

**DOE Bioenergy Technologies Office (BETO)
2021 Project Peer Review**

**Advanced Biofuels and Bioproducts Process Development Unit
(ABPDU) Operations,
Lawrence Berkeley National Laboratory (LBNL)**

03/24/2021

Systems Development and Integration

Deepti Tanjore

Lawrence Berkeley National Laboratory



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

ABPDU Overview

What are you trying to do?

The ABPDU was initiated by ARRA funds in 2010 to scale-up technologies with a bioenergy focus.

The total investment to date has been ~\$43M (\$17.7M ARRA and \$25M BETO funds)

Timeline

White Paper submitted in	2009
ARRA funds, Construction, Installation, and Commissioning	2010 - 2012
Operational since	2012
Worked with all three BRCs	2014
Focus shifted to Industrial Collaborators and Bioproducts along with Biofuels	since 2015



In 2011: *“The objective of the ABPDU is to provide the industry and DOE with a Process Development Unit (PDU) capable of demonstration production of advanced biofuels at small scale. Additionally, this facility will provide a means to translate the technologies from laboratory scale to commercial operation created by DOE Researchers (e.g., DOE Bioenergy Research Centers (BRCs)), U.S. industry, and non-profit organizations.”*

Worked with over 60 companies

Why is it important?

Biofuels & Biomass

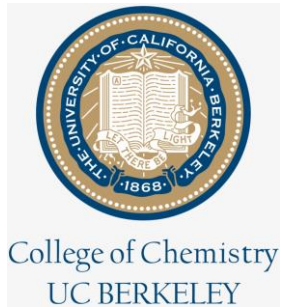
Materials & Chemicals

Food, Health, & Ag



Worked with academic collaborators as well

Why is it important?



Scope of the ABPDU Operations Annual Operating Plan

How is it done today and what are the limits?

Task 1: Partnering and Project Development

- supports staffing time and activities to bring increasing partner usage

Task 2: Facility Readiness

- Utilities, service contracts, engineering support, equipment maintenance and upgrades, spare parts, office supplies, admin support, EH&S support, to have the facility operational and available for partner use.

Task 3: Process Benchmarking and Prototyping

- prepares the facility and team for new client processes and identifies bottlenecks in processing and equipment readiness.

Task 4: PDU Teaming with Other National Labs

- participate in the PDU Working Group; Report PDU utilization

No variance or scope change has occurred in the past three years

Project Risks

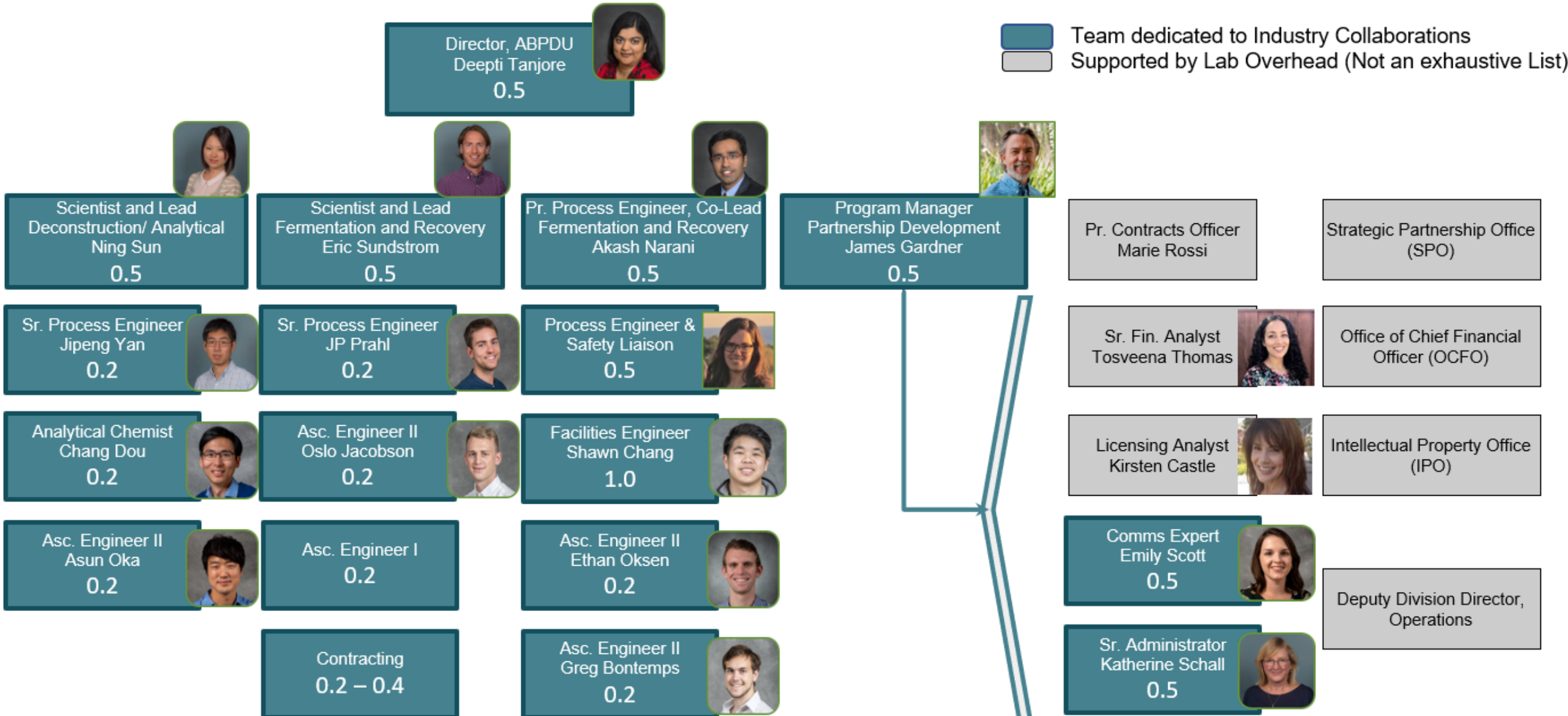
What are the risks?

Name	Status	Target Completion	Severity	Response	Description
Funding shortfall	Not active	09/30/2021	High	Develop other funding sources; adjust service offered	Insufficient corporate sponsorship - Industry downturn or lack of need for services
Unplanned Downtime	Active	09/30/2021	Moderate	Fewer FTEs available for PM and contingency for repairs, backups and replacement	Periodic equipment and utility failures
Inadequate staffing	Active	09/30/2021	Moderate	Training, team building, incentives	Increased team turnover

1- Management: ABPDU Org Chart and Support from AOP

Explanation of how the project is structured

Most employees utilize ABPDU Ops AOP to work with industry. Only a single employee is fully supported by ABPDU AOP.



