Towards a Circular Dairy Industry

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GREAT LAKES BIOENERGY RESEARCH CENTER

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Current Challenges In Dairy Industry with Coproducts/Waste Streams

- We spend a lot on “waste treatment” at the farm and cheese plant
- Low value coproducts (permeate, acid whey, etc) are often used as animal feed
- Coproducts are often land spread
  - Potential negative environmental impact due to leaching of nitrogen, phosphorus and other materials into the soil, groundwater or atmosphere.
  - More challenging as environmental regulations get stricter.
- Volumes getting larger
- Drying is expensive and shipping them overseas for animal feed, is that environmentally sustainable?

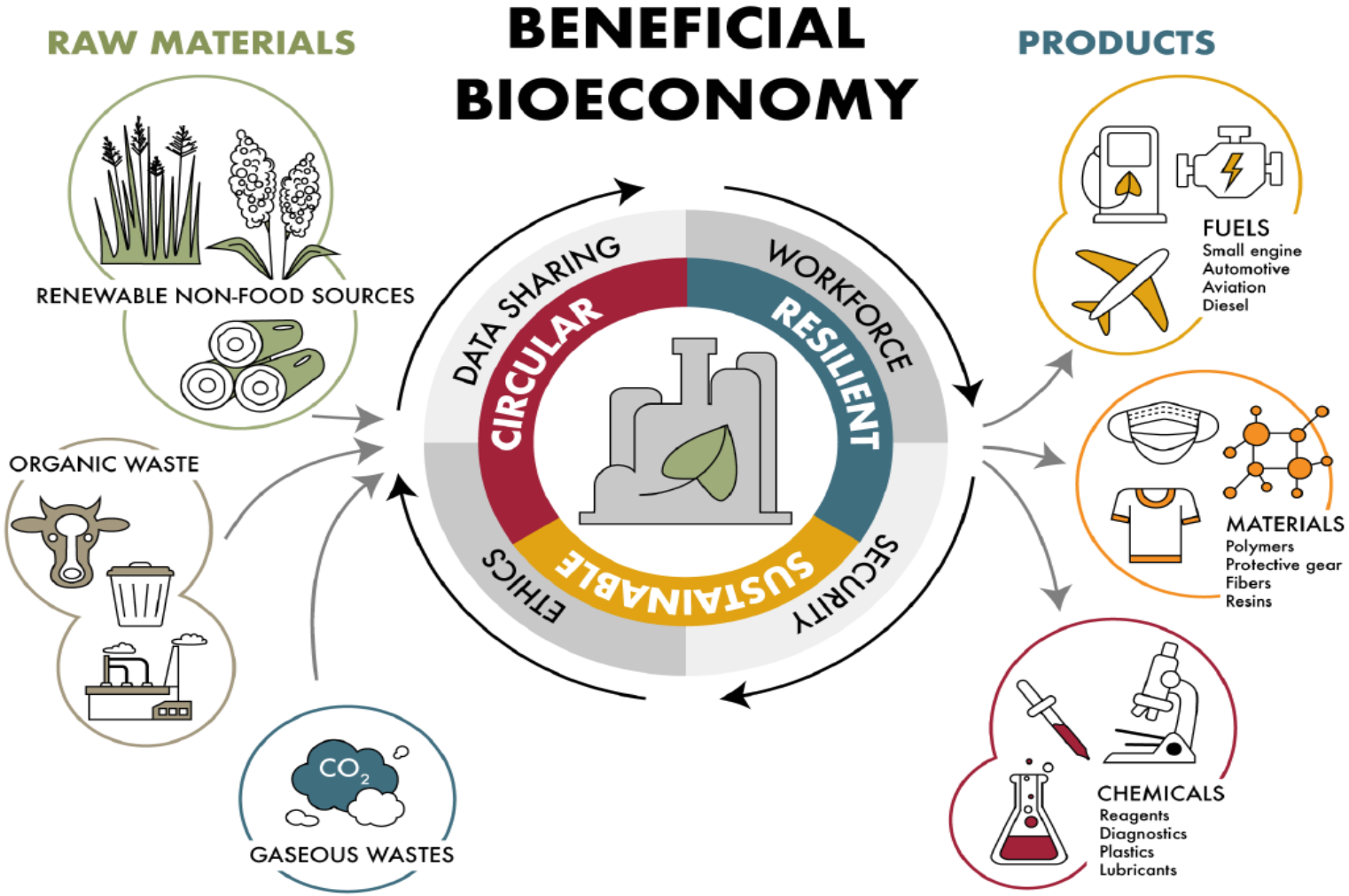
Plastics

- Most plastics used for food packaging are fossil derived
- Only around 1% of plastics are biobased
