AB PDU - Determining R&D Problems in Scale-Up and Resolving them by accessing National Lab Resources

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ABPDU: Enabling biofuel and bioproduct scale-up R&D

• 15,000 square foot Demonstration Lab established in 2009
• Managed by DOE EERE from the BioEnergy Technologies Office (BETO)

• A bio-process research incubator / accelerator – industry-friendly IP rights, cost-recovery project fee structure, experienced team, and Bay Area location
Facility at a glance – from bench to pilot
Over 30 industry partnerships to date

<table>
<thead>
<tr>
<th>Biofuels &amp; biomass</th>
<th>Materials &amp; chemicals</th>
<th>Food &amp; health</th>
<th>Waste &amp; water</th>
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</thead>
<tbody>
<tr>
<td>Total</td>
<td>AFINGEN</td>
<td>Es BioSolutions, Inc</td>
<td>FATER SpA</td>
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<tr>
<td>United Catalyst</td>
<td>Visolis</td>
<td>Rho Renewables, Inc</td>
<td>Recology Waste Zero</td>
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<td>Checkerspot</td>
<td>Ripple Foods Hampton Creek</td>
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<td>Pareto Biotechnologies</td>
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<td></td>
<td>Lygos</td>
<td>Kiverdi</td>
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<td>Sylvatex</td>
<td>Zymogen</td>
<td>Clara Foods</td>
<td>Aequor</td>
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<td>Microvi Biotechnologies</td>
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<td>Perfect Day</td>
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<td>Ginkgo Bioworks™ The Organism Company</td>
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<td>Amyris</td>
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Completed projects

Ongoing
The bioprocess incubation ecosystem

**DOE-funded capabilities at National Laboratories**
- Agile BioFoundry
- JGI
- Molecular Foundry
- Small Business Vouchers Pilot
- Sandia National Laboratories
- BETO Technology-to-Market
- cyclotronroad
- CHAIN REACTION INNOVATIONS

**Bay Area incubators**
- INDIE BIO
- illumina
- qb3 ucb-ucsc-ucsf

**Non-dilutive federal funding**
- DOE
- NSF
- NIH
- USDA
- DARPA
- SBIR-STTR America’s Seed Fund™
Case study: Visolis fermentation platform

Proven at 300lt pilot scale indicating 60-90c/lb production cost at scale

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Current</th>
<th>2017</th>
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</thead>
<tbody>
<tr>
<td>Yield</td>
<td>60%</td>
<td>80%</td>
</tr>
<tr>
<td>Titer</td>
<td>70g/l</td>
<td>120g/l</td>
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<tr>
<td>Cost at scale</td>
<td>60-90c/lb</td>
<td>45-70c/lb</td>
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<tr>
<td>Average product value</td>
<td>$2/lb</td>
<td>$1/lb</td>
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<tr>
<td>Total addressable market</td>
<td>$1 billion</td>
<td>&gt; $10 billion</td>
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Case study: Lygos malonic acid verification

3rd party validation of final project metrics was performed at the ABPDU (50-liter scale)

- Problems were encountered obtaining cellulosic sugars within allowed budget, limiting fermentation scale

- Demonstrated successful scaleup of fermentation process with real-world cellulosic sugars*

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<tr>
<th>Parameter</th>
<th>As % of Control Fermentations</th>
</tr>
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<tbody>
<tr>
<td>Yield</td>
<td>120%</td>
</tr>
<tr>
<td>Titer</td>
<td>99%</td>
</tr>
<tr>
<td>Productivity</td>
<td>99%</td>
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* Confidential commercial provider
Case Study: Perfect Day Studies for Low-Cost Carbon Sources for Protein Production

Fermentation Process Optimization and Scale-Up

2L Fermentation to study cheaper C-sources

Dry cell weight [g L⁻¹]

- A5 - CS Hydrolysate
- A6 - CSL
- A7 - Industrial glucose
- A8 - Glucose control

BETO Technology-to-Market
Case Study: Heliobiosys
Cyanobacterial Polysaccharide study with Sandia

BETO Technology-to-Market

(a) Hydrogel behavior  (b) Microscopic View

Raceway Ponds at Sandia

Correlation of viscosity with Polysaccharide production
Providing a critical resource and direct support of several DOE / EERE / BETO programs and consortia
Key outcomes for private sector collaborators

- Several competitive awards as preludes or follow-ons to sponsored projects
- Numerous partners have set up their own labs or pilot plants and secured private financing while / after working with ABPDU
- Product launches and commercial / pre-commercial scale-up & scale-down

[Image of Small Business Vouchers Pilot]

ABPDU: Enabling bioprocess scale-up research

- Leveraging national lab resources to understand and resolve problems in scale-up research
- Improved R&D capabilities in this subject
- Cross-pollinate ideas with subject matter experts
- Exposure to industry-wide problems that can be addressed through BETO funded consortia programs