2013 DOE Bioenergy Technologies Office (BETO) Project Peer Review

9.1.3.1 Algae-Based Integrated Assessment Framework: Development, Evaluation, and Demonstration

May 20-23, 2013
Algae Platform

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Goal Statement

Reduce the cost of producing algal oil by investigating technology and operational tradeoffs through a comprehensive framework that couples the Biomass Assessment Tool (PNNL) and the Algae Logistics Model (INL) to consider productivity, resource requirements, and feedstock supply systems.

Quad Chart Overview

Timeline
Project start: 10/01/10
Project end: 5/31/13
Percent complete: 95%

Barriers
At-B: Limitations of Analytical Tools and Capabilities for System-Level Analysis
Ft-A: Feedstock Availability & Cost
Ft-M: Overall Integration and Scale-up

Budget
Total project funding: $704k
DOE share: 100%
Funding for FY11: $352k
Funding for FY12: $352k
Funding for FY13: $0

Partners/Collaborators
Pacific Northwest National Laboratory
NAABB
Utah State University

Project Overview

- **Develop an algae supply and logistics model**
  - Couples with productivity and resource assessment models
  - Enables dynamic assessment of algal production systems using site-specific productivity, resources, land cost, etc.
  - Explores alternative algal production system design configurations
- **Collaborate with the Pacific Northwest National Laboratory to develop a model integration framework**
  - Facilitates integration of disparate models datasets
  - Investigates tradeoffs with technology decisions and operation assumptions
  - Informs algal production system scaling and uncertainty through integrated analyses

1 - Approach

- **Limitations of existing algae production system analysis**
  - Alternative algal production system designs
  - Spatial and temporal variability on cost and performance
  - Large-scale assessments considering multiple scenarios for thousands of potential sites
  - Utilization of disparate models and datasets
- **Address limitations through development of an integration framework to evaluate algal production systems considering productivity, resource requirements, and algae feedstock logistics**

1 – Approach (cont'd)

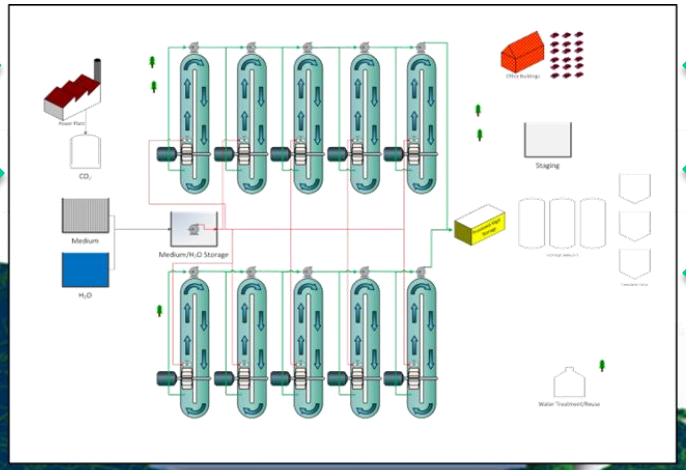
Productivity & Resources

Process Design & Costs

Biomass Assessment Tool

Spatial Variation

Temporal Variation

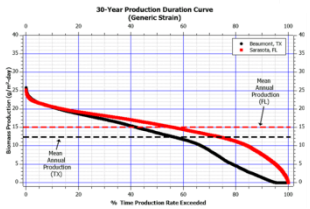


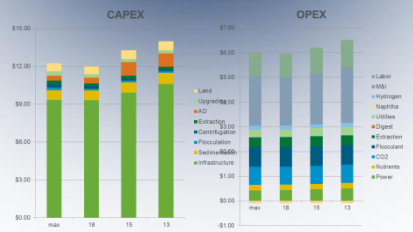
Pathway

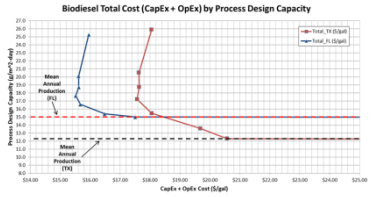
Capacity Alt.

