

BIOBASED DIOLS AND DIACIDS

ED DE JONG 10 MARCH 2025

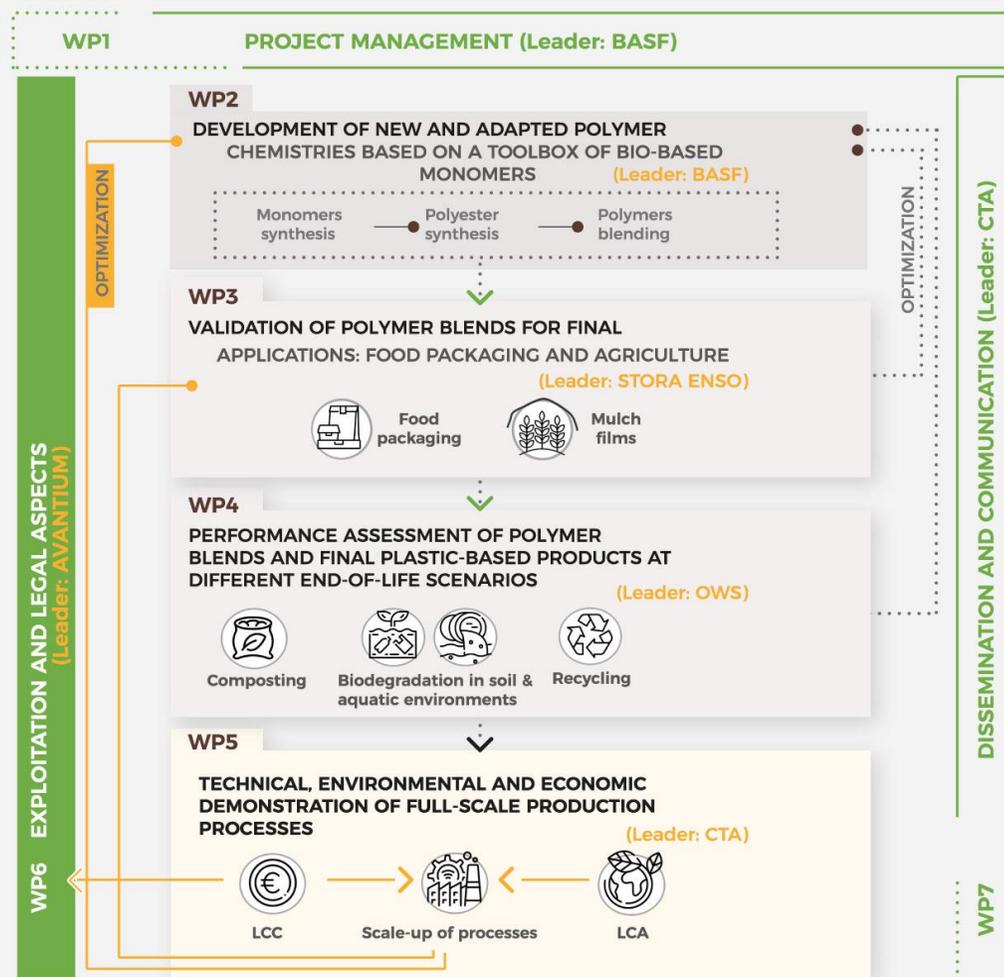


REBIO?TION

REBIOLUTION - 101082040

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REBIOLUTION PROJECT



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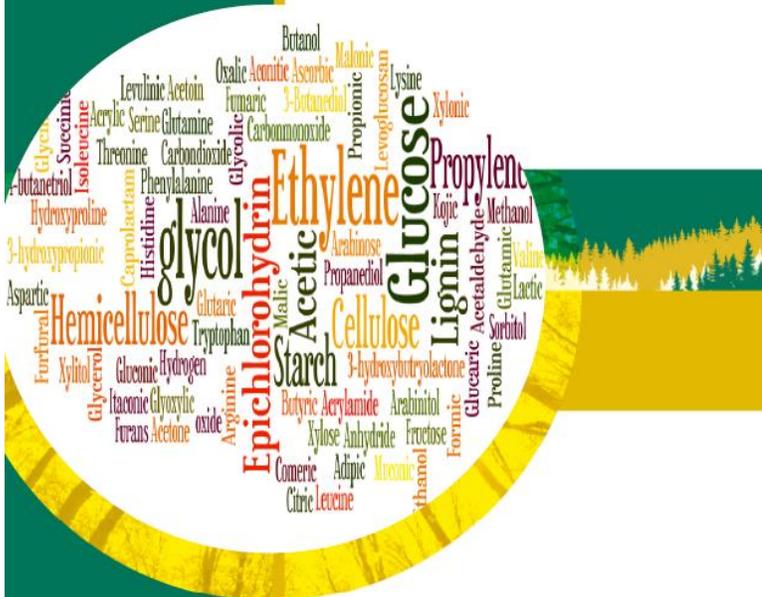
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STATUS OF BIOBASED CHEMICALS, A 2020 UPDATE

IEA BIOENERGY T42

Technology Collaboration Programme
by IEA

Bio-Based Chemicals A 2020 Update



This report was issued on behalf of IEA Bioenergy Task 42 BioRefining in a Circular Economy. It addresses the main bio-based chemicals that could potentially be co-produced with secondary energy carriers in integrated biorefinery facilities. It is an update of the 2011 report.

