



Feedstock Diversification through Innovation

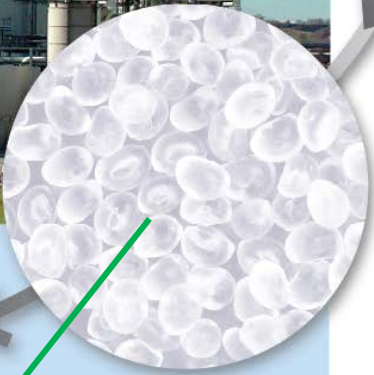
Ken Williams

November 3, 2015

Feedstock Diversification through Innovation

- **Who is NTR?**
- Why is NTR doing this?
- What feedstock(s) make sense?
- How long will it take?

“turning greenhouse gases (GHG) into performance products”



**1.5 Billion lb
Milestone**

Who we are

- World's first and largest bioplastics producer
- World-scale plastics facility
- 2002 Winner - Presidential Green Chemistry Challenge
- DOE partner (1998-2008) to develop world-scale biorefinery (over \$18M in DOE support)
- Proprietary portfolio of Ingeo bio-polymers & intermediates
- Peer reviewed LCA, strong eco-profile
- Global customer base and product adoption
- Ingeo applications with breadth across markets, geographies, and retail applications

ingenious natural selection

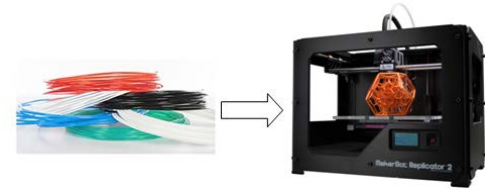
Where are we in the market....