Components

Algae Logistics Model

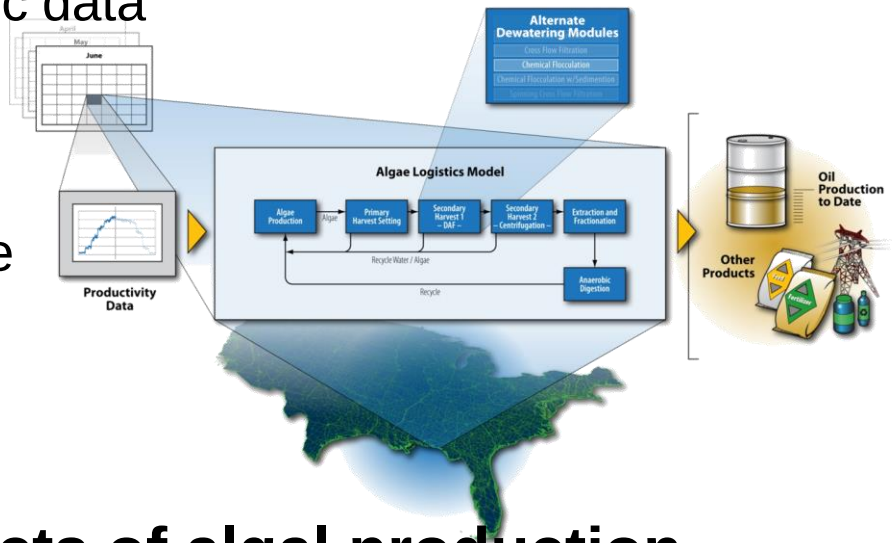






1 – Approach (cont'd)

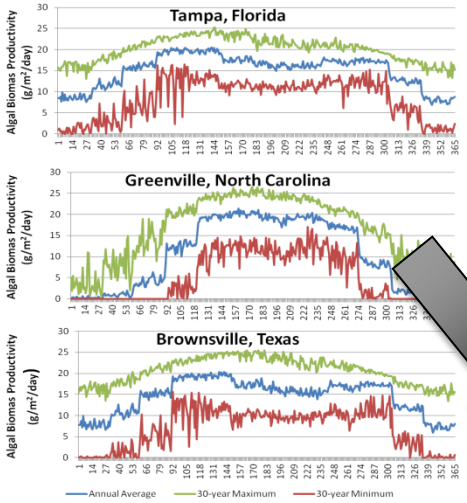
- **Algae Logistics Model (ALM)**
  - Performs mass and energy balances to assess CAPEX and OPEX
  - Composed of process modules to enable system reconfiguration
  - Modules are developed in system dynamics software package enabling assessment at any temporal scale
  - Interfaces with production and resource assessment models and datasets to incorporate site-specific data
- **Integrated Assessment Framework (IAF)**
  - Couples ALM and Biomass Assessment Tool (BAT) to facilitate the distribution of data between integrated models
  - Enables integration of additional disparate models and datasets

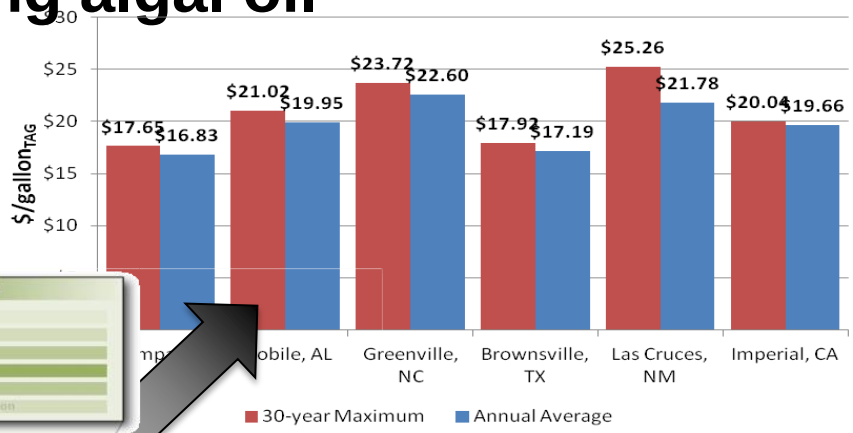


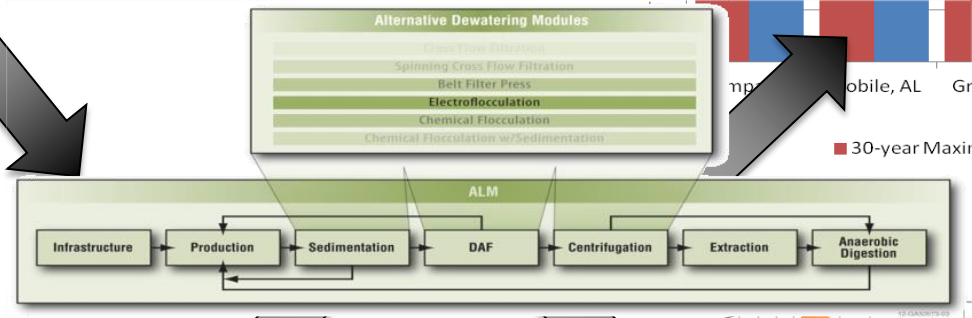
- **Apply the IAF to assess impacts of algal production system scaling, technologies, and operation assumptions on cost at a local, region, and national scale**

