Chapter 2: Cultivation

Algae as a Wastewater Treatment Solution/Opportunities for Niche Micro-Algae Farms

Conveners: Deborah Newby; Lowell Collins

Discussion:

This session was convened to discuss algae as a solution to on-farm and industrial effluent streams, including animal wastes (solid and urine wastes), municipal wastewater, and food and manufacturing water waste streams. Based on the discussions, there are a large number of potential niche opportunities where algae production objectives and wastewater treatment necessities can be, and sometimes are, synergized. The participants felt that these niche opportunities are not getting appropriate prioritization within the BETO program, that the synergies with wastewater treatment are not better communicated (EPA sets and regulates wastewater standards), and that funding opportunities do not traditionally target these opportunities.

Key issues and realizations:

- There is need for robust, scalable handling and conversion technologies to enable these integration opportunities.
- Niche opportunities exist for wastewater treatment.
- Government players need to work together to achieve success.
- Policy, siting, and fast-track permitting are needed.
- Reasonable business models for wastewater cultivation are needed to leverage efforts.

Next steps:

- DOE should work to strengthen the relationship with EPA to better understand the opportunities for combining EPA wastewater treatment and DOE algae production interests.
- DOE should investigate both domestic and international opportunities for algae as a wastewater treatment solution.
- There is a need to better understand and promote business case scenarios for algae wastewater cultivation.

Guiding Questions:

1. What is the time horizon for this topic or issue; will this impact algal biofuel production in the near, mid, or long term?
    - There are some near- and mid-term opportunities, but it is expected that it will take time to make significant impacts in this area and change current practices.
2. Has this topic been included in the National Algal Biofuel Technology Roadmap; and if not, should it be?

- Wastewater cultivation is addressed in the current Algae Roadmap, but there is a need to fine-tune the information and prioritize the opportunities that exist in the marketplace.

3. What is the BETO Algae Program role in furthering this topic or addressing this issue?
    - The DOE should promote wastewater cultivation as a viable option for algae production. The DOE-USDA joint solicitations should be written to specifically include algae topics. Small Business Innovation Research (SBIR) solicitations could also include specific algae topic areas. Participants sited the DOE recognition of energy-water interdependency issues and the Energy-Water Nexus Initiative initiated in 2004, and that opportunities exist for algae to lower the cost and energy intensity of wastewater treatment and/or improve the quality of waste effluent streams prior to their release into the environment.

Poster:

As presented above

Anaerobic Digestion and Recycling of Water and Nutrients

Convener: Lowell Collins

Discussion:

What do you do with the large quantity of diverse algae?
Anaerobic digestion (AD) is a potential source for hydrogen to feed back into the system process by cracking the methane, or possibly using cultures that will directly produce the hydrogen. Evaluation of these sources would require a TEA, but no pipeline would be required, and you could use a much lower quality of gas.

AD is also one way to recover nutrients. AD has the potential to concentrate nutrients, but very little application to biofuels. There would not be enough nutrients available in the waste streams to make any difference.

The price of natural gas makes this technology not economically viable. AD can be a competitive product if green gas becomes a regulated standardized product/market.

Guiding Questions:

1. What is the time horizon for this topic or issue; will this impact algal biofuel production in the near, mid, or long term?
    - AD is a short term technology used for nutrient recycling but has very little energy production potential. It is an enabling technology.
2. Has this topic been included in the National Algal Biofuel Technology Roadmap; and if not, should it be?
    - Nutrient recovery technology is in the Algae Roadmap. It's best if it is not tied to energy production as there is little energy production potential, but it can improve an energy production facility's sustainability/economics.
3. What is the BETO Algae Program role in furthering this topic or addressing this issue?
    - The DOE could make the nutrient recovery or energy production decision and enable research to develop technology to improve efficient production of biogas.

Poster:

1. Enabling Technology near- and longer-term
2. Yes
3. Nutrient Recovery allows for process efficiency; DOE backing research to improve enabling technology for efficient production.

