Marketplace Opportunities Integration of Biobased & Conventional Plastics Forum

Project Partners: MN Corn Growers Assoc., MN Soybean Growers Assoc., Jim Lunt & Associates LLC

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Agricultural Utilization Research Institute

About AURI

The Agricultural Utilization Research Institute (AURI) helps develop new uses for agricultural products through science and technology, partnering with businesses and entrepreneurs to bring ideas to reality. We work in four core industry areas:

- **Food**
- **Renewable energy**
- **Biobased products**
- **Coproduct utilization**

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Agricultural Utilization Research Institute

From Idea to Reality

At AURI, we believe that implementing innovation takes:

- **good ideas, generated through applied research with our partners,**
- **hands-on scientific technical assistance, and**
- **a strong resource network.**

In the end, this all works together to generate economic impact.

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Why We're Here Today

So, today we have some idea-generating research that we want to share with you.

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Why We're Here Today

Purpose-Outcomes

- Present an accurate portrayal of the plastics industry and opportunities for additional development of biobased materials/plastics.
- The potential market for biobased materials offers opportunity for agricultural commodities and coproducts and to create economic impact for MN.

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Introductions

- Over 40+ years in the plastic's industry.
- One of the founding members of NatureWorks LLC.
- A recipient of the Green Chemistry Award in 2002.
- Managing Director of Jim Lunt & Associates LLC., specializing in the emerging bioplastics industry.

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Marketplace Opportunities for the Integration of Biobased and Conventional Plastics

Sponsors:

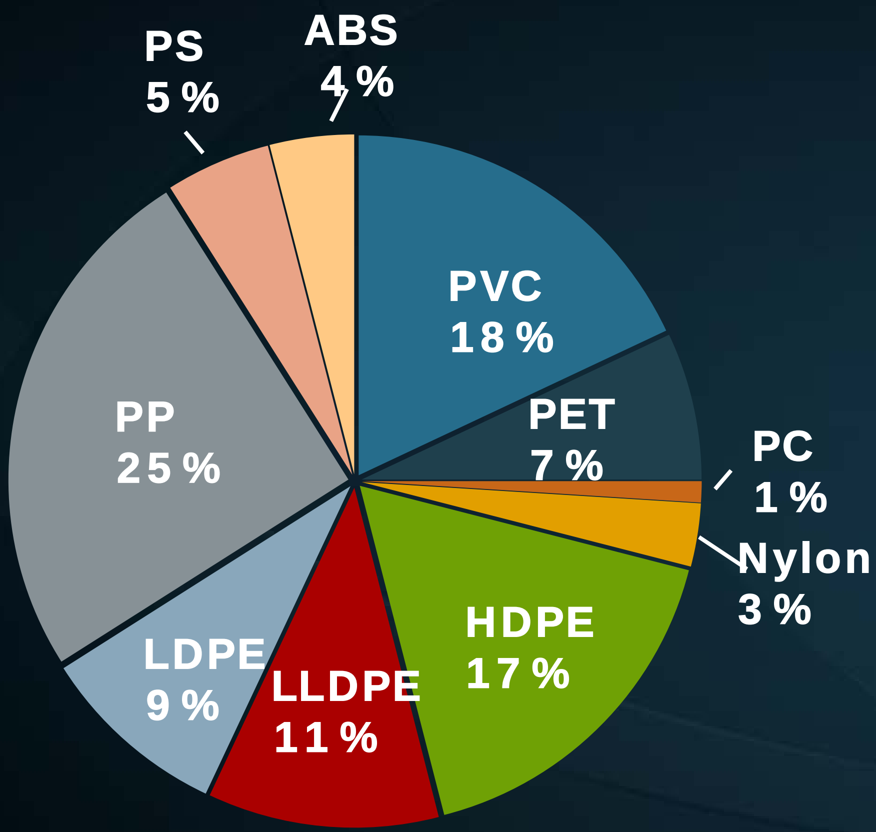
- Agricultural Utilization Research Institute(AURI).
- Minnesota Corn Research & Promotion Council.
- Minnesota Soybean Research & Promotion Council.

JIM LUNT & associates llc

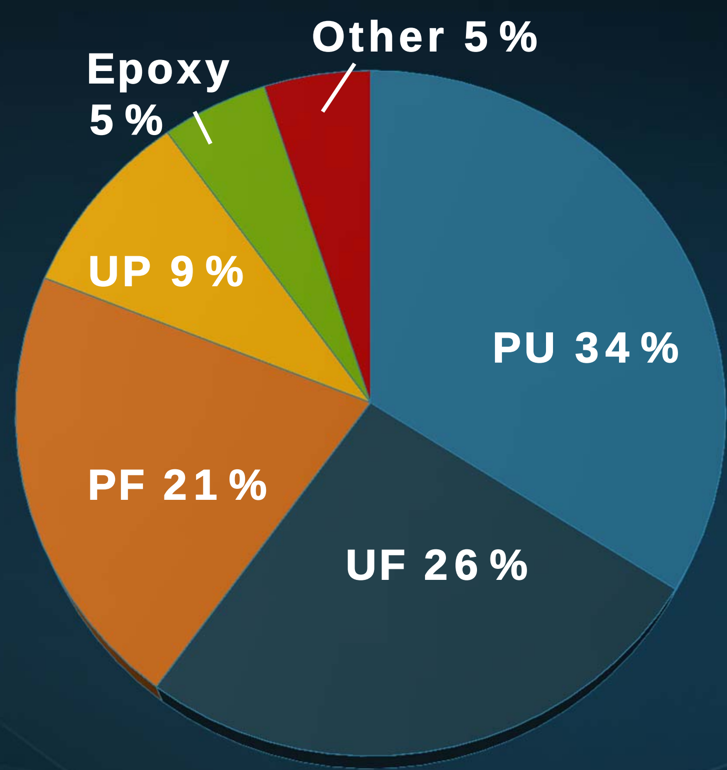
Presentation Outline

- ❖ The Oil Based Plastics Industry.
- ❖ Evolution and Drivers for Bioplastics.
- ❖ Bioplastics Definitions and Classification.
- ❖ First and Second Generation Bioplastics.
- ❖ Bioplastics Growth Projections and Market Trends.
- ❖ Developments in Feedstocks.
- ❖ Conclusions.

Conventional Oil Based Plastics

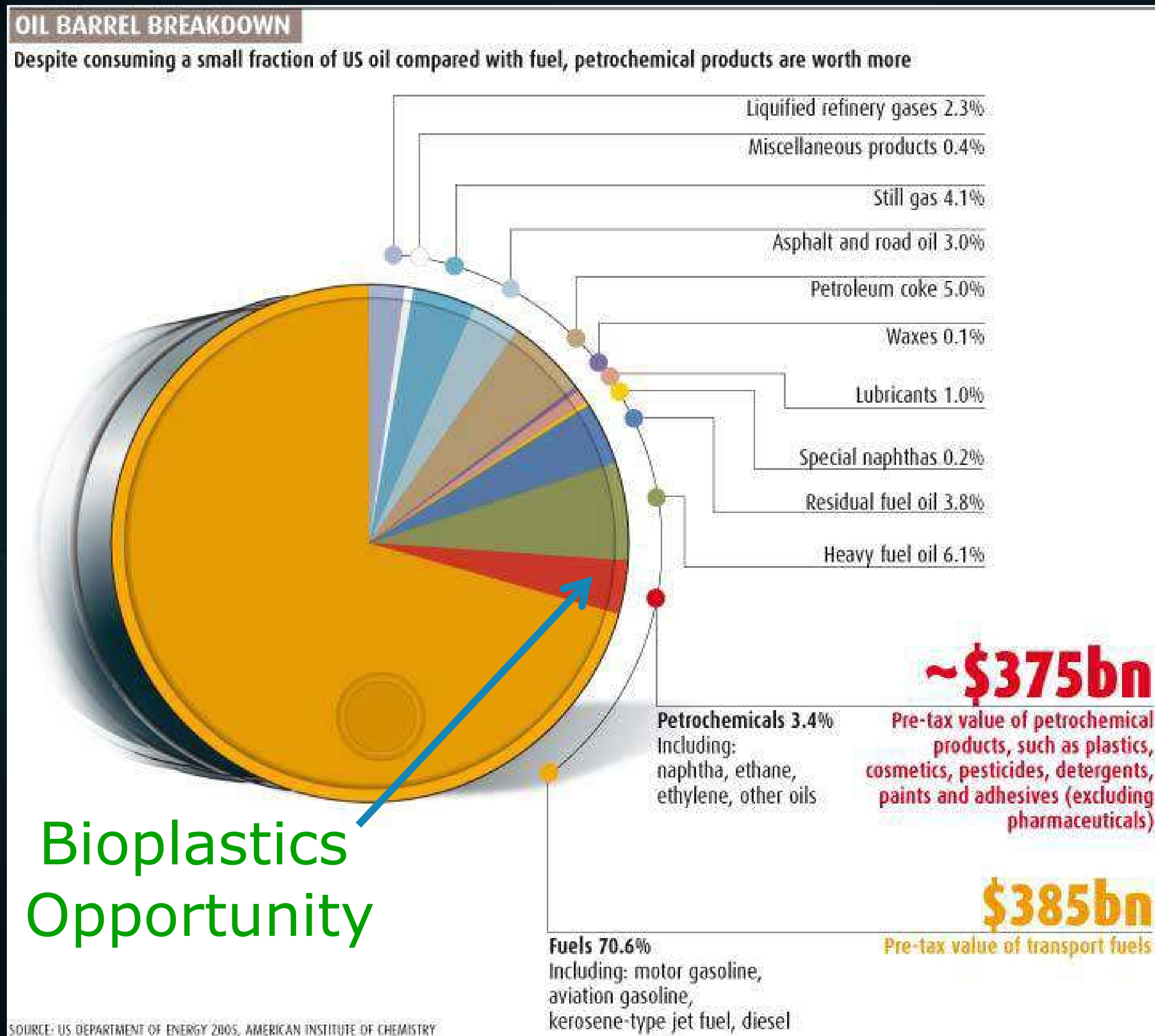


Thermoplastics
(270 million tonnes in 2014)



Thermosets
(90 million tonnes in 2016)

The Bioplastics Opportunity



Evolution of Bio plastics Drivers

1990. "New" biodegradable/compostable plastics. Alternative disposal option to landfills. Single use applications. Starch/sugar feedstocks.

2000. Compostable/renewable resource alternatives to oil based plastics.

2005. Sustainability, compostable, GHG, energy use, LCA, Legislation.

2010. Durable biobased equivalents to oil based plastics.

2014. Durable, biobased content, sustainability. Monomers from non food renewable resources. Alternative feedstocks.

Today's Drivers for Bioplastics

Renewable resource versus oil based.

Reduced environmental impact.

Concerns about human health.

End-of-Life disposal issues – Landfill.

Legislative initiatives.