Semi-durables



Durables



3D printing



Single Use

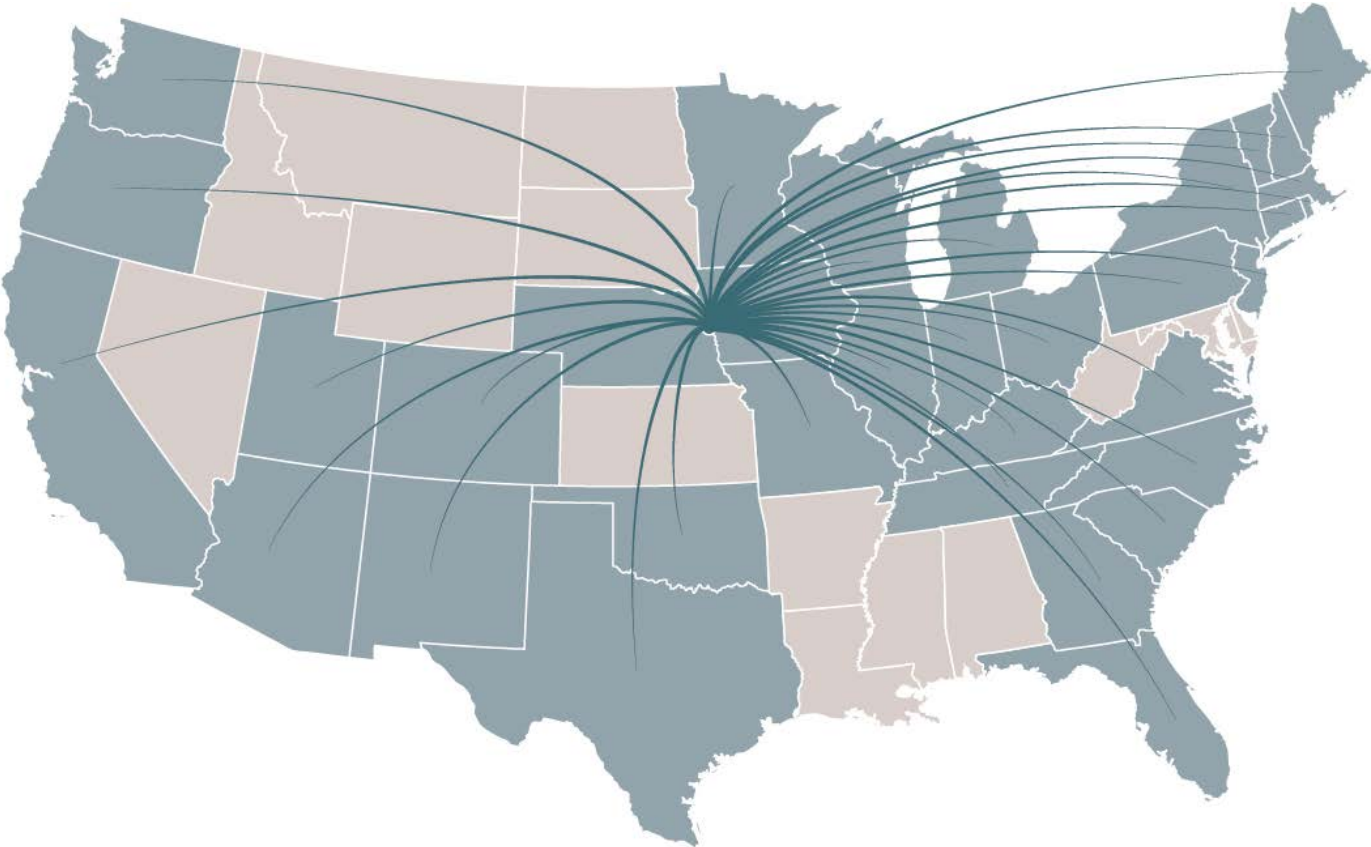


ingenio

naturally advanced materials

 NatureWorks

NatureWorks is fueling green jobs and innovation in the national bioeconomy



Manufacturers in 36 states produce products using Ingeo and retailers like Walmart & Target feature Ingeo packaging or products in all 50 states

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What We've Learned with Ingeo™ Biopolymers in the Marketplace

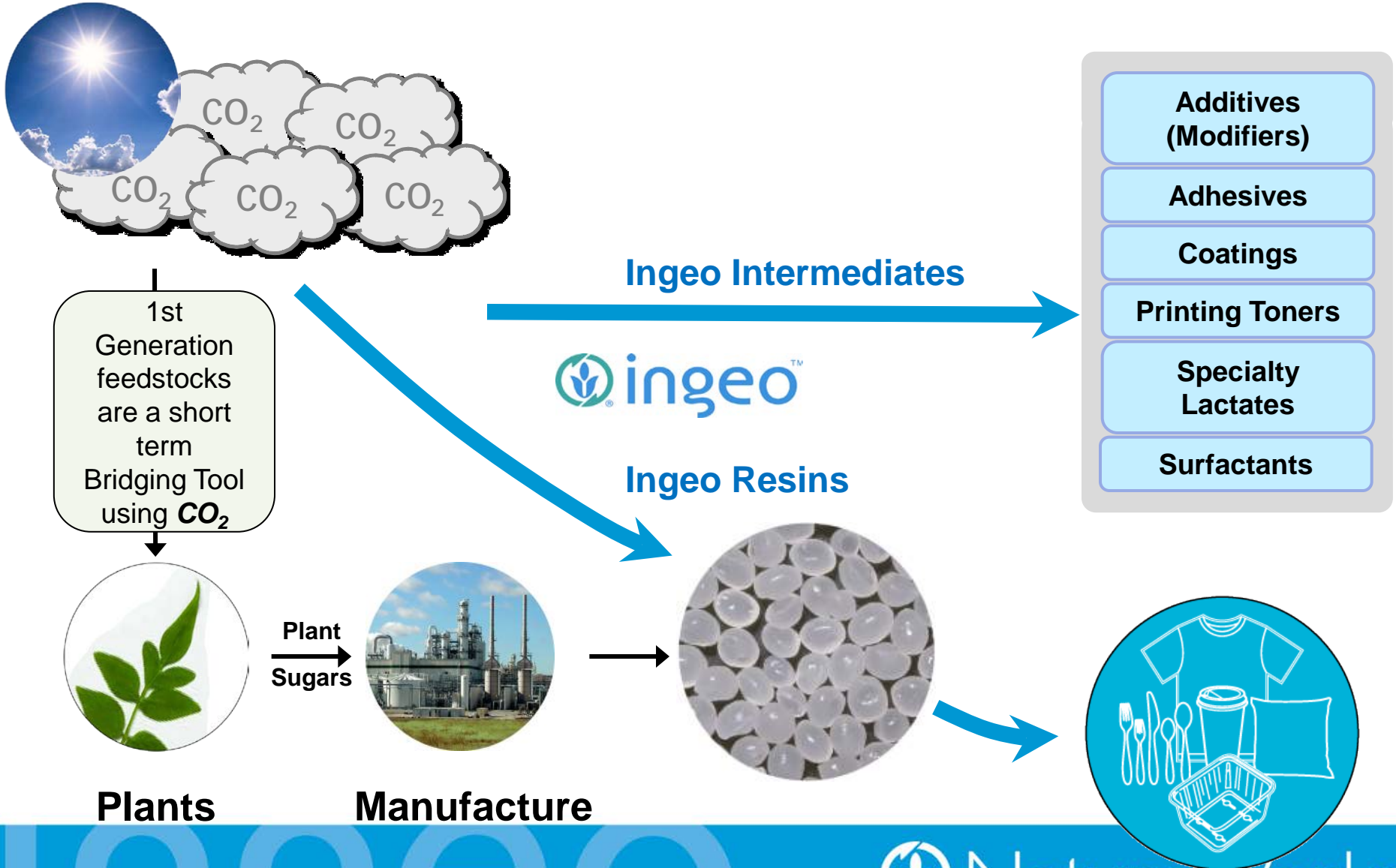
- Many NGOs and customers would prefer we used non food biomass as the source for our sugars
- No green premium
- Must compete on price and performance with petroleum-based competition. *We compete today with PS, PET and PP.*
- In order to maintain our low cost position, we must lower the cost of inputs (e.g. energy, materials)
- Biopolymer and Ingeo growth will accelerate as costs are removed from the value chain

