Summary of Bioprocessing Separations Consortium
Industrial Listening Day

Held
May 23, 2017 at BWI Sheraton

Report v1 dated: June 30, 2017

BIOPROCESSING SEPARATIONS CONSORTIUM

Introduction

On May 23, 2017, representatives from industry met with national laboratory scientists and engineers to discuss key challenges in bioprocess separations from an industrial standpoint. The workshop sought to generate discussion regarding informing future work of the consortium through identifying knowledge gaps and prioritization of separations challenges.

Companies represented spanned a range of small startups to established multinationals, all involved in developing technologies and/or producing bio-based products such as fuels, chemicals, materials and food or feed from biomass and other agricultural resources. The organizations in attendance were:

Industry:

- ADM
- Ajinomoto
- Alfa-Laval
- Amyris
- BASF
- BP
- Chemours
- DuPont
- DWH Consulting
- Kalion
- PTI Solutions
- Sigma-Aldrich
- Solvay

National Labs:

- Argonne
- Lawrence Berkeley
- Los Alamos
- NREL
- Oak Ridge
- Pacific Northwest

Federal Agencies and National Associations:

- American Institute of Chemical Engineers (AIChE)
- American Chemical Society (ACS)
- Department of Energy (DOE) Advanced Research Projects Agency - Energy (ARPA-E)
- DOE Advanced Manufacturing Office
- DOE Bioenergy Technologies Office
- RAPID Manufacturing Institute

The workshop agenda (shown below) sought feedback from industry regarding challenges in bioprocessing separations, how industry would like to work with the labs regarding these challenges, and developing specific plans for collaborations between the labs and industry for addressing bioprocess separations challenges. Each section of this report summarizes key findings of the breakout sessions that cover each of these topics.

Start	End	Activity
9:00	9:20	Welcome, introductions and listening day objectives
9:20	10:00	Bioprocessing separations challenges overview (categories, products, processes) and existing National Lab capabilities relevant to separations R&D)
10:00	10:15	Refreshment break and networking
10:15	11:30	Breakout session #1 – *Existing Technologies and Needs* – ideation and brainstorming to flag industry-relevant Separations issues that are holding back process development, scale-up and bioproduct and biofuel commercialization
11:30	12:00	Brief report-outs from breakout groups
12:00	1:30	Lunch and networking (on your own)
1:30	2:45	Breakout session #2 – *How to work together (interaction with National Labs)* – ideation and brainstorming around project / program management to better engage National Labs with industry partners on Separations R&D
2:45	3:15	Brief report outs from breakout groups
3:15	3:30	Refreshment break and networking
3:30	4:15	Breakout session #3 – *Future Directions / Consortium Opportunities and Tuning* – synthesis of output from breakout sessions 1&2 and development of next steps to make Separations R&D at the National Labs as useful to industry as possible
4:15	4:45	Brief report outs from breakout groups
4:45	5:00	Closing
5:00	evening	Hosted reception

The final section of this report spells out some potential priorities for new R&D, mechanisms for enhanced public-private partnerships, and better modes of communication to enable and accelerate separations R&D at the National Laboratories that is relevant and useful for industrialization of emerging and existing biofuels and bioproducts.

Existing Technologies and Needs in Bioprocess Separations R&D

Separations needs in the bioprocessing industry are influenced by the products and fuels that are under development.

Classes of Products: Several product classes were discussed as potential focus areas for technology development as outlined in the following table.

Product Class	Associated Barriers Discussed	Possible Solutions Discussed
Alcohols	High energy requirements for distillation and dewatering	Membranes for dewatering, process configuration-based approaches, and molecular interactions.
Organic acids (monomers of low molecular weight acids, short chain fatty acids)	High purity necessary for polymer applications.	Resin-based capture, moving bed-type chromatography. Focus on removing the organic from the water rather than dewatering. Improve predictions of acid-water interactions.
Aldehydes and Ketones (furfural, butyraldehyde, acetone)	Can inhibit fermentation	In-situ removal from fermentation broth.
Oils and fatty acid (oleic and linoleic acids), hydrophobic biofuel precursors	Isolation of closely-related structures with different properties	Exploit charged character Chromatography potentially with silver-functionalized resin. In-situ removal. Intracellular product recovery through dewatering, cell lysis, lipid secretion, and separating lipid products from membrane lipids.

