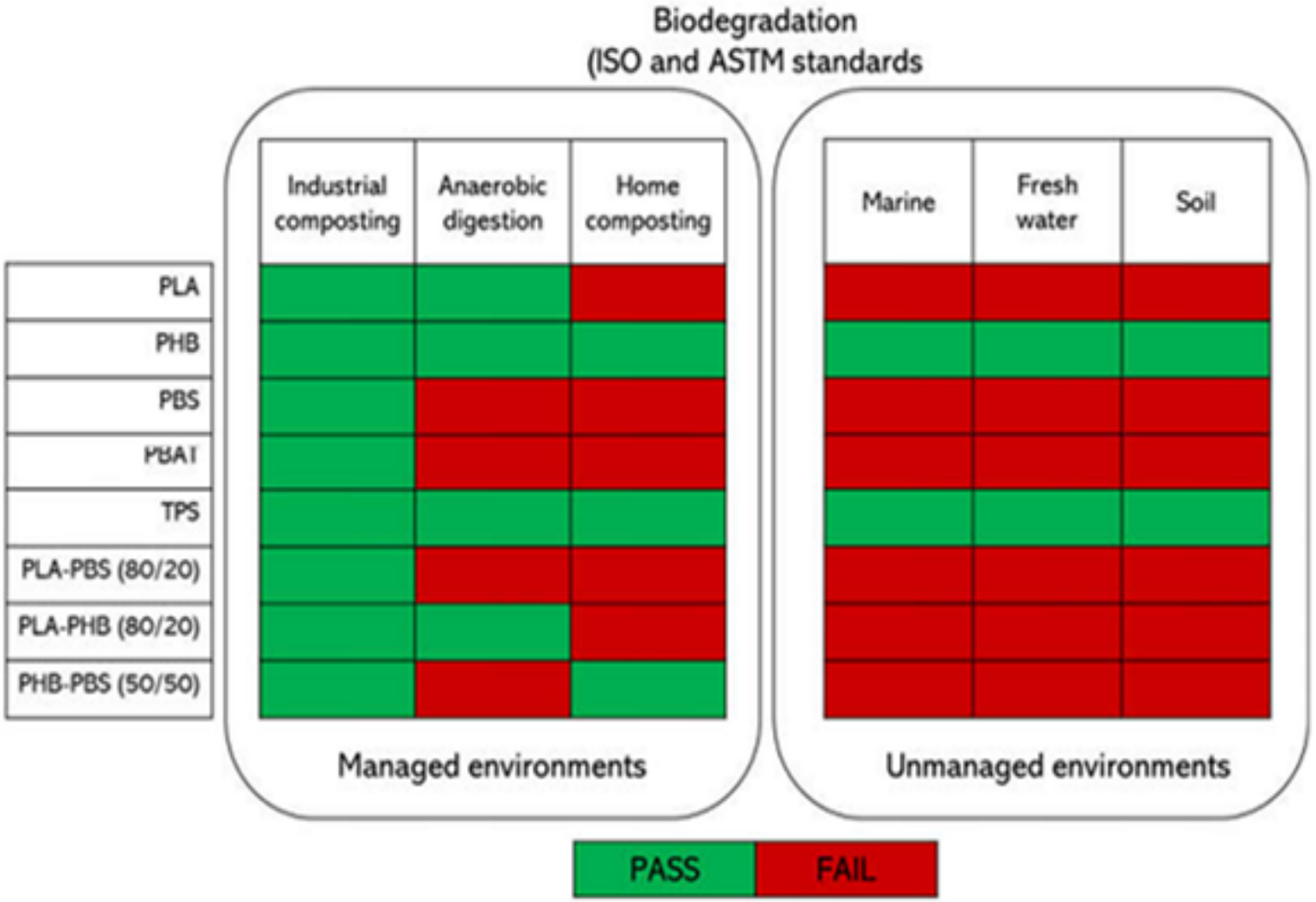


FEEDSTOCK

END-OF-LIFE

Bio-based **bio-PE, bio-PET** **PLA** Recyclable	Bio-based **Cellulose, chitosan, corn zein, algae, plant- fiber blends, starch blends** **PLA, TPS, PHAs, bio-PBS** Biodegradable
Landfilled **Conventional plastics** Fossil-based	Biodegradable **PBAT, PBS** Fossil-based

Biodegradation Comparisons



R. Shogren, D. Wood, W. Orts, G. Glenn "Plant-based materials and transitioning to a circular economy" Sustainable Production and Consumption 19 (2019) 194–215

“Biodegradable” vs. “Oxo-degradable” vs. “Compostable”

‘A material **degraded by the action of microorganisms** and ultimately converted to water, carbon dioxide and/or methane and new bacterial biomass.

