



# Bio-Oxo Technology

DE-EE0005773

12/2014-12/2017

---

## Easel Biotechnologies LLC

Dr. Lars Rohlin

Business Officer: Dr. Shahrooz Rabizadeh

Principal Investigator: Dr. Yixin Huo

U.S. DOE Advanced Manufacturing Office Program Review Meeting

Washington, D.C. May 28-29, 2015

This presentation does not contain any proprietary, confidential, or otherwise restricted information.

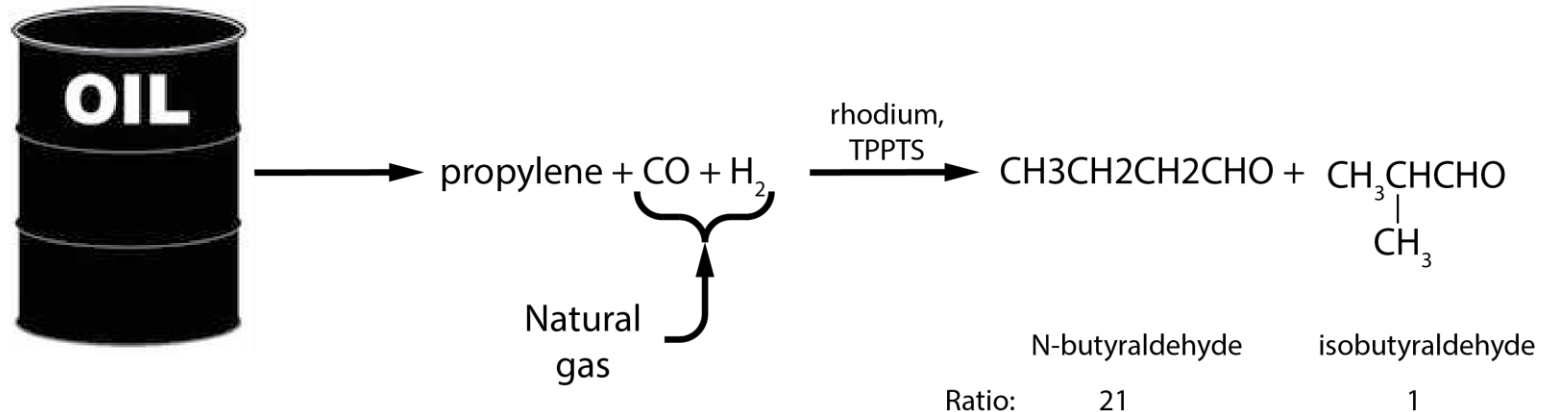
# Project Objective

---

- **Convert renewable feed stocks into isobutyraldehyde for use in a wide variety of everyday products including plastics, resins, paints and lubricants using only a biological process.**
- **What is the problem?**
  - Natural cells produce very little aldehydes if any at all.
  - Aldehydes are unstable and reactive compounds.
- **Why is it difficult?**
  - Aldehydes are more toxic to bacterial cells than alcohols.
  - Toxins and inhibitors such as acetate, formate and 5-(hydroxymethyl)furfural are created during the deconstruction process of non-food cellulosic carbon.

# Technical Approach

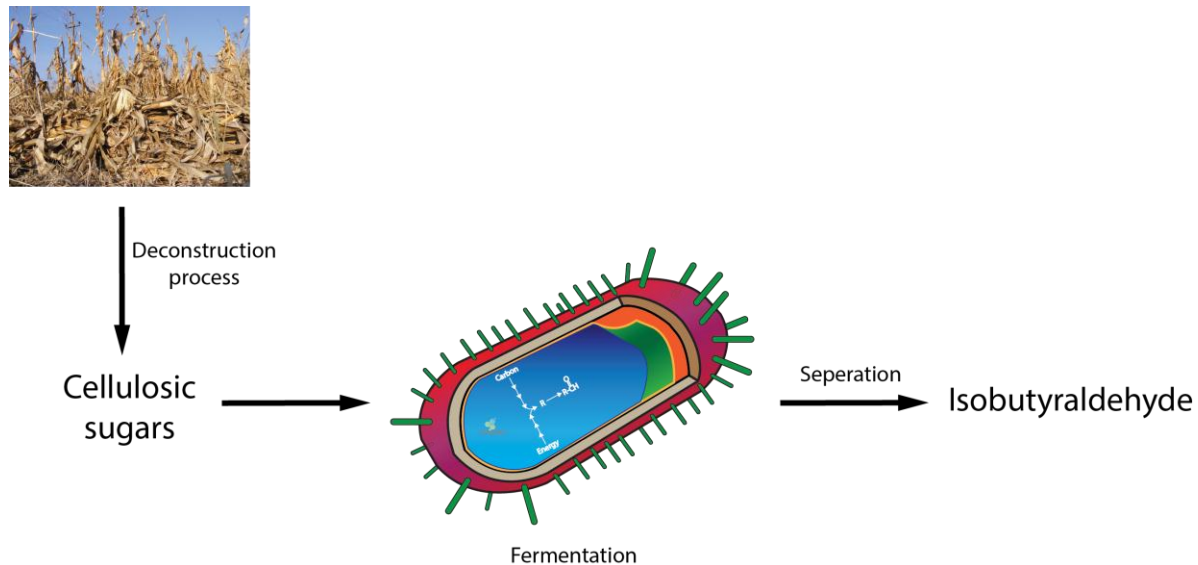
- **Current Best Practice for Chemical Oxo Process**
  - Ruhrchemie/Rhone-Poulenc oxo process.
  - Aqueous biphasic catalysis.
  - Geared toward n-butyraldehyde.
  - Use fossil fuels for starting materials.
  - Overall market size: 7,000,000 ton/year.



