

# Feasibility of Replacing Synthetic Plastics with Biopolymers

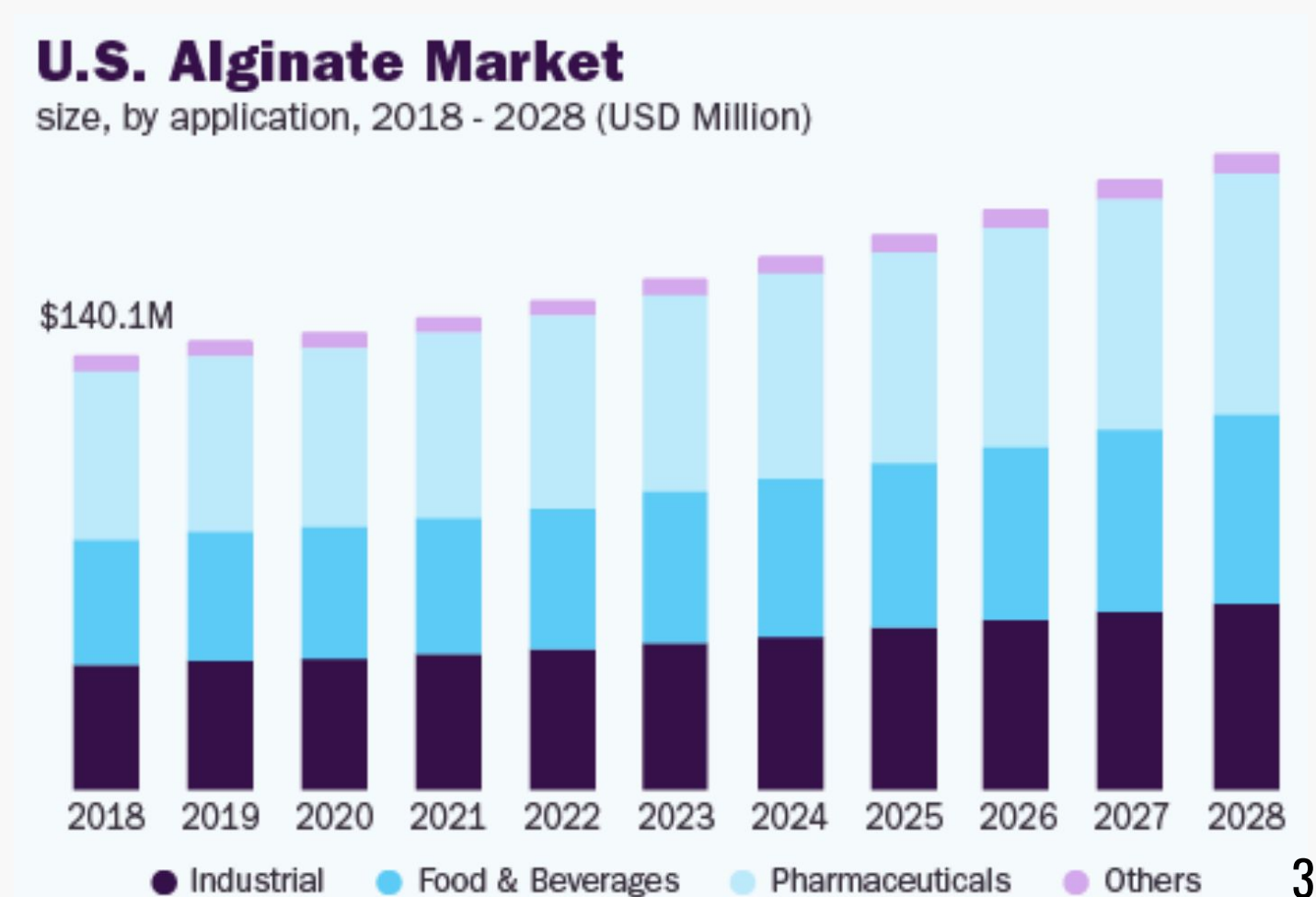
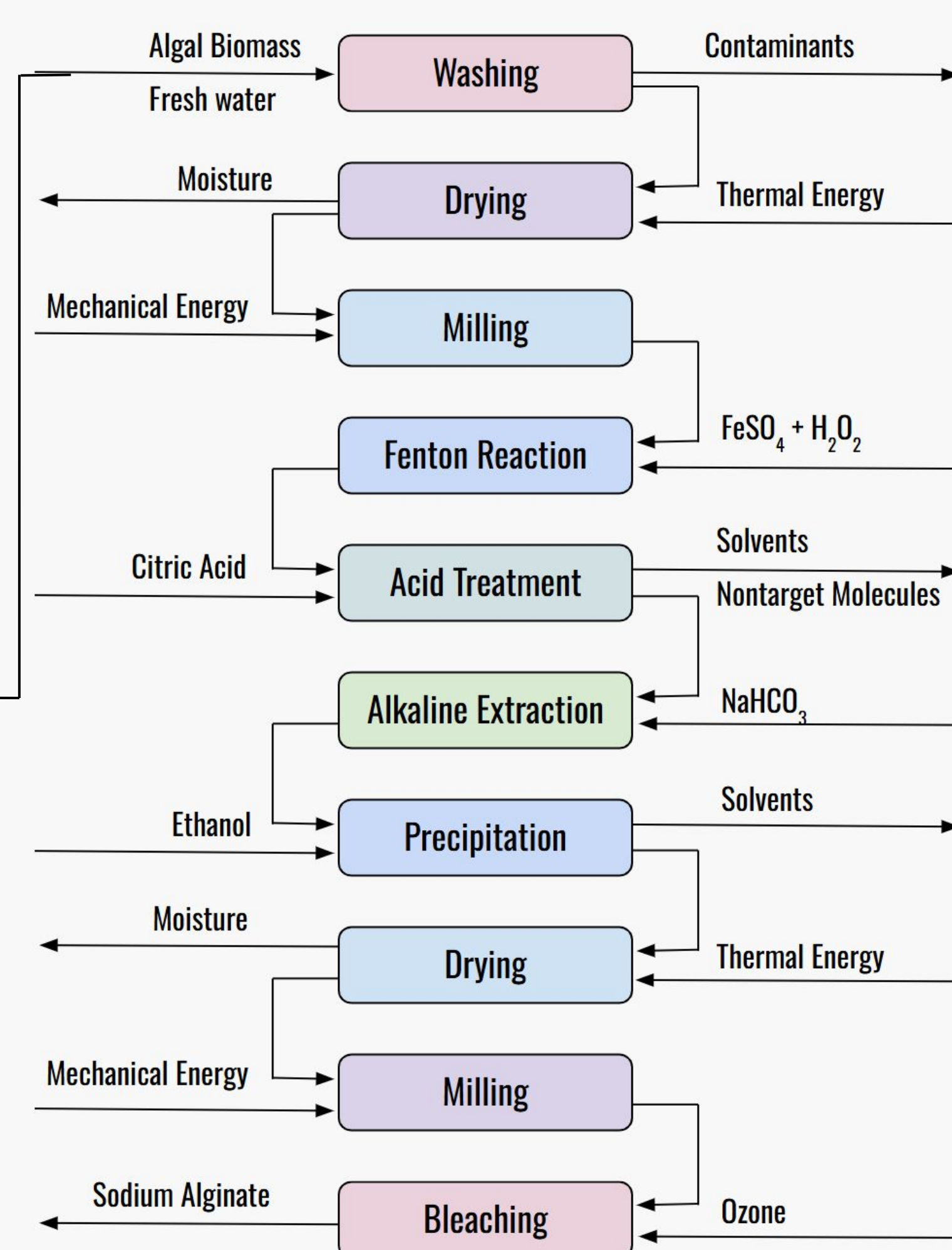