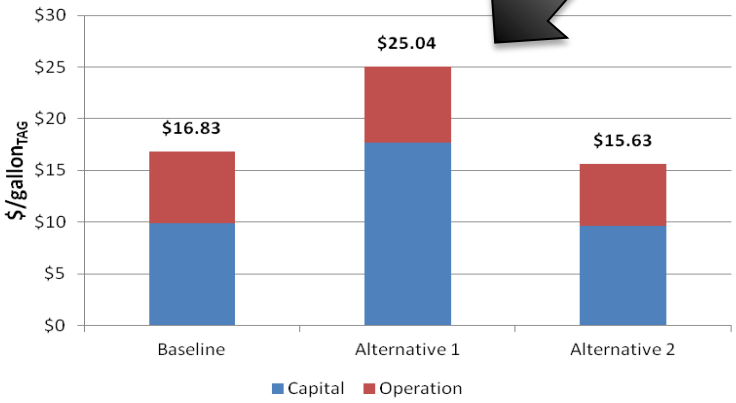
2 - Technical Accomplishments/ Progress/Results

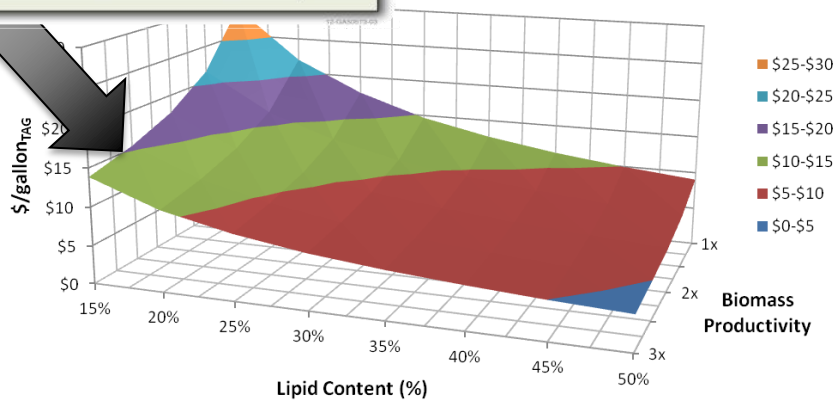
- **Results from ALM for producing algal oil**





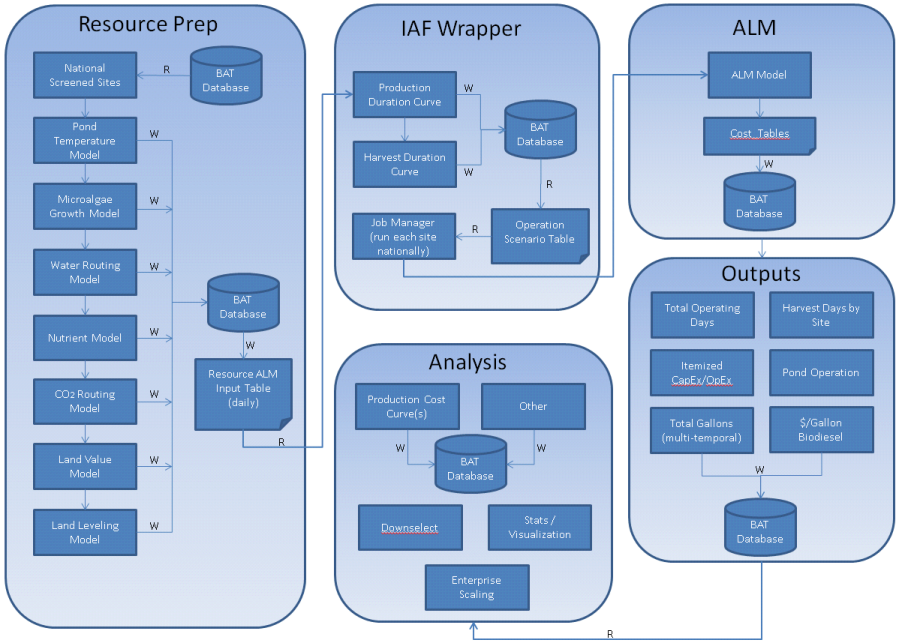






