TRANSITIONING BACK TO ABPDU AOP

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

Deepti Tanjore, ABPDU

Impact
Helping Companies Grow

What do you like?

- "Great resource to bridge the gap between academia and commercial scale. Unique in the industry."
- "Well stocked with supplies, motivated and enthusiastic ABPDU team which also provides helpful ideas and insight."
- Openness to novel approaches and new ideas
- "The professionalism"

What is not working for you?

- "Scheduling is not as flexible or fast as other CDMO's - sometimes as a startup this is a very valuable thing for a CDMO to offer"

What changes are needed?

- ""Working with Commercial Scale Manufacturers to translate start up success at ABPDU to commercial production faster."

72

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

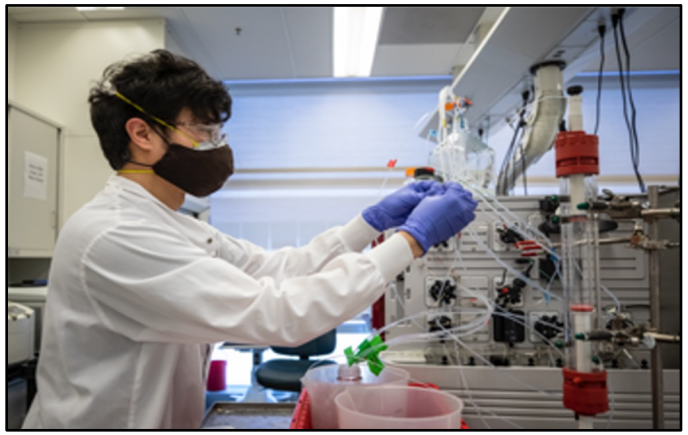
Mission Relevance: ABPDU's stated mission is to *expedite the commercialization of advanced, next-generation biofuels and bioproducts by providing industry-scale test beds.* This allows for ABPDU to be relevant to the BETO portfolio in a versatile manner and is unique in that sense.

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.

DIGESTIVA
Solving Protein Digestion

Scale-up to 2L bioreactor and enzyme recovery

CASPR BIOTECH



Scale-up to 10L bioreactor and enzyme purification

SWIFTSCALE BIOLOGICS

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

ABPDU

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.

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.

Market and Societal Benefits: More than 17 commercial products, launched from work conducted at the ABPDU, have enabled the growth of the Bioeconomy.

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.

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.

Market and Societal Benefits: More than 17 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 eight years with an increased focus on Technology Maturation. Now, ABPDU has transitioned into an advisory role to other facilities that are building up their own PDUs

culture U.S.ARMY CHEMICAL BIOLOGICAL CENTER BIOSTL DRIVING ST. LOUIS INNOVATION BioMADE™

ABPDU

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.

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.

Market and Societal Benefits: More than 17 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 eight years with an increased focus on Technology Maturation. Now, ABPDU has transitioned 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.

ABPDU

Quad Chart Overview (AOP Project)

Timeline

- 10/01/2021
- 10/01/2024

	FY22	Active Project
DOE Funding	3.0 Million (FY22) 3.0 Million (FY23)	

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. Onboarding new gas fermentation capabilities and intensifying conversion of gaseous feedstocks will enable rapid prototyping and accelerate time to market for novel gas conversions while minimizing redundant private sector capital investment.