Definitions for Bio Plastics

Biodegradable or Compostable Bioplastics

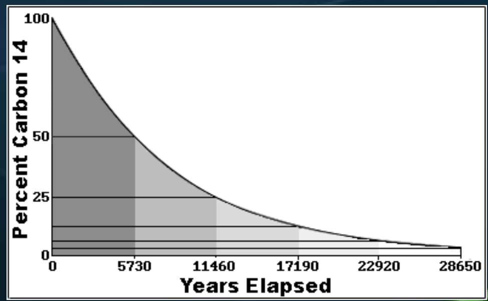
Meet all scientifically recognized standards for biodegradability and compostability of plastics and plastic products.

Independent of carbon origin-(i.e. Ecoflex, PBS, PLA). Focus is on end-of-life or disposability.

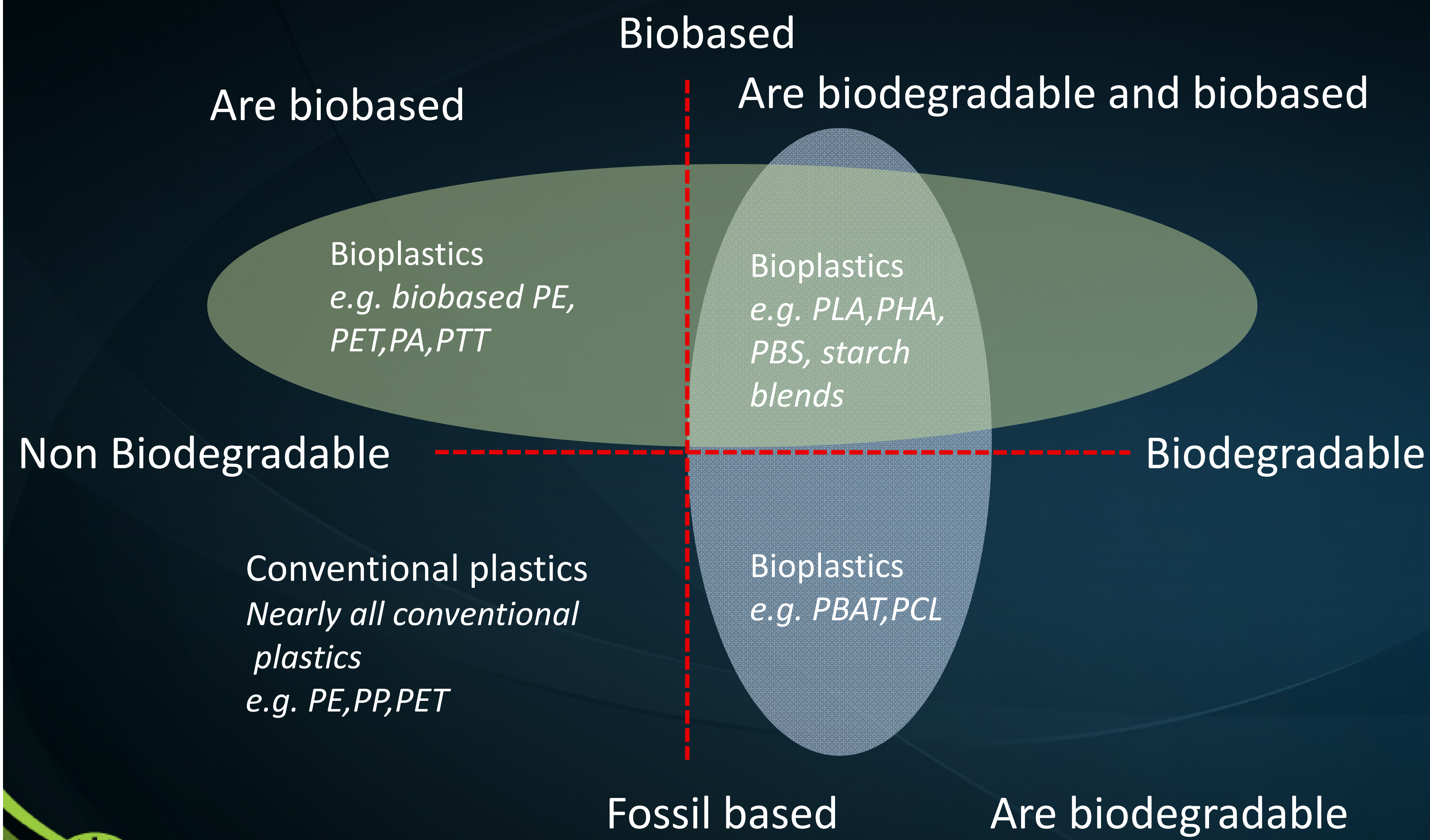
Biobased Products

Must be organic and contain some percentage of recently fixed (new) carbon found in biological resources or crops.

Focus on renewable resource based origin. Uses C^{14} content measurement.



Classification of Bioplastics



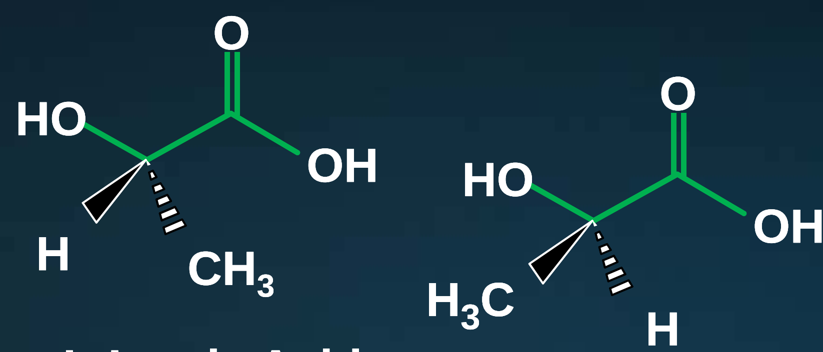
Eu. Bioplastics

First Generation Bioplastics

Starch/PLA/ECOFLEX

Compounded,
Biobased
& Compostable

Polylactic Acid (PLA)



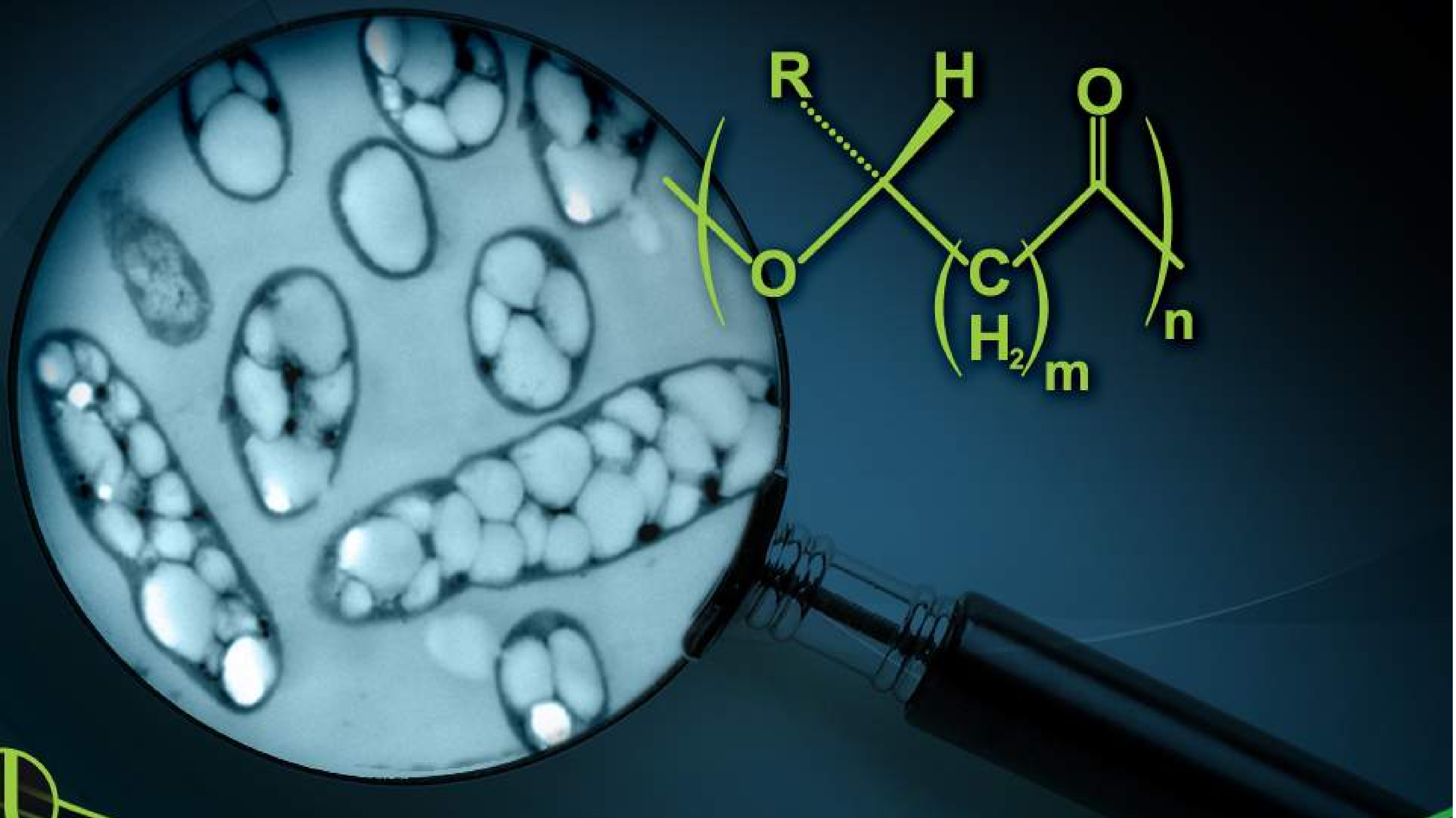
L-Lactic Acid

D-Lactic Acid
(0.5%)

100% Renewable & Compostable

First Generation PHA’s

Compostable, biodegradable and renewable



PHA picture courtesy of Telles

Target Plastics and Applications for First Generation Bioplastics

Polystyrene.
Single use food serviceware- Rigid trays, containers, cutlery, cups, packaging.

PVC.
Gift cards and cash cards.

PET.
Food trays, containers, film and fibers.

ABS.
3D printing (Emerging application PLA/starch blends)

Polymer Properties

Property	Units	PLA	PS	PET	PVC*	PP
Tens. St.	MPa.	53.1	45.5	58.6	49	35.9
Elong. To Break	%	4.1	1.4	5.5	25-45	350
Tens. Mod	GPa.	3.45	3.03	3.45	2.83	1.31
Izod Impact	J/M	16	21.4	26.7	80	48.1
Glass Transition	^0C	58	98	74	74	-20
Melting Point	^0C	130-170	none	270	none	165
S.G.		1.25	1.05	1.34	1.4	0.9

* General purpose PVC.