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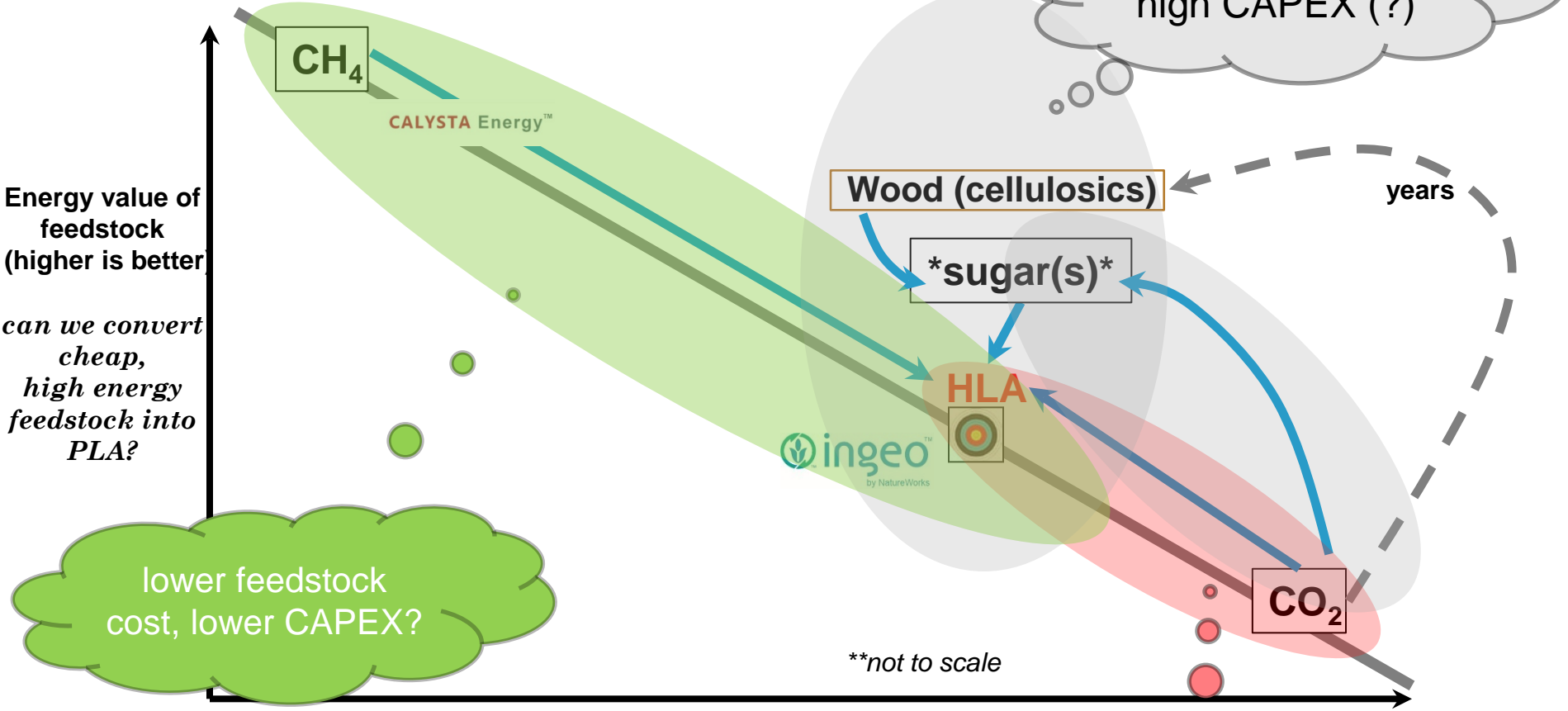
NatureWorks is a company formed with the mission of turning greenhouse gases (GHG) into performance products



Feedstock Food Chain...