- Most plastics used in food packaging are nonrecyclable and are not biodegradable
- Plastic waste is a major environmental concern
- Concerns over ingestion of microplastics
- By 2030 U.S. plastics industry's contribution to climate change is estimated to become equal to coal-fired power stations

Circular Bioeconomy and Dairy

- Dairy produces a lot of organic feedstocks (e.g., manure, acid whey, cheese whey, permeate, etc)
- These feedstocks contain a simple sugar (compared to lignocellulosic type (forestry products) materials)
- Could be fermented into a wide range of “green” chemicals
  - Beyond biodigesters
- We already have lactic acid bacteria that ferment lactose, they can engineered to produce target chemicals
- Renewable source
- Great sustainability story for the dairy industry (feed the world, save the planet…..)

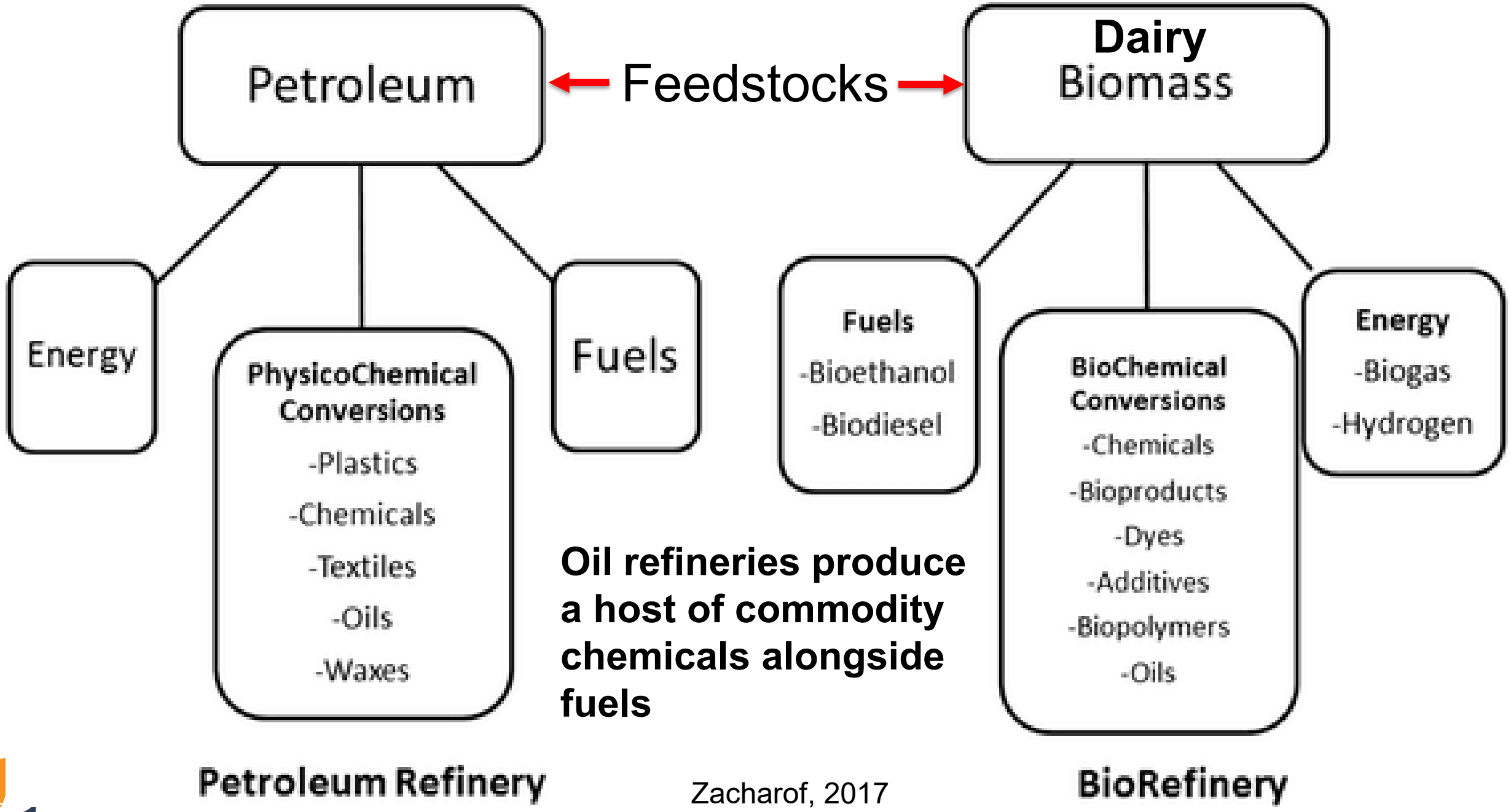
Could We Use Dairy Co-Products to Make Value-Added Ingredients