Conventional plastics such as polyethylene (PE) which include an **additive designed to help them** break down and **fragment**

Certified compostable products, breakdown under specific conditions in specific time frames.

Standardized tests vs. Certifications

Standardized test method - general measure of compost biodegradation, designed to yield **reproducible and repeatable test results**

Certifications **verify** that products and packaging have been **independently tested** according to scientifically based standards

There are **many standardized tests** in this space, but in North America **only industrial composting certifications** are available.

Industrial Compost Certifications

COMPOSTABLE

Biodegradable Products Institute | US COMPOSTING COUNCIL

BPI COMPOSTABLE

COMMERCIALLY COMPOSTABLE ONLY. FACILITIES MAY NOT EXIST IN YOUR AREA. CERT #0000000

INDUSTRIAL COMPOSTABLE DIN Geprüft

COMPOSTABLE www.compostable.info

Only available to **food service items, food packaging** and **yard waste products**

Industrial Compost Certifications

COMPOSTABLE

Biodegradable Products Institute | US COMPOSTING COUNCIL

- 90% disintegration within **12 weeks**
- 90% conversion to CO_2 within **26 weeks**
- **Heavy metal** and **PFA** analysis
- **Plant germination** toxicity
- **Soil invertebrate** toxicity

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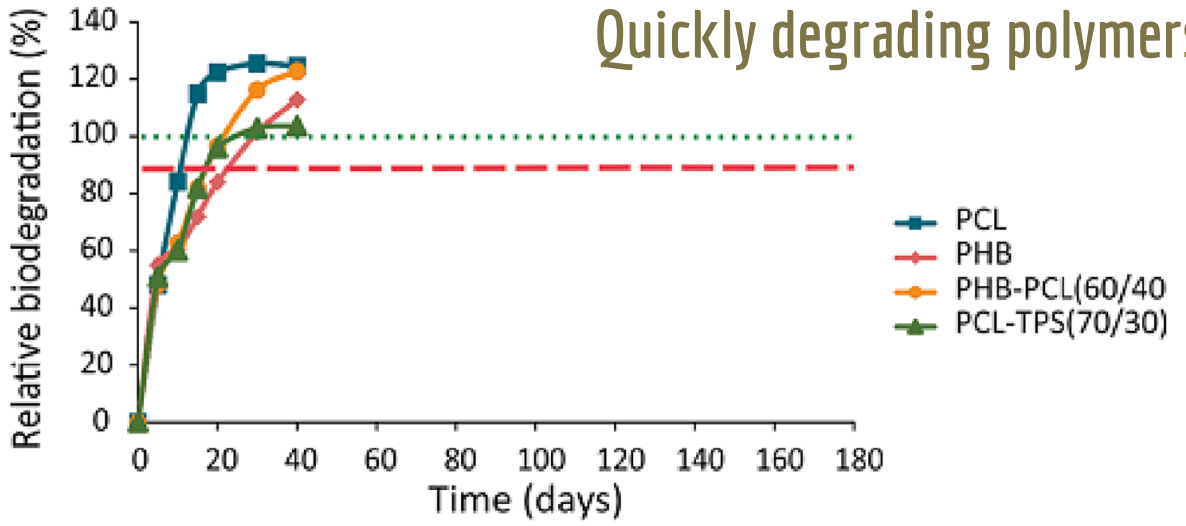
However, industrial composting plant have:

- an **active phase** for **3-6 weeks**
- **post-composting stabilization** for **8-12 weeks**