Mass Culture Limiting Resources

Convener: Robin Gerlach

Discussion:

When scaling cultures, carbon dioxide (CO_2) as well as a number of other resources must be accounted for.

Mass culture limiting resources include:

- Water (quantity and quality)
- Nutrients (Nitrogen (N), Phosphorous (P), etc.)
  - How much do nutrients need to be recycled for the process to be economical?
  - Recycling needs are a function of process and where N is sourced from.
- CO_2/inorganic carbon
  - Interaction with EPA proposed rule (electricity generators must capture or store some carbon)
- Light
  - Production decreases proportional to light, but light is not as much of a limiting factor as temperature in winter seasons. Regions with cold winters are less ideal than areas without ample light.
- Temperature/climate
- Land
- Capital
- Temporal (diel cycles, temperature)
- Energy and energy return on investment (EROI). If the EROI is low, the system will not be economical
- Co-location of resources (including CO_2, water, energy, nutrient, waste treatment services, upgrading facility)
- Recycling
  - Recycling is necessary as analysis shows that replacing 50% of US fuel requires a 6x increase in N use and a 3x increase in P
- Impact on (high-value) co-products
- Complementary pathways
- Wastewater/anaerobic digesters
  - Algae, bacteria, archaea, zooplankton, co-cultures
- Hydrothermal liquefaction (HTL) preprocessing
  - Inhibitors
- TEA Integration
- Light and temperature are highest priority, but can be addressed via siting. Inorganic carbon (CO_2) becomes biggest limiting factor.
- DOE should put a priority on maximizing return on N and P from downstream processing in usable forms.
- Cannot optimize unit operations in isolation of other limiting resources.

- Government subsidies would be prudent until the industry can stand on its own (i.e. Brazil as a case study).
- Need for more robust TEA and public models.

Guiding Questions:

1. What is the time-horizon for this topic or issue; will this impact algal biofuel production in the near, mid, or long term?
    - This issue is relevant at all time scales; limiting resources are indefinite factors.
2. Has this topic been included in the National Algal Biofuel Technology Roadmap; and if not, should it be?
    - Inorganic carbon needs to be discussed more in the Roadmap
3. What is the BETO Algae Program role in furthering this topic or addressing this issue?
    - BETO should conduct:
        - Supply availability/resource assessments
        - Feasibility studies (recycling nutrients)
        - Research on how to produce algae in lower temperatures (temperature agnostic strains)
        - Research on disruptive technology
        - Transparent and accessible TEA models

Poster:

1. Timeframe
    a. Inorganic carbon supply and accessibility – Immediate/near-term
        i. Proposed EPA rule on carbon capture and storage/reuse
    b. N, P, Water – Near-term and on-going
    c. Location (T, hV)
    d. Co-location

2. In Roadmap
    a. No
    b. Yes

3. BETO Role
    a. Supply Availability
        i. In culture
        ii. To plant
    b. Feasibility Studies - Transparent and accessible TEA models
    c. Low temperature algal production
    d. Assessment

DISRUPTIVE TECHNOLOGIES

Algal Agriculture vs. Water Utilization

Convener: Randy Ryan

Discussion:

Is the use of wastewater for algae cultivation a false hope? Is the use of wastewater realistic and should it be used as an argument for algae-based biofuels? There is a concern that it is not and that it will eventually seriously impact the credibility of algae. Who is actually using wastewater?

How much wastewater is realistically available? Available wastewater in Arizona is expensive and not readily available. Arizona wastewater is already reclaimed. Wastewater varies seasonally and geographically and requires piping to supply it to cultivation sites located in remote places, creating a trade-off between the cost of land and the availability of wastewater.

There are costs associated with wastewater cleanup which would be necessary in order to get co-products such as pharmaceuticals from algae cultivation.

How much value is there in the nutrients from wastewater? There is an argument that the nutrient gain is minimal compared to the cost of land located near wastewater supply.