U.S. Produces:
120 billions pounds of liquid whey
600,000 tons of dry permeate
About 2M metric tons of acid whey

Key Targets for Bio-based chemicals

- Range of organic acids
  - e.g., medium chain fatty acids, succinic acid, lactic acid
- Precursors for biodegradable bio-plastics, options:
  - polylactic acid and
  - polyhydroxybutyrate, PHB
- Other biobased platform chemicals (used to make other higher value-added products)
  - e.g., 1,3-propanediol, 1,4-butanediol
  - About 90% of chemicals currently used are fossil derived
- Food materials/supplements


Petroleum
Feedstocks
Dairy Biomass
Energy
PhysicoChemical Conversions
-Plastics
-Chemicals
-Textiles
-Oils
-Waxes
Fuels
Fuels
-Bioethanol
-Biodiesel
BioChemical Conversions
-Chemicals
-Bioproducts
-Dyes
-Additives
-Biopolymers
-Oils
Energy
-Biogas
-Hydrogen
Oil refineries produce a host of commodity chemicals alongside fuels
Petroleum Refinery
Zacharof, 2017
BioRefinery

Contents lists available at ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

Enhanced polyhydroxybutyrate production from acid whey through determination of process and metabolic limiting factors

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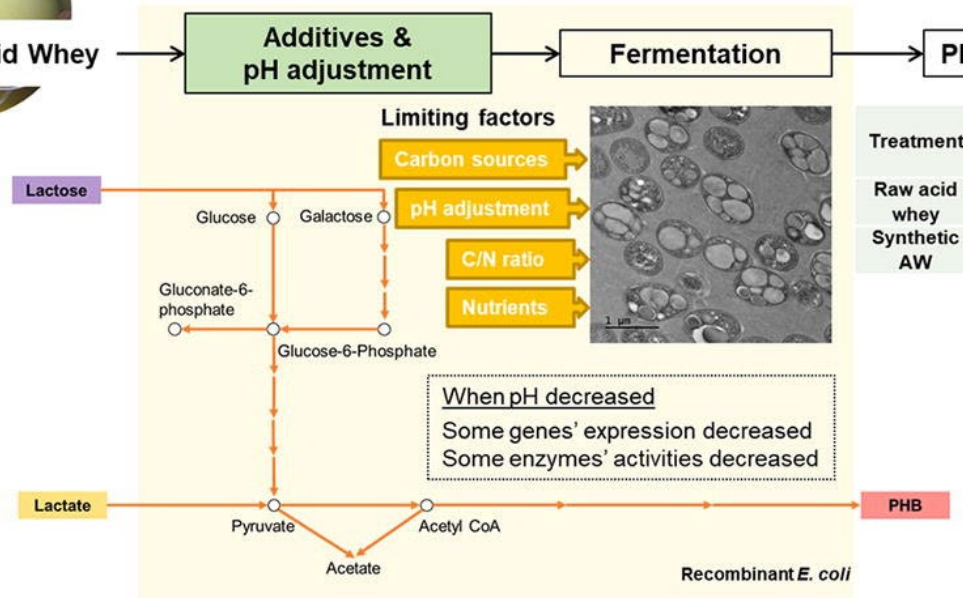
Production of bio-based plastics (PHB) from acid whey