Compostable Bioplastics Do Not Readily Meet The Needs for Durables

Areas of Concern

Starch Blends	**PLA**	**PHA'S**
Hydrolytic stability	Hydrolytic Stability	Hydrolytic Stability
Distortion Temp	Distortion Temp (amorphous)	√
Vapor Transmission	Vapor Transmission	√
Shelf Life	Shelf Life	Shelf Life
	Impact Resistance	Processability
	Melt Strength	Melt Strength
		Economics

PLA Property Modification Technologies

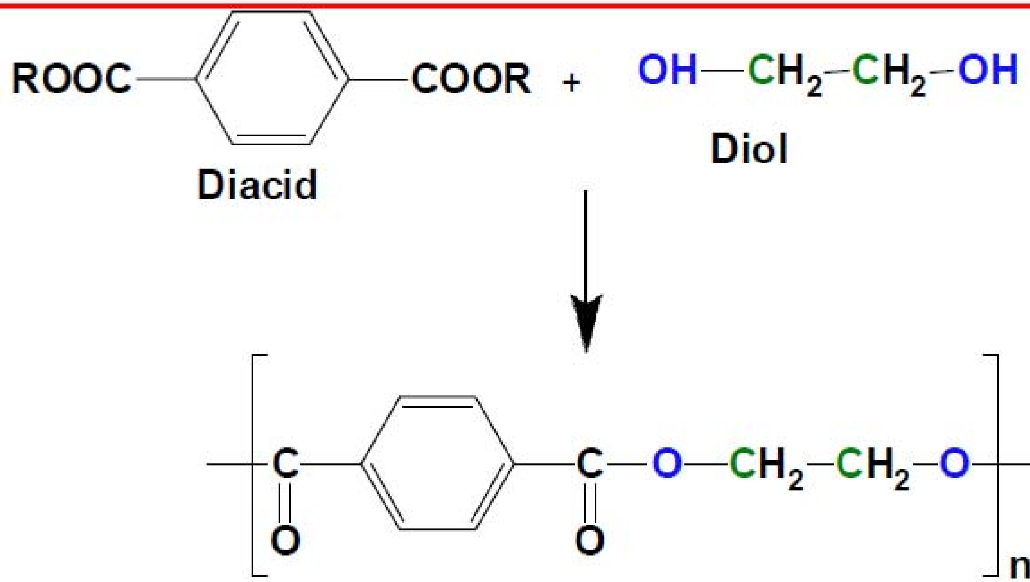
- Improved stiffness - fillers, fibers, nucleating agents.
- Improved impact or flexibility - impact modifiers, plasticizers, copolymers.
- Flammability - non halogenated flame retardants , blends.
- Temperature resistance -blends, nucleating agents, sterecomplex, copolymers.
- Extensional viscosity -peroxides, epoxy branching agents.
- Barrier properties –plasma, silicone dioxide, aluminum coatings.
- Lower color - blue tone.
- Reduced hydrolysis- carbodimide.

Second Generation Bioplastics.

Commercial Biobased Non Compostable Plastics

MAJOR SUPPLIER	BIOBASED PRODUCT.	% RENEWABLE CARBON.
Braskem	HDPE,LDPE.	89-100
FENC/ Teijin/ Indorama	Bio PET	20
DuPont	PTT, nylon 6.12	28
Arkema	Nylon 11, Pebax Rnew ®.	50-100
Dow, Cargill	Soy-based urethanes	22-70
Ashland, Reichhold	Bio unsat.Polyesters	8-35
Ecopoxy, Entropy	Bio epoxies.	17-25

Biobased carbon in PET



PET

Acid component = 8C; glycol component = 2C;

Acid component = 68.75%; glycol component = 31.25% on mass basis

Bio (carbon) content is 20% if two petro carbons substituted by bio carbons – by using the glycol (diol) component from bio(plant sources)

Contains 31% renewable resource (20%C) based on bio ethylene glycol.

New Biobased Plastics

Company	Product	Bio component (s)	Status
Segetis	Polyketals	Levulinic acid	Early stage Commercialization
Avantium	Polyethylene furanoate	Furan dicarboxylic acid	Development
Novomer	Polypropylene carbonate	Carbon dioxide	Commercial
Newlight technologies	PHA	Carbon dioxide. Methane	Development
DSM, Arkema, BASF, DuPont, Evonik	Polyamides	Castor oil/ amino undecanoic acid	Commercial.

Key Bio Monomers for Thermoplastics

Ethylene/ethylene glycol	Braskem, India Glycols.
TPA	Gevo, Anellotech, Amyris, Genomatica, UOP, Global Bioenergies, Sabic, Virent,Chemtex.
Succinic acid	PTT, DSM, BASF, Bioamber, Roquette, Mitsubishi Chem., Myriant, Purac.
Adipic acid	Rennovia, Verdezyne, Genomatica.
Butane diol	Genomatica, Myriant, BioAmber.
FDCA	Avantium.
Ketals	Segetis, XLTerra/Reluceo.
Caprolactam	Amyris.
Acrylic acid	Ceres, Dow/OPX.
Isosorbide	ADM, Roquette.
Propylene	Braskem.
Propane 1,3 diol	DuPont / Tate & Lyle.

Key Bio Monomers for Thermosets.

Polyurethanes. Soy based polyols	Cargill, Dow
Unsat. Polyesters. Glycerol Propylene glycol	Ashland, Cargill, ADM, Dow Chemicals, BASF
Epoxies. Epichlorohydrin	Solvay

Projected Biomaterials Vol. Trends

Bioplastics are still less than
1% of the approximate 270 million tonnes
of plastics in use today.

Projected 19%AGR

Biomaterials Market Studies

Study	Report Date	Projected Global Capacity End of Period (tonnes)	Projected Global Demand End of Period (tonnes)	Time Period Covered
Nova Institute	2013	12 million	12 million	2020
Eu. Bioplastics	2013	6.2 million	Not given	2017
Freedonia	2011		1.0 million	2015
World bioplastics	2009		0.9 million	2013
Freedonia	2008		0.816 million	2013
PRNewswire	2010		0.138 million*	2014
Eu Bioplastics	2007	1.36 million		2011
PROBIP	2009	2.94 million		2020
SRI	2010		0.281million*	2014
SPE	2010		0.75 million	2014
BCC Research	2010		3.231 million	2015
PIRA			0.884 million**	2015-2020

*Biodegradable plastics only **Biodegradable packaging only

2013 Sales Estimate for Bioplastics

Product	2013 Bioplastics Manufacturing Capacity (million tonnes)	2013 Sales Estimates. (million tonnes)
"Green" Polyethylene	0.12	0.06
Bio PET	0.66*	0.66*
PLA	0.26	0.2
Starch Blends	0.2	0.15
PHA's	0.02	0.005
Others	0.05	0.02
Totals	1.31	1.095

* Contains only 30% renewable resource (20%C) based on bio ethylene glycol.

Jim Lunt & Associates LLC. Estimates

Projected Durables Growth

Increasing demand for biobased, durable products in electronics and automotive applications.

By 2015 durables are expected to account for almost 70% of bioplastics capacity – compared with 7% in 2009.

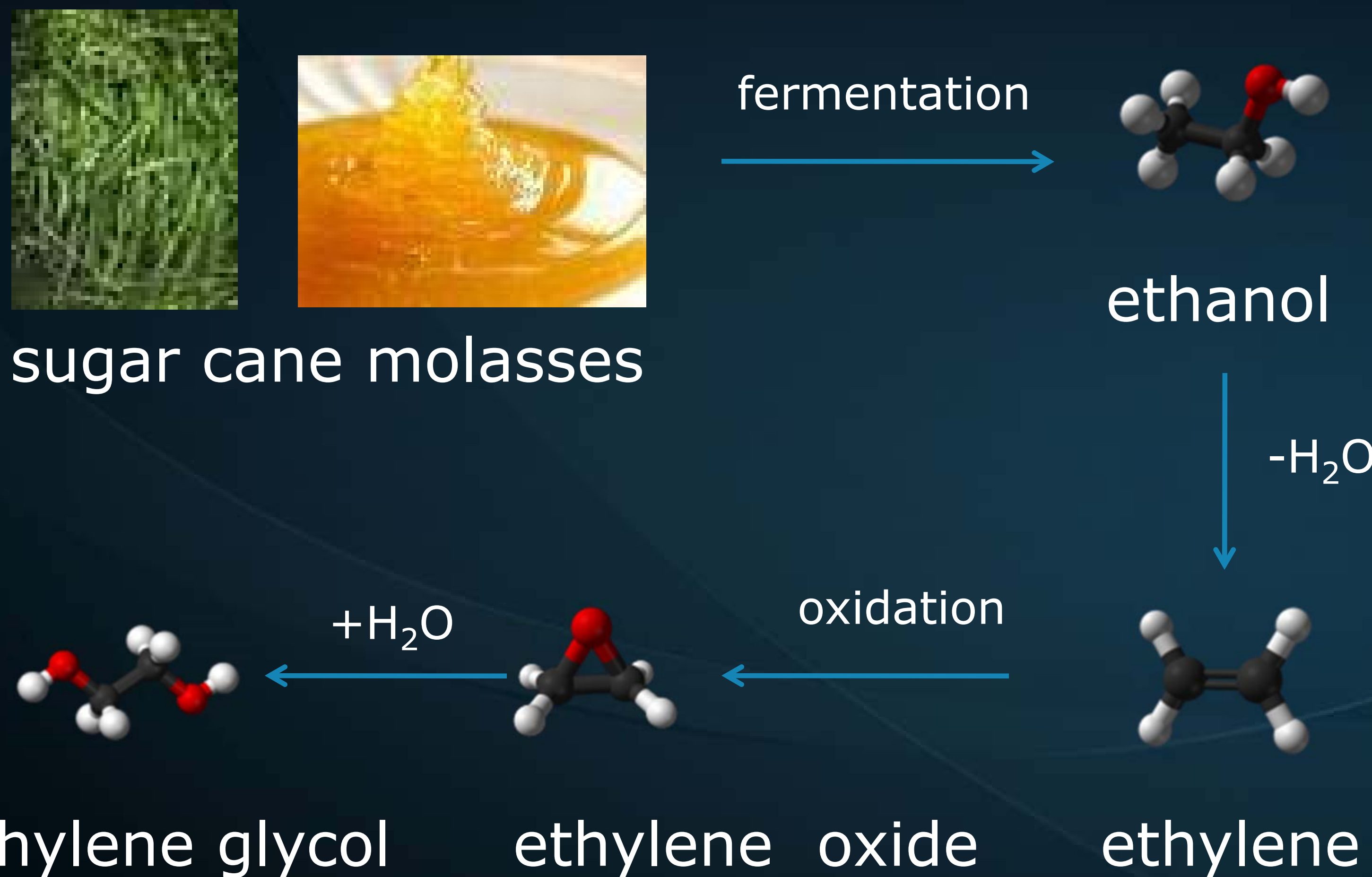
Why The Change?

- "Compostables" performance v durables.
- Continuing lack of infrastructure for use and disposal of compostable plastics.
- Increasing demand for biobased, semi-durable and durable products for household goods, electronics and automotive applications.
- Increasing interest and developments in existing and new monomers from renewable resources.