An alternative to wastewater could be agricultural water

- Could enhance algae biomass using agricultural water.
- Should algae cultivation be integrated with Ag? Crop rotation.
- Biomass can be utilized for feed.
- Reduces shipping requirements.
- The target is irrigated agricultural water, not rainwater.

Guiding Questions:

1. What is the time horizon for this topic or issue; will this impact algal biofuel production in the near, mid, or long term?
    - The time horizon is immediate/near term.
2. Has this topic been included in the National Algal Biofuel Technology Roadmap; and if not, should it be?
    - There is a perception in the Algae Roadmap that the economics of algae production are dependent on utilization of wastewater and waste nutrients. But the DOE needs to reexamine the Roadmap specific to the use of wastewater and determine whether it is practical in practice. DOE should re-evaluate siting and the scale for wastewater use. DOE should also re-evaluate its position on water unfit for land crops (page 83, section 9.4 – wastewater requirement). There is an argument that Ag water is a viable/feasible option for algae cultivation/water efficiency, logistically.
3. What is the BETO Algae Program role in furthering this topic or addressing this issue?
    - The DOE needs to re-evaluate its emphasis on using wastewater systems.

Poster:

1. Research to address question
    - Evaluate site and scale vs. wastewater
    - Wastewater and reducing cost of producing biofuels
    - Real cost of water clean-up
    - Piping requirements

2. Roadmap – unrealistic
    - Stating economics of algae
    - Dependent on wastewater and nutrients
    - Economics of land = wastewater $ gain
    - Evaluate site and scale for wastewater use

3. Reevaluate algae biofuels roadmap; emphasis using wastewater as a source; Ag water should be evaluated as increased water use efficiency. Page 83 section 9.4.

Inevitably, wastewater treatment and recycling must be incorporated.

Uncertainty in Feedstock Crop Production and Crop Rotation

Convener: Mark Wigmosta

Discussion:

This session was convened to discuss the uncertainty and variability associated with algal crop production and mechanisms to address these impacts and ensure more consistent levels of productivity. With the fundamental concerns of the group focused on the need to increase the overall productivity of algal production systems and not impact the quality of the algae and intended downstream processes or marketability of the algae, the group discussed a range of issues associated with risks that algae crops face. Among the topics discussed were impacts associated with climatic uncertainty, maintaining narrow species spectrums, predatory strains and integrated pest management (IPM), cyanobacteria and other aquatic species, polyculture systems, survival and tolerance to extremes, and solutions to short term variations.

Key challenges:

- There needs to be a better understanding of the cost impacts of various production risk mitigation strategies.
- Rigorous engineering limits for algae production systems need to be defined based on TEA and LCA.
- Finding and investigating in the right bio-engineering design solutions.
- Understanding the associative impacts that weather, seasonality, and climate change have on algae feedstock production and pond recoverability.
- The classification of algae as a crop.
- Understanding polyculture and extremophiles as potential risk mitigation strategies.
- Cost-effective monitoring and surveillance of algae crops for maximized production yields.
- Development of effective Integrated Pest Management (IPM) responses to minimize variability and losses in algae feedstock production. Multi-tropic level IPM is not very well understood.

Next steps:

- There is a need for increased funding in this area to reduce uncertainty in algae feedstock production.
- Increased interagency collaborations might be needed to ensure recognition of algae as a legitimate crop in all 50 states (currently it is recognized in 3 states), and that growers have the same rights to crop insurance as those growing terrestrial crops.
- Consider how the existing testbeds can be used to reduce these uncertainties.
- Promote the development of an open platform for conducting TEA and LCA analysis.

Guiding Questions:

1. What is the time horizon for this topic or issue; will this impact algal biofuel production in the near, mid, or long term?

- Action in the near term is needed to improve algae feedstock production and increase yield rates, but these activities will likely span the near-, mid-, and long-term timeframe as they do in the growth of terrestrial plants.