Would you rather walk uphill or downhill?

sugar(s)
today: corn → dextrose
cellulosics → mixed C5/C6 sugars
CO₂ → sucrose



Carbon oxidation state

Low titer, low productivity, 2D modular approach

We are committed to feedstock diversification:

Investment in innovation and R&D collaboration to grow our Ingeo feedstock portfolio.

Performance materials made by transforming whatever are the right, abundant, local resources

1st Gen: GHGs to Lactic Acid via Ag Feedstocks

1st step



Where we are today

Dextrose from corn starch

“Bridging Crops”

2nd step

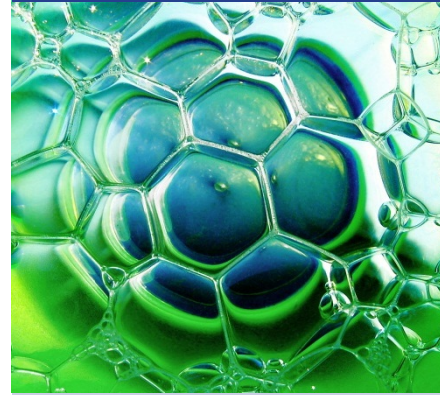


Where we are going now

Sucrose from locally abundant materials such as sugar cane

Next Gen: GHGs to Lactic Acid

Direct Conversion



Next 3-6 years

CO₂ to lactic acid technology?