IEA Bioenergy

IEA Bioenergy: Task 42: 2020: 01

Overview of market size and commercialization potential of biobased chemicals

<https://task42.ieabioenergy.com/publications/bio-based-chemicals-a-2020-update/>

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WHY PRODUCING BIOBASED CHEMICALS (IN CONJUNCTION WITH BIOENERGY) IN A BIOREFINERY

- To supply the market with sustainable/renewable chemicals
- To improve the economics of bioenergy production
- To partly make use of existing industrial (energy) infrastructure potentially decreasing initial investments and shorten time-to-market
- To make scaling up easier (makes plant already commercial viable at smaller scales)
- Unique functionality
- Medium term CO₂ storage (depending on chemical)
- Reduction of non renewable energy usage (NREU) usage (both because of renewable product and less fossil fuel used in production)

MARKET SIZE IN 2020

Fossil based Chemicals:

>330 million tonnes

Main molecules:

methanol, ethylene, propylene, butadiene, benzene, toluene and xylene

Biobased Chemicals & derived Materials:

90 million tonnes

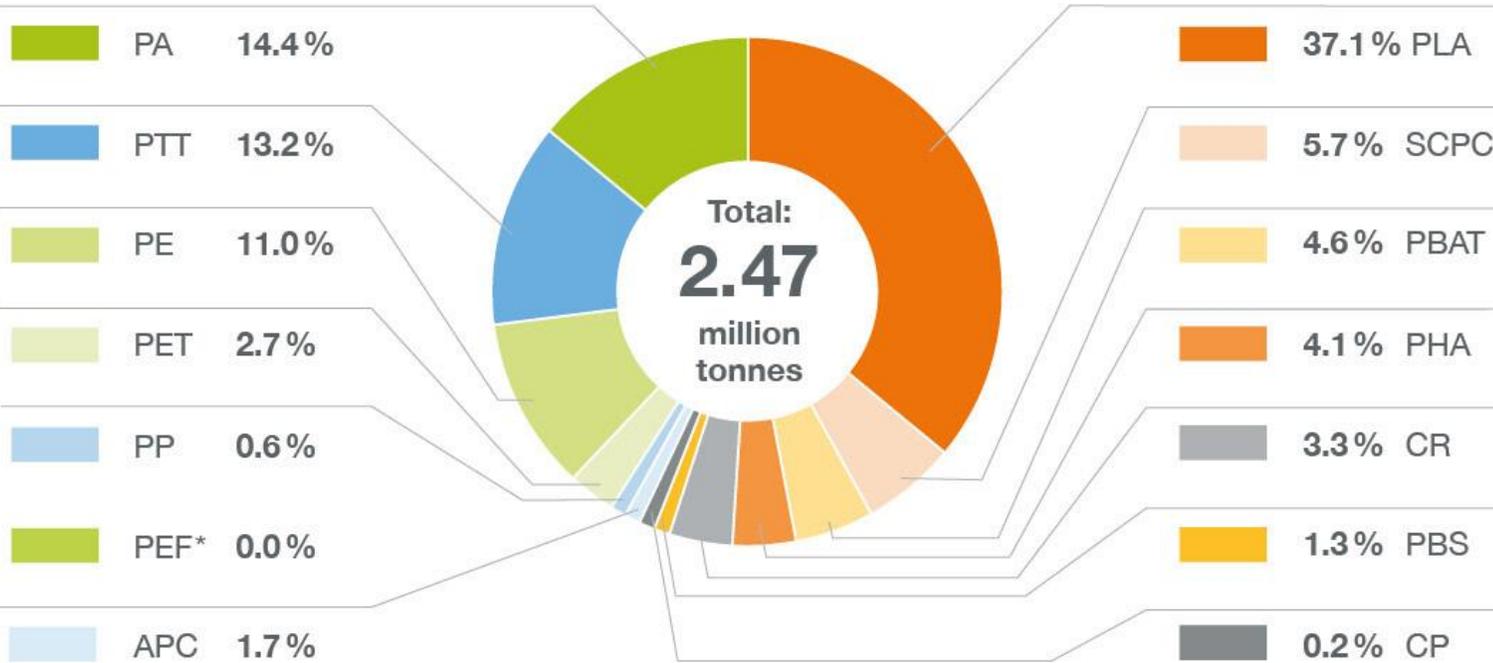
Main molecules:

Fermentation products (e.g. ethanol), fatty acids (derivatives)