Treatment	PHB content (% of CDW)	PHB yield (g/L)
Raw acid whey	70	4.0
Synthetic AW	86	3.0

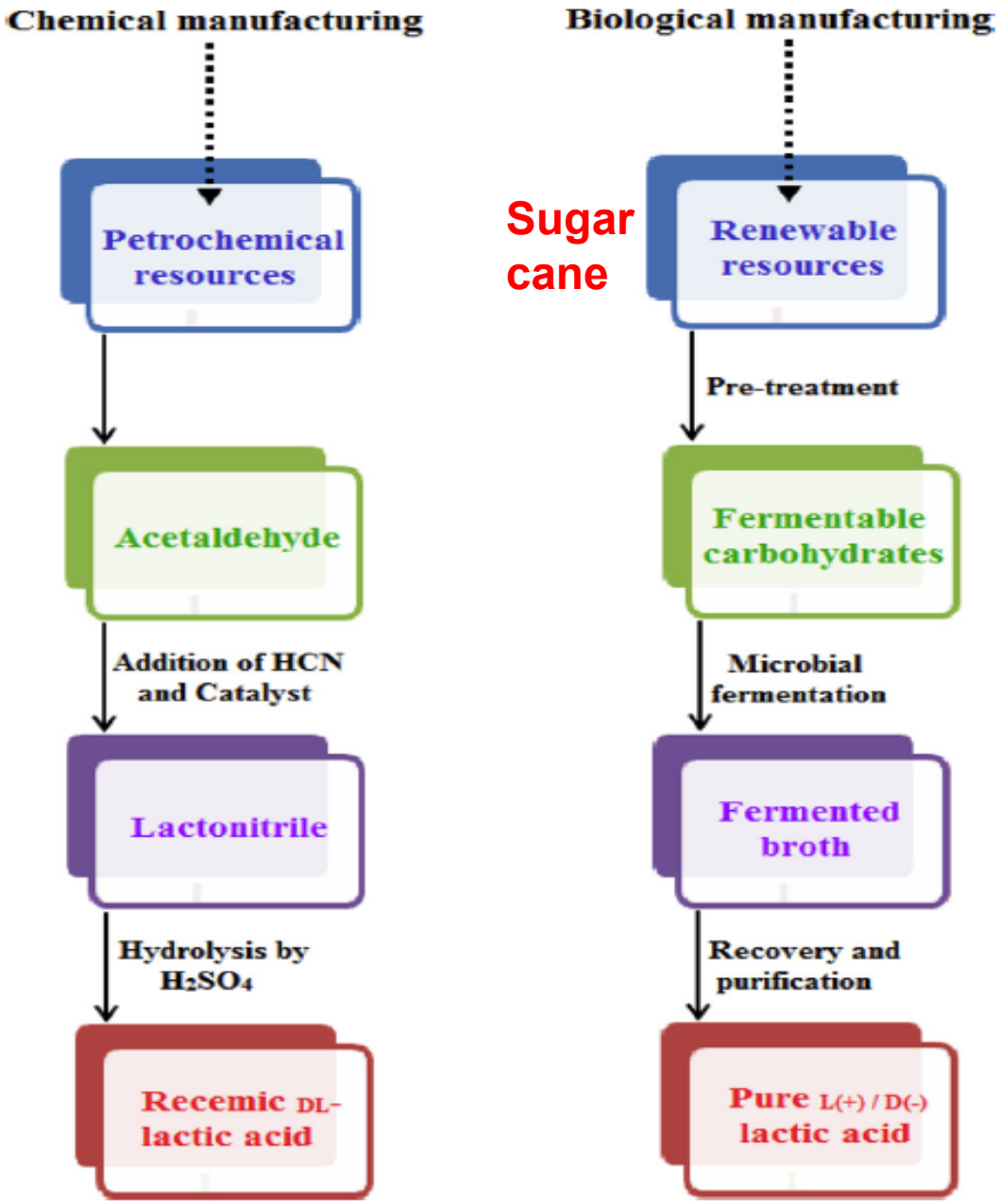


Fig. 2 — A schematic representations of the two manufacturing processes of lactic acid.