2. Has this topic been included in the National Algal Biofuel Technology Roadmap; and if not, should it be?
    - Uncertainty in algae feedstock production is addressed in the current Roadmap, but the participants felt that greater emphasis is needed. For instance, the group noted that polyculture systems and extremophiles deserved greater prominence in the Algae Program's focus. The group also felt that there was a need for broader consideration on bio-prospecting; the development/engineering of algae genotypes and phenotypes; and the engineering of the associated unit operations needed to accrue success in reducing algae production uncertainties.
3. What is the BETO Algae Program role in furthering this topic or addressing this issue?
    - The group felt that DOE had a role in developing a strong knowledge base for algae production information and data. The group suggested funding university/industry sabbatical opportunities that would result in a cross-fertilization of the algae related wisdom. The group also believed that DOE needed to provide sound leadership in the areas noted in both Question 2 and Next Steps as presented above.

Poster:

Key challenges

- Better understanding of cost impacts of risk mitigation strategies
- Defining engineering limits based on TEA and LCA
- Finding/investing in the right integrated bio-engineering design solutions
- Climate impacts/seasonal/weather/issues and recoverability and productivity
- Algae classified as a crop
- Polyculture and extremophiles - understanding as a risk mitigation strategy
- Cost effective surveillance and IPM response

Next Steps

- Funding
- Interagency collaboration
- Look at how testbeds are used; promote
- Open platform for TEA

Q1: Timeframe: Near-, mid-, long-term
Q2: In Roadmap: Polyculture and extremophiles deserve greater prominence, broader consideration of bio-prospecting. Co-development/integration of geno/pheno types engineering and the associated units of operation
Q3: DOE BETO Role: Fund sabbaticals for university/industry cross fertilization of algae wisdom; see Q2 and Next Steps

Optimizing Low-Cost Cultivation Design

Convener: Braden Crowe

Discussion:

How does cultivation design impact biomass productivity? The costs of cultivation designs have a large impact on their implementation. Both capital expenditures (CAPEX) and operating expenditures (OPEX) have to be considered, but it is a mistake to separate these two costs. They need to be combined to get a reasonable expectation of the costs of ownership. The lifetime of the system is also an important metric when calculating the cost of ownership. Risk will also impact this cost and so it needs to be quantified, specifically in terms of reliability of the system. The realistic lifespan and system depreciation should be treated as variables in the cost of ownership calculation.

What can be changed in order to reduce costs and/or increase productivity? The system carbon footprint cost is important to consider in terms of nitrogen, fertilizers, and scalability. The DOE could help establish a widely used cost of ownership model to standardize these costs.

Other issues to consider:

- What is the minimum size required to demonstrate scalability?
- In terms of inoculum production, how is the system operated (i.e. batch, continuous)?

What are the TEA key targets? Energy consumed versus energy produced is a key measurement in TEA models. Pond liner costs represent a significant cost of ownership, but how do you treat the soil in order to reduce ash content? There need to be standards for pond liners. Current regulations are inconsistent, and there is a lot of uncertainty for stakeholders in terms of groundwater and soil contamination. What are some alternative liners, and how will they affect the cost of ownership? The use of non-agricultural land for algae production is a key target in these assumptions. The flue gas source, water availability, and soil type can all be adjusted in TEA models.

What is the role of photobioreactors (PBRs)? PBRs do not require pond liners and can be constructed in more locations than ponds, and water resource loss is mostly resolved by allowing access to environments that might not otherwise be possible with ponds. There are regulatory requirements for secondary containment, however, in an enclosed pond hybrid system. Offshore PBRs may solve land use, land cost, and siting issues. PBRs use CO_2 more efficiently, and there are more options for strain selection.

The testbed facilities can fill some knowledge gaps for system design, but this is not typical farming and so it is unlikely that traditional farmers will ever be able to produce algae. Maybe the USDA is not the correct agency for this task. The industry is more interested in cost per feedstock; are you going to have just one product, or do you want to have multiple product streams? There should be a system designed for farmers where they can have crop flexibility, and this does not allow for the installation of PBRs or liners. A different model is to use land and water that has no other use. There is increased productivity when using agricultural land for algae production because it is already established, is owned by farmers, and has wells installed. This would mean that the economics of the end product have to compete with their current agricultural product, possibly competing with a food crop. Algae most likely won't work as a 100% animal feed, just a portion.