CH₄ to lactic acid technology

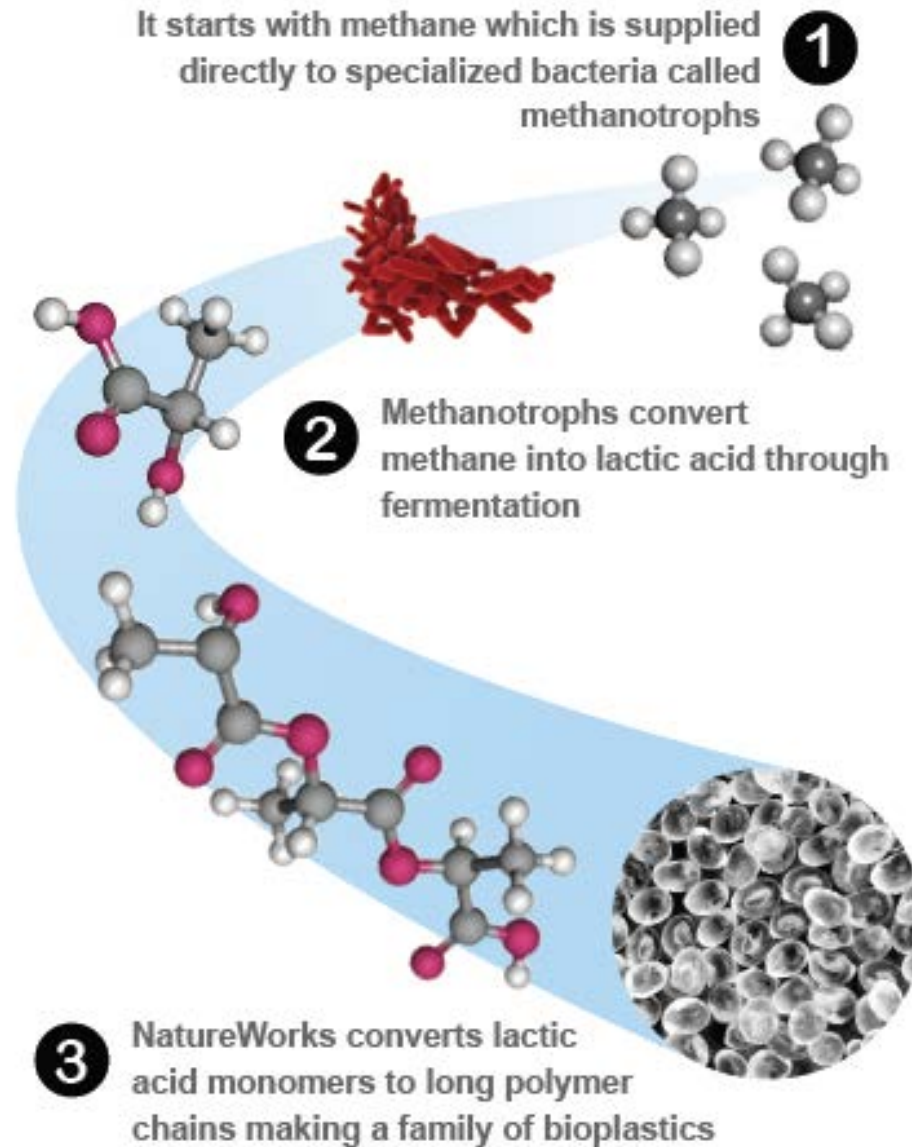
via Cellulosic Sugars



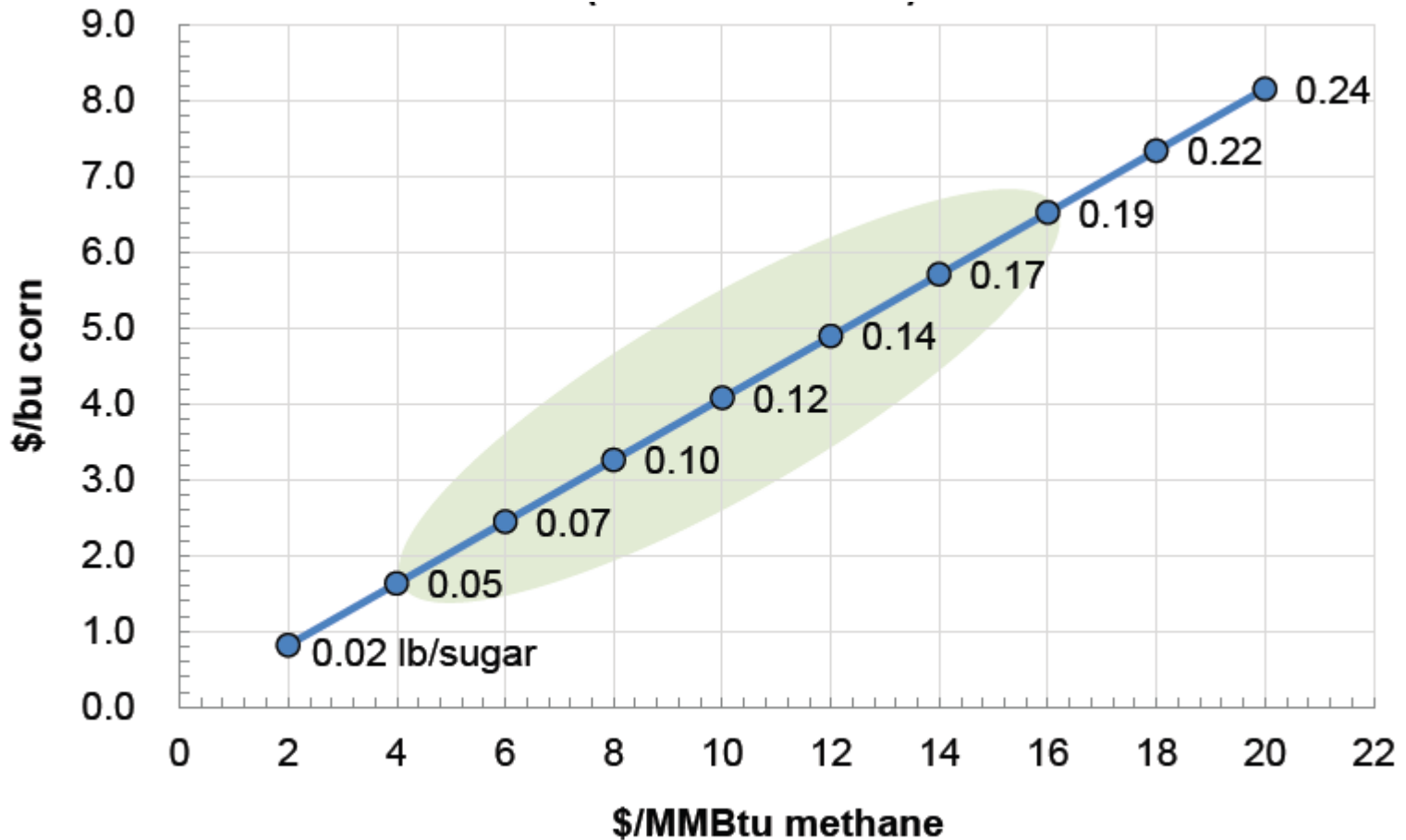
Next 3-6 years?

Lignocellulosics: Sugars from bagasse, wood chips, switch grass or straw.