1 – Management

Task 1 – Partnering and Project Development

Responsibilities of team members and risk mitigation

Supports staffing time and activities to bring increasing partner usage

✓ A. Start at least one new industry-sponsored project per quarter.



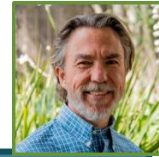
✓ B. Have a positive impact in the bio-economy through increased industry outreach and partnerships, measured by delivering 6 oral presentations or organizing booths at conferences in a fiscal year.



✓ C. Document at least one new commercial product introduction or private financing event for an industrial project partner during FY20 based on contributions developed through ABPDU project work.

Perfect Day

Project Risk Avoided: Funding Shortfall



Program Manager
Partnership Development
James Gardner



Director, ABPDU
Deepti Tanjore



Pr. Process Eng., Co-Lead
Ferm and Recovery
Akash Narani



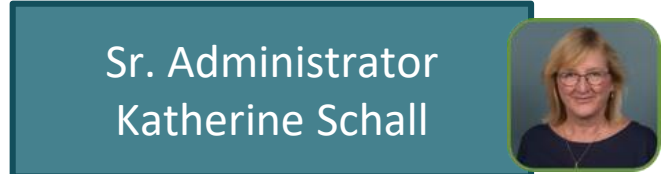
Scientist and Lead
Decon/ Analytical
Ning Sun



Communications Expert
Emily Scott



Scientist and Lead
Ferm and Recovery
Eric Sundstrom



Sr. Administrator
Katherine Schall

1 – Management

Task 2 – Facilities Readiness

Responsibilities of team members and risk mitigation

Utilities, service contracts, engineering support, equipment maintenance and upgrades, equipment, spare parts, office supplies, admin support, EH&S support, and overhead for space to have the facility operational and available for partner use.

- A. Complete Industry project(s) sponsored under Directed Funding Opportunities decided in late FY18 from BETO’s Separations Consortium Project, Agile BioFoundry Project and the SDI Program.
- B. Complete any agreed capital upgrades and equipment procurement to expand/ update ABPDU capabilities based on SDI RFI

Facilities Engineer
Shawn Chang



Process Engineer &
Safety Liaison
Laura Fernandez



Contracting and Student
Interns

Pr. Process Eng, Co-Lead
Ferm and Recovery
Akash Narani



Director, ABPDU
Deepti Tanjore



Sr. Administrator
Katherine Schall




1 – Management

Task 3 – Process Benchmarking and Prototyping

Responsibilities of team members and risk mitigation

Director, ABPDU
Deepti Tanjore



Prepares the facility and team for new client processes and identifies bottlenecks in processing and equipment readiness.

- ✓ Maintain FTE utilization in direct support of projects to at least 85%


Actual: 97 – 100% actual

The remainder time is used in training and ops support.

Project Risk avoided: Inadequate staffing



Scientist and Lead Decon/ Analytical
Ning Sun



Scientist and Lead Ferm and Recover
Eric Sundstrom



Pr. Eng & Co-Lead Ferm and Recovery
Eric Sundstrom



Sr. Process Engineer
Jipeng Yan



Sr. Process Engineer
JP Prah




Process Engineer & Safety Liaison
Laura Fernandez



Analytical Chemist
Chang Dou



Asc. Engineer II
Oslo Jacobson



Asc. Engineer II
Ethan Oksen



Asc. Engineer II
Asun Oka



Asc. Engineer I

Asc. Engineer II
Greg Bontemps



1 – Management

Task 4 – PDU Teaming with Other National Labs

Responsibilities of team members

Task 4: PDU Teaming with Other National Labs

- participate in the PDU Working Group; Report PDU utilization

- ✓ • Attend monthly calls to share LBNL Contracting and other Best Practices with other PDUs
- ✓ • Monitor and report FTE and equipment utilization in quarterly reports
- ✓ • Share budget updates with BETO quarterly



Director, ABPDU
Deepti Tanjore



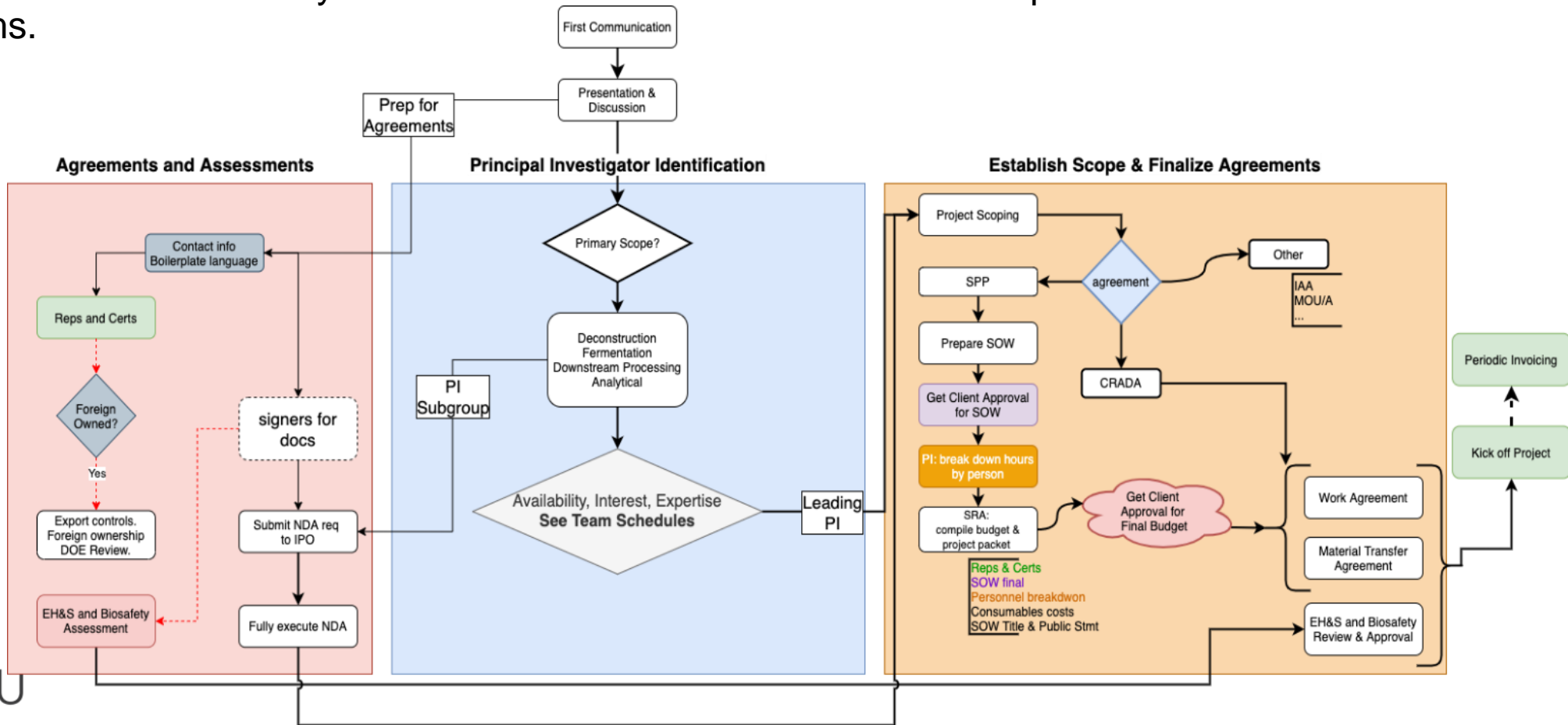
Program Manager
Partnership Development
James Gardner