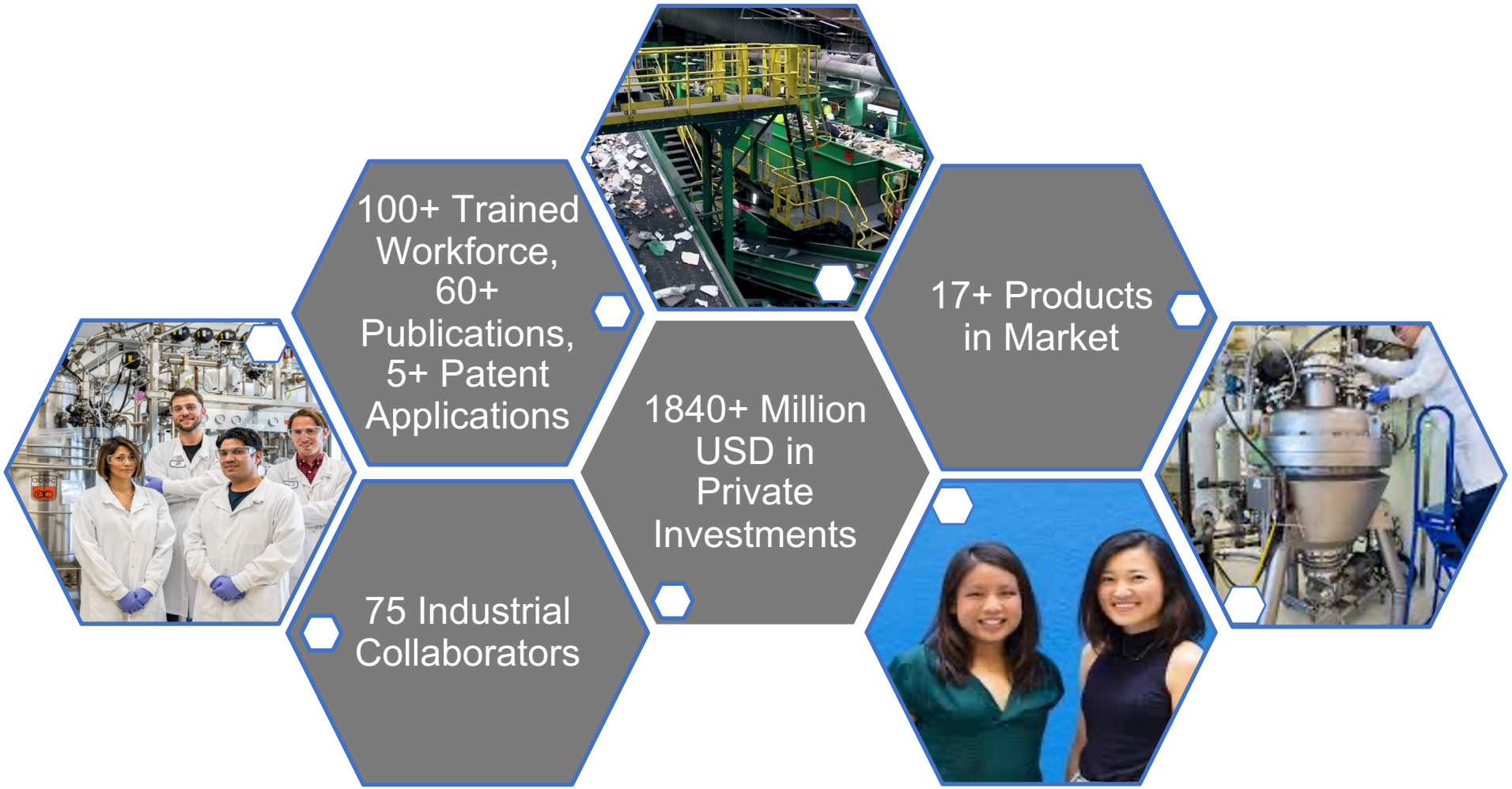
End of Project Milestone

- Purchase and install at least two new equipment per previous industry requests annually.
- Demonstrate hydrogen and methane conversion in 500mL pressurized fermenters to achieve >10g/L dry cell weight. Publish best practices for safe and effective scale-up and scale-down of aerobic gas fermentations
- Apply images and subpopulations' data from flow cytometry to AI models for detection of unanticipated events
- Publish four newsletters and conduct four safety workshops annually.
- Train at least four SULI, CCI, GEM interns/ students annually.
- Document at least one commercialization effort of a technology in BETO Conversion mission space annually.

Funding Mechanism:

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

ABPDU



49M ABPDU Funding-to-Date

($17.7M ARRA funds and $31M BETO AOP)

Additional Slides

Additional Slides
Responses to Previous Reviewers' Comments

- The lessons learned on these projects do not appear to have a home within BETO.