Global production capacities of bioplastics 2024

Biobased, non-biodegradable
43.7%

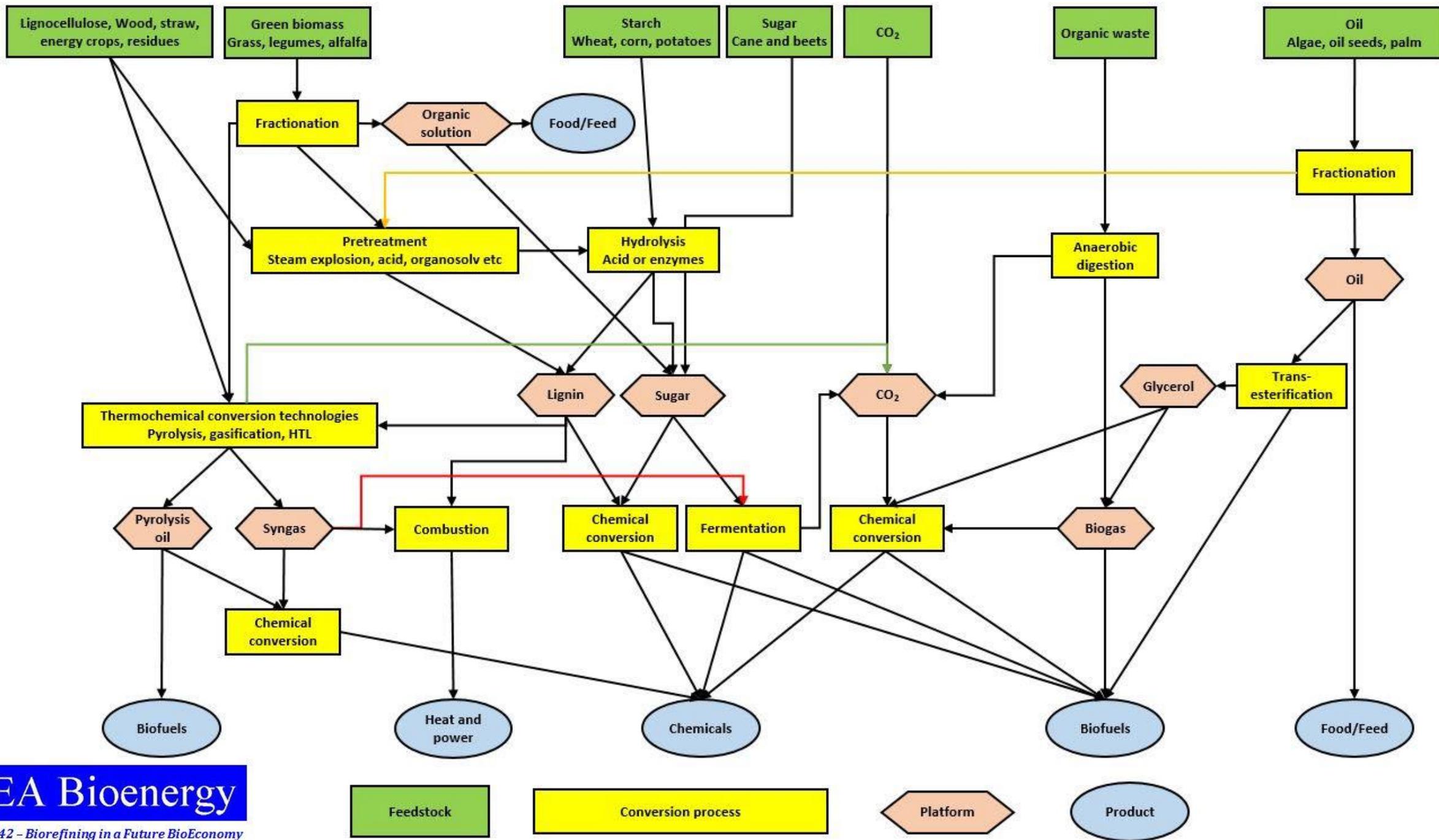
Biobased, biodegradable
56.3%



APC Aliphatic Polycarbonates
 CP Casein Polymers
 CR Cellulose Regenerates
 PA Polyamides
 PBAT Poly(Butylene Adipate-co-Terephthalate)

PBS Polybutylene Succinate and Copolymers
 PE Polyethylene
 PEF Polyethylene Furanoate
 PET Polyethylene Terephthalate

PHA Polyhydroxyalkanoates
 PLA Polylactic Acid
 PP Polypropylene
 PTT Polytrimethylene Terephthalate
 SCPC Starch Containing Polymer Compounds



DOMINANT PLATFORMS

Syngas Platform

Biogas Platform

C6 sugar platform*

C6/C5 sugar platform

Plant-based Oil Platform*

Algae Oil Platform

Organic Solutions Platform

Lignin Platform

Pyrolysis Oil Platform

* Currently the dominant platforms for biobased chemicals

DROP-IN VERSUS UNIQUE FUNCTIONALITY

Property	Drop-Ins (MEG)	New Functionality (FDCA)
Time to Market	+++	+/-
Improved properties	+/-	+++
CAPEX	----	--
Own market space	---	+++
Fossil competition	---	++
Regulatory (Reach/EFSA)	++	---
Legislation (a.o. PPWR)	--	--
Value Chain	++	--
Circularity	+++	--

BIOBASED CHEMICALS TABLE

- Gives an overview of the biobased chemicals status in two categories
 - High growth potential
 - In the pipeline (demonstration or pilot facility running)
- Organized from C1 (methanol, formic acid etc) to C10
- Exhaustive list but certainly not complete
- Biobased Chemicals Field is very dynamic at the moment so new changes / additions needed
- ReBiolution focusses on co-polyesters so we will focus on available diols and diacids

BIOBASED DIOLS (ADAPTED FROM TABLE REPORT)

Cn	Diols with strong growth potential		Diols in the pipeline	
	Chemical	Company	Chemical	Company
2	Ethylene glycol (MEG)	India Glycols Ltd, <i>UPM</i> , <i>Sustainea (Braskem/Sojitz Corp)</i> , <i>Avantium</i>		
3	1,3-Propanediol	Covation Bio		
3	Propylene Glycol (1,2-Propanediol)	ADM, Oleon, <i>UPM</i> , <i>Sustainea</i> , <i>Avantium</i>		
4	1,4-Butanediol	Genomatica, Novamont, Qore (JV between Cargill & Helm AG)	2,3-Butanediol	Biokemik, Intrexion
			1,5-Pentanediol	Pyran
6	Isosorbide	Roquette, Samyang Innochem	1,6-Hexanediol	Rennovia

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BIOBASED DIACIDS (ADAPTED FROM TABLE REPORT)