Methane to Biopolymer



Methane vs Corn to HLA (feedstock cost)



Calculation assumptions:

- 1 Heating value of methane = 20,000 BTU/lb, methane to lactic yield = 80% of 1.875 g/g theoretical / 90% sugar to lactic acid yield
- 2 Corn to sugar yield = 34 lb/bu

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Q2-2013 R&D Partnership Established

CALYSTA Energy™

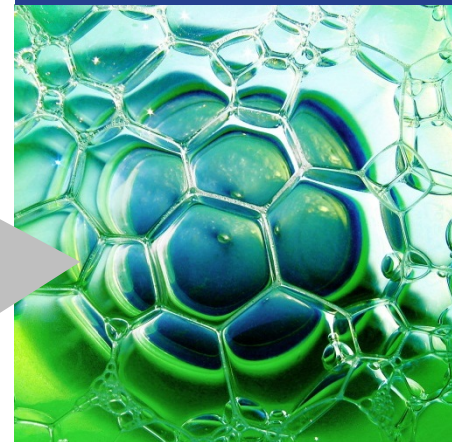
 NatureWorks

Calysta Energy™ and NatureWorks Announce an R&D Collaboration to Transform Methane into the Lactic Acid Building Block for Bioplastics

MENLO PARK, Calif., and MINNETONKA, Minn., June 18, 2013 — Calysta

Energy™ and NatureWorks have entered into an exclusive, multi-year collaboration to research and develop a practical, world-scale production process for fermenting methane – a potent greenhouse gas (GHG) – into lactic acid, the building block for ...

Direct Conversion



Next 3-6 years...

CH₄ to lactic acid technology

We are committed to feedstock diversification:

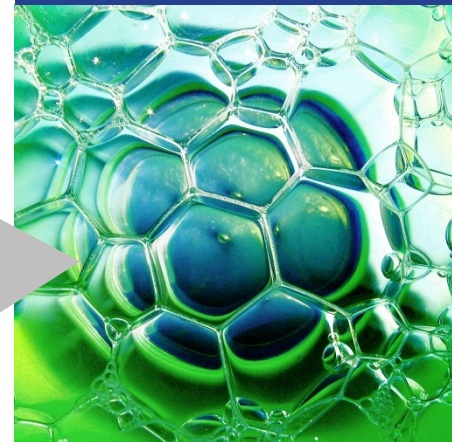
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Successful conversion of methane to HLA

Menlo Park, CA – June 16, 2014 – Calysta, Inc. (www.calysta.com) today announced it has successfully fermented methane into lactic acid, under a research collaboration with NatureWorks. Lactic acid is the building block for NatureWorks Ingeo™ lactide intermediates and polymers used in consumer and industrial products worldwide. The joint development program, started in June 2013 between Calysta and NatureWorks, is focused on creation of a commercially viable methane-to-lactic-acid process. The key aims are providing a structurally simplified, lower cost Ingeo production platform and diversifying NatureWorks' feedstock portfolio.