  Between the technical tasks and our participation in consortia, we are sharing as many lessons learned as possible. Based on our interactions with industry, we are in a good position to identify industry-wide issues that no one company is incentivized to solve. We leverage this knowledge to inform BETO AOPs and consortia research programs, generating IP which will benefit the entire industry. We are also preparing youtube videos of safe equipment operation to share knowledge publicly (Slide #19). Through the Masters in Bioprocess Engineering Program at UC Berkeley, ABPDU shares much of our know-how in the lab classes. These alumni often join companies that further BETO's mission, e.g. Zymochem, Visolis, Lanzatech, etc. (Slide #24)

- While word of mouth appears to be more than sufficient for advertising, additional effort should be made to reach out to industry and look to identify additional opportunities.

  We now have a strategic approach with website, newsletters, and social media presence along with content development in the form of case studies, alumni profiles, video training materials, etc. We present at many conferences and engage in National Academies' workshops, etc. to meet potential collaborators proactively. Please see slide #13.

- The process in determining what new equipment is purchased by the PDU was not discussed. There is a risk not mentioned in the presentation that the equipment at the PDU will not be of interest to industry

  All our equipment purchases are based on the feedback we received during industry listening day. We not only operated, but continue to develop the off-the-shelf equipment into capabilities with industry-aligned objectives. Please see #29 and #32 for more details.

Additional Slides
Publications, Patents, Presentations, Awards, and Commercialization

FY21

Publications

- Banerjee, Deepanwita, Thomas Eng, Andrew K. Lau, Yusuke Sasaki, Brenda Wang, Yan Chen, Jan-Philip Prahl*, et al.* "Genome-Scale Metabolic Rewiring Improves Titers 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.
- Geiselman, Gina M., James Kirby, Alexander Landera, Peter Otoupal, Gabriella Papa, Carolina Barcelos, Eric R. Sundstrom*, et al.* "Conversion of Poplar Biomass into High-Energy Density Tricyclic Sesquiterpene Jet Fuel Blendstocks." *Microbial Cell Factories* 19, no. 1 (2020/11/12 2020): 208. https://doi.org/10.1186/s12934-020-01456-4.
- Kirby, J., Geiselman, G.M., Yaegashi, J. et al. "Further engineering of R. toruloides for the production of terpenes from lignocellulosic biomass". *Biotechnol Biofuels* (2021). https://doi.org/10.1186/s13068-021-01950-w
- Yan, Jipeng, Ling Liang, Qian He, Carolina Gutierrez, Chia-Hsi Chu, Todd R. Pray, and Ning Sun. "Conversion of Paper and Food-Rich Municipal Solid Waste Streams to Ethanol through Bioprocessing." *ACS Sustainable Chemistry & Engineering* (2020) https://doi.org/10.1021/acssuschemeng.0c05923.
- Barcelos, Carolina A., Asun M. Oka, Jipeng Yan, Lalitendu Das, Ezinne C. Achinivu, Harsha Magurudeniya, Jie Dong, Simay Akdemir, Nawa Raj Baral, Chunsheng Yan, Corinne D. Scown, Deepti Tanjore, Ning Sun, Blake A. Simmons, John Gladden, and Eric Sundstrom. "High-Efficiency Conversion of Ionic Liquid-Pretreated Woody2Biomass to Ethanol at the Pilot Scale," *ACS Sustainable Chemistry and Engineering.* (2021) https://dx.doi.org/10.1021/acssuschemeng.0c07920
- C. E. Lawson, J. M. Martí, T. Radivojevic, S. V. R. Jonnalagadda, R. Gentz, N. J. Hillson, S. Peisert, J. Kim, B. Simmons, C. J. Petzold, S. W. Singer, A. Mukhopadhyay, D. Tanjore, J. G. Dunn, H. G. Martin. "Machine learning for metabolic engineering: A review." *Metabolic Engineering* (2020). https://doi.org/10.1016/j.ymben.2020.10.005
- T. Eng, D. Banerjee, A. Lau, E. Bowden, R. Herbert, J. Trinh, J.P. Prahl, A. Deutschbauer, D. Tanjore, A. Mukhopadhyay "Engineering Pseudomonas putida for efficient aromatic conversion to bioproduct using high throughput screening in a bioreactor." *Metabolic Engineering.* (2021). https://doi.org/10.1016/j.ymben.2021.04.015
- Lalitendu Das, Ezinne C. Achinivu, Carolina Araujo Barcelos, Eric Sundstrom, Bashar Amer, Edward E. K. Baidoo, Blake A. Simmons, Ning Sun, and John M. Gladden. "Deconstruction of Woody Biomass via Protic and Aprotic Ionic Liquid Pretreatment for Ethanol Production." *ACS Sustainable Chemistry & Engineering* (2021) https://doi.org/10.1021/acssuschemeng.0c07925
- Keasling, J., Garcia Martin, H., Lee, T.S. et al. "Microbial production of advanced biofuels." *Nat Rev Microbiol* (2021). https://doi.org/10.1038/s41579-021-00577-w