2 – Approach

Task 1 – Partnering and Project Development

Technical Approach

To establish a collaboration via a contract with LBNL, we follow the Workflow given below to ensure that we can deliver on the 12-week timeline for Strategic Partnership Program (SPP) contracts. Co-operative Research And Development Agreements (CRADA) and other contracts can take longer depending on the review of contract terms by the collaborators. Industrial collaborators prefer SPP contracts due to favorable IP terms.



2 – Approach

Task 1 – Partnering and Project Development

Technical Approach, Change in response to 2019 peer review comment

Peer Review Comment: It is not clear what external outreach is made by LBNL to bring projects to ABPDU.

Response: We hired a communications expert to generate three stories and a newsletter every quarter.

Regular Communications via quarterly newsletter

(<https://mailchi.mp/f8855bfee857/abpdu-newsletter-signup>)

Website Updates and Case Studies

(<https://abpdu.lbl.gov/our-collaborations/case-studies/>)



The Reactor
NEWS FROM THE ABPDU

Scaling up science during a global-scale emergency



The ABPDU has been working during the shelter-in-place orders to help two companies scale-up production of new technologies that could aid in ending the COVID-19 pandemic.

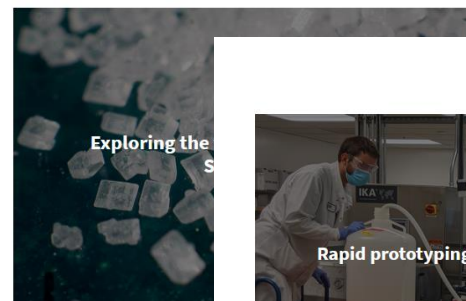
Checkerspot



Recology



Sugarlogix



*Sugarlogix is a biotech startup d
component in infant formula.*

ZymoChem



Geltor



Huue

Digestiva



Good digestion is a key factor in overall health. In particular, protein digestion combats muscle loss, improves nutrition, and boosts immunity.



2 – Approach

Task 2 – Facilities Readiness

Technical Approach

Primary responsibilities of Facilities Engineer:

- Provide multi-support to ensure equipment and utilities are serviced and maintained well, to minimize downtime.
- Serve as point of contact and ABPDU's liaison with external vendors, building owners, Laboratory Division Facilities, Transportation and Engineering personnel.
- Manage subcontracts with a broad range of vendors for the utilities, equipment, instruments, and services.
- Prepare the sub-contractor job hazard analysis (sJHA) and work with LBNL facilities and electrical safety groups to make sure all hazards are reviewed and documented.
- Schedule Preventative Maintenance services, upgrades, and repairs for all utilities and equipment.
- Inform ABPDU teams with facility/equipment related updates (weekly SCRUM, lab update emails).

Maintenance and On-Call Response to emergency alarms from:

Waste Treatment Unit

- Steam boilers and steam traps
- Chillers/Process Chilled Water
- Air compressor
- Reverse Osmosis Deionized (RODI) Water System
- Clean Steam generator

Responsibilities associated with Lab spaces:

- Maintenance
- Cleaning
- Shipping and Receiving and Mid-week Task Requests
- Chemical and Waste Management