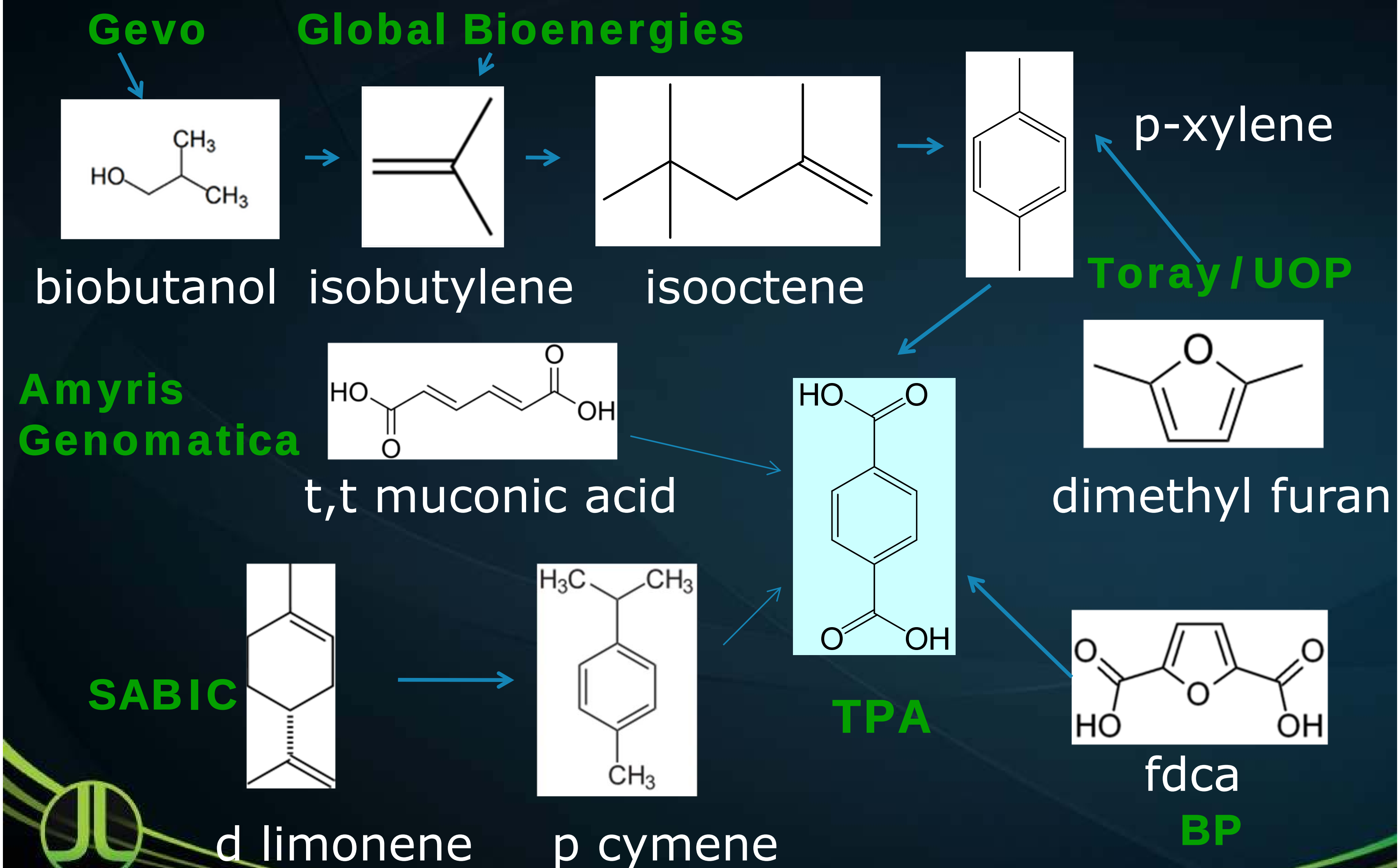
Key Bio Monomer Activities.

Bio Ethylene Glycol (MEG)

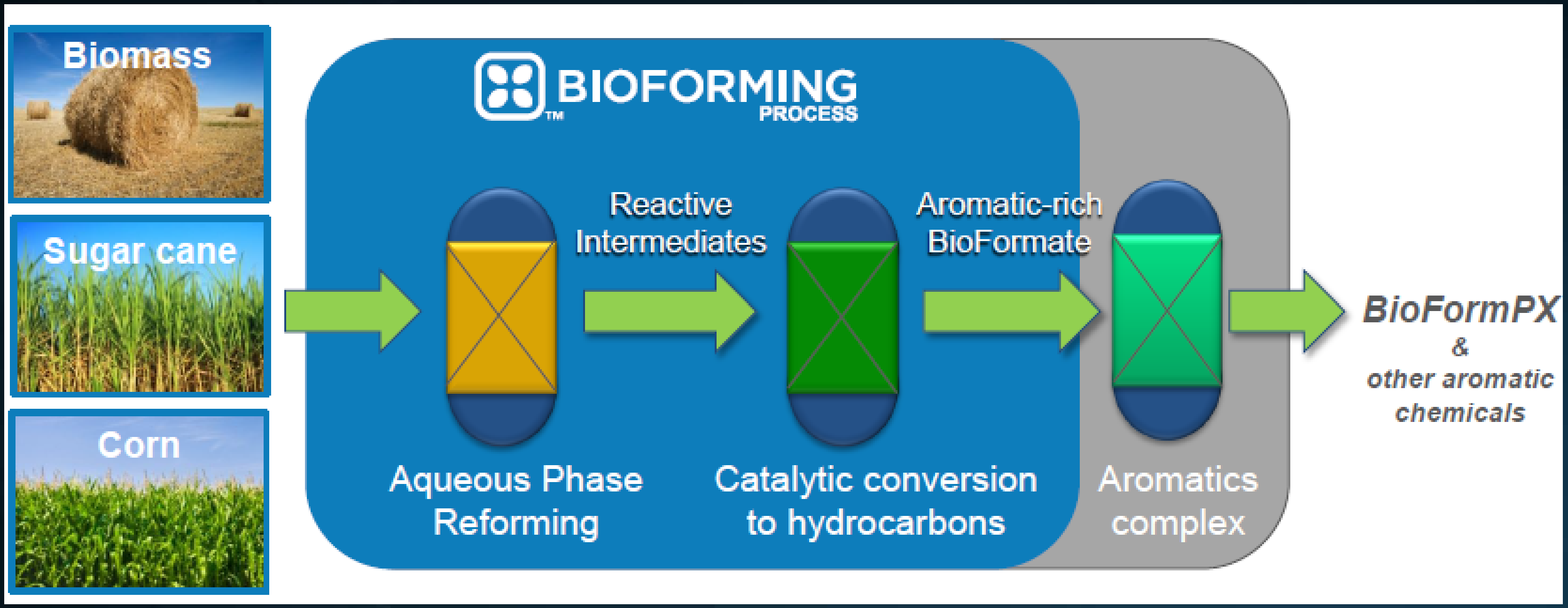
India Glycols, GTC, FENC, JBF



Bio Terephthalic Acid (TPA)

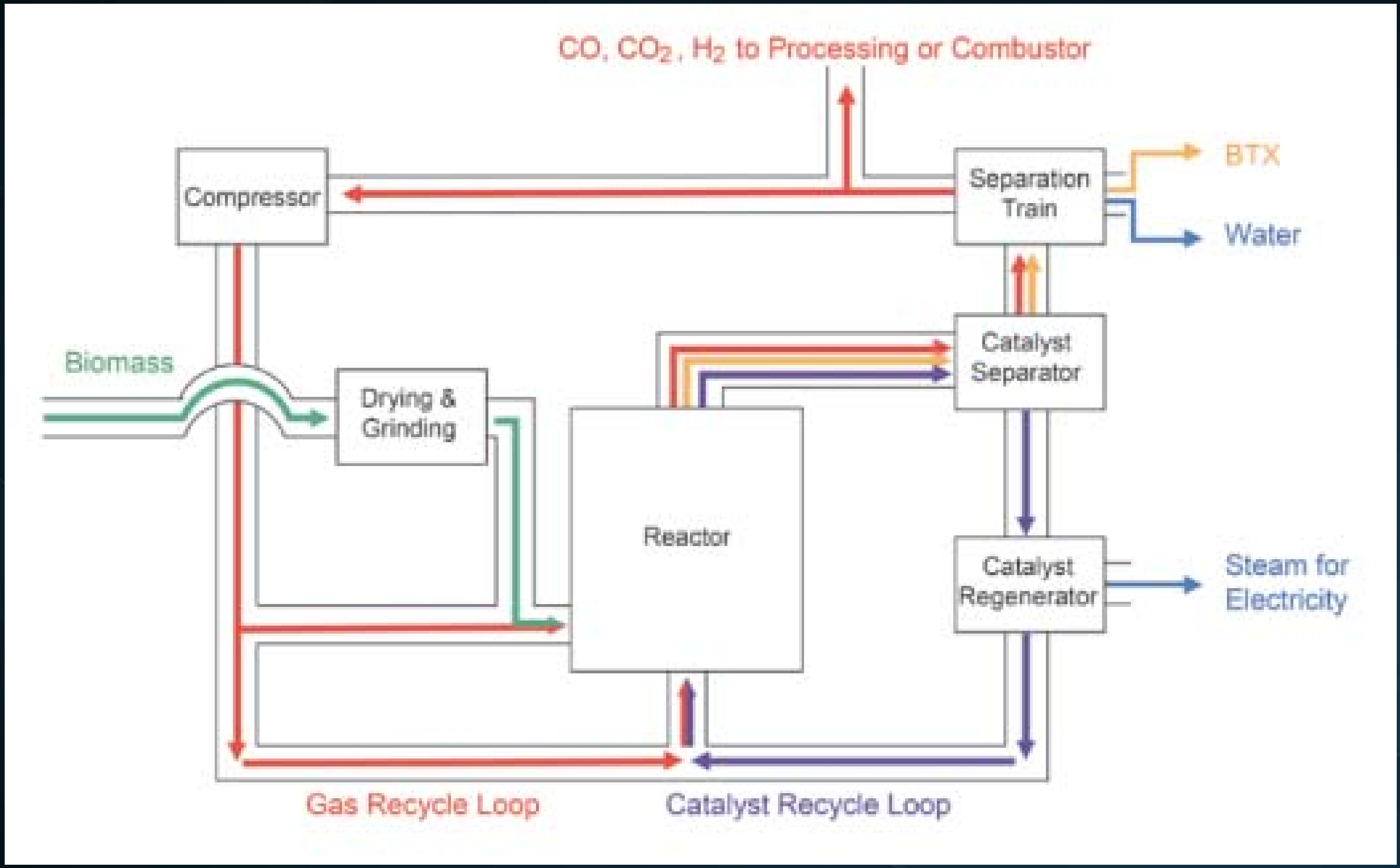


Biobased p-Xylene (PX)



Virent Process.