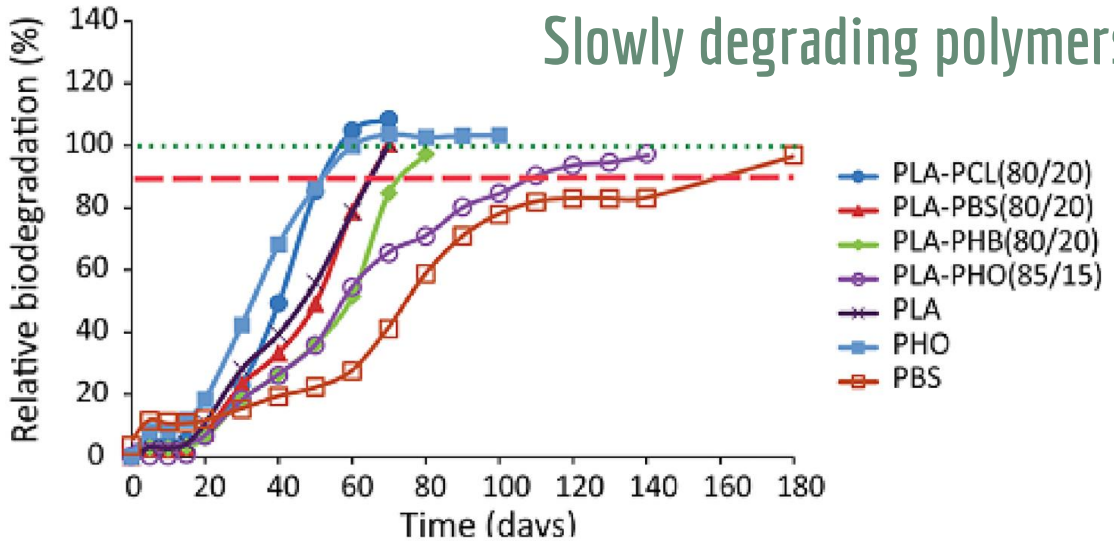
Pass/Fail Certifications*

**No indication of how fast products will break down*

Quickly degrading polymers



Slowly degrading polymers

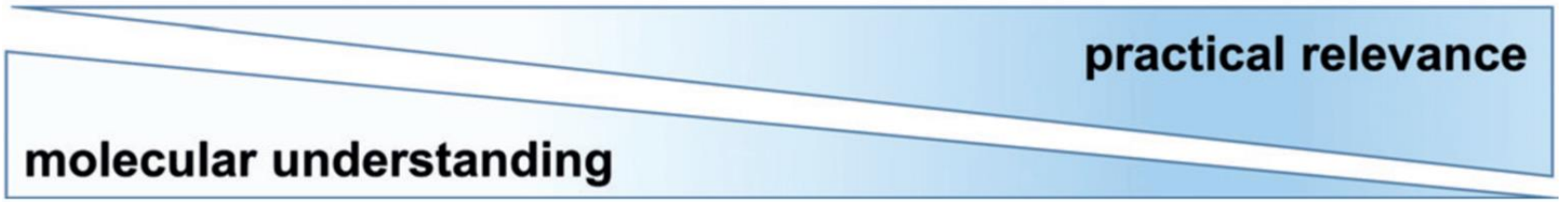


Narancic, T.; Verstichel, S.; Reddy Chaganti, S.; Morales-Gamez, L.; Kenny, S. T.; De Wilde, B.; Babu Padamati, R.; O'Connor, K. E., Biodegradable Plastic Blends Create New Possibilities for End-of-Life Management of Plastics but They Are Not a Panacea for Plastic Pollution. *Environmental Science & Technology* **2018**, *52* (18), 10441-10452

How viable are laboratory tests?

Laboratory tests should be coupled with field tests

	TESTING CONDITIONS	
Mature compost		Food waste, yard waste
Individual components		Whole product
Optimal temp. and humidity		Fluctuating temp. and humidity
Simplified environment		Complex environment
Ideal conditions for biodegradation		Variable conditions for biodegradation



Haider, T.; Völker, C.; Kramm, J.; Landfester, K.; Wurm, F. R., Plastics of the future? The impact of biodegradable polymers on the environment and on society. *Angewandte Chemie International Edition* 2019, (58), 50-62.

Field test performance

Compost Manufacturing Alliance:

Testing to determine the breakdown of products using modern, large-scale compost manufacturing technologies

Adding compostable food service packaging **(FSP)**:

- **No effect** on the **biochemistry or nutrient value** of finished compost
- Acts as a **bulking agent** similar to wood
- **Active composting often extended** beyond typical operational time-frames; stringent **pile management implemented**

Table 3. Main characteristics of some biodegradable materials.

Material	C/N ratio	Moisture content (%)	Structure
Optimum value	***20 – 30***	***45 – 55***	***Loose for air access***
Grass	12 – 20	80 – 90	Poor
Food, vegetable waste	12 – 25	70 – 90	Poor
Leaves	30 – 60	40 – 50	Average
Tree and bush clip-pings	100 – 150	Moist to dry	Good
Paper/paperboard	200 – 400	5 – 20	Average
Biopolymers	> 100	0 – 20	Average

Compost Manufacturing Alliance https://compostmanufacturingalliance.com/

Foodservice Packaging Institute and Biodegradable Products Institute, " Field Study: Foodservice Packaging as Compost Facility Feedstock." 2018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Sustainable Solutions
Questions? Queries? Quandaries?
Dr. Love-Ese Chile
GreyToGreenSolutions.com
LoveEseChile.com
If the future can be positive, why choose differently?
- Michael Braungart, Cradle to Cradle Design