Bio-Oxo Technology

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Easel Biotechnologies, LLC

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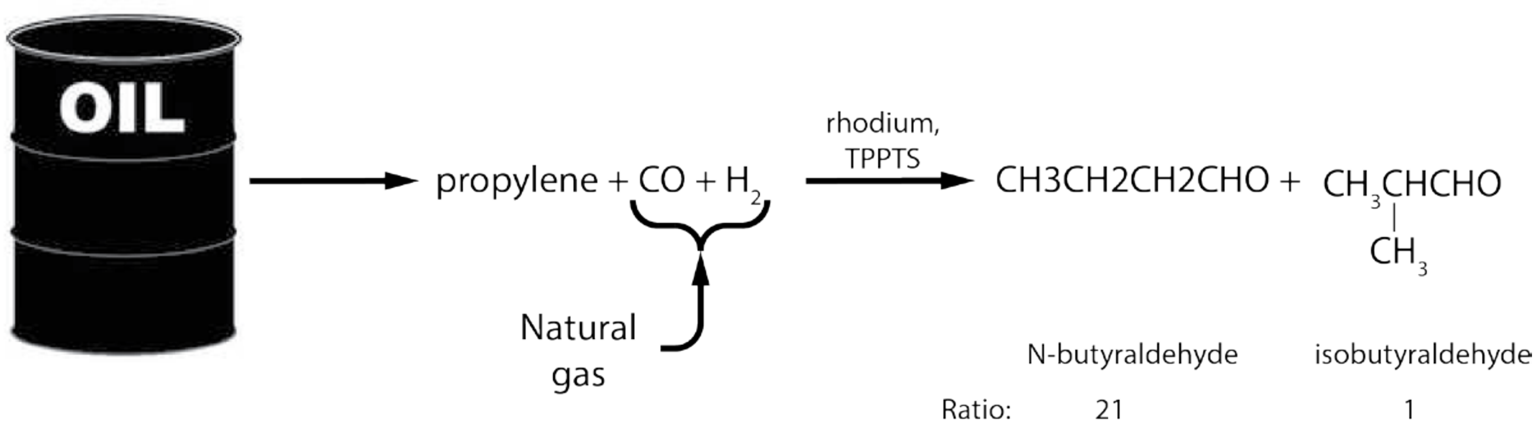
Project Objective

- **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.