Other bioproducts that are of interest to industry include nucleic acids, proteins, and high margin products in addition to large molecules that are emerging as promising. Other high margin products mentioned were detergents and lubricants. Additionally, separations applications for lignin remain important.

Bioprocesses present unique challenges and opportunities for the application and development of technologies to separate both desired products and unwanted contaminants.   Specific challenges include solids handling given the prominent role of high-solids streams in bioprocesses, improved fractionation of biomass, yield losses arising from solids entrainment, the temperature sensitivity of many bio-derived molecules rendering them less suitable for distillation, the need for high product quality and purity, and the significant challenge of water treatment and reuse. Removing acids without neutralization would also be beneficial.

Types of Technologies: Participants in the workshop discussed technologies that could be improved or developed to address bioprocess separations challenges. Distillation, a separations workhorse, can be ideal as a product finishing step (e.g., when the product concentration exceeds 20%). This technology is not ideal for high-volume applications in the bioproduct space. What is clear is that to adapt to new feedstocks and products other processes need to mimic distillation's flexibility. Other processes such as chromatography, filtration, and adsorption should be deployed more in bioprocess separations along with membranes.

One system that distillation is not adequate for is the separation and purification of fatty acids. Rather than employ distillation and purification in this case, there is a need to remove continuously the product when it is very dilute. Furthermore, continuous fermentation including the development of an economic technique for cell retention was raised as a key technology development need. Recovering spent fermentation waste is also desirable.

Another key need raised is the development of new technologies for selective de-lignification. Serial dilution in process trains was raised as a key challenge that could be addressed through dispersing an adsorbent or micelle that can be collected. Membranes could also address this need, although membrane fouling needs to be addressed as a part of membrane-based approaches. Overall, it is important to consider incremental or imperfect separations approaches in which purity targets may be addressed step wise in different sub-processes rather than all at once in a single unit operation.

Notably, fermentation-based approaches to produce bioproducts or biofuels face a challenge of contaminants that are produced during the fermentation. Contaminants can come from the feedstock or be inherent to the fermentation process, present in the media or being introduced as microbial by-products. To deal with contaminant challenges, there is a need to clean up the feedstock, for example by reducing the salt load in the hydrolysate. Overall, if cellulosic sugars could be made clean and facile for subsequent processing as corn syrup, there would be more applications for using cellulosic feedstocks for bioproducts and biofuels.

An alternate view was that the feedstock and efficiency of separations might be able to be a bit "sloppy" in some places. It would be desirable to put in only the energy really needed to improve processes to achieve the desired purity level. For this desired state, a comprehensive evaluation of conversion processes must occur to examine where control over contaminants is necessary and possible. It is essential to explore the tradeoffs of feedstock versus product purification and influence on downstream steps and process economics. For example, feedstock specification and standardization could play important roles in setting up separations processes for success in the overall conversion of biomass to fuels and products. Specific to sugar feedstocks, it was proposed that one should consider matching the abundance and quality of a sugar source to the relative value of a product, such that higher quality feedstocks are used on higher values products. Industry participants pointed out that there is an opportunity here for the Agile BioFoundry and the Separations Consortium to work together to generate a systems approach to limiting the negative influence of contaminants in bioprocessing.

Algal-based processes have unique challenges including non-destructive product recovery options. Techniques such as swings in pressure or pH may be advantageous. In general, oil-water separations deserve attention and technologies such as continuous centrifugation may play a role. Dewatering options for microbial systems need to be explored as well. The role of process intensification was also discussed because it could help reduce product inhibition if products were separated directly from fermentation broth. It was suggested, however, that existing technology perhaps should be the basis of process integration to limit risk. It was also noted that for process intensification the use of waste streams might be good 'early adoption' opportunities, in order to develop the technologies on a low or negative value stream before applying those process intensification approaches to other systems.

In some cases, bioprocesses can be viewed through a lens of complementary or co-processing with petroleum-based compounds (e.g., co-blending of fuels). Some separations issues span both petro- and bio-based processing. One example is developing gas-gas separations for olefinic and alkane C_1-C_4 compounds, which would benefit both processing types. Generally, there was interest in the concept of bio-petrorefinery hybrid scheme, with the aim of leveraging resources and knowledge in the petrochemical field.