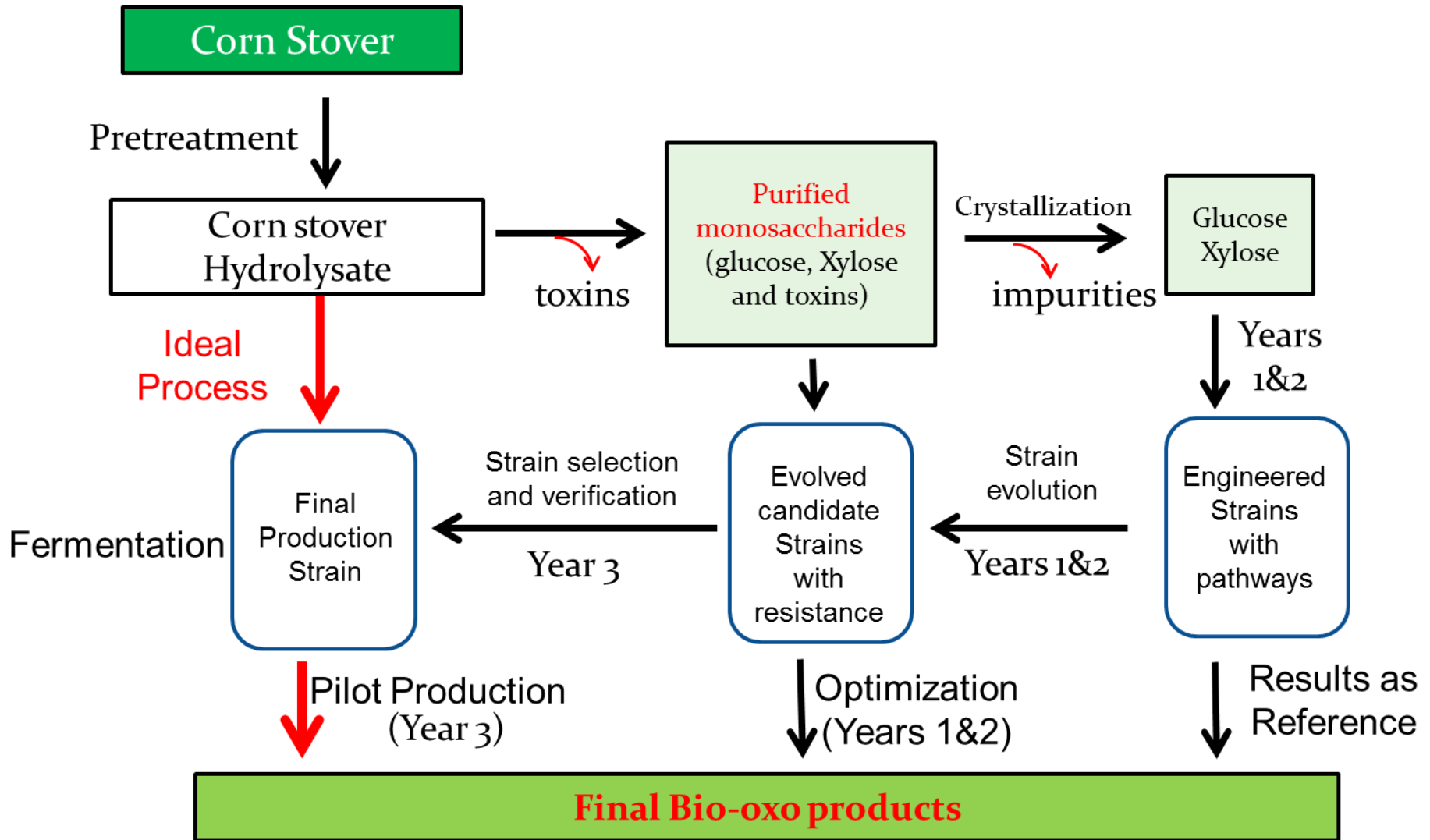
# Technical Approach

- **Bio-oxo approach**

- Easel process is the first approach to produce isobutyraldehyde biologically.
- In situ removal of product for continuous production.
- Longer fermentation.