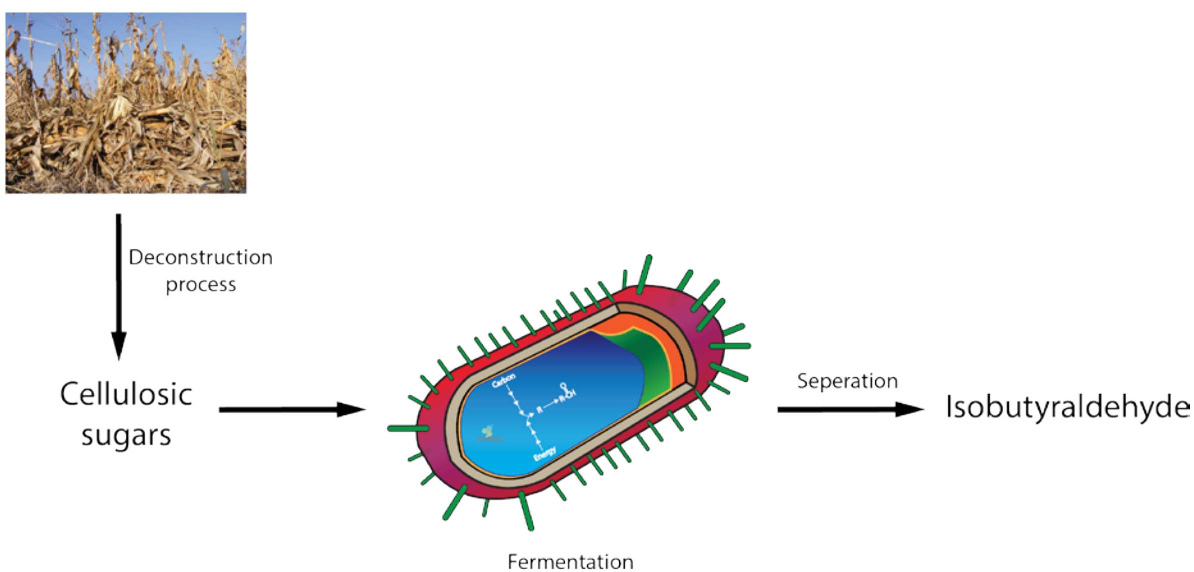
Technical Approach

- **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.