Guiding Questions:

1. What is the time horizon for this topic or issue; will this impact algal biofuel production in the near, mid, or long term?
    - In the short term, the focus should be on products, and in the long term the focus can shift to fuels, with knowledge gained through the production of products.
2. Has this topic been included in the National Algal Biofuel Technology Roadmap; and if not, should it be?
    - The Algae Roadmap should increase the focus on productivity. The importance of yield is currently addressed, but there should be more focus on the cost needs. The Roadmap should incorporate more innovative ideas to address simplicity, reliability, distribution of CO_2, and cost of the cultivation system. This will entail different solutions for different environments, not a singular solution.
3. What is the BETO Algae Program role in furthering this topic or addressing this issue?
    - The DOE can promote interagency cooperation among the USDA and EPA on regulatory issues as well as funding to provide consistency to stakeholders.
    - DOE is looking for a singular solution, but there will have to be multiple solutions for different applications and different environments.
    - If the DOE only spends funding on solving the problems with advancing biofuels, they may not solve the problems that are relevant for products. The problems that are pertinent for products have to be addressed to advance the industry and begin to compete with oil. The revenue generated by products will help solve a lot of the economic problems.
    - The DOE is focused too narrowly and should investigate innovations such as solar-thermal integration.
    - DOE should work with other agencies because they are all focusing on different aspects of algae products. DOE only cares about fuel, but the products are the focus of other agencies; they need to cooperate to support the economic development of the algae industry.
    - DOE needs to focus on Technology Readiness Level (TRL) 1, 2, and 3, and not just 4 – 7[4]. There are basic research elements that need inter-agency communication and support to develop technology readiness.

[4] See the TRL definitions in the *Bioenergy Technologies Office Multi-Year Program Plan*. DOE/EE-0915.Washington, DC: U.S. Department of Energy, 2013. bioenergy.energy.gov/pdfs/mypp_may_2013.pdf

Poster:

1. Goals:
   - Short-term – Fundamental problems addressed; look into alternative sources first
   - Mid- to Long-term – More towards agronomy based systems

2. Yes it is already mentioned, but now do we retool this? Incorporate solar-thermal into portfolio

3. Emphasize how to get to no-cost cultivation systems
   - Include co-products that enable fuel production
   - Biofuel development requires interagency cooperation to advance the technology readiness level
   - Be realistic about the current TRL

Sensors and Systems for Precision Algae Agricultural Production

Convener: Albert Vitale

Discussion:

This topic was convened to address the development of precision algae production systems. The participants recognized the importance of sensors, real-time data acquisition and analysis, and the impact that these systems and controls will have on developing large-scale algae production systems. The group discussed the various controls and key monitoring parameters that may be needed to improve the automation of algal production systems and alert operators to conditions that may impact the algae cultivation and production processes.

Key issues and realizations:

- There is a need for reliable, consistent, accurate, and integrated measurement and control solutions to improve algae yields and quality and reduce uncertainty in algae production systems.
- The solutions need to provide lower cost of ownership, i.e., offer real time data to improve system operations and performance and lower overall maintenance costs.
- Economies of scale are an important issue in this topic.

Next steps:

- Research is needed to understand the key monitoring parameters for improved automation.
- Research and development activities are needed to better understand the operational requirements for large-scale algae production operations. Algae specific data logging, collection, management, and analysis requirements are not well understood, but there is significant knowledge in the area of manufacturing and automation that can be leveraged to ensure the development of state of the art automation in algae production.
- There is a need to better understand the role of in-situ measurements techniques vs. refractive and reflective measurement techniques in the monitoring of algae production.