2 – Approach

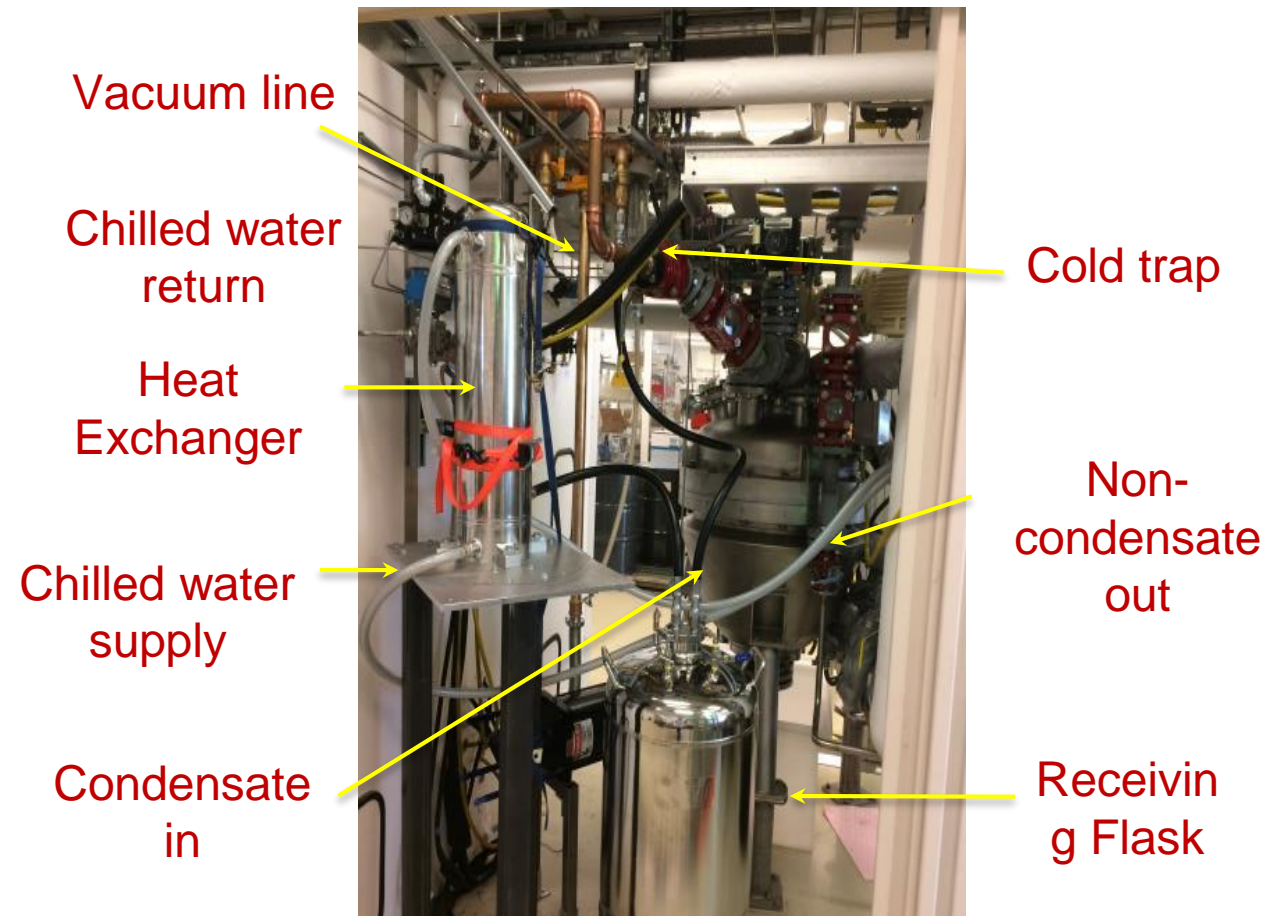
Task 2 – Facilities Readiness

Technical Approach

New Equipment Commissioning



Sartorius Ambr 250, commissioned March 2019
\$51K ABPDU (8%), JBEI \$294K (46%), ABF 294K (46%)



Andritz Vacuum Evaporation at
100L scale, \$35K ABPDU

2 – Approach

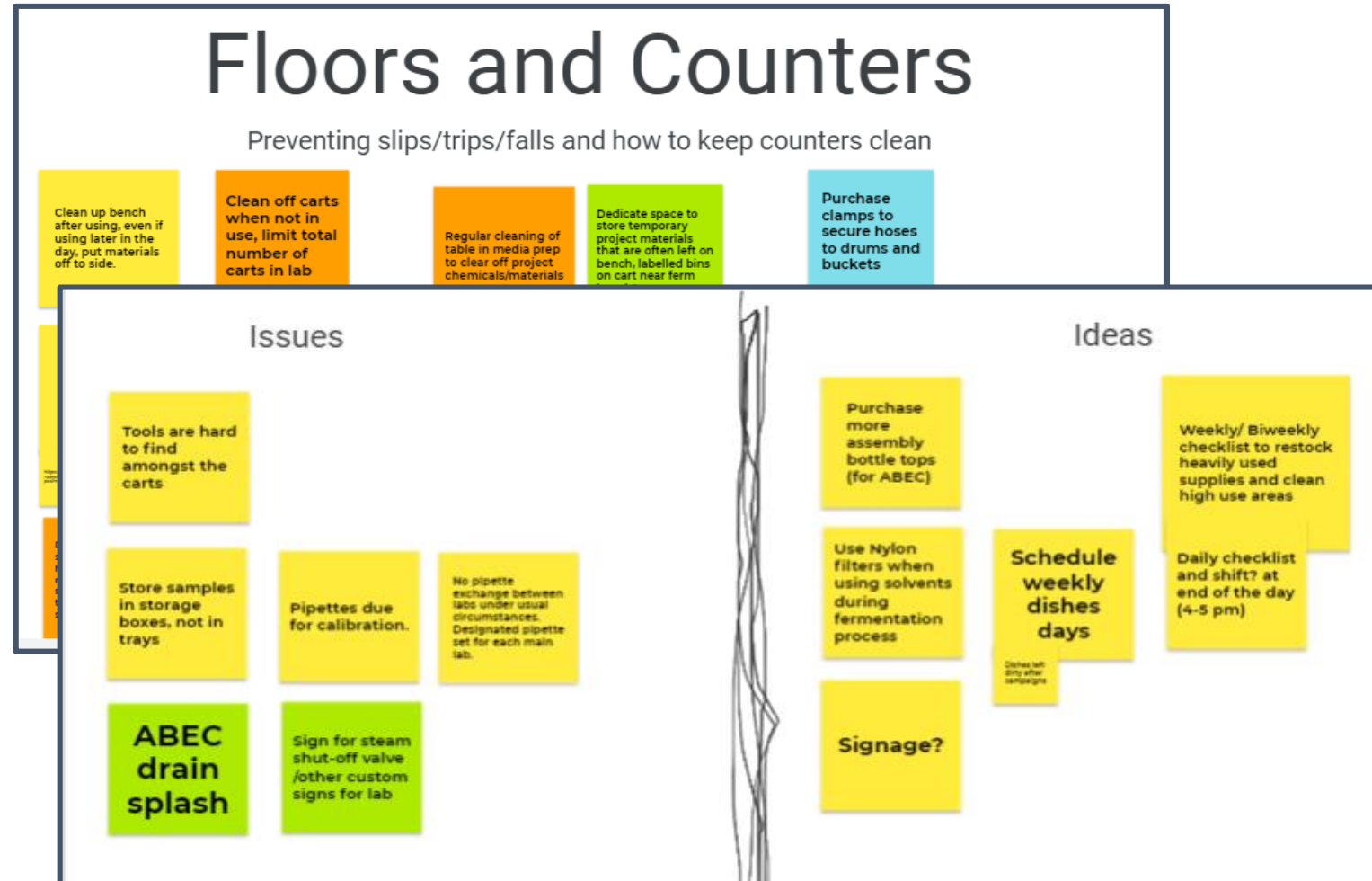
Task 3 – Process Benchmarking and Prototyping

Addressing Safety Challenges

We converted our Safety Meetings into Workshops and applied Design Thinking approach to be more Proactive than Reactive to safety concerns.