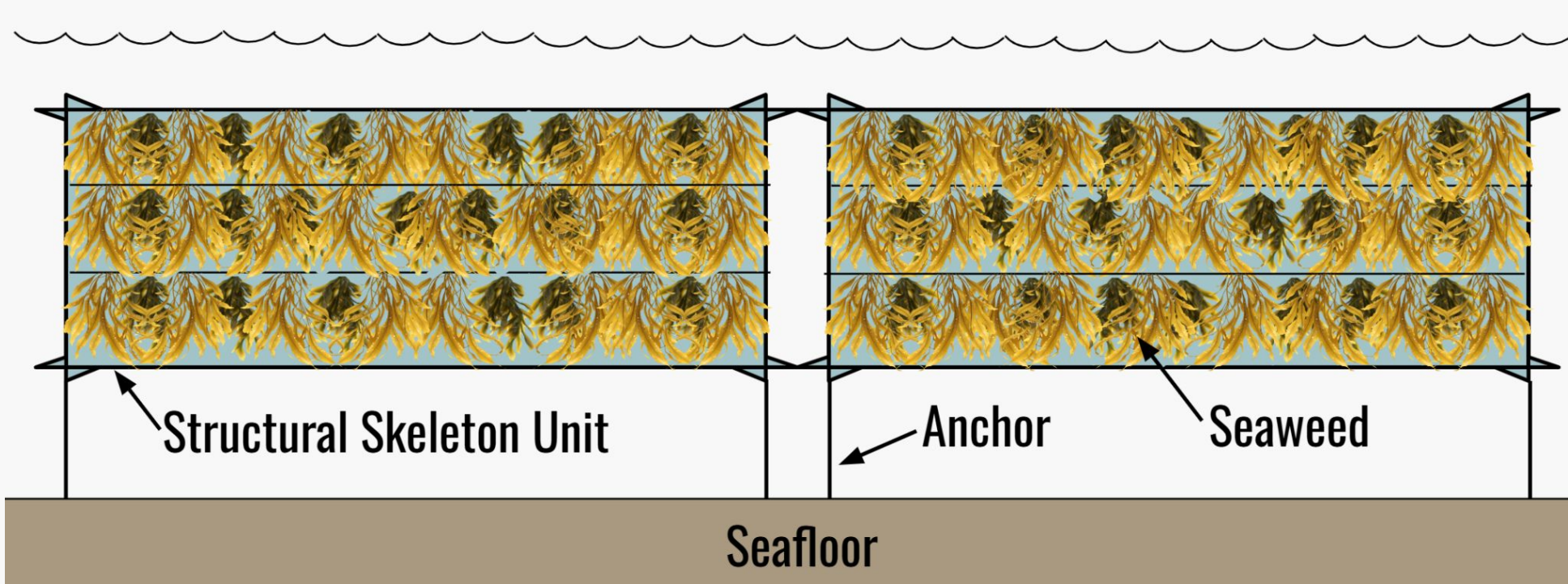
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## Project Goal and Motivation