Guiding Questions:

1. What is the time horizon for this topic or issue; will this impact algal biofuel production in the near, mid, or long term?
    - There is an immediate, near-, mid-, and long-term need for continuous improvements in measurement and control.
2. Has this topic been included in the National Algal Biofuel Technology Roadmap; and if not, should it be?
    - Large scale algal biofuel production is not possible without significant improvements in the area of automation; sensors and systems for precision algae agricultural are the key to making these improvements.
3. What is the BETO Algae Program role in furthering this topic or addressing this issue?

- DOE should work with industry and researchers to advance the current state of technology to the levels necessary to sustain large scale cultivation, including reducing sensor cost, improving sensor quality, and ensuring sustainable productions.

Poster:

1. Timeframe: There is an immediate, near-, mid-, and long-term need for continuous improvements in measurement and control.

2. Is it in the Roadmap?: Large-scale algae biofuel production is NOT possible without significant improvements in this area. It is essential to include this in the roadmap.

3. DOE BETO Role: Work with Industry and researchers to advance current technology to advance the technologies to the levels necessary to sustain large-scale cultivation:
   - Needed to reduce cost
   - Needed for reliable sustainable production

New Co-Products

Convener: Robert McCormick

Discussion:

What are viable algae co-products (defined in this context as anything other than fuel)? Fuel is the main product because most of the energy goes into producing fuel, even if it does not make the most money.

Co-product list - Niche (N) vs. Commodity (C):

- Carotenoids (N)
- Oleochemicals (C)
- Omega-3 fatty acids (N)
- Carbohydrate fermentation
- Protein Products
  - Enzymes (N), (C)
  - Animal feed (C)
- Polymers (C)
- Pharmaceuticals (N)
- Human food chain
- Bio-char (coal is 50/70 per ton, may be co-products in activated carbon replacements, soil enhancement)
- Fertilizer (phosphorous, nutrients that are not recycled but are used for other applications)
  - This could require more costs in re-purchasing the needed nutrients.

Co-products for specific products might regulate how you run your system (such as nutraceutical food chain regulations). GMO co-products would make GM fuel very expensive. Since the economics that allow GMO non-fuel products to make a profit are slim, it probably would not make sense to pull from the product line to produce a fuel. This makes no economic sense for GM fuel product lines.

What are the research needs for co-products?

- The market size for co-products needs to be better understood. There will possibly be completely different markets for each co-product. Valuing co-products might occur naturally as the commercialization of biofuels advances. This has been seen in history multiple times. The market size is small or saturated for some of these co-products (Oleochemicals ->Polymers [carbohydrates, proteins], Oleochemicals->Petrochemical substitute). "Replacing the whole barrel" refers to any products that can replace the petrochemical market, but how much petroleum can we displace? Algae can replace oleochemicals, polymers from carbohydrates/proteins, and carbohydrates, and renewable plastics (from sugars or proteins).
- Research is needed in algal biomass and product composition characterization to best determine what co-products can be made. This includes recovery and separation of valuable components, analytical methods, and organic constraints. Fourier transform ion cyclotron resonance mass spectrometry is a great but expensive analytical technique to understand hundreds of compounds.

- The environmental sustainability of these products needs to be investigated. LCA is an important tool; the GHG emissions must be improved over petroleum for DOE to consider funding.
- Research is needed in the photosynthetic production of commodity chemicals.
- Intellectual property issues need to be resolved.

Some very interesting chemicals may result from the HTL process and from the non-upgraded products. Upgrading can reduce use in some commodity-product markets (example of detergents). This might need to be investigated. Co-product models are not clearly defined; the technology might not be able to cope with the higher revenues. What is the technology readiness level for these technologies, are they ready for the market? TEAs will be speculative at first but will be able to show if there is an opportunity for economic gain. These technologies need to be integrated in the R&D portfolio. DOE could something like what the National Advanced Biofuels Consortium (NABC)[5] did and start with a lot of co-product options and then compare their TEAs.

