Building the future of low carbon transportation through integrated basic science

Jay Keasling, CEO
JBEI Partners - 5 DOE National Labs, 6 Universities

- Funded by DOE
- Started in 2007
- Renewed in 2012
- $25M/year
- Renewed in 2017
JBEI provides the basic science for converting biomass to fuels

Establish the scientific knowledge and new technologies to transform the maximum amount of carbon available in bioenergy crops into biofuels and bioproducts.
Three major sources of carbon in plants

- Cellulose
- Hemicellulose
- Lignin
Technoeconomic model benchmarks economic impact of JBEI goals

Available at econ.jbei.org
Initial calculated fuel price reflects JBEI’s high-risk research program
Eight key factors have the biggest impact on the price of biofuels

- Increase C6/C5 ratio
- Lower lignin content
- Lower IL price
- Lower IL use
- Less enzyme use
- Increase biofuel yield
- Increase fermentation productivity
- Lignin valorization
Eight key factors have the biggest impact on the price of biofuels.

**JBEI technology development & improvement scenarios**

- **Increase C6/C5 ratio**
- **Lower lignin content**
- **Lower IL price**
- **Lower IL use**
- **Less enzyme use**
- **Increase biofuel yield**
- **Increase fermentation productivity**

Lignin valorization
Plants have lots of holes that we would like to fill with sugar
Can we fill the fibers up with cellulose?
Why is growth affected when lignin or xylan is highly reduced?
Transcription factor engineering directs cellulose to fibers and lignin only to vessels

Yang et al 2013 Plant Biotechnol J 11:325
Engineered plants contain approximately twice the sugar as the native plants.

Yang et al. 2013 *Plant Biotechnol J* 11:325
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JBEI technology development & improvement scenarios

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Lignin valorization
Ionic liquids pretreatment produces clean cellulose/hemicellulose
IL pretreatment generates higher sugar yields than any other pretreatment.

Gao et al 2014 Biotech for Biofuels 7:71
Singh et al 2015 Frontiers in Energy Res 2:1
Ionic liquid pretreatment works on a variety of feedstocks and mixed feedstocks

Li et al. 2013 *BioEnergy Research* 6(1):14-23
Ionic liquids can be made from lignin: “Bionic Liquids”

Feedstock → Pretreatment → Conversion of lignin to “Bionic Liquids”

Cellulose
Hemicellulose

Socha et al 2014 PNAS 111:35
“Bionic Liquids” have comparable performance to petroleum-based ILs

Socha et al 2014 PNAS 111:35
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Engineered microbes convert sugars into advanced biofuels.
Phase separation allows simple purification of fuel
Engineered microbes convert sugars into advanced biofuels

Methyl ketones

Bisabolane

Dimerized pinene

Isopentanol

sugars
The DBTL technologies developed in JBEI will outfit the next generation of biofoundries.
JBEI’s research program has reduced the fuel cost 10,000 fold.

Corn stover, IL pretreatment, microbe utilizes C6 sugars to produce isopentenol.
How do we make biofuels affordable?

Corn stover, IL pretreatment, microbe utilizes C6 sugars to produce isopentenol

How do we achieve these fuel costs?

Minimum Biofuel Selling Price ($/gal, log scale)

$311K SOT 2007

$35 SOT 2017

< $2.50
Eight key factors have the biggest impact on the price of biofuels

**JBEI technology development & improvement scenarios**

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- **Lignin valorization**
Lignin utilization

Hemicellulose

Cellulose

Lignin

Joint BioEnergy Institute
JBEI’s efforts to utilize lignin

- Polysaccharides, lignin
- Lignin-derived intermediates, sugars
- Ionic liquids and depolymerization enzymes matched with lignin linkages
- Lignin optimized for deconstruction and conversion
- Engineered metabolism matched with lignin-derived intermediates for uptake and conversion

- TEA and LCA of entire JBEI process
- Lignin analytics, HT enzyme screening, bioinformatics
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Target bioproducts

- Therapeutics: Highest margin, highest regulatory risk
- Nutraceuticals
- Specialty Materials and Chemicals
- Commodity Materials (Plastics, nylon)
- Fuels: Largest markets, highest revenue risk
Target bioproducts

- Therapeutics
- Nutraceuticals
- Specialty Materials and Chemicals
- Commodity Materials (Plastics, nylon)

- Large markets,
- Large margins,
- Low regulatory risk
Safe colorants for food and dyes for clothing
Rare flavors and fragrances
High performance materials for clothing, electronics, airplanes, and automobiles
Target bioproducts

- Therapeutics
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- Specialty Materials and Chemicals
- Commodity Materials (Plastics, nylon)

Largest markets, highest revenue risk
Biodegradable and recyclable plastics
JBEI’s Commercial Impact

- 277 Invention Disclosures
- 174 Patent apps/ Copyrights
- 89 IP Licensed*
- 33 Issued Patents

*Licensed IP that includes patents, patent applications, foreign patent applications and copyright

Plus: one JBEI affiliated invention disclosure and agreement; not included here

As of 12/31/2017
JBEI interactions with industry
Technology maturation: State of California Matching Funds

• $3M project awarded by the State of California to JBEI as cost share
• Partnership with Aemetis
• Deployment and demonstration of an IL-based process for production of an advanced biofuel
• Using California wild type woody biomass feedstocks
Thanks to …

The JBEI Team

DOE for funding