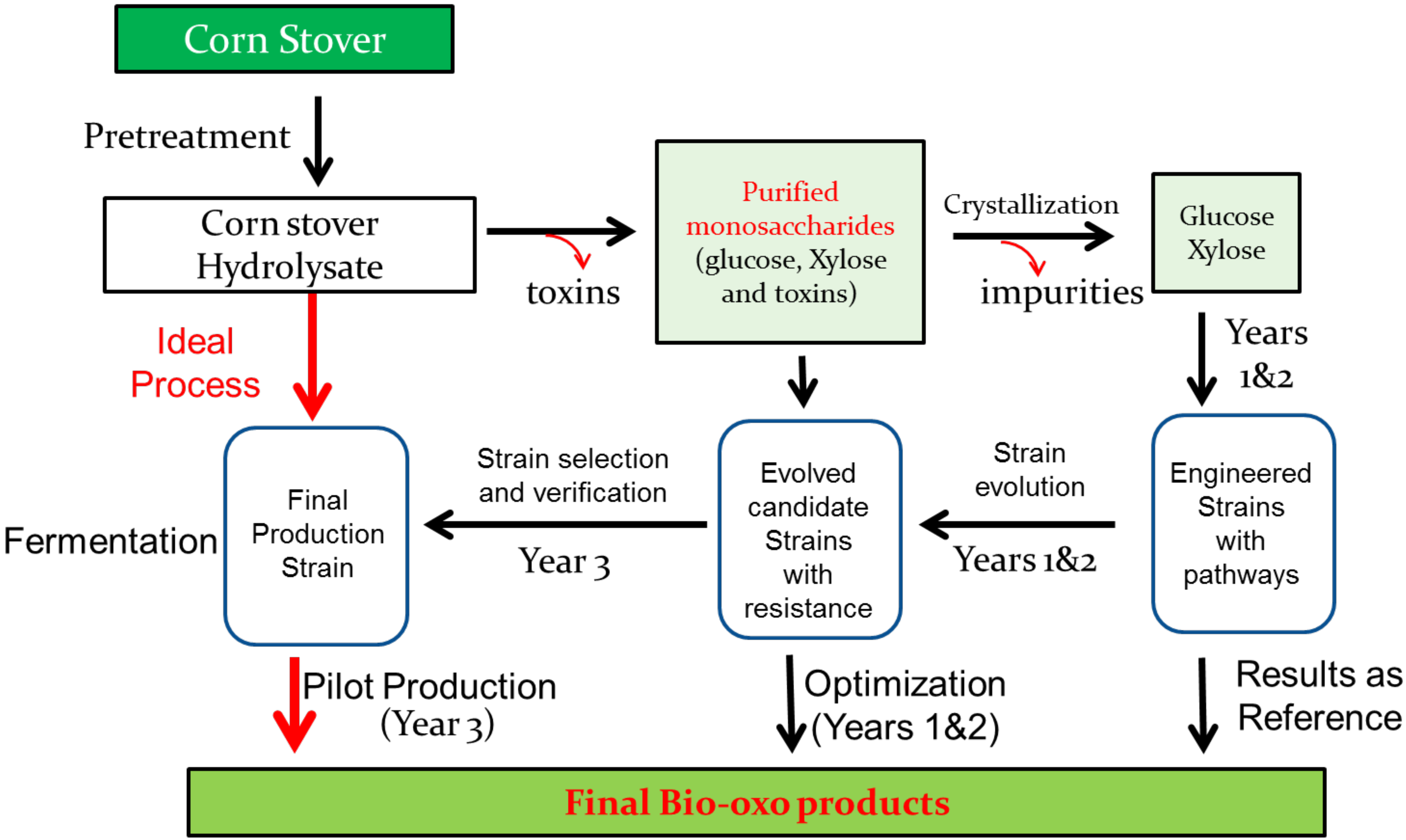


Technical Approach

- **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

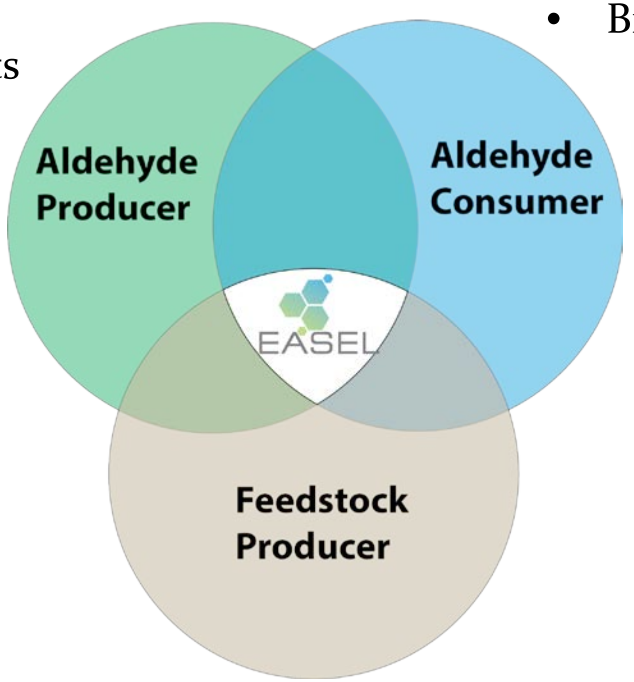


Transition (beyond DOE assistance)

Commodity chemicals produced from renewable resources with a reduced carbon footprint at a cost competitive price.

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

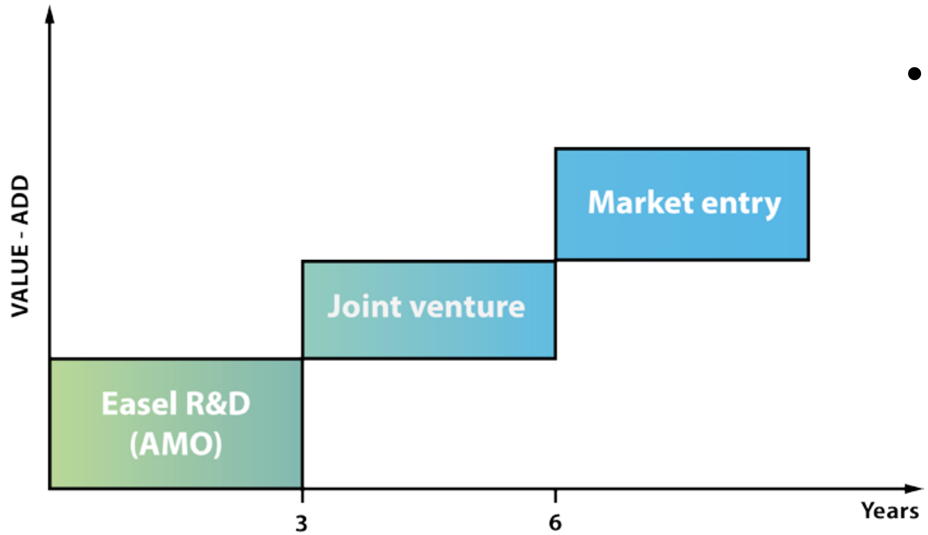
- Reduce fossil fuel dependence
- Bio-based manufacturing