Cn	Diacids with strong growth potential		Cn	Diacids in the pipeline	
	Chemical	Company		Chemical	Company
4	Succinic acid	In the past: Reverdia, Myriant, Succinity	3	Malonic acid	Lygos, Sirrus
6	FDCA	Avantium, StoraEnso, Sugar Energy	6	Adipic acid	Toray Industries, Genomatica
9	Azelaic acid	Matrica SpA (JV Novamont, Eni), Emery Oleochemicals, BASF, Croda	6	Itaconic acid	Itacoconix, Riverland trading, Qingdao Kehai Biochemistry Co
10	Sebacic acid	Arkema, BASF, Wilmar Int, Sebacic India Ltd, Hengshui Jinghua Chemical Co., LTD, <i>Lacamas Laboratories</i>			

PRODUCT COMMERCIALIZATION KEY CRITERIA

Market assessment

Market fundamentals (local, regional, global)
Feedstock availability & price
Utilities (steam, gas, electricity etc) availability & price
Product profitability
Competitive nature of market
Need for partnerships
Downstream development opportunities

Technology assessment

Commercial experience
Bankability
Necessary capital investment
Process complexity
Access to technology
Environmental considerations

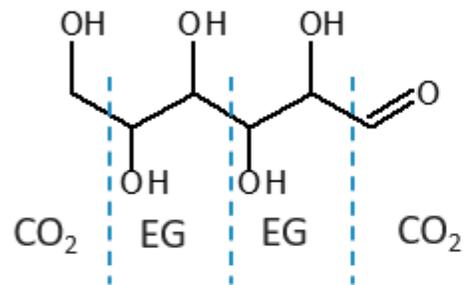
DOMINANT PRODUCTION ROUTES BIOBASED DIOLS AND DIACIDS

- For the selected diols and diacids the dominant feedstock sources as well as production routes are illustrated
- Some literature references are given for further reading

1,2-MONO ETHYLENEGLYCOL (MEG)