# Process Overview

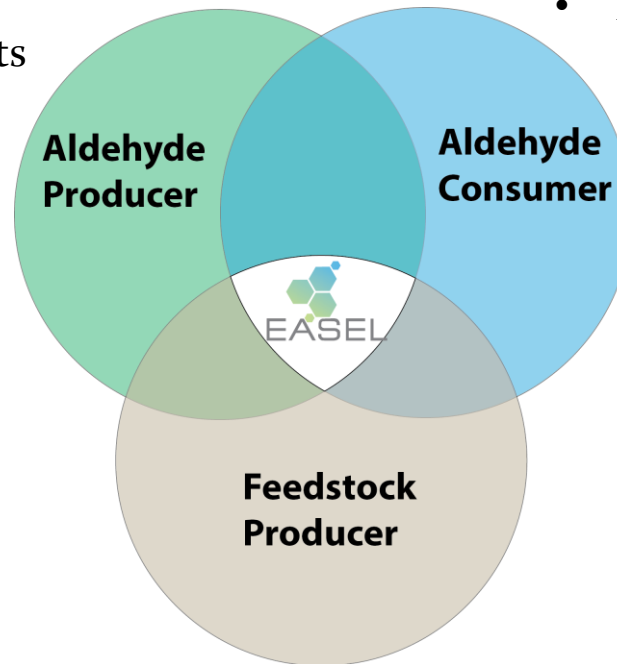


# Transition and Deployment

**Commodity chemicals produce from a renewable resources that is environmentally friendly with a reduced carbon footprint and at a cost competitive price will benefit all.**

- Apply their expertise and economy of scale
- Reduce fossil fuel dependence
- Offer bio-based “green” products
- Premium pricing

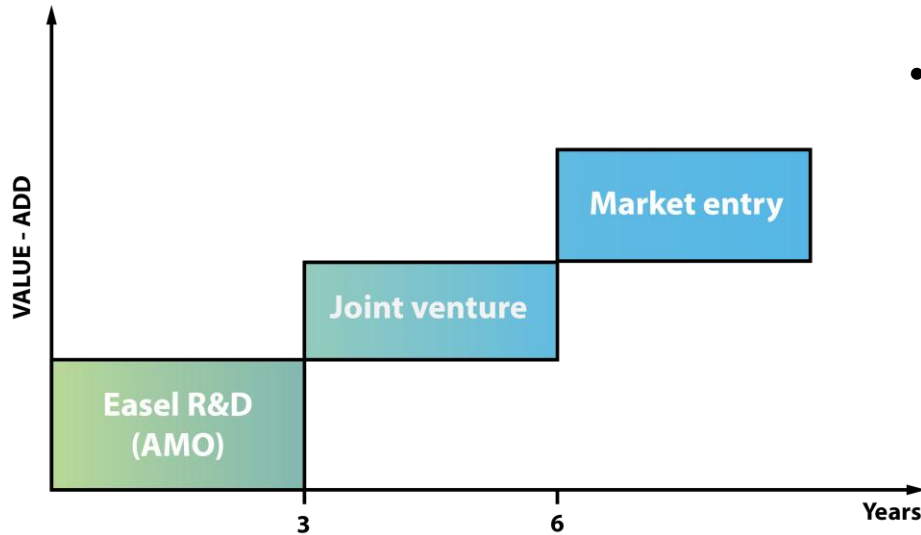
- Reduce fossil fuel dependence
- Bio-based manufacturing