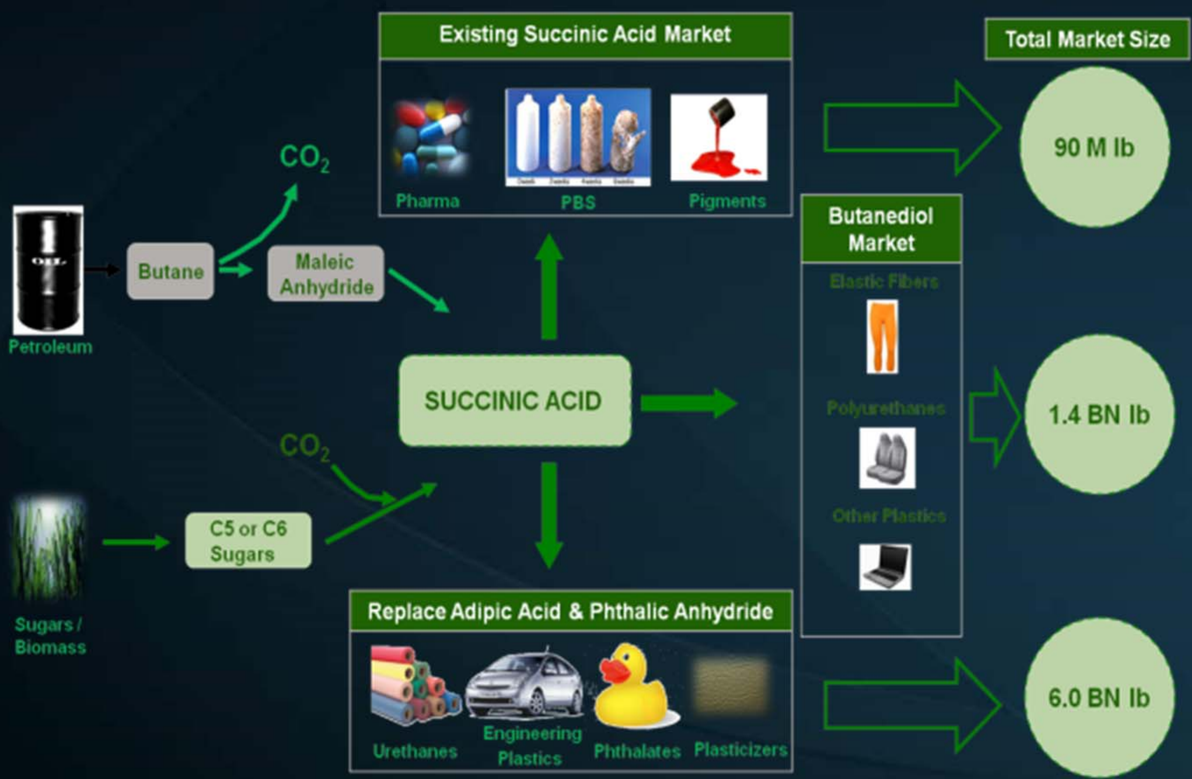
Anellotech Process- Bio BTX



BTX=benzene, toluene, xylenes mixture.

Bio Succinic Acid and Derivatives

Biobased Succinic Acid



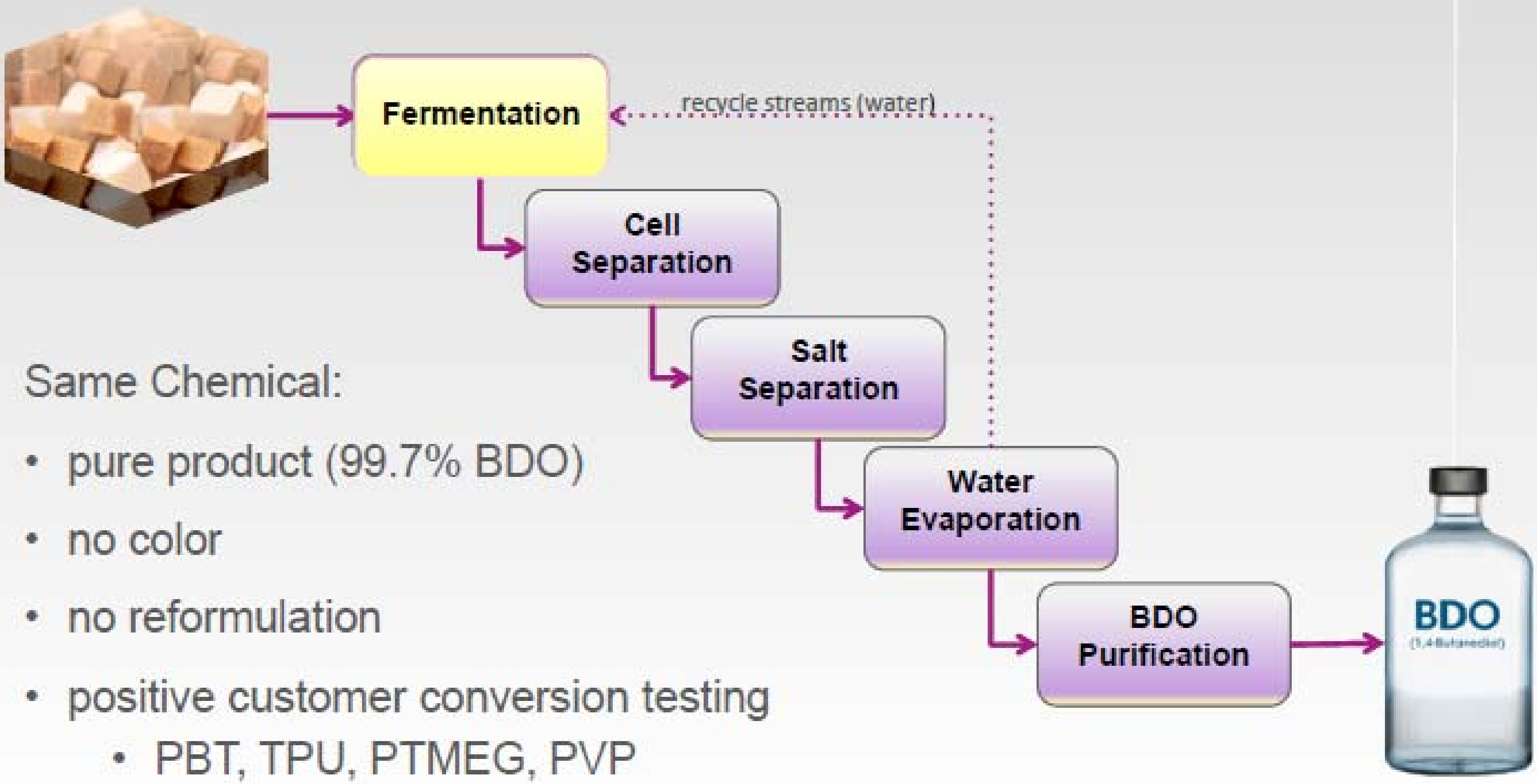
Succinic acid/PBS
- BioAmber
- PTT
- MCC
- DSM/Roquette
- BASF/Purac

Butane diol
- Genomatica

Adipic acid
- Rennovia
- Verdezyne

Courtesy Myriant

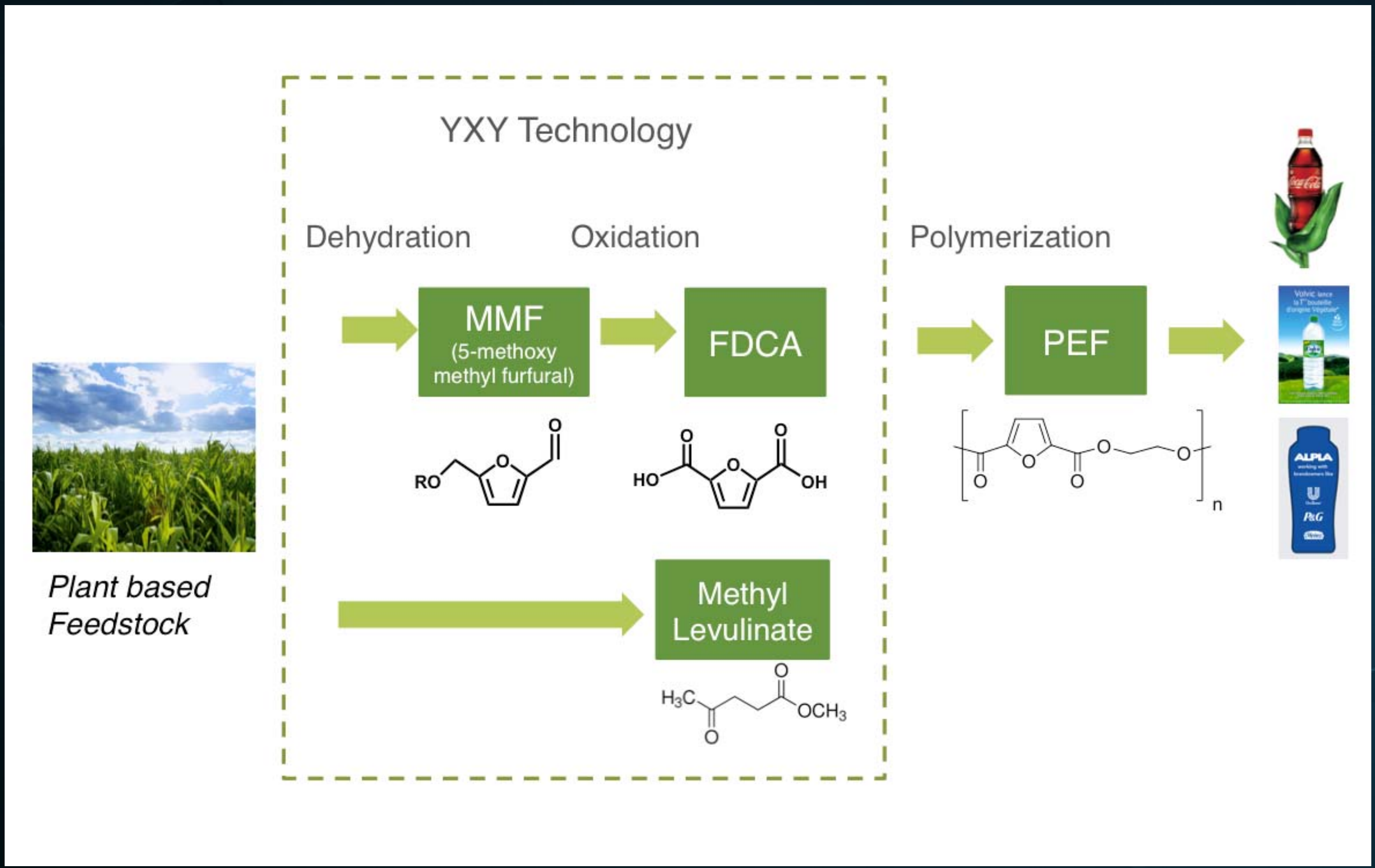
Bio Butane Diol



Same Chemical:

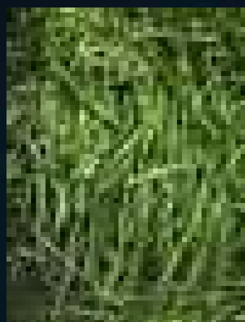
- pure product (99.7% BDO)
- no color
- no reformulation
- positive customer conversion testing
  - PBT, TPU, PTMEG, PVP

Bio FDCA (furan 2,5 dicarboxylic acid) - Avantium

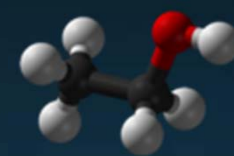


Key Biobased Polymer Activities.