Current Commercial Production of Bio-based MEG

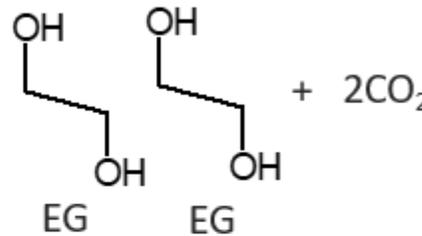
Fermentation



Fermentation, dehydration,
Oxidation, hydration

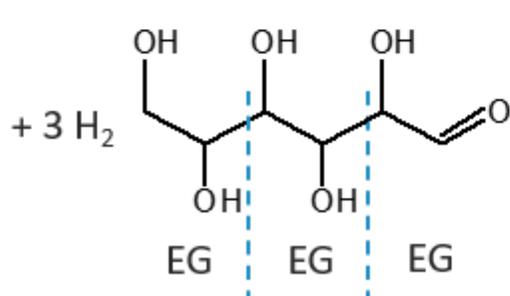
4 steps

Max theoretical
yield = 67%



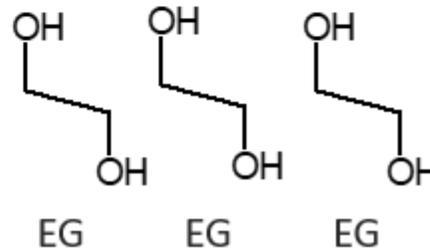
Avantium Ray Process

Hydrogenolysis



Catalysis
1 step

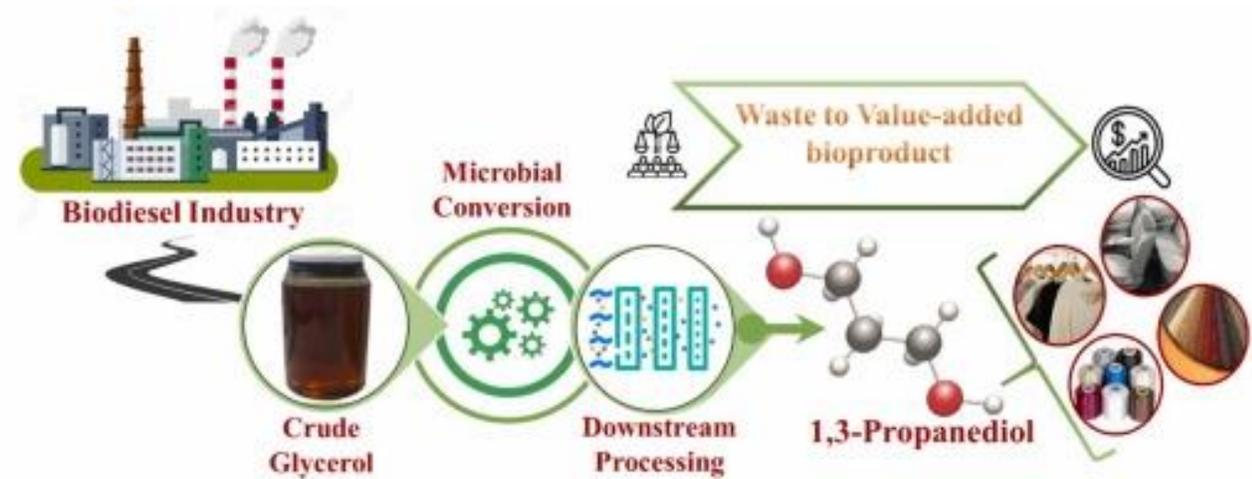
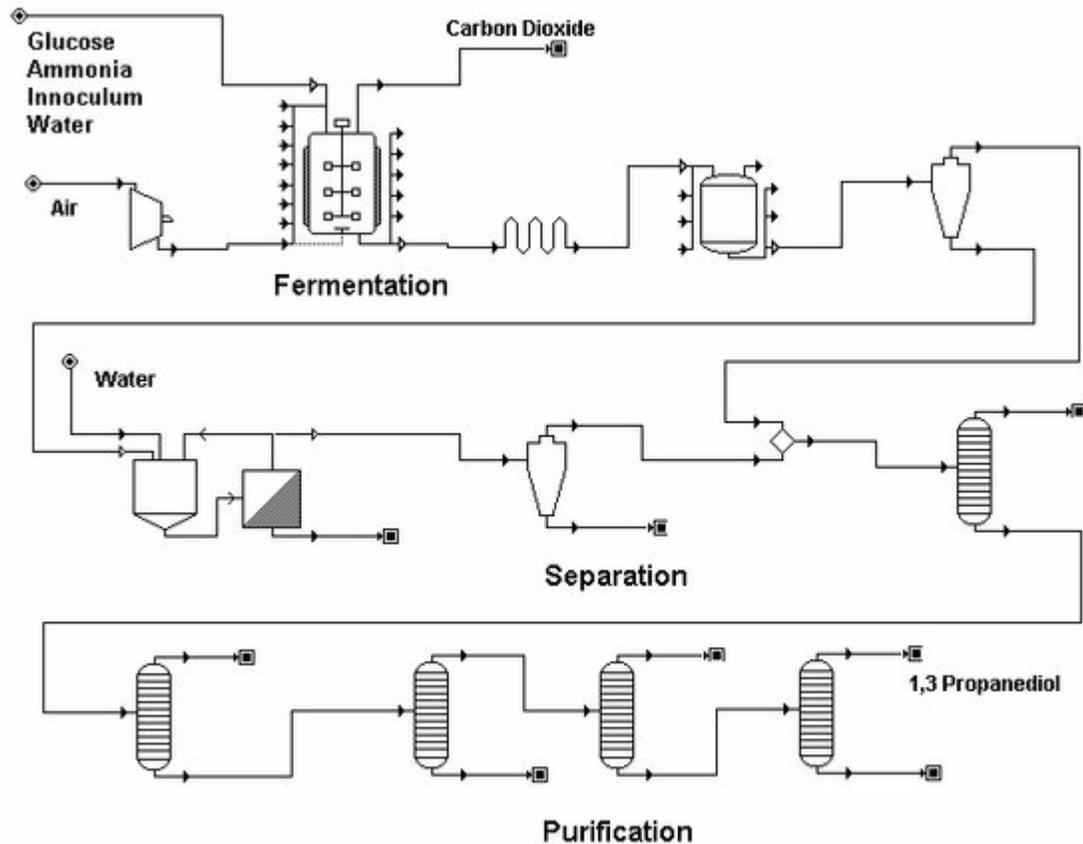
Max theoretical
yield = 100%



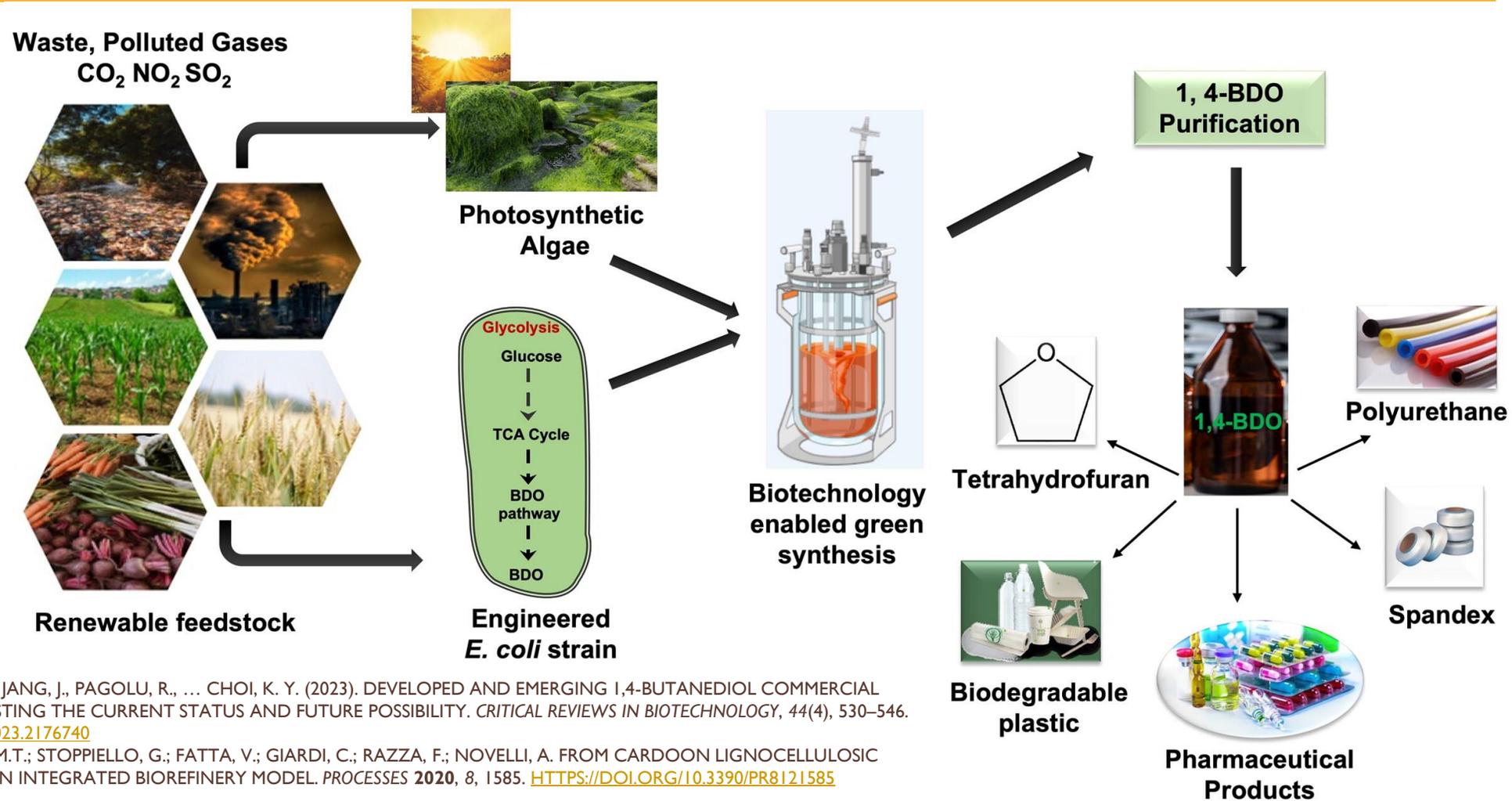
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1,3-PROPANEDIOL