The need for an improved understanding of bioprocessing separations from a process to molecular level was also underscored during the workshop. Notably, there are no general design principles for separations of bio-based products, leaving their isolation, separation, and purification unpredictable. There is therefore a significant scientific and engineering opportunity for additional development for bio-based processes. In particular, there are obvious opportunities for material design, perhaps employing machine learning or other accelerated approaches to, for example, testing resins for separations relevant to particular bioprocess systems (e.g., dilute aqueous streams of alcohols, organic acids, aldehydes, and other compounds). Also, membranes designed to be specific to classes of compounds would be of interest.

Process models for separations such as in Aspen should be developed to the extent possible. Using these models to better understand scaling, for example of chromatographic methods, would be helpful in addition to exploring hybrid approaches to separations. Molecular simulations that quantify and predict performance should inform these types of modules. Potential modeling includes quantum mechanical models of materials interaction with materials and each other as mixtures. Mixtures could include salts, organics, suspended solids, and other fermentation broth components. There is a core need for an empirical dataset and database to inform both molecular-level and process-level based models. This type of database can inform a holistic approach towards developing suitable processes based on molecular properties.

Participants also discussed methods of evaluating the effectiveness of separations approaches. Essential metrics include lifetime capital and operating expenses in additional to a quantitative understanding of the scalability and controllability of these processes. It was noted that it can be challenging to acquire new membranes and materials at a high level of reproducibility and consistency – quality control when trying to scale new technologies can be challenging. Waste heat recovery was also raised as an important challenge to increase bioprocessing viability. The question was also posited: Should we show success with a biorefinery that uses traditional separations methods (even if it isn't economically viable), and then intensify processes? Or, do we need to do process intensification first to realize a successful biorefinery?

It is important to note that separations needs in bioprocesses are more varied than simply recovering and purifying products. For example, better fractionation of biomass is needed, since feedstock variability affects final purity. Also, there is a need to examine the value and sustainability implications of recovering secondary products and additional biogenic carbon from waste streams. A baseline treatment for such an organic-containing waste stream is anaerobic digestion to produce heat and power.

There is an important opportunity for detailed analytics of waste streams from bio-based processes such as extractives from lignocellulose to identify target compounds as one example. Once the contents of characteristics of better waste streams are understood, there is an opportunity to assess how they might be recovered and the associated costs and sustainability implications. Characterization and assessment of potential value-added approaches to recover renewable carbon are not a focus of many biofuel and bioproduct companies who are at early stages of technology development. This area is then a prime opportunity for national laboratory –based research to aid industry in this facet of bioprocessing. There may, for example, be an opportunity to upscale, rewire, and convert mixed streams into more valuable products employing techniques such as reactive distillation. Electrocatalysis may be an additional beneficial technique to upgrade carbon.

Improving and Enabling Industry Interaction with National Laboratories for Separations R&D

Discussions in this section focused on improving Separations Consortium communication and outreach in addition to processes and scope of laboratory-industry collaborations.

Currently, stakeholders use the following methods, to different extents, to track BETO's work in Separations:

- BETO website
- LinkedIn accounts of BETO leadership
- Biofuels Digest newsletter
- Concierge (personal connections to lab researchers)
- Literature searches to find experts in a given area
- Conferences
- BETO news blast

There was variability in awareness of the resources listed above. Overall, stakeholders highlighted that it is extraordinarily difficult to know which labs house which capabilities in terms of expertise and equipment. In general, stakeholders sought more information regarding when funding opportunities would be announced and how to form partnerships for addressing those opportunities.   Formulating partnerships are difficult when it is unknown which labs are experts in which areas and have certain pieces of equipment. An app was suggested that could help link up industry needs and National Laboratory resources. As a first step, the Separations Consortium leadership can serve as a concierge to link interested industry partners to National Laboratory resources.

Several specific suggestions were made about the Consortium website, which could include an interactive scheme of the capabilities matrix to guide visitors to desired resources. In addition, it could include a general scheme of a bioprocess and clicking on a given unit operation would lead the visitor to relevant contacts and capabilities. Capabilities including characterization, analysis, and modeling should be included in this diagram. Importantly, the website should show up in major search engine searches. The website should also make clear that the Consortium requests input from industry and takes it into account when formulating a research agenda. Furthermore, the website should clarify that the Consortium is open to addressing separations challenges in the production of both fuels and products. Finally, the Consortium website needs to lay out clearly how industry can work with the consortium including timelines.