- Increase efficiency
- Reduce waste
- Additional revenue stream

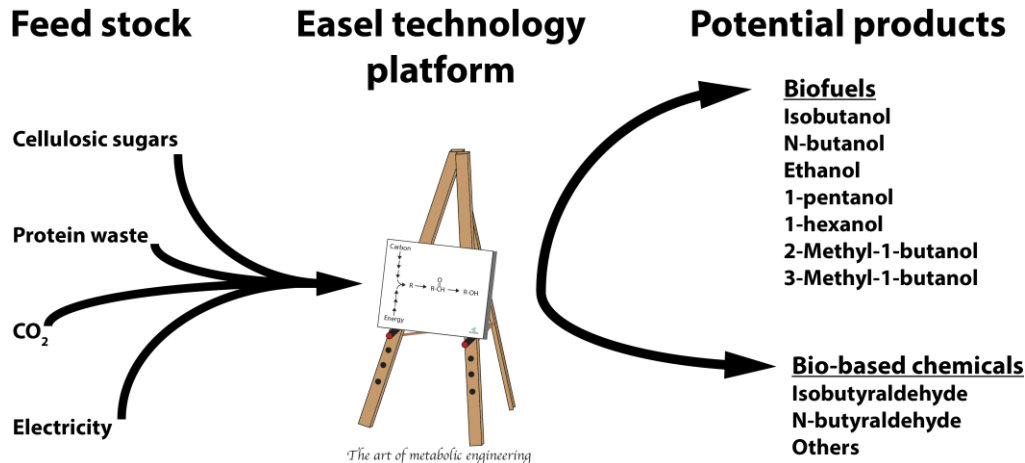
# Transition and Deployment

- Easel commercialization approach



- Next step: Find a strategic partner to form a joint venture to initiate a demonstration plant. Preferable the partner is a current aldehyde producer.

- Technology sustainment



- Our technology allows us to quickly pivot and extend the technology to other bio-based chemicals and biofuels.

# Measure of Success

---

- Introduce a new class of fermentation processes.
- New bio-based aldehyde will mean more “green” products manufactured for consumer markets.
- Reduce fuel consumption by equivalent of 50 million barrels of liquid petroleum gas per year.
- Reduce natural gas consumption by 13 billion cubic feet per year.
- Additional revenue stream for feed producers.



# Project Management & Budget

Project duration: 3 years

Go/No Go Decision point and final delivery schedule.

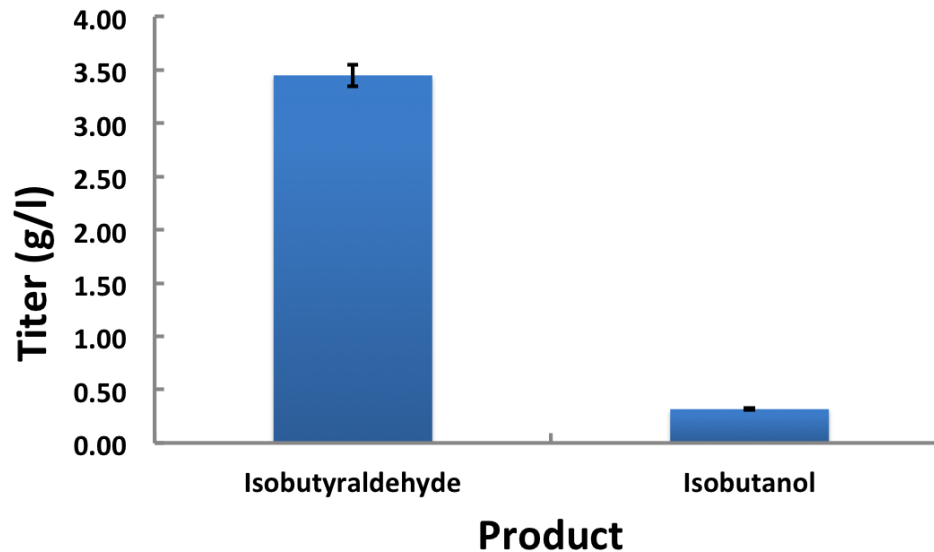
Task	Title	Go/No Go Decision point	Time
1	Improve Isobutyraldehyde Productivity by Strain Engineering and Develop Fermentation and Separation Process	Productivity: 0.3 g/L/hr Titer: 10 g/L	2015 Q4
2	Strain and Pathway Optimization and Development of Integrated Processes.	Productivity: 0.6 g/L/hr Titer: 30 g/L	2016 Q4
3	Demonstrate the Integrated Production Process in Pilot Scale (30L).	Productivity: 1.0 g/L/hr Titer: 50 g/L Theoretical yield: 60%	2017 Q4

Total Project Budget	
DOE Investment	2,000,000
Cost Share	500,000
Project Total	2,500,000

# Results and Accomplishments

---

- Completed first quarter out of 3 years, met milestone
- Current titer from corn stover hydrolysate 3.5 g/l



- Improve titer 15 fold by
  - Genetic engineering
  - Strain development
  - Fermentation optimization and product removal