1,4-BUTANEDIOL



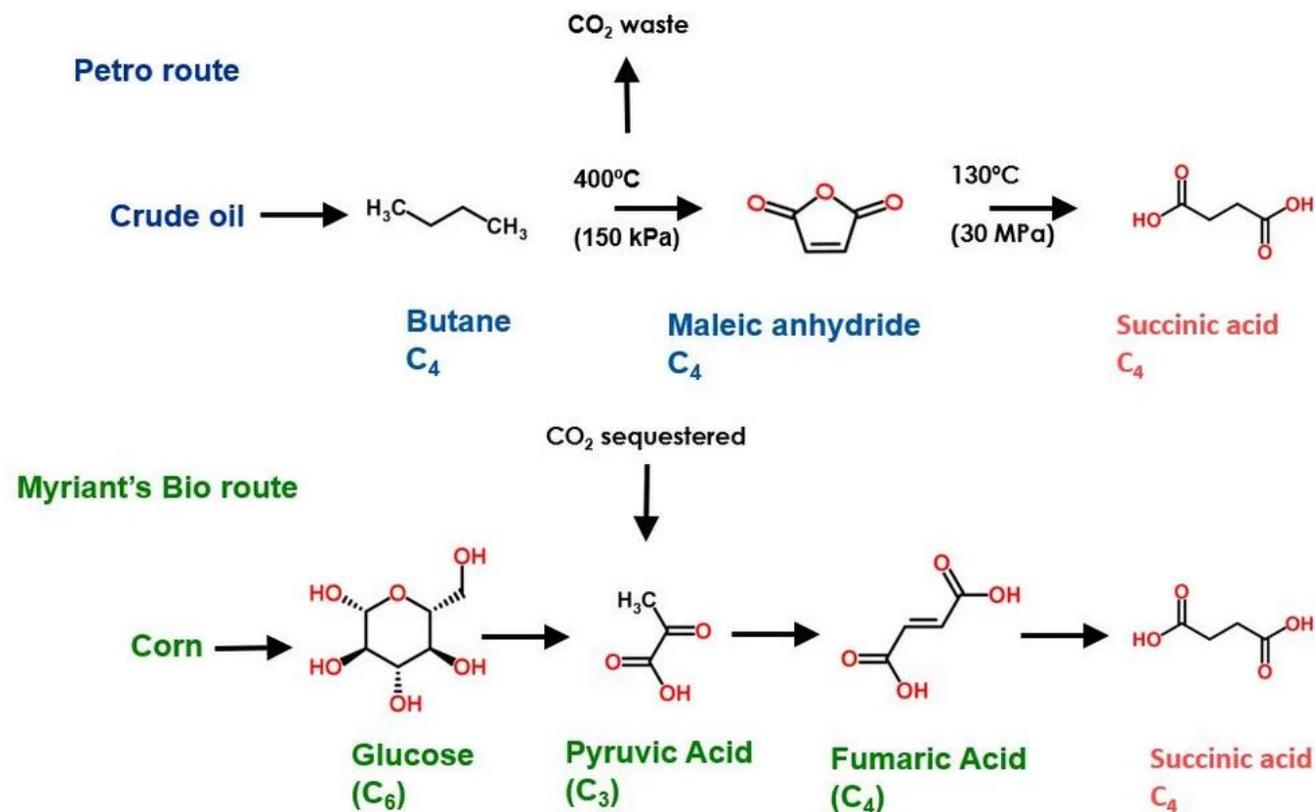
KUMAR, P., PARK, H., YUK, Y., KIM, H., JANG, J., PAGOLU, R., ... CHOI, K. Y. (2023). DEVELOPED AND EMERGING 1,4-BUTANEDIOL COMMERCIAL PRODUCTION STRATEGIES: FORECASTING THE CURRENT STATUS AND FUTURE POSSIBILITY. *CRITICAL REVIEWS IN BIOTECHNOLOGY*, 44(4), 530–546.