Suggestions from workshop participants included labs making better use of new media and leveraging staff at labs who are outreach professionals and know how to canvass LinkedIn and other social media for likely stakeholders. Furthermore, following the strong examples of other consortia, including the Energy Materials Network, can help the Separations Consortium design their website for greatest utility. One element that should be included on the Separations Consortium website is PI biographies and areas of expertise. Leveraging BETO’s news blast email to provide consortium updates would be a good step towards generating more knowledge in the stakeholder community about the consortium. Targeting specific conferences for presentations or special sessions could be advantageous. Examples of conferences include the Symposium on Biotechnology for Fuels and Chemicals, the Advanced Bioeconomy Leadership Conference, Recent Advances in Fermentation Technology (RAFT), and TCBiomass as well as more general conferences like AIChE. In all of these venues, publicizing separations-related success stories including timelines and deliverables and the trajectory of the technology after it “left” the consortium would be helpful to raise awareness of the consortium’s capabilities.

Linking with related efforts and groups would be advantageous to the Separations Consortium. These include the AIChE Separations Division, who publicize SmartBriefs as a means of advertising Consortium work. It may be advantageous to add non-profit separations groups to the Consortium’s Advisory Board.

A key take-away message from the discussion on communications is that multiple communication channels are necessary to disseminate the work and opportunities for collaboration with the consortium.

Participants suggested different areas for working with the labs in the area of separations. These included de-risking technologies and validating results generated at industrial research facilities. Furthermore, it would be beneficial to have a pipeline of scales available at the National Laboratories, from bench to pilot. One such project could entail conducting scale-up and production from bench-to-pilot of intermediates of interest in a supply chain.

Data management and sharing is another facet of collaboration that the national laboratories should consider. NIST and DOE projects that manage and curate significant amounts of data should be sources of ideas for how the Consortium can address this topic.

Techno-economic analyses that BETO supports are recognized as a valuable resource, albeit one that companies must adjust to fit their particular technology and fill gaps while using the TEAs largely as a point of comparison. Overall, harmonizing TEA and LCA among different pathways was suggested.

Workshop participants also considered contracting mechanisms for working with the labs. Current preferred working arrangements include Work for Others (WFO) contracts, Cooperative R&D Agreements (CRADA), and through competitive funding opportunities. An EU consortium, SPIRE, was pointed to as an example of an effective collaboration of industry and government laboratories. Another suggested model for industry-laboratory was the Advanced Manufacturing Office's National Network for Manufacturing Innovation.

Challenges and risks currently inherent in working with the labs were also discussed. First, the process of formal partnerships, for example, through CRADAs, are tedious and best suited for small studies. Once in place, formal contracts can be hard to adjust when the scope needs to be revised as results come in that affect direction. There was a question as to whether the consortium could operate partly as a user facility while taking into account some drawbacks of current user facilities. For example, the long lead times to learn of the fate of a proposal to access a user facility (up to six months) is not viable in commercial development time frames. Some facilities (e.g., the Environmental Molecular Sciences Laboratory at Pacific Northwest National Laboratory, and the Joint Genome Institute) have funds to cover user costs. For a group like the Separations Consortium that does not have this support, however, there is essentially an added cost to the user. It was suggested that the Consortium look to academic or National Network for Manufacturing Innovation (NNMI) consortium models to consider routes to funding the group's efforts. Ongoing efforts to harmonize and streamline business models of the different labs should target limiting contracting differences with different labs. Ongoing communication with industry should lead to enhanced incorporation of industry priorities in national laboratory research.

Notably, participants cited many advantages of working with the national laboratories including leveraging specialized capabilities at the labs that are not easy to access "in-house" at companies, especially small businesses. Furthermore, labs offer flexibility around intellectual property because, unlike working with academic institutions, working with labs does not always require making results public. It was pointed out that EU labs have favorable IP terms that may be worth considering. Furthermore, it was suggested that companies and teams maintain firewalls to protect IP. The National Advanced Biofuels Consortium was pointed to as a successful model in handling IP between national labs and industry. Furthermore, it may be possible to disseminate data associated with projects at the pre-competitive level whereas as TRL levels rise, data must be protected to a greater extent.

Cost shares for competitive projects can be between 20-50% but these can be in-kind, which makes the prospect of working through this route viable. The labs offer smaller opportunities that can be a good fit for small projects. These opportunities include SBR (through EERE) and the Small Business Voucher programs.