Ghaffar et al. (2014) J. Rad. Res. Appl. Sci. 7:222

- Worldwide demand for lactic acid is about 150,000 tons per annum (close to $3 billion)
- Compound growth rate of >10%
- Yield is about 1 gram of lactic acid from 1 gram of lactose

Critical Components to Utilizing Renewable Feedstocks to Make New Bio-based Chemicals

Engineering microbes

Reactor design and conditions

Isolation and purification*

*CDR is investing in scaling up bioreactors and isolation/purification technologies

Scaleup*

TEA (technoeconomic analysis)

National Science Foundation

https://beta.nsf.gov/funding/initiatives/regional-innovation-engines

Through a bold, new U.S. National Science Foundation initiative, the Regional Innovation Engines, or NSF Engines, program catalyzes and fosters innovation ecosystems across the U.S. to:

- Advance critical technologies
- Address national and societal challenges
- Foster partnerships across industry, academia, government, nonprofits, civil society, and communities of practice
- Promote and stimulate economic growth and job creation
- Spur regional innovation and talent

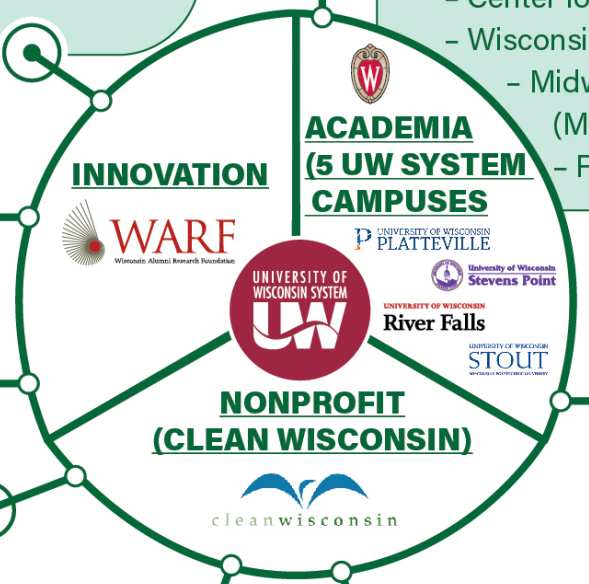
Type 1 Grants: $1M
Planning for an Engine
Type 2 Grants: $160M
over 10 years

Decarbonize Agricultural Residues by bio-Transformations (DART) submitted by UW-Madison

- Use various agricultural feedstocks to power a bioeconomy
- Renewable agricultural feedstocks would be turned into green chemicals by new biorefineries, and other bioconversion technologies.
- Type 1 proposal

PI: Lucey, UW-Madison

Partners in the DART Program



Economic Development
- All Nine Regional Economic Development Partners for Wisconsin
- Wisconsin Economic Development Corp (WEDC)
- Wisconsin Technology Council

Food Companies/Producers, Trade Associations
- Schreiber
- Organic Valley
- Agropur
- Johnsonville
- Dairy Farmers of Wisconsin (DFW)
- Center for Integrated Agricultural Systems (CIAS)
- Wisconsin Cheesemakers Association (WCMA)
- Midwest Food Products Association (MWFPA)
- Food and Beverage Wisconsin (FaB)

Utility Companies
- Alliant Energy

Ag Biotechnology
- Ginkgo Bioworks

Accelerators
- gener8tor
- Discovery to Product (D2P)
- Forward Biolabs

Regional Colleges
- Madison Area Technical College
- Blackhawk Technical College
- Lakeshore Technical College
- North Central Technical College

Government
- Wisconsin Department of Agriculture, Trade and Consumer Protection (DATCP)
- State of Wisconsin: Dept of Workforce Development (DWD)
- Dept. of Natural Resources (DNR)

Startups & Commercialization Support
- Examples could include: Ourobio, Supersonic
- Institute of Business & Entrepreneurship
- Center for Technology Commercialization

Concluding Remarks

- We can turn our problems into opportunities and value-added products
- By using biofermentation of our waste streams, we can produce various types of renewable, green chemicals/plastics for the future
- A regional initiative like DART could facilitate this major change in our agricultural sector – becoming more climate smart or towards net-zero