Direct Conversion

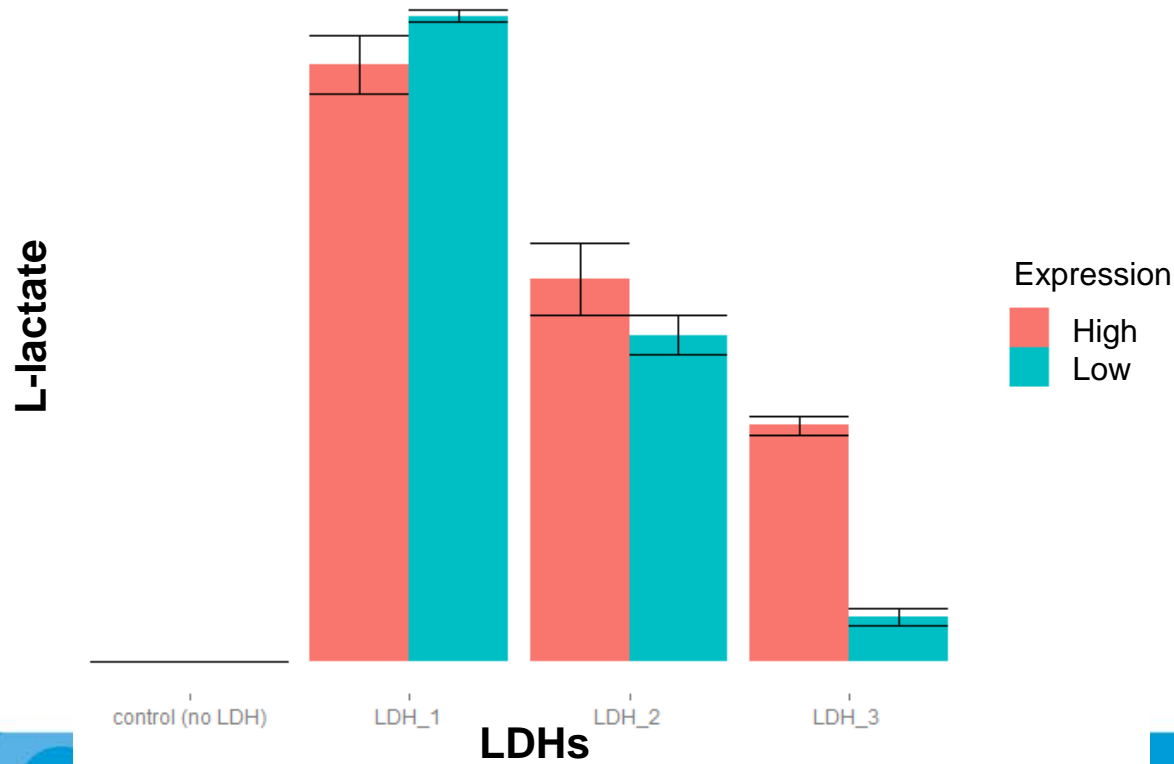


Next 3-6 years...

CH₄ to lactic acid technology

Lactic Acid Production from Methane

World's first demonstration of L-lactate production from an engineered strain

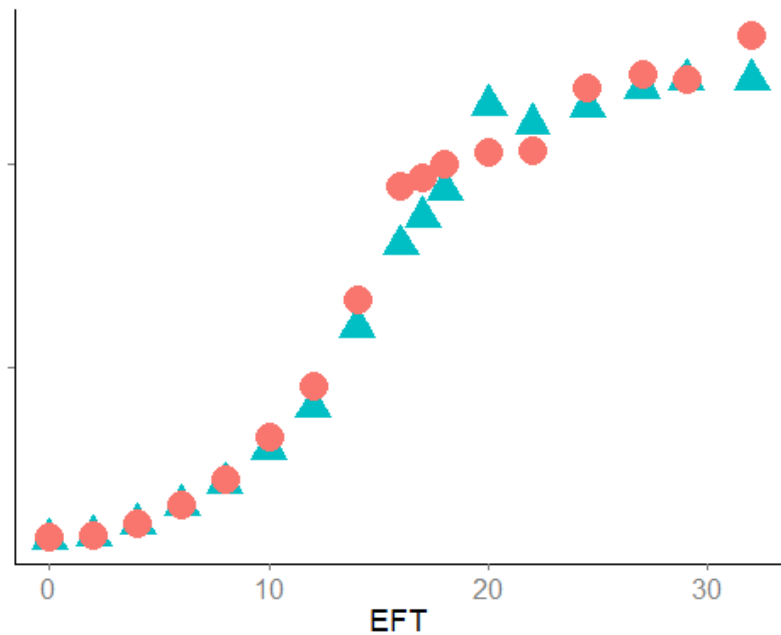


Lactic Acid Production from Methane

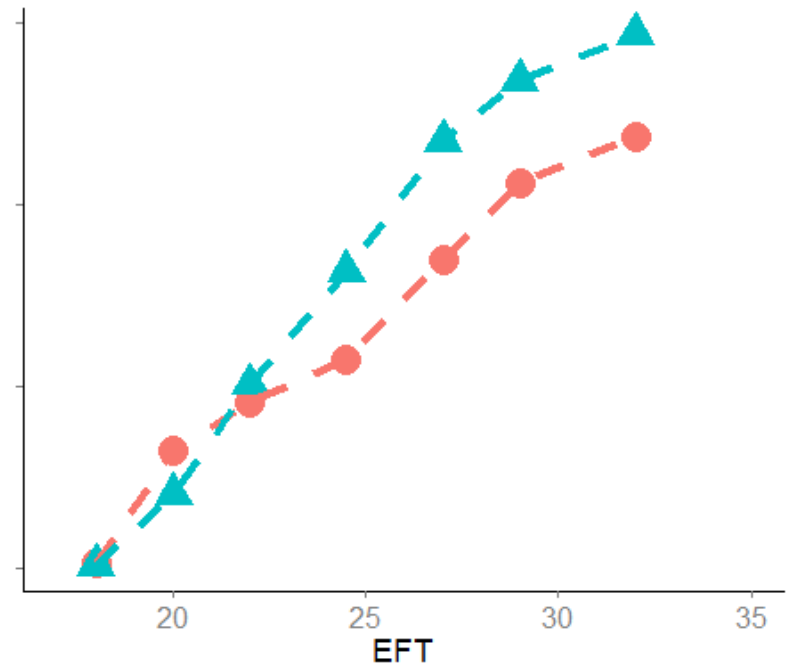
World's first demonstration of L-lactate production from an engineered strain