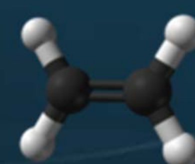
Braskem "Green Polyethylene" from Sugar Cane



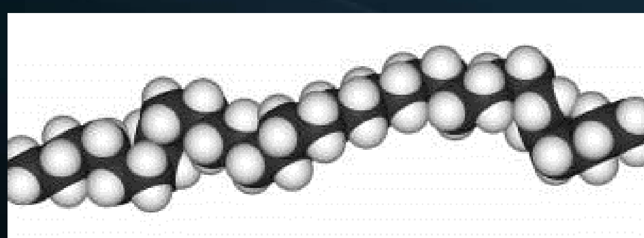
sugar cane molasses



ethanol



ethylene

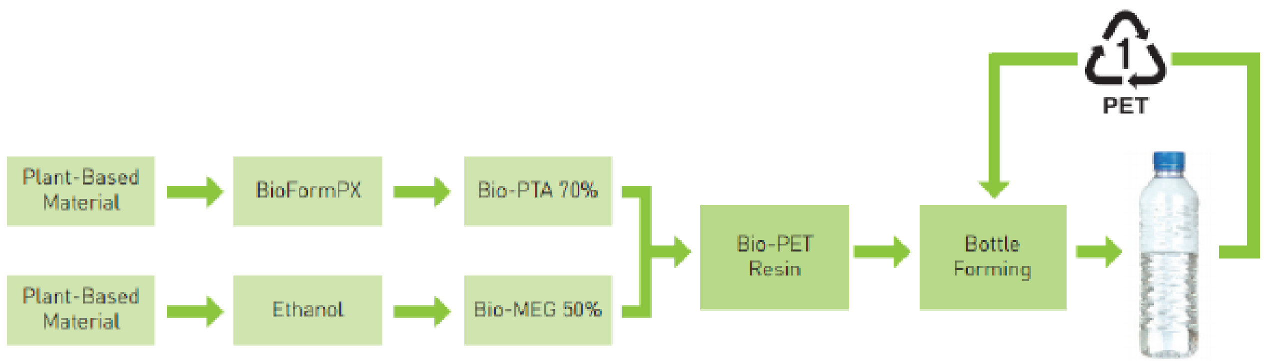


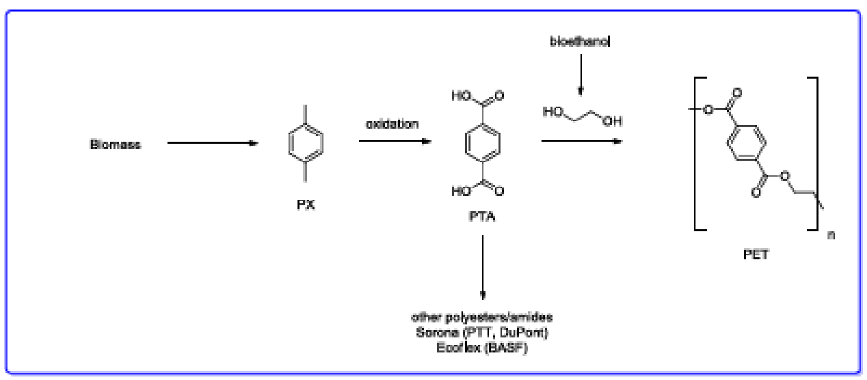
HDPE polyethylene

Bio PET

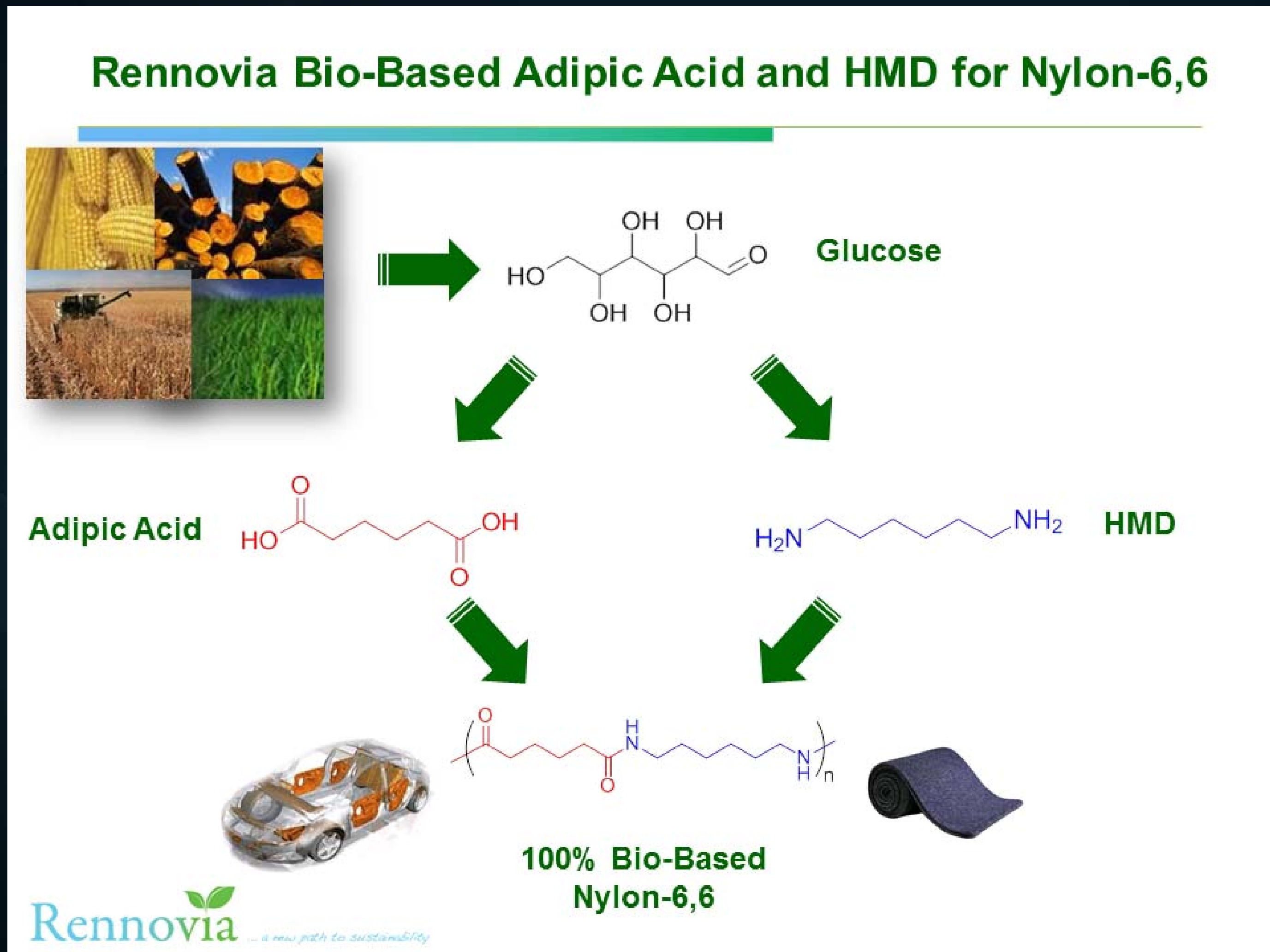
Plant-based polyethylene terephthalate (PET) Synthesis/Production