[HTTPS://DOI.ORG/10.1080/07388551.2023.2176740](https://doi.org/10.1080/07388551.2023.2176740)

DE BARI, I.; GIULIANO, A.; PETRONE, M.T.; STOPPIELLO, G.; FATTA, V.; GIARDI, C.; RAZZA, F.; NOVELLI, A. FROM CARDOON LIGNOCELLULOSIC BIOMASS TO BIO-1,4 BUTANEDIOL: AN INTEGRATED BIOREFINERY MODEL. *PROCESSES* 2020, 8, 1585. [HTTPS://DOI.ORG/10.3390/PR8121585](https://doi.org/10.3390/PR8121585)

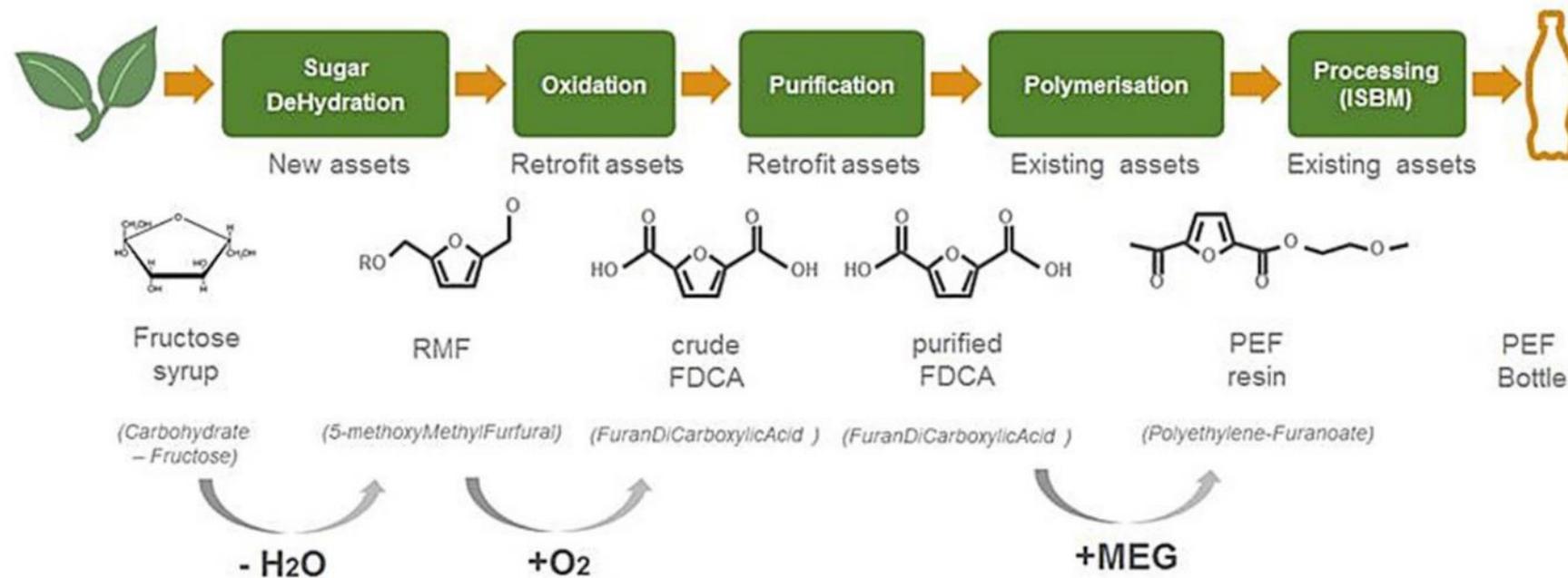
SUCCINIC ACID

Petrochemical vs Bio-routes to succinic acid



[HTTPS://WWW.RESOURCEWISE.COM/CHEMICALS-BLOG/BIOBASED-SUCCINIC-ACID-IS-THE-SUSTAINABLE-ROUTE-BECOMING-ECOMICALLY-VIABLE-ONCE-MORE](https://www.resourcewise.com/chemicals-blog/biobased-succinic-acid-is-the-sustainable-route-becoming-economically-viable-once-more)