Fermentation (2L)

Growth (OD600)



Lactate accumulation



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\$2.5 DOE BETO Grant for Biogas to HLA

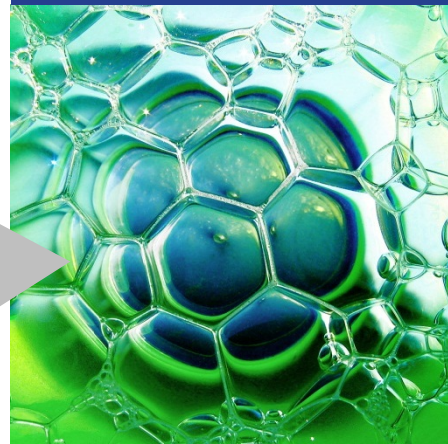
CALYSTA Energy™

 **NatureWorks**

DOE AWARDS \$2.5 MILLION TO NATUREWORKS TO TRANSFORM BIOGAS INTO THE LACTIC ACID BUILDING BLOCK FOR INGENEO

MINNETONKA, Minn., October 30, 2014 -- The U.S. Energy Department's Office of Energy Efficiency and Renewable Energy, Bioenergy Technologies announced a grant of up to \$2.5 million to NatureWorks, one of the world's leading suppliers of bioplastics, in support of an ongoing program that aims to sequester and use methane, a potent greenhouse gas, as a feedstock for the company's Ingeo™ biopolymers and intermediates.

Direct Conversion



Next 3-6 years...

CH₄ to lactic acid technology

Ingeo
naturally advanced materials

 **NatureWorks**

Lactic Acid Production from Biogas

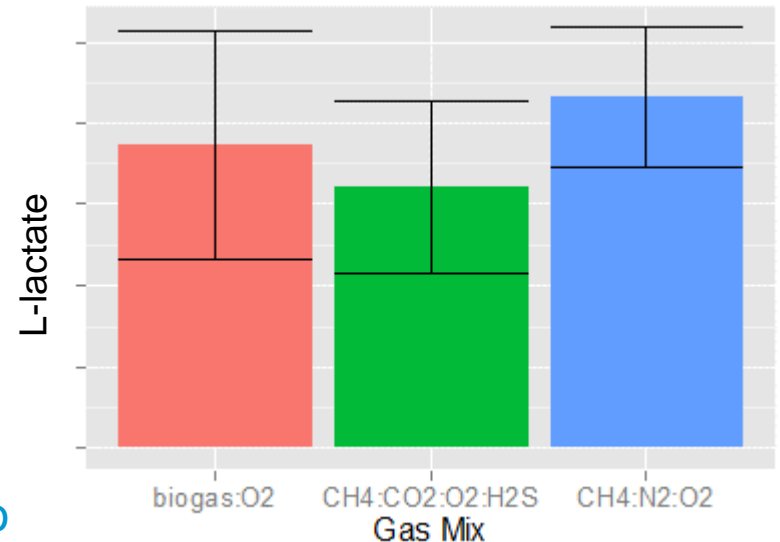
- In addition to methane, biogas contains CO_2 , H_2S and other components that may inhibit growth and/or lactate production.
- Our strains are able to grow and produce lactate from biogas.

Typical Biogas composition:

- 60 % methane
- 39 % carbon dioxide
- 1 % other gases



Methane diluted with either nitrogen or carbon dioxide produces similar amounts of L-lactate to biogas → *no significant toxicity*



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NTR/ Calysta Collaboration -- Recapping

- NatureWorks and Calysta developing methane to HLA process (joint R&D effort)
- Expected cost: \$multi-MM development cost
- Expected timeline: multi-year effort to pilot plant
- Goal: significantly lower Ingeo™ cost
- Real project with real \$ currently invested that has potential to lead the way towards sustainable/renewable US biochemical industry

INNOVATION TAKES ROOT

A Collaborative Biopolymers Forum
for the Global Ingeo Community

SAVE THE DATE FOR 2016

MARCH ★ APRIL

30 TO 01

Orlando, World Center Marriott

@NatureWorks



innovationtakesroot.com



Innovation Takes Root (ITR) is a unique conference bringing together global users of Ingeo biopolymer for 3-days of collaboration, learning, panel discussions & networking



Naturally advanced materials made from locally abundant and sustainable natural resources

Thank you.



@natureworks



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www.natureworkslc.com