- Synthetic plastics are non-biodegradable, turning into microplastics and causing environmental harm after disposal. Petrochemical feedstocks used pose additional threats global health.
- Biodegradable biopolymers produced from sustainably sourced plant/microorganism feedstocks present a possible solution to plastic pollution.
- The project goal is to evaluate the feasibility of replacing synthetic plastics with 2 different biopolymers: alginate and polyhydroxyalkanoates (PHAs). The aim is to evaluate the end-of-life value of these biopolymers and compare with synthetic plastics.

## Alginate: Algae-Derived Biopolymer

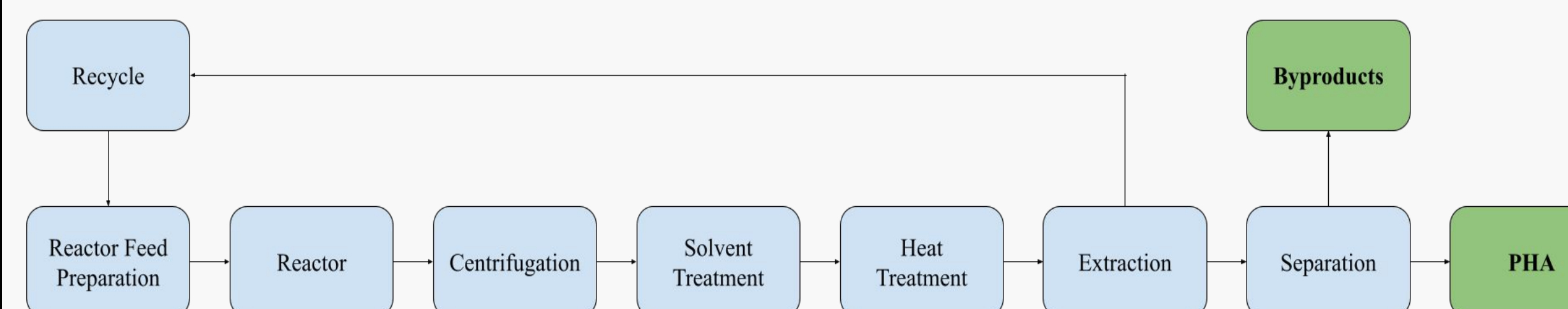
- Currently used in **food, medical, and cosmetic** fields: material properties suitable for replacing some petrochemical products
  - Packaging
  - Gels
  - Antioxidant Coatings
- Feedstock: ocean-farmed algae, especially brown macroalgae, grown in carbon-negative operations



- Production costs (\$/kg) with current technology:
  - Alginate: 7.66
  - Polyethylene: 1.20
  - Polypropylene: 1.30
- Currently viable for high value or low volume uses
  - Wound dressings
  - Food thickening agent
- Low value/high volume uses could reach viability with lower production costs
  - Biodegradable packaging
  - Edible protective films
- Trends show industry growth