FDCA



FDCA: A 100% BIOBASED AROMATIC DIACID



Key-benefits FDCA

100% Biogenic Carbon

Aromatic Diacid

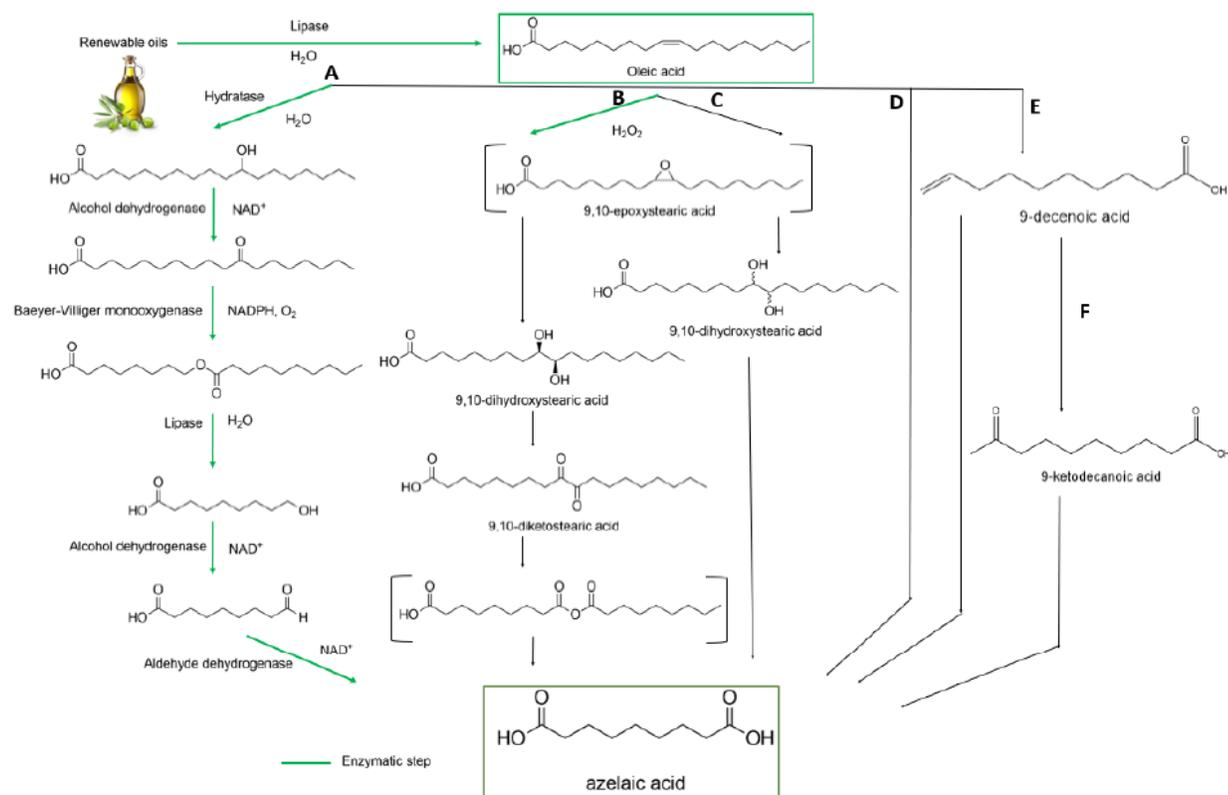
Replacement for fossil-based PTA
(purified terephthalic acid)

Differentiators

- ✓ More soluble in MEG
- ✓ More reactive in esterification
 - ✓ polar furan ring

**FDCA 'Nature's PTA' is an alternative
for fossil-based aromatic diacids**

AZELAIC ACID



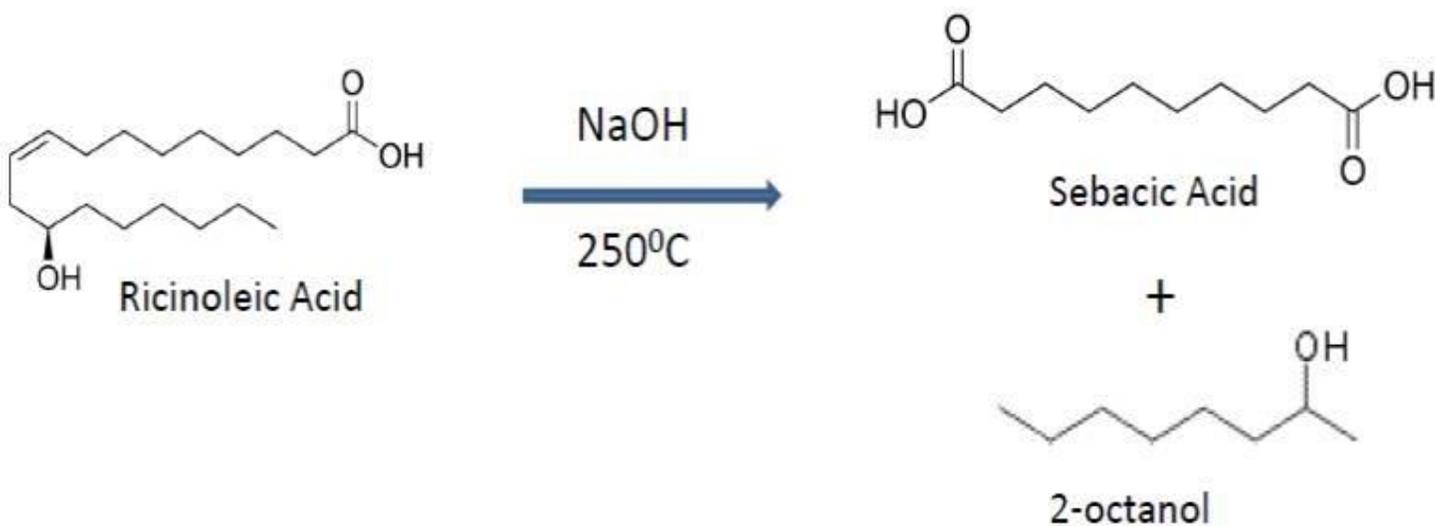
TODEA, A.; DEGANUTTI, C.; SPENNATO, M.; ASARO, F.; ZINGONE, G.; MILIZIA, T.; GARDOSSI, L. AZELAIC ACID: A BIO-BASED BUILDING BLOCK FOR BIODEGRADABLE POLYMERS. *POLYMERS* **2021**, *13*, 4091. [HTTPS://DOI.ORG/10.3390/POLYM13234091](https://doi.org/10.3390/polym13234091)

Figure 1. The main routes reported for synthesis of azelaic acid starting from oleic acid: **A**—enzymatic route [39], **B**—chemo-enzymatic route [2], **C**—two step route with epoxide [34], **D**—direct cleavage, **E**—two step pathway with metathesis of oleic acid, **F**—three step route [28].

SEBACIC ACID



Conversion of Ricinoleic Acid to Sebacic Acid



CONCLUSIONS

- 1st Generation Glucose and triglycerides dominant feedstock sources
- Several biobased diols and diacids are commercially available
- Drop-in molecules vulnerable for oil-price fluctuations

QUESTIONS / ACKNOWLEDGEMENTS

Thank you for your attention

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