- Increase efficiency
- Reduce waste
- Additional revenue stream

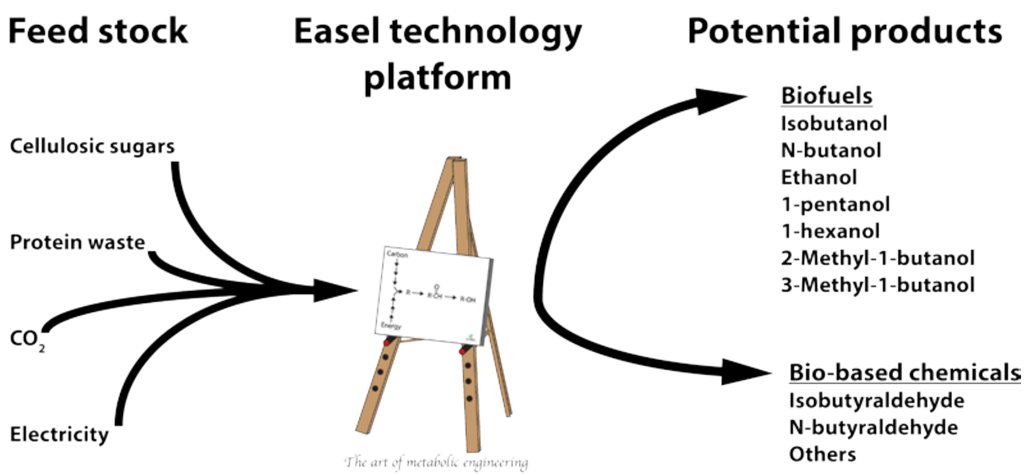
Transition (beyond DOE assistance)

- **Easel commercialization approach**



- Next step: Find a strategic partner to form a joint venture to initiate a demonstration plant. Preferably, 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 an 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: 3.5 years

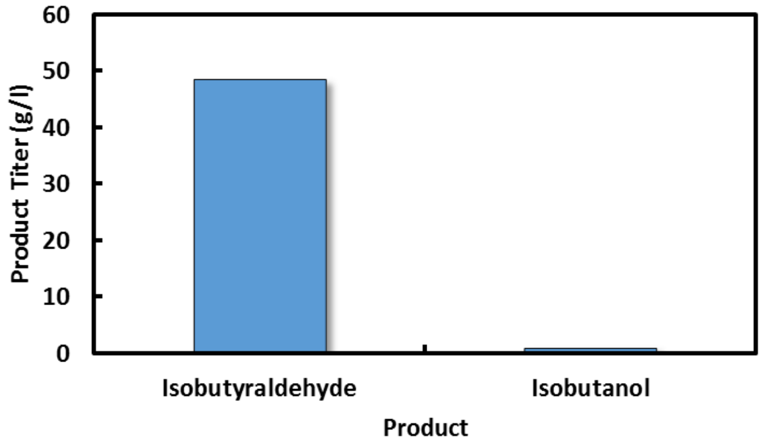
Go/No Go Decision point and final delivery schedule.

Task	Title	Go/No Go Decision point	Time	
1	Improve Isobutyraldehyde Productivity by Strain Engineering and Develop Fermentation and Separation Process (2L).	Productivity: 0.3 g/L/hr Titer: 10 g/L	2015 Q4	√
2	Strain and Pathway Optimization and Development of Integrated Processes (2L).	Productivity: 0.5 g/L/hr Titer: 30 g/L	2016 Q4	√
4	Demonstrate the Integrated Production Process in Pilot Scale (30L).	Productivity: 1.0 g/L/hr Titer: 50 g/L Theoretical yield: 60%	2018 Q2	

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

Results and Accomplishments

- Completed nine quarters out of 3.5 years, met all Go/No Go
- Concurrently metabolize glucose and xylose
- Current titer from corn stover hydrolysate: 48 g/L in 2 liter working volume



- Commenced 10L working volume fermenter, 30L fermenter next
- **GOAL:** To Improve titer 1.25-fold by and increase yield 2-fold
  - Genetic engineering and strain development
  - Fermentation optimization and product removal