- Green PET production

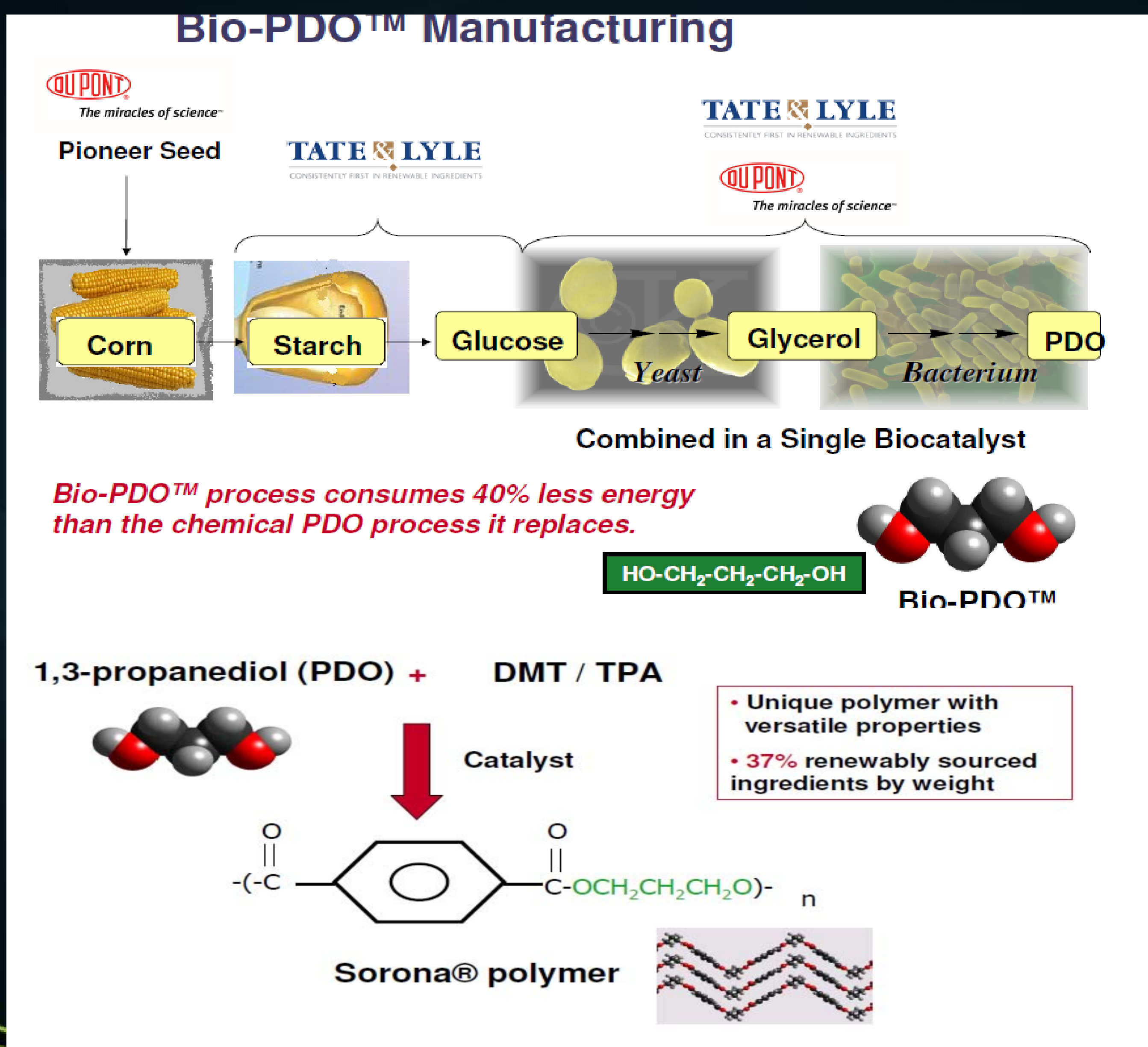




Nylon 6,6

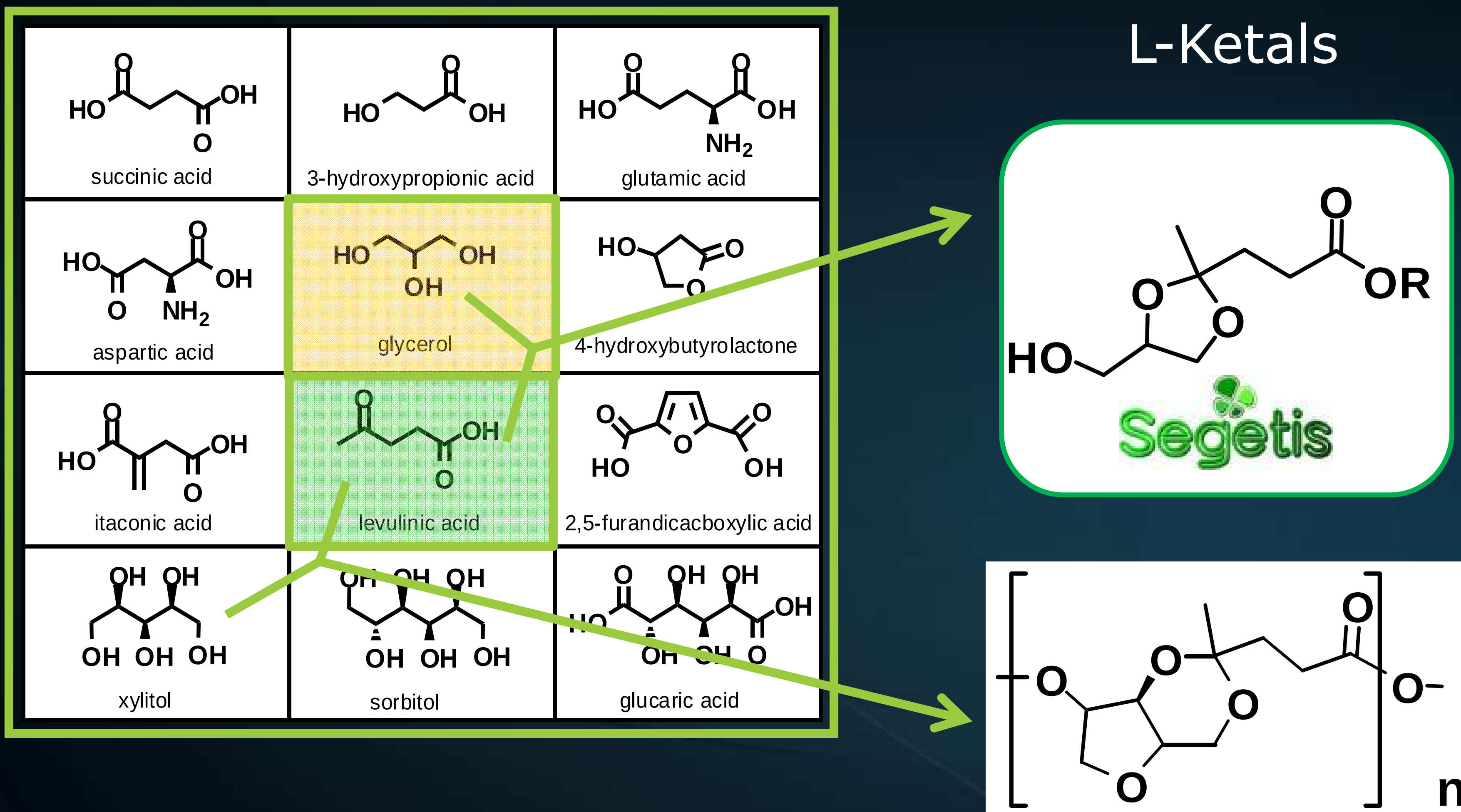

Rennovia Bio-Based Adipic Acid and HMD for Nylon-6,6
Glucose
Adipic Acid
HMD
100% Bio-Based
Nylon-6,6
Rennovia

Sorona™-PTT


Bio-PDO™ Manufacturing
The miracles of science
Pioneer Seed
TATE & LYLE
Corn
Starch
Glucose
Yeast
Glycerol
Bacterium
PDO
Combined in a Single Biocatalyst
Bio-PDO™ process consumes 40% less energy than the chemical PDO process it replaces.
$HO-CH_2-CH_2-CH_2-OH$
Bio-PDO™
1,3-propanediol (PDO) +
DMT / TPA
Catalyst
• Unique polymer with versatile properties
• 37% renewably sourced ingredients by weight
$-(-C(=O)-C_6H_4-C(=O)-OCH_2CH_2CH_2O)-_n$
Sorona® polymer

Ketal Plasticizers/Poly XLK

L-Ketals



PXLK

RELUCEO
XLTerra

Today's Bioplastic Feedstocks

All refined sugars - dextrose, glucose, sucrose.

Concerns with Existing Feedstocks from Food Crops

The Food versus Fuel debate:

- Food Crops Diversion to Fuels/Plastics
- Land Use
- Fertilizer Use
- Pesticide Use
- The "Ripple Effect "

Use of GMO's

More "Sustainable" Biomass Feedstocks

Lignocellulose
(wood, corn stover, other agricultural residues)

Oil seeds (soy, rape/canola, palm, coconut, Jatropha)

Microalgae

Macroalgae (kelp)

Waste:

- MSW, food processing (cellulosic)
- Used fats and oils
- Animal processing wastes (rendering, feathers, hair, manure)

Leading Biomass Source – Lignocellulosics

Source: Virent –"The Future For Bioplastics Feedstocks"

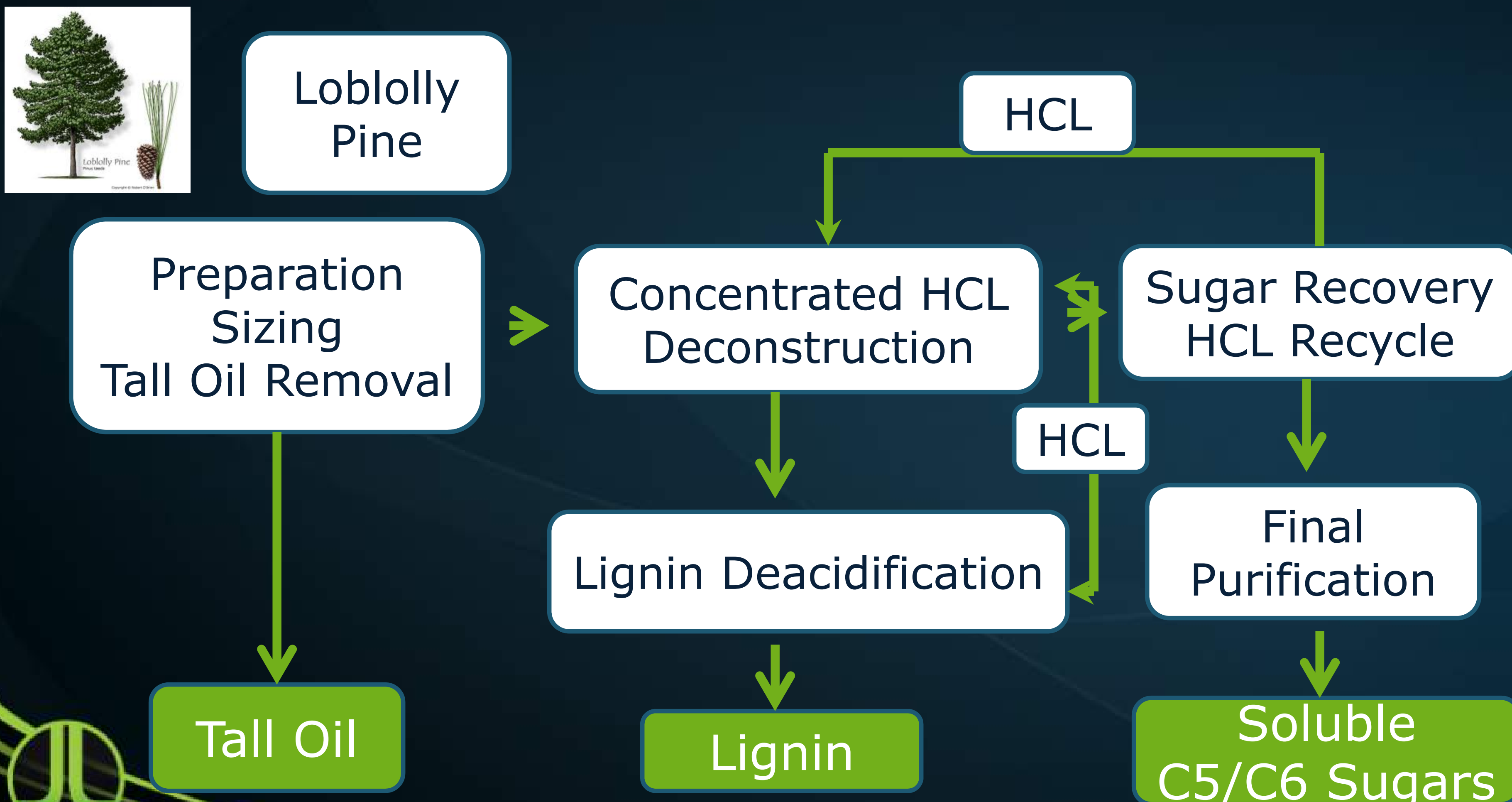
Extracting Sugars From Cellulosics

Most Common Approaches

Dilute acid and enzyme hydrolysis	Concentrated acid extraction
Wet oxidation and enzyme hydrolysis	Catalytic biomass deconstruction

Commercially Proven Technology

Virdia (Stora Enso) Process (c1938)



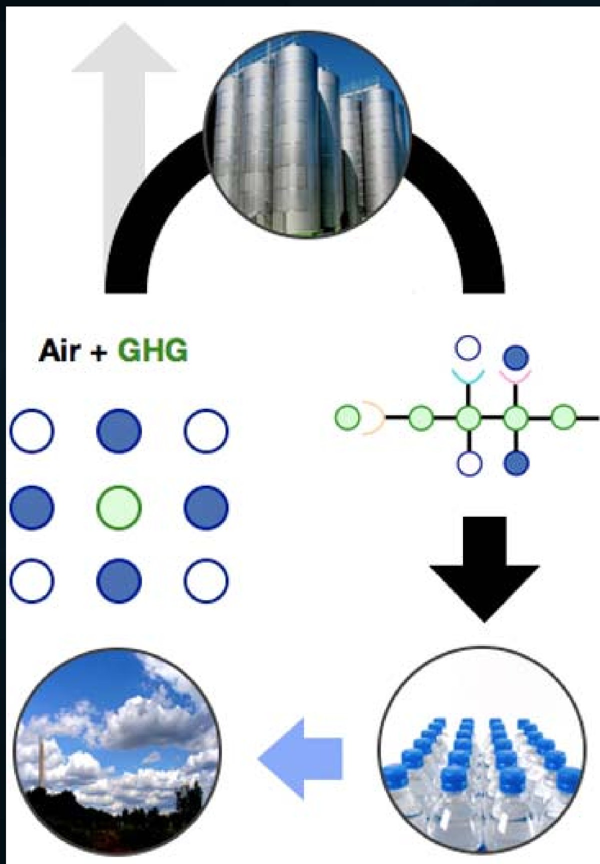
•Virdia
•Chemtex/M&G- Beta Renewables
•American Science and Technology (AST)