Additional Slides
Publications, Patents, Presentations, Awards, and Commercialization

FY22

Publications

- Chen, Chyi-Shin, Akash Narani, Aigerim Daniyar, Joshua McCauley, Sarah Brown, Todd Pray, and Deepti Tanjore. "Ensemble Models of Feedstock Blend Ratios to Minimize Supply Chain Risk in Bio-Based Manufacturing." *Biochemical Engineering Journal* (2020/12/24/ 2020): 107896. https://doi.org/https://doi.org/10.1016/j.bej.2020.107896.
- Jipeng Yan, Eric C. D. Tan, Rui Katahira, Todd R. Pray, and Ning Sun. "Fractionation of Lignin Streams Using Tangential Flow Filtration." *Industrial & Engineering Chemistry Research* (2022) https://doi.org/10.1021/acs.iecr.1c02052
- P. Cruz-Morales, K. Yin, A. Landera, J. R. Cort, R. P. Young, J. E. Kyle, R. Bertrand, A. T. Iavarone, S. Acharya, A. Cowan, Y. Chen, J. W. Gin, C. D. Scown, C. J. Petzold, C. Araujo-Barcelos, E. Sundstrom, A. George, Y. Liu, S. Klass, A. A. Nava, J. D. Keasling. "Biosynthesis of polycyclopropanated high energy biofuels." (2022). *Joule*. https://doi.org/10.1016/j.joule.2022.05.011
- Otoupal, P.B., Geiselman, G.M., Oka, A.M. et al. "Advanced one-pot deconstruction and valorization of lignocellulosic biomass into triacetic acid lactone using Rhodosporidium toruloides." *Microb Cell Fact* (2022). https://doi.org/10.1186/s12934-022-01977-0

FY23

Publications

- Kim, C., et al (2022). "Coupling gas purging with inorganic carbon supply to enhance biohydrogen production with Clostridium thermocellum." *Chemical Engineering Journal* (2022) https://doi.org/10.1016/j.cej.2022.141028
- Valencia, L.E., Incha, M.R., Schmidt, M. et al. "Engineering Pseudomonas putida KT2440 for chain length tailored free fatty acid and oleochemical production." *Commun Biol* (2022). https://doi.org/10.1038/s42003-022-04336-2
- Huntington, T., Baral, N., Yang, M., Sundstrom, E., Scown, C. "Machine learning for surrogate process models of bioproduction pathways." *Bioresource Technology.* (2022). https://doi.org/10.1016/j.biortech.2022.128528
- Liu, D., Baral, N., Liang, L., 1, Scown, C., Sun, N. "Torrefaction of almond shell as a renewable reinforcing agent for plastics: techno-economic analyses and comparison to bioethanol process." *Environmental Research: Infrastructure and Sustainability.* (2023). https://doi.org/10.1088/2634-4505/acb5c0