Guiding Questions:

1. What is the time horizon for this topic or issue; will this impact algal biofuel production in the near, mid, or long term?
   - In the short and medium term, these co-products are more important to the economics of the system, and then as the market for fuels takes off the co-products can be less important. This needs to be a significant portion of the DOE's funded portfolio in the short, mid, and long term.
2. Has this topic been included in the National Algal Biofuel Technology Roadmap; and if not, should it be?
   - This issue is addressed in the Algae Roadmap, but only for the niche products. The commodity products are not addressed well. BETO should add co-products to the Roadmap to improve environmental and economic sustainability.
3. What is the BETO Algae Program role in furthering this topic or addressing this issue?
   - BETO's role should maybe be minimal in this issue as the market is the bigger driver; though they may be able to guide the industry to incorporate value-added co-products.
   - The DOE's top ten list of bio-chemicals is a great resource and maybe algae chemicals should be added to that list.
   - BETO could incorporate research on co-products into TEAs. This would require some level of process design and a very deliberate effort. Instead, BETO could produce a more general TEA that takes into account an existing facility and taking out different products, as in an integrated biorefinery instead of a specific biorefinery where you can adjust your products based on market needs.

[5] The National Advanced Biofuels Consortium is a collaboration among DOE national laboratories, universities, and private industry that is developing technologies to produce infrastructure-compatible, bio-based hydrocarbon fuels. NABC is led by the National Renewable Energy Laboratory and Pacific Northwest National Laboratory and was funded by the DOE under the American Recovery and Reinvestment Act in 2009.

- BETO could compare feedstock to fuel and co-product pathways, and incorporate co-products into the BETO portfolio.

Poster:

Time horizon: Near- & mid-term

Roadmap: Yes, but currently niche – change to commodity.

DOE/BETO: Add co-products based on economic and environmental sustainability to roadmap (commodity). Impact of co-products on TEA:

- Compare feedstock to fuel and co-products pathway
- Co-product scenarios in integrated biorefinery
- Co-products integrated into R&D portfolio and the deployment and demonstration portfolio
- Co-products language in FOAs.

Chapter 3: Processing and Conversion

Energy Efficient Harvesting, Dewatering, and Extraction

Convener: John Groppo

Discussion:

Harvesting and dewatering design must consider the energy intensity of the operations and energy return on investment. The classical system is outdated and does not focus enough on upstream impacts on downstream operations. The goals of system design are to minimize energy intensity and overall operating cost.

Operations starting with an algae concentration of 0.5 g/L and through primary concentration/settling to 2 g/L need to be continuous, scalable, and with an optimized retention time. This has not been demonstrated on a continuous basis. Moving to 60 g/L methods include dissolved air filtration, belts, or acoustics, but there is a need for new filtration technology. Centrifuges deal with 100-200 g/L. These system designs should consider multi-product models and account for non-biofuel products. Foreign material removal is important for the filtering process.

Scaling these systems is a major issue requiring advances in engineering and CAPEX. Processes should be engineered in a system-design framework, considering both impacts on upstream and downstream processes. There is a need for data on larger scale processes, utilizing existing facilities; small scale projects do not relate to bigger projects. A databank of process performance at existing facilities would be beneficial to the industry.

Harvesting facilities need products for testing. Small companies need the feedstock producers to provide them with this feedstock for testing, and DOE could facilitate this interaction.

Optimized systems should integrate aquaculture, harvesting, and extraction, as well as investigate co-energy strategies to leverage existing sources of energy to minimize CAPEX.

Guiding Questions:

1. What is the time horizon for this topic or issue; will this impact algal biofuel production in the near, mid, or long term?
    - Efficient harvesting and extraction is a limiting factor for commercialization and so it needs to happen first, within the near term.
2. Has this topic been included in the National Algal Biofuel Technology Roadmap; and if not, should it be?
    - This issue is already discussed in the Algae Roadmap, but deserves more attention.
3. What is the BETO Algae Program role in furthering this topic or addressing this issue?