Extracting Sugars From Cellulosics

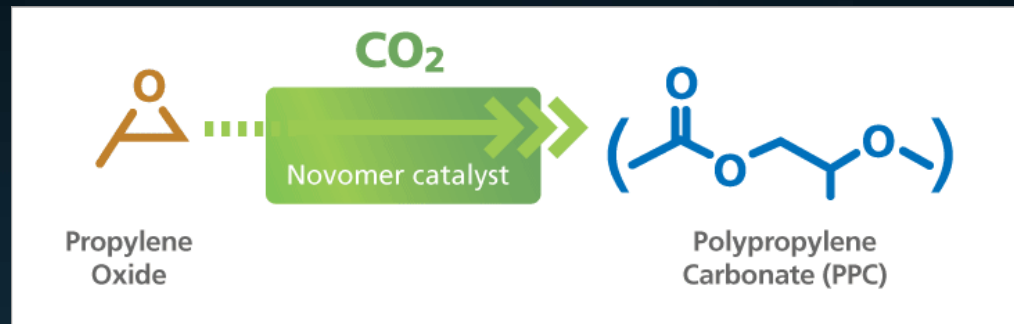
Pilot Scale

- Renmatix
- Chemtex/M&G- Beta Renewables
- American Science and Technology (AST)

Green House Gases as Feedstocks

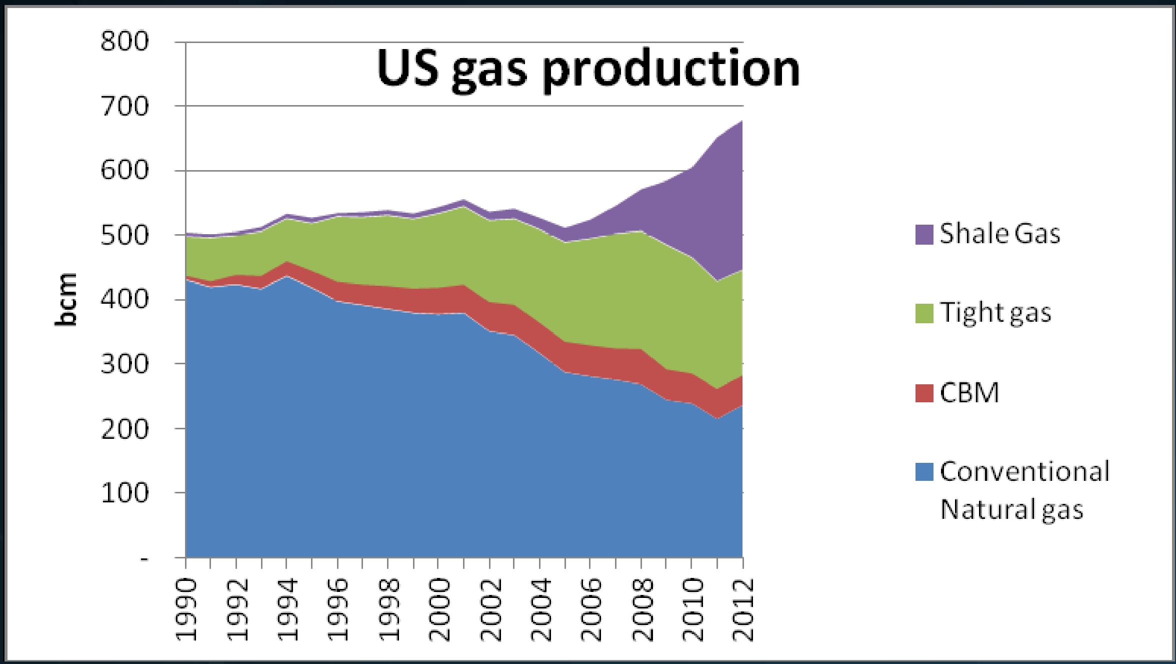


Newlight Technologies PHA’s



Novomer PPC

Shale Gas-Emerging Threat to Bioplastics?



- ➢propylene, butadiene and aromatics yields cut by as much as 55%.
- ➢ Ethylene/polyethylene costs decreased.

Challenges/Opportunities for Bio Materials

- Oil pricing continuing to increase.
- Improved performance/ reduced cost for compostables.
- Composting/recycling infrastructure developments.
- Expanding from single-use compostable to durable applications.
- Moving to non-food source feedstocks.
- Competition from carbon dioxide based plastics.
- Natural gas dynamics on polyolefin/ aromatics pricing.

Thank You

JIM LUNT & associates llc

www.jimluntllc.com

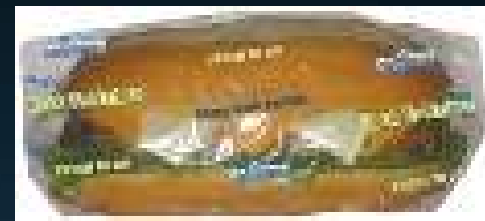
Bioplastic Products In The Marketplace

Extra Slides

PLA


Rigids
Food Serviceware
Films
Nonwovens / Fibers
Durables
Lactides
Bus. Dev.
INGEO™ LACTIDES
Incubator
ingenious materials from plants not oil
2
ingeo™
© 2011 NatureWorks LLC

Cellulose Acetate



Compounded PLA/Starch Blends

Green Polyethylene

Bio PET


Coca-Cola
DASANI

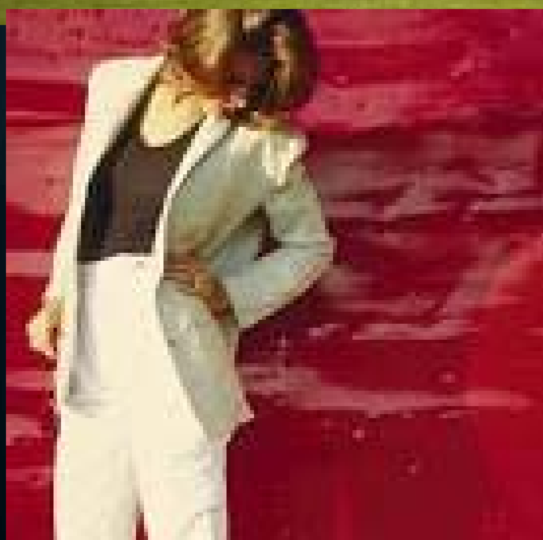

HEINZ
GUESS WHAT MY BOTTLE IS MADE OF?
TOMATO KETCHUP

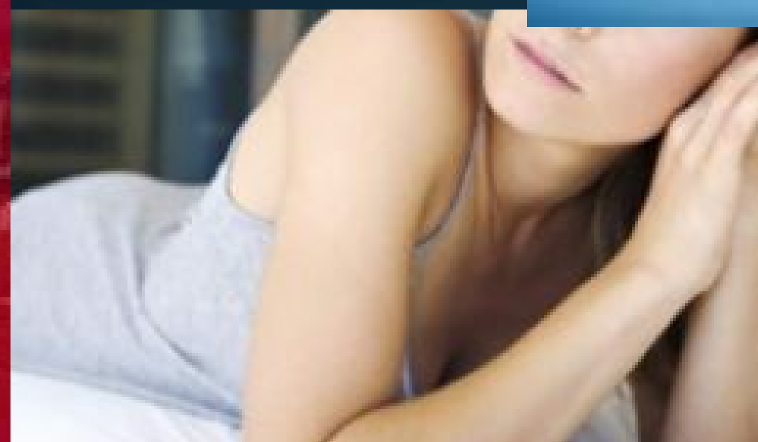

Transparent Packaging Inc.
RUB FOR SCENT
Clean-Up
With Our Innovative Clear Packaging Solutions and These Complimentary Monitor Wipes


adidas
moves
pulse


speck

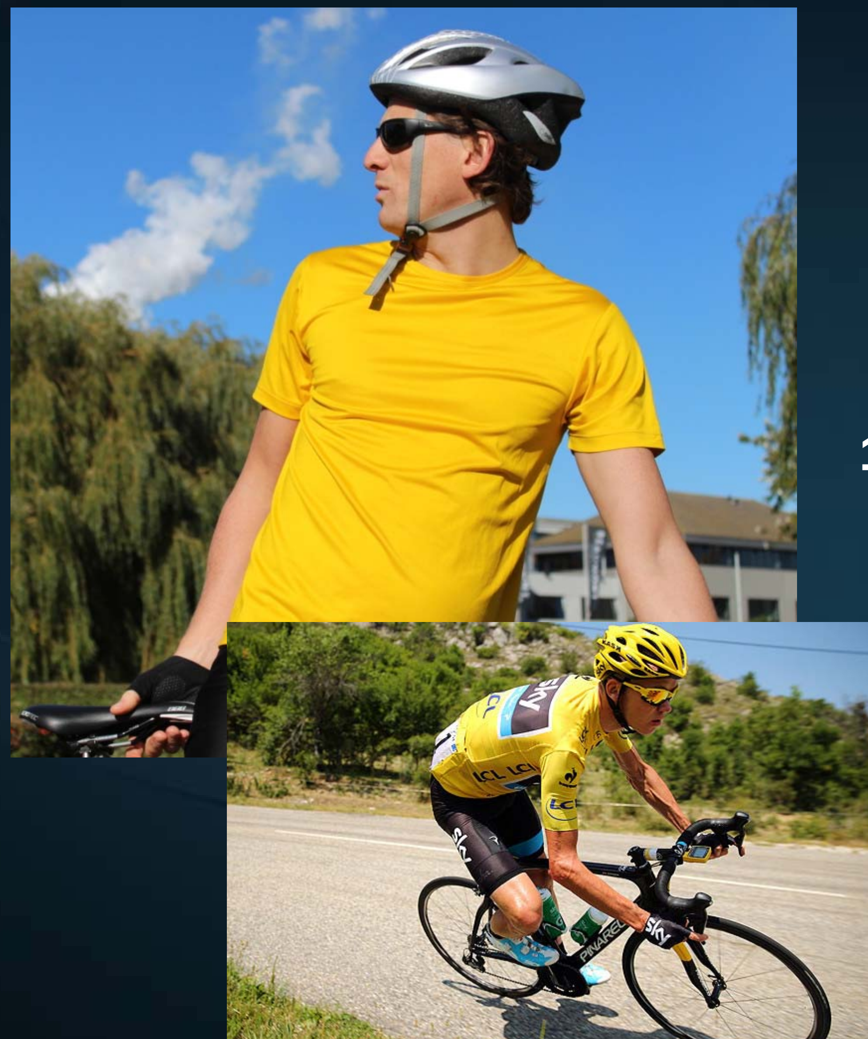
Sorona





Avantium PEF

T-shirts -100% recycled PEF bottles



Made from 100% Recycled PEF

Conventional polyester spinning technology

Conventional polyester dyeing technology