Specific examples of next steps included:

- Focus on website improvement to make capabilities, scope, industry engagement clear
- Improving communication through use of new media and sending key links/announcements to a core group of stakeholders (e.g., BETO and DOE press releases)

- Examine IP protection processes
- Speed up user facility proposal process if the Consortium would be operated like a user facility
- Laboratory teams could visit potential industry partners to assess potential needs. At the next level, secondments or embedded investigative teams could work on-site at companies.
- Continue to interact with industry to gauge value proposition of Consortium and take into account as design Consortium structure, research agenda
- Provide lessons learned including negative results to allow stakeholders to avoid technology that did not work
- Provide training to laboratory researchers on working with industry in terms of desired deliverables and approach

Future Directions and Opportunities

Fundamentals and process modeling: A key overriding theme discussed during the listening day is that identifying specific target molecules and processes that will purify them requires new approaches in how to assess these molecule-technology pairs in terms of functionality and scalability. For example, chromatography- and membrane-based unit operations can be applied to almost any bio-based product technology. However, when introducing a new product, processes such as chromatography may only be a starting point for analysis and perhaps will not be directly applicable to industrial scale separations. Shortening the span from bench-scale to industry application is important and better modeling methods are needed for these separations technologies that can't yet be robustly simulated in the way, for example, that distillation or evaporation can be in current software applications such as Aspen Plus. Industry and National Lab participants at the Listening Day agreed to follow up and identify collaboration opportunities focused on the gaps in properties databases and process modeling tools for unit operations such as simulated moving bed chromatography and membrane separations processes which are anticipated to be widely applicable for efficient bioprocessing operations. It was recommended that DOE should invest in a small-scale experimental and modeling projects to develop databases for separations other than distillation. For example, a key focus on fundamental molecular modeling to define chemical-materials interactions along with semi-empirical data via high-throughput screening tools to generate structure-activity relationships in separations processes could lead to better property databases for complex, real-world aqueous mixtures. This type of work should eventually make its way to the peer-reviewed academic literature as well chemical engineering and biotechnology separations textbooks and provide industry-wide enablement.

New process development and optimization: Several focus areas were proposed by industry stakeholders where the National Labs could develop broadly enabling process technologies in a pre-competitive fashion. One major area was the development of lower-cost, selective, anti-fouling membranes for use in bioreactors which may be applicable to a wide range of product molecules and classes. Another gap the Labs could play a role in addressing would be developing methods for the fractionation and utilization of spent fermentation biomass. Also, increasing energy efficiency and cost savings in separations needs to be a key driver, and the development of better off-line analytics and on-line measurements for separations performance is critical for this effort and this could include analysis of membrane fouling/membrane autopsy to inform improved separations materials design. Another priority focus area flagged by several industry participants is the development of continuous fermentation and product recovery processes. For this process, key performance indicators, targets and metrics could include achieving efficient product recovery at target titer and product purity levels. In addition, contamination levels, process lifetime, energy consumption and overall cost and GHG reduction targets will play a key role. Several recovery process variants were identified for use in conjunction with continuous fermentation such as *in situ* product recovery, external batch recovery, and the use of bioprocess slipstreams coupled with a membrane and broth recycle back to the bioreactor. Bioreactor process sizing of 10-30 L for development was stated as a useful pre-pilot scale. Some potential tasks and milestones related to developing processes for continuous fermentation and product recovery include: 1) TEA grounded in real data and focused on current state of technology and near-term deployments in addition to target case (sometimes called n^{th} plant) and an LCA model relevant to the product in question. 2) Comparison of continuous processing vs. fed-batch and batch mode separations efficiency and performance. 3) Feasibility evaluation of other relevant technologies and identification of feasible options such as centrifugation, membranes, reactive membranes, etc. 3) Determination of viable feedstocks based on process stability and product quality and specification analysis using real world feedstocks and real world upstream processing. To ensure success, critical resources would include National Lab teams, equipment vendors, and industrial technology and product developers.

Better communication and awareness of National Lab capabilities and objectives: A communications and familiarity gap remains between the National Laboratories and Industry regarding laboratory capabilities and industry interest. Currently, laboratories have expressed interest in intellectual property development, technology development, and fee-for-service work. The labs are still learning about industry interest and capabilities. Improving mutual understanding could be resolved through site visits to industry and the labs and special sessions on separations at industry conferences, among other approaches. Improving mutual understanding can help build the consortium's stakeholders and participants.

