*Bioenergy Technologies Office*

# 2017 Program Management Review

## *Advanced Algal Systems*

**Eric Jarvis**

**Arlington, Virginia**

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# Peer Review Process



| NAME | AFFILIATION |
|---|---|
| Eric Jarvis* | Independent Consultant |
| Toby Ahrens | U.S. Department of Agriculture, National Institute of Food and Agriculture |
| Louis Brown | Synthetic Genomics |
| Bill Crump | Leidos |
| Sarah Smith | A.E. Allen Laboratory, Scripps Institution of Oceanography |
| Rebecca White | Qualitas Health |

# Review Panel Approach



- 39 projects presented over the course of four days
- Discussions of goals, project management, accomplishments, relevance to BETO goals, future work plans
- Mix of sun-setting (7), ongoing (24), and new (8) projects
- Q&A from panel and audience
- No confidential information presented
- Following review, panel members made very detailed evaluations, received PI responses

# Project Scores



- Average Weighted Scores ranged from **3.75** to **9.00**, with a median of **7.50**

| | SunSetting | Ongoing | New |
|---|---|---|---|
| Average Scores | 7.24 | 7.30 | 7.67 |

- **Top 5** performing projects:
  - Global Algae Innovations, ABY Phase 2
  - Arizona State University, ATP3
  - NREL, Algae Technology Educational Consortium
  - Global Algae Innovations, TABB
  - NREL, Algae Biofuels TEA

# #1 & #4: Global Algae Innovations, Inc.



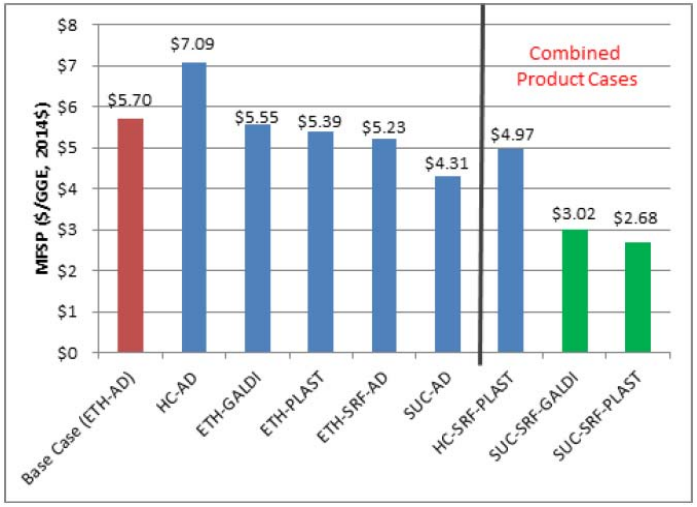
- GAI presented on sun-setting (ABY Phase 2) and ongoing (TABB) projects
- Impressive progress
  - Improved strains, cultivation methods
  - Novel harvest/dewatering technology
  - Integrated process at large scale demonstrated
  - Research tightly linked to cost models
  - Claims of a modeled $3.33/GGE MFSP


# #2 & #5: Bedrock Projects



## Arizona State University, ATP3

- Algae Testbed Public-Private Partnership
- Resource for entire algal community
- Long-term, multi-regional growth data to establish state-of-technology
- Methods development, standardization, harmonization


## NREL, Algae Biofuels TEA

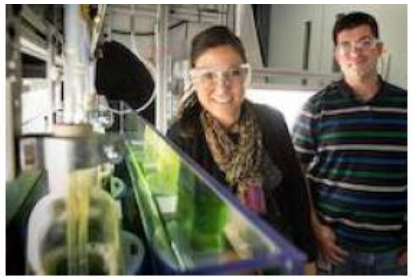
- Supports industry and research communities with in-depth techno-economic analyses
- Guides research priorities for BETO
- Critical evaluation of process and co-product scenarios

Other bedrock projects include NREL's Algal Biomass Valorization and PNNL's Microalgae Analysis projects

# #3: Educational Consortium



- Algae Technology Educational Consortium
- Collaboration between NREL and USM
- Goal to meet expected need for skilled algal technicians
- Working to establish coursework and degree programs through academic partners

# Overall Impressions: Impact



- Excellent research productivity across the portfolio
- Significant advances enabled by BETO funding
  - Private sector cannot yet substitute
- 2015 Peer Review findings being addressed
  - Emphasis on co-products, saline strains, productivity targets
- Current SOT solidified (ATP3, NREL TEA)
  - Advances still required across value chain
  - Further productivity improvements key
  - Co-products essential for economic viability
- Several projects poised for impact in co-products
  - NREL ABV, ABC; Algenol; CSM-PACE
- Industry-led deployment on path to BETO's goals

# Overall Impressions: Innovation



- BETO's FOA process has attracted highly innovative approaches
- Five areas stood out:

1) Strain improvement
   - Innovative tools, strains, datasets coming online
   - Cas9, non-GMO engineered strains
   - Rapid screening methods
   - Classical breeding (LANL)
2) Carbon capture
   - High alkalinity cultivation (U. Toledo)
   - Carbonic anhydrase (PNNL)
   - Large-scale absorber unit (GAI)

Photo: R. Sayre, LANL

Photo: D. Hazlebeck, GAI

# Overall Impressions: Innovation, *continued*

3) Crop monitoring and protection
   - Addressing yield losses due to predators and pathogens
   - Chemical signatures of impending crashes (UCSD)
   - Pond microbiomes, selecting probiotics (LLNL)

Photo: R. Davis, SNL

4) Algal polyculture using impaired water
   - High productivity plus water remediation and nutrient recycle
   - Algae Turf Scrubber (SNL)
   - Wastewater systems (Cal Poly, MicroBio)

5) Direct production of chemicals/fuel intermediates
   - Cyanobacterial production in PBRs
   - Ethyl laurate (ASU) or ethylene (NREL)

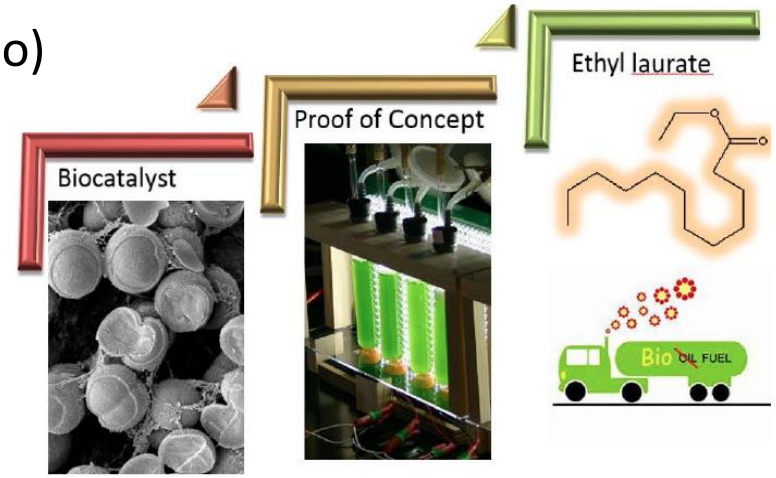



Figure: W. Vermaas, ASU

# Overall Impressions: Gaps/Focus



- Overall no notable gaps – well balanced portfolio
  - Broad coverage of entire process chain, various TRLs
  - Excellent tie-in between TEA/LCA and BETO decision making
- Consistent theme was lack of interaction between researchers and end users
  - Fuel intermediate refiners, co-product industries
- Relatively little work on harvest/dewatering
- Co-products of increasing importance
  - Little consensus on best co-products to pursue (value *vs*. market size)
  - Assumed *vs*. demonstrated value (*e.g*., feeding trials, co-polymer testing)
- Regulatory issues
  - GMO deployment, GMP requirements

# Overall Impressions: Synergies



- Overall excellent synergies between projects
  - Consortia are models of inter-laboratory cooperation (*e.g.*, DISCOVR, ATP3, NREL ABP)
  - Little duplication of effort, some redundancy beneficial
- Some opportunities for additional synergy noted
  - Interactions between national labs and industry (*e.g.*, quality *vs*. value of fuel intermediates)
  - Methods standardization and units reported
  - Competing processing pathways (*e.g.*, ALU/CAP vs. HTL)
  - Projects integrating herbaceous feedstocks (INL, ASU) should interact with cellulosic biomass industry

# Overall Recommendations



1) Productivity improvements still paramount
   - Continue research on tools, strains, carbon uptake, product/co-product yields, cultivation practices, crash resistance, etc.
   - Continue improvement of realistic lab-scale testing and iteration between lab and field; larger, longer-term outdoor demonstrations
   - Continue funding both incremental improvements and potentially transformational concepts
   - Maintain critical mass and varied approaches

## 2) Foster connections with industry

- Researchers need buy-in from real-world algae producers on new concepts, modeling assumptions
- Market assessments are needed for evaluation of potential co-products
- Researchers and industry should work together toward consensus on products best suited to algal systems
- Buy-in from end users of fuel/chemical products is needed (including cost penalties for quality issues)
- Value of algae-derived co-products must be demonstrated
- Mechanisms needed to leverage data confined within companies (including lessons learned)

# 3) Encourage agronomic viewpoint

- Agronomic approaches to crop improvement and integrated pest management are needed
- Collaboration with trained agronomists and the USDA should be encouraged
- Long-term field testing at scale required for meaningful results
- Associated regulatory issues need to be addressed (GMO deployment and GMP protocols for some co-products)