Each Team Member contributes a Safety Concern for Voting

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-5	-4	-3	-2	-1	0	1	2	3	4	5	<input type="checkbox"/>
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-5	-4	-3	-2	-1	0	1	2	3	4	5	<input type="checkbox"/>
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-5	-4	-3	-2	-1	0	1	2	3	4	5	<input type="checkbox"/>



2 – Approach

Task 3 – Process Benchmarking and Prototyping

Addressing Safety Challenges

Prototype/ Test: A Proactive Solution



Electrical drops for cord trip prevention and other issues in spills

2 – Approach

Task 4 – PDU Teaming with Other National Labs

Addressing Communication Challenges and Industry Concerns

24 companies attended the Inaugural Industry Listening Day in October 2019 with ABPDU and DOE



2 – Approach

Task 4 – PDU Teaming with Other National Labs *Addressing Communication Challenges and Industry Concerns*

We shared industry comments with other PDUs and are currently working on responses to the comments



3 – Impact

ABPDU AOPs can help Commercialize Novel Technologies from Small Businesses

“ZymoChem’s novel high cell density growth decoupled production bio-processes is more complex than typical fermentation processes used in industry. Working with the ABPDU to validate our company’s C2 technology and bio-process at the pilot scale along with generating kg-quantity samples as part of our SBV work has directly contributed to an agreement with a large strategic partner and traction with investors.”



Harshal Chokawala, CEO and Founder ZymoChem

3 – Impact

ABPDU AOPs can help Commercialize Novel Technologies from Small Businesses



Brian Lee,
Former Sr. VP,
Visolis

"Lab Call (*Seedling*) supported our first 20L fermentation, which was very important for us. Scale-up and integration of processes is essential for many companies to generate not only competent proposals to FOAs, but also pitches to investors, partners, etc. It is an integral part of commercialization."

"DFOs or SBVs allow the company to tailor the project for our critical needs rather than fit into the the scope and direction of a FOA, which often don't perfectly align. FOA reviewers seem to prefer proposals involving larger scale campaigns (1000L+). To win their confidence, we will have to test the technology at 100L+ scale. The SBV with NREL and PNNL helped us with the same."

3 – Impact

Disseminating the Experience by training a Strong and Diverse Workforce entering Industry and Academia

90+ Trained Alumni from the ABPDU now working at various Companies, Universities, and National Labs.

A complete list provided here: <https://abpdu.lbl.gov/about-us/alumni/>

Select Profiles listed here:



Hunter Zeleznik
Fermentation Employee
LanzaTech



Brett Russell
Fermentation Employee
Visolis BV



Priyanka Singh
Fermentation Intern
UC Riverside



Gabriella Papa
Analytical Employee
University of Milan



Kevin Hernandez
Fermentation Intern
Zymergen



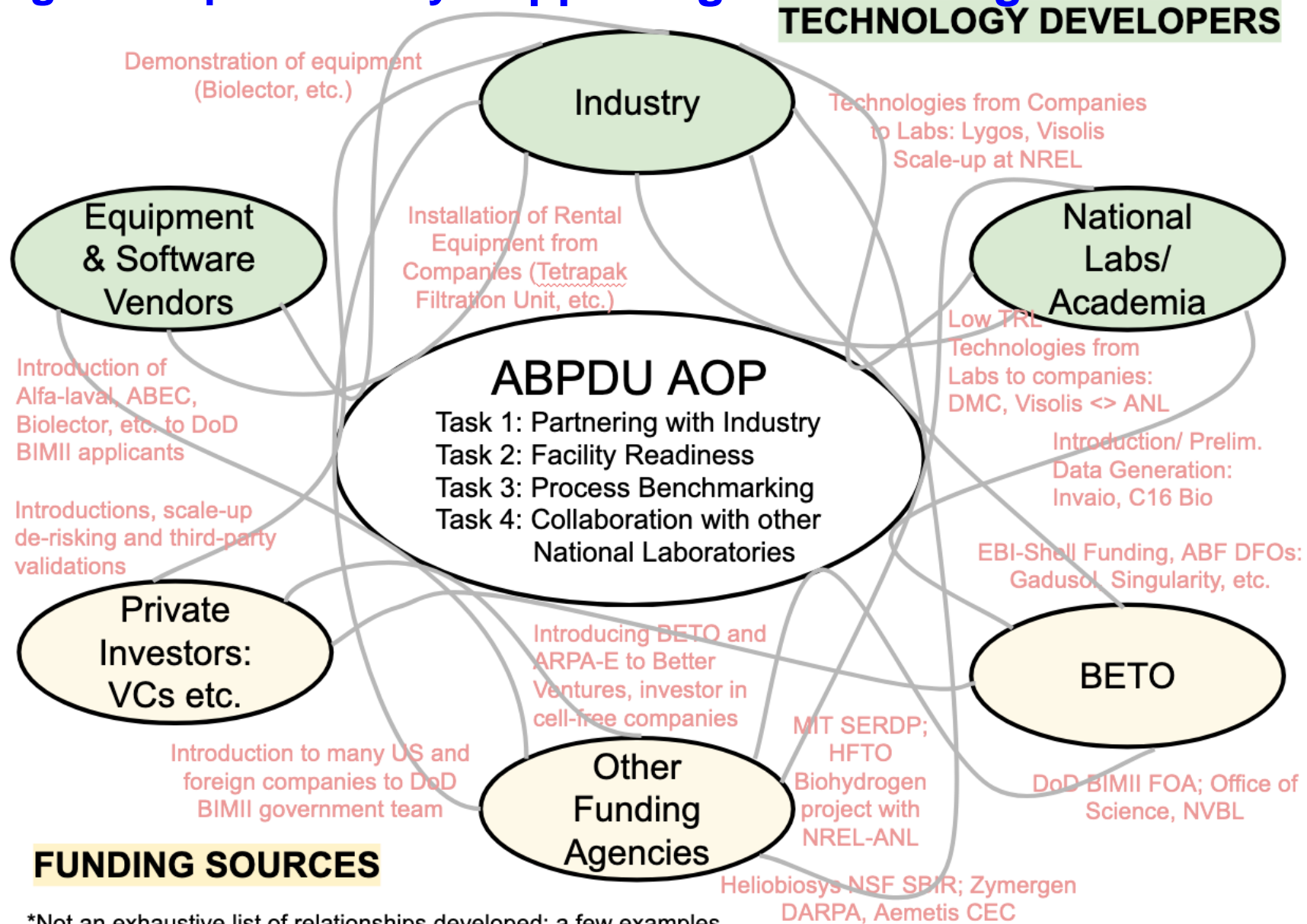
Firehiwot Tachea
Fermentation Employee
Culture Biosciences