More efficient collaboration models: Given all the ideas and potential priorities identified during the Listening Day, it became apparent, based on industry stakeholder feedback, that the mechanisms for public-private partnership with the National Labs needs to be more flexible and streamlined to enable more rapid advances in bioprocess separations R&D. One idea along these lines is for DOE to consider Separations Consortium membership cost share with a sliding scale model to engage industry at different levels. It was also proposed that the Labs develop advisory services to assist with equipment and vendor selection by industry partners. In addition, the Labs could perhaps engage in "directed" procurement of equipment at Labs to support industry R&D in response to an RFI. This would perhaps lead to modular, skid-mounted, portable equipment than can be deployed at different labs and companies as needed. Industry stakeholders also emphasized the importance of the National Labs bridging the gap and doing the R&D that academics and industry won't or aren't capable of, in particular around 1) generating experimental and computational data to translate academic work to industrialization, 2) managing multi-scale demonstration facilities for novel separations (bench to pilot-scale), 3) piloting innovative and risky separations technologies, and 4) developing high-throughput technologies for experimental screening of separations development (especially around materials design and screening) for material-chemical interactions,

Finally, participants in the Industry Listening Day shared a desire that DOE issue a Request For Proposal for separations R&D to facilitate industry and National Lab partnerships in this area, with a potential goal or outcome being the maturation of the Separations Consortium to the point that it is a recognized Center of Excellence and hub for companies to join as part of the consortium and help fund work and develop new technologies together.

Appendix: Breakout Questions

Breakout 1:

- What types of biofuels and bioproducts are being developed in industry, and what are the specific challenges for each of them as separations processes are scaled-up?
- What different types of product specifications and levels of purity are required for the applications (e.g. plastics, fibers, aviation fuel blendstocks, solvents, etc.) being developed from bio-based chemical and fuel intermediates?
- What new process variations (e.g. based on filtration, centrifugation, sorbents, chromatography, extraction, leaching, etc.) or unit operation integration and intensification could be applied to more efficiently perform separations during production of bio-based chemicals and fuels?
- What impact would switching to biomass feedstocks such as energy crops and ag residue have on separations processes for molecules already being produced from petroleum, gas, or simple sugar feedstocks such as corn starch, grains or juices and syrups?
- Are there specific solid-solid, solid-liquid, liquid-liquid, gas-liquid, gas-gas, solid-liquid-liquid separations processes that are necessary to develop for different classes of products and end-use applications?
- Are there other additional aspects of these processes, besides the direct product stream, in which separations challenges exist. For example, could improved separations of certain waste or side streams reduce costs or increase sustainability?"
- Is there a need to develop new technologies that are targeted specifically at bioprocessing-related challenges (e.g., developing new functional materials) or does it seem that tweaks to available technologies such that they work for bioprocessing separations is the best way to go?
- Other?

Breakout 2:

- How would your company or others in industry prefer to work with the National Labs?
- Based on your prior experience collaborating with National Labs what are some of the things that worked well or could be changed to work better?
- What best practices from business-to-business partnerships would you recommend in terms of communication, data sharing and collaborative R&D between industry and the National Labs?
- Based on what you've seen of current National Lab projects, how could they be made more accessible and open to industry engagement?
- What lessons learned from your own company or industry would you recommend the National Labs to enhance public-private partnerships to develop Separations technologies?
- Where do you currently find information on National Lab activities? How useful or accessible is such information? How familiar do you feel you are with national lab capabilities in separations or other areas?
- How can we provide information that is helpful? Quarterly emails with updates about the consortium? Capabilities look-up on our website?
- Other?

Breakout 3:

- What key learnings or connections have you made in looking back at the first two breakout sessions and report outs?
- Is anything missing from what's been said earlier in the day? What new ideas have come to mind?
- What unique R&D can the National Labs implement to complement and best serve a broad range of industry stakeholders?
- What R&D priorities (e.g. process development, scale-up, product classes, feedstock types) should the Separations Consortium consider adopting to be most relevant and impactful with the bioproducts and biofuels industry?
- What next steps do you think would be most useful for your company to engage with the Labs and the Separations consortium?
- What resource needs (time, people, funding) do you think are important to develop in working together with the National Labs and the Separations Consortium?
- Other