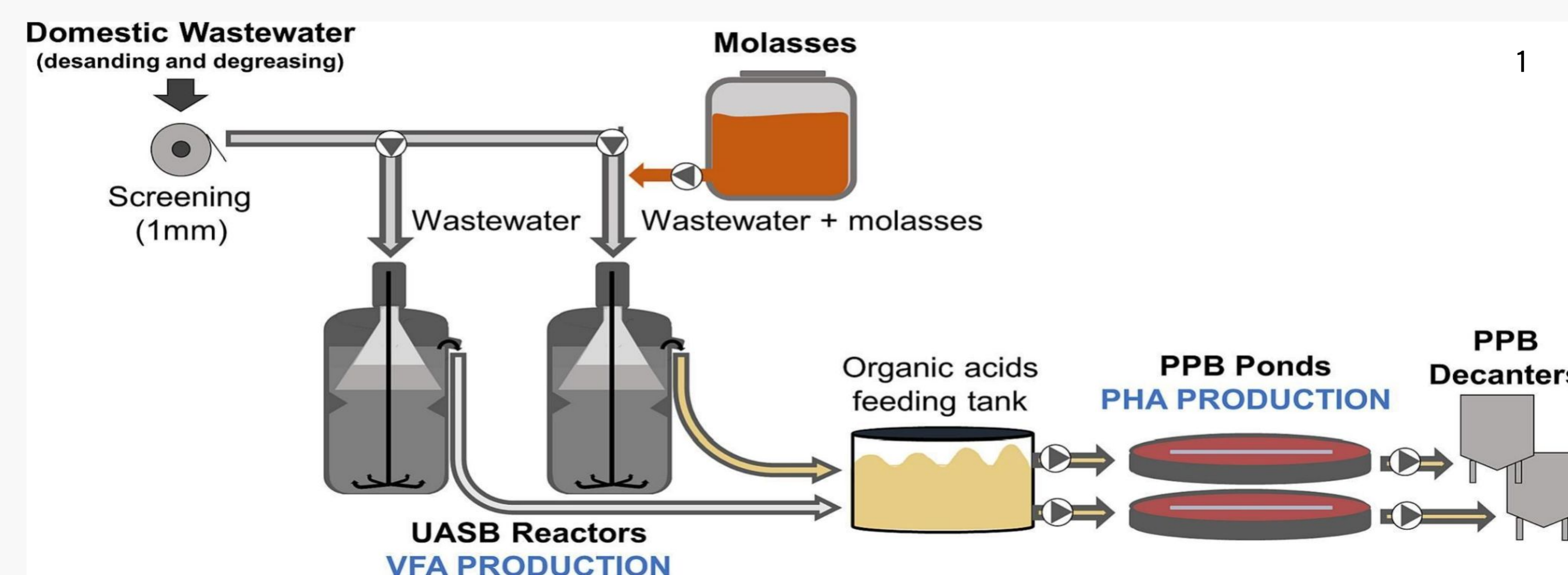
## PHAs: Bacterial Fermentation Product

### Bacterial Fermentation BFD



- PHAs have been used in various ways, such as filaments and bottles
- Tunable properties make PHAs highly a promising carbon-negative polymer

### High-Rate Algal Pond PFD



Mechanical Property	P3HB	PP	PET	LDPE	HDPE	PLLA	PDLLA 1
Tensile modulus (GPa)	3-3.5	1.95	9.35	0.26-0.5	0.5-1.1	2.7-4.14	1-3.45
Tensile Strength (MPa)	20-40	31-45	62	30	30-40	15.5-150	27.6-50
Elongation at break (%)	5-10	50-145	230	200-600	500-700	20-30	1.5-20
Degree of Crystallinity (%)	50-60	42.6-58.1	7.97	25-50	60-80	13.94	3.5
Melting Temperature (°C)	165-175	160-169.1	260	115	135	170-200	amorphous
Glass Transition Temperature (°C)	5-9	-20--5	67-81	-130-100	-130-100	50-60	50-60

- Similar properties to many common polymers
- 500,000 gallon feedstock loses \$120 million yearly
  - \$233 million cost
  - \$112 million revenue

## Conclusions

- Alginate and PHAs have material properties which make them good candidates for replacing certain petrochemical plastics.
- More development is needed before these polymers can be economically produced at large enough scale to replace a significant portion of petrochemical plastic consumption.
  - PHAs rely on bacterial fermentation which incurs high operational costs, and so cannot reach economic viability without significant improvements in fermentation technologies.
  - Alginate is currently viable for mid-sized production for high-value products, economies of scale cannot yet support a sale price competitive with petrochemical plastics for low-value products.

## References

1) Almeida et al., *Sci. Total Environ.* **2024**, 912, 168899  
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 3) Grand View Research. (2021). *Alginate market size, share & trends analysis report by product, by application, by region, and segment forecasts, 2021-2028*. <https://www.grandviewresearch.com/industry-analysis/alginate-market>