Nora Honeycutt
Fermentation Intern
National Renewable Energy
Laboratory

3 – Impact

Disseminating the Experience by Supporting the Budding BioEconomy



4 – Progress and Outcomes

Task 3 - UC Berkeley Masters in Bioprocess Engineering Lab Course at the ABPDU *Most important Accomplishments*

Bioprocess Engineering Program Description

PROFESSIONAL MASTERS DEGREE IN BIOPROCESS ENGINEERING

- Program Description
- Application Process
- Degree Requirements
- Tuition & Fees



PROGRAM DESCRIPTION

The Master of Bioprocess Engineering (MBE) degree will provide graduates upon completion of a 9-month program with an understanding and ability to apply Bioprocess Engineering to a number of key technological needs spanning multiple industries. These include methods to produce biofuels, bio-based chemicals, proteins, pharmaceuticals, and other high-value biologics; how to design and/or operate appropriate unit operations (e.g., fermentation systems), mammalian-cell culture systems, and instrumentation to monitor and control biotechnological processes; and how to apply and test

Berkeley College of Chemistry



JP Prah,
Sr. Process Engineer at the ABPDU

Instructor in MBE degree

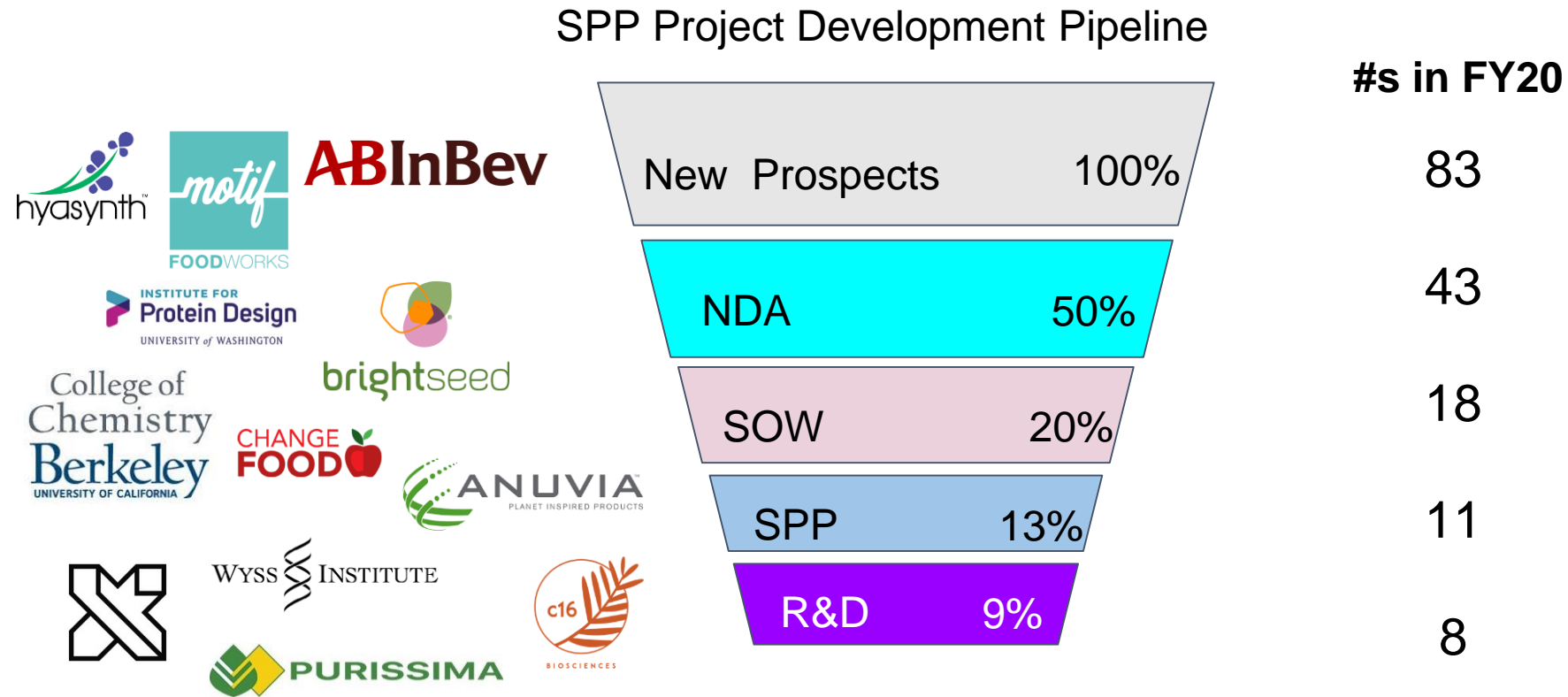
<https://chemistry.berkeley.edu/grad/cbe/bioprocess-engineering/program-description>

4 – Progress and Outcomes

Task 1 – Partnering and Project Development

Most important Accomplishments

We executed 8 SPPs in FY20, and accomplished the milestone (4 SPP per year).



SPP Conversion Rate = 9%; CRADA Conversion Rate ~7% and is highly dependent on Funding Opportunity, often from Government Agencies.

4 – Progress and Outcomes

ABPDU mentioned in DoD's FOA for BioIndustrial Manufacturing Innovation Institute *Most important Accomplishments*

The DoD BIMII Government Team has expressed specific interest in including ABPDU in BioMADE, a recently funded institute.

3. The MII is encouraged to seek collaborations with federal government organizations post award, such as:
 - a. **Combat Capabilities Development Center (CCDC) Chemical Biological Center:** The US Army's Biomanufacturing Facilities are located at the Combat Capabilities Development Center (CCDC) Chemical Biological Center on the campus of Aberdeen Proving Ground, Maryland. The 20,000 sq./ft. pilot-scale fermentation and downstream processing complex can scale from 5 to 1500 liters. The Army Biomanufacturing Facilities are designed to optimize the growth and production of bacterial, yeast, and mammalian biological and chemical product lines produced by synthetic biology. The program is co-located with the Advanced Chemical Laboratories which offer world class chemical and biological characterization under stringent quality programs. CCDC CBC also hosts the Advanced Design Manufacturing facilities which offer rapid prototyping, injection molding, and computer aided engineering expertise which allows for the capability to go from small scale culture to rapid prototyping at a single campus if required.
 - b. **DOE Advanced Biofuels and Bioproducts Process Development Unit:** The Advanced Biofuels and Bioproducts Process Development Unit is a 15,000 square foot scale-up facility with fermenters at scales ranging from 0.25 to 300L and more than half-a-dozen different downstream recovery and purification unit operations, including centrifugation, filtration, distillation, and chromatography. The ABPDU has worked with 49 industrial collaborators in developing their technologies and generating grams to kilograms-scale product for testing and evaluation. Many companies introduced their products to the market while working with the ABPDU and prior to investing in their own pilot plants. The equipment and expertise available at the ABPDU was also leveraged by academic collaborators to generate highly-relevant publications. Learn more at: <https://abpdu.lbl.gov/>.

Summary

Mission Relevance: ABPDU's stated mission is to *expedite the commercialization of advanced, next-generation biofuels and bioproducts by providing industry-scale test beds*. This allows for ABPDU to be relevant to the BETO portfolio in a versatile manner and is unique in that sense.

The key barriers that ABPDU addresses from BETO MYPP:

- Integration and testing of component technology elements
- Developing multiple technology pathways and products
- Developing higher value fuels and products
- Intensifying process designs
- Molecular efficient biorefineries
- Developing cost effective conversion technologies
- Increasing feedstock value - increasing types and quantities of biomass and waste streams



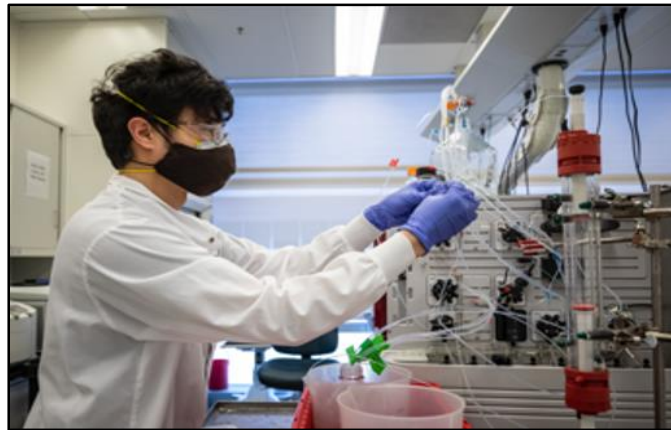
*Not an exhaustive list of collaborations addressing key barriers listed in BETO MYPP

Summary

Versatile support during National Emergencies: Whereas ABPDU was established with ARRA funds, released to counter one national emergency, because of our versatile nature, we are now helping companies scale-up and counter another national emergency, COVID-19.



Scale-up to 2L bioreactor
and enzyme recovery



Scale-up to 10L bioreactor
and enzyme purification



Scale-up to 300L bioreactor
for cell-free catalysis

Summary

Market and Societal Benefits: More than 12 commercial products, launched from work conducted at the ABPDU, have enabled the growth of the Bioeconomy.



Advisory Role: The ABPDU has evolved over the past six years with an increased focus on Technology Maturation. More recently, ABPDU has been transitioning into an advisory role to other facilities that are building up their own PDUs.



Other Funding Agencies: DoD, State of California, and several other funding agencies are valuing ABPDU's contribution in this space.

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Quad Chart Overview (AOP Project)

Timeline

- 10/01/2018
- Project end date

	FY20	Active Project
DOE Funding	2,191,233 USD	7.1 Million USD Total 2.5 Million (FY19) 2.3 Million (FY20) 2.3 Million (FY21)

Project Partners*

- No Partners

Barriers addressed

Utilizing existing infrastructure as much as possible.

Enabling private industry in commercially deploying technologies.

Balancing between technologies with significant nearer-term impact via SPP projects and those with longer-term potential for biofuels and bioproducts via CRADAs and AOP projects.

Project Goal

The ABPDU was authorized and commissioned to act as a shared community resource to provide process optimization, prototyping, development, and piloting and scale-up services to the biofuels and bioproducts community including industry, academia and the National Labs.

End of Project Milestone

- Start at least one new industry-sponsored project per quarter.
- Make 6 oral presentations or organize booths at conferences
- Maintain FTE utilization above 85% based on project hours.
- Complete Industry project(s) sponsored under Directed Funding Opportunities decided in late FY18 from BETO's Separations Consortium Project,
- Complete any agreed capital upgrades and equipment procurement to expand / update ABPDU capabilities based on ADO RFI;
- Continue to participate in the joint working group with the other PDUs user facilities for cross-training and information sharing.

Funding Mechanism:

AOP Project (Direct-Funded Lab Project); CPS Agreement Number: 22407; WBS#: 2.6.1.101



Contact us at

abpdu@lbl.gov

Additional Slides

Additional Slides

Responses to Previous Reviewers' Comments

- **Weakness:** It is not clear what external outreach is made by LBNL to bring projects to ABPDU.

We hired a communications expert who is working on updating our website, developing case studies and stories, and publishing the stories through social media. Some of this effort is listed in Slide# 16.

- **Weakness:** No details on how upcoming projects meet BETO goals.

The summary slide #28 details ABPDU's mission and its alignment with BETO goals

- **Weakness:** Agreements with partners should find a way to publish 'key lessons learned' for dissemination to the industry as a whole; proprietary information can be stripped, but technology is available to multiple partners and operations learnings have potential for significant impact.

While we are still looking for opportunities to share “lessons learned,” the UC Berkeley Masters Program is one conduit through which we are sharing practical experience in equipment operation with the students.

Additional Slides

Publications, Patents, Presentations, Awards, and Commercialization

FY19

Publications

- Baral, Nawa Raj, Eric R Sundstrom, Lalitendu Das, John Gladden, Aymerick Eudes, Jenny C Mortimer, Steven W Singer, Aindrila Mukhopadhyay, and Corinne D Scown. "Approaches for More Efficient Biological Conversion of Lignocellulosic Feedstocks to Biofuels and Bioproducts." *ACS Sustainable Chemistry & Engineering* 7, no. 10 (2019): 9062-79. <https://doi.org/10.1021/acssuschemeng.9b01229>.
- Narani, Akash, N. V. S. N. Murthy Konda, Chyi-Shin Chen, Firehiwot Tachea, Phil Coffman, James Gardner, Chenlin Li, *et al.* "Simultaneous Application of Predictive Model and Least Cost Formulation Can Substantially Benefit Biorefineries Outside Corn Belt in United States: A Case Study in Florida." *Bioresource Technology* 271 (2019/01/01/ 2019): 218-27. <https://doi.org/10.1016/j.biortech.2018.09.103>.
- Wehrs, Maren, John M. Gladden, Yuzhong Liu, Lukas Platz, Jan-Philip Prah, Jadie Moon, Gabriella Papa, *et al.* "Sustainable Bioproduction of the Blue Pigment Indigoidine: Expanding the Range of Heterologous Products in *R. Toruloides* to Include Non-Ribosomal Peptides." 10.1039/C9GC00920E. *Green Chemistry* 21, no. 12 (2019): 3394-406. <https://doi.org/10.1039/C9GC00920E>.
- Wehrs, Maren, Jan-Philip Prah, Jadie Moon, Yuchen Li, Deepti Tanjore, Jay D. Keasling, Todd Pray, and Aindrila Mukhopadhyay. "Production Efficiency of the Bacterial Non-Ribosomal Peptide Indigoidine Relies on the Respiratory Metabolic State in *S. Cerevisiae*." *Microbial Cell Factories* 17, no. 1 (2018/12/13 2018): 193. <https://doi.org/10.1186/s12934-018-1045-1>.
- Wehrs, Maren, Deepti Tanjore, Thomas Eng, Jeff Lievens, Todd R. Pray, and Aindrila Mukhopadhyay. "Engineering Robust Production Microbes for Large-Scale Cultivation." *Trends in Microbiology* 27, no. 6 (2019/06/01/ 2019): 524-37. <https://doi.org/10.1016/j.tim.2019.01.006>.
- Yan, Jipeng, Ling Liang, Qian He, Chenlin Li, Feng Xu, Jian Sun, Ee-Been Goh, *et al.* "Methyl Ketones from Municipal Solid Waste Blends by One-Pot Ionic-Liquid Pretreatment, Saccharification, and Fermentation." *ChemSusChem* 12, no. 18 (2019): 4313-22. <https://doi.org/10.1002/cssc.201901084>.

FY20

Publications

- Geiselman, Gina M., Xun Zhuang, James Kirby, Mary B. Tran-Gyamfi, Jan-Philip Prah, Eric R. Sundstrom, Yuqian Gao, *et al.* "Production of Ent-Kaurene from Lignocellulosic Hydrolysate in *Rhodospiridium Toruloides*." *Microbial Cell Factories* 19, no. 1 (2020/02/05 2020): 24. <https://doi.org/10.1186/s12934-020-1293-8>.

Additional Slides

Publications, Patents, Presentations, Awards, and Commercialization

FY20

Publications (contd.)

- Ju, Zhaoyang, Weihua Xiao, Xiaoqian Yao, Xin Tan, Blake A. Simmons, Kenneth L. Sale, and Ning Sun. "Theoretical Study on the Microscopic Mechanism of Lignin Solubilization in Keggin-Type Polyoxometalate Ionic Liquids." 10.1039/C9CP05339E. *Physical Chemistry Chemical Physics* 22, no. 5 (2020): 2878-86. <https://doi.org/10.1039/C9CP05339E>.
- Liu, Di, Gina M. Geiselman, Samuel Coradetti, Ya-Fang Cheng, James Kirby, Jan-Philip Prah, Oslo Jacobson, *et al.* "Exploiting Nonionic Surfactants to Enhance Fatty Alcohol Production in *Rhodospiridium Toruloides*." *Biotechnology and Bioengineering* 117, no. 5 (2020): 1418-25. <https://doi.org/10.1002/bit.27285>.
- Liu, Shihong, Lalitendu Das, David N. Blauch, Charlie Veronee, Chang Dou, John Gladden, Ning Sun, and Aaron M. Socha. "Statistical Design of Experiments for Production and Purification of Vanillin and Aminophenols from Commercial Lignin." 10.1039/D0GC01234C. *Green Chemistry* 22, no. 12 (2020): 3917-26. <https://doi.org/10.1039/D0GC01234C>.
- Ray, Allison E., C. Luke Williams, Amber N. Hoover, Chenlin Li, Kenneth L. Sale, Rachel M. Emerson, Jordan Klinger, *et al.* "Multiscale Characterization of Lignocellulosic Biomass Variability and Its Implications to Preprocessing and Conversion: A Case Study for Corn Stover." *ACS Sustainable Chemistry & Engineering* 8, no. 8 (2020/03/02 2020): 3218-30. <https://doi.org/10.1021/acssuschemeng.9b06763>.
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- Yan, Jipeng, Oluwafemi Oyedeji, Juan H. Leal, Bryon S. Donohoe, Troy A. Semelsberger, Chenlin Li, Amber N. Hoover, *et al.* "Characterizing Variability in Lignocellulosic Biomass: A Review." *ACS Sustainable Chemistry & Engineering* 8, no. 22 (2020/06/08 2020): 8059-85. <https://doi.org/10.1021/acssuschemeng.9b06263>.
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Additional Slides

Publications, Patents, Presentations, Awards, and Commercialization

Patent Application

- “Fermentative process for production of polycyclopropanated polyketides.”

Inventors: Pablo Cruz-Morales, Kevin Yin, Robert Bertrand, Ethan Oksen, Aidan Cowan, Yuzhong Liu, Eric Sundstrom, Jay D Keasling

Applicants: The Regents of the University of California, Oakland, CA (US)

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Publications

- Banerjee, Deepanwita, Thomas Eng, Andrew K. Lau, Yusuke Sasaki, Brenda Wang, Yan Chen, Jan-Philip Prah, *et al.* "Genome-Scale Metabolic Rewiring Improves Titer Rates and Yields of the Non-Native Product Indigoidine at Scale." *Nature Communications* 11, no. 1 (2020/10/23 2020): 5385. <https://doi.org/10.1038/s41467-020-19171-4>.
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Patents Awarded

- “Method to produce a Polysaccharide Gel by Increasing the pH of the Polysaccharide.” Patent No. : US 10,907,223 B2 (45) Date of Patent : Feb. 2, 2021

Inventors: Mona Mirsiaghi; Eric Sundstrom; Deepti Tanjore; Todd Pray; Rocco L. Mancinelli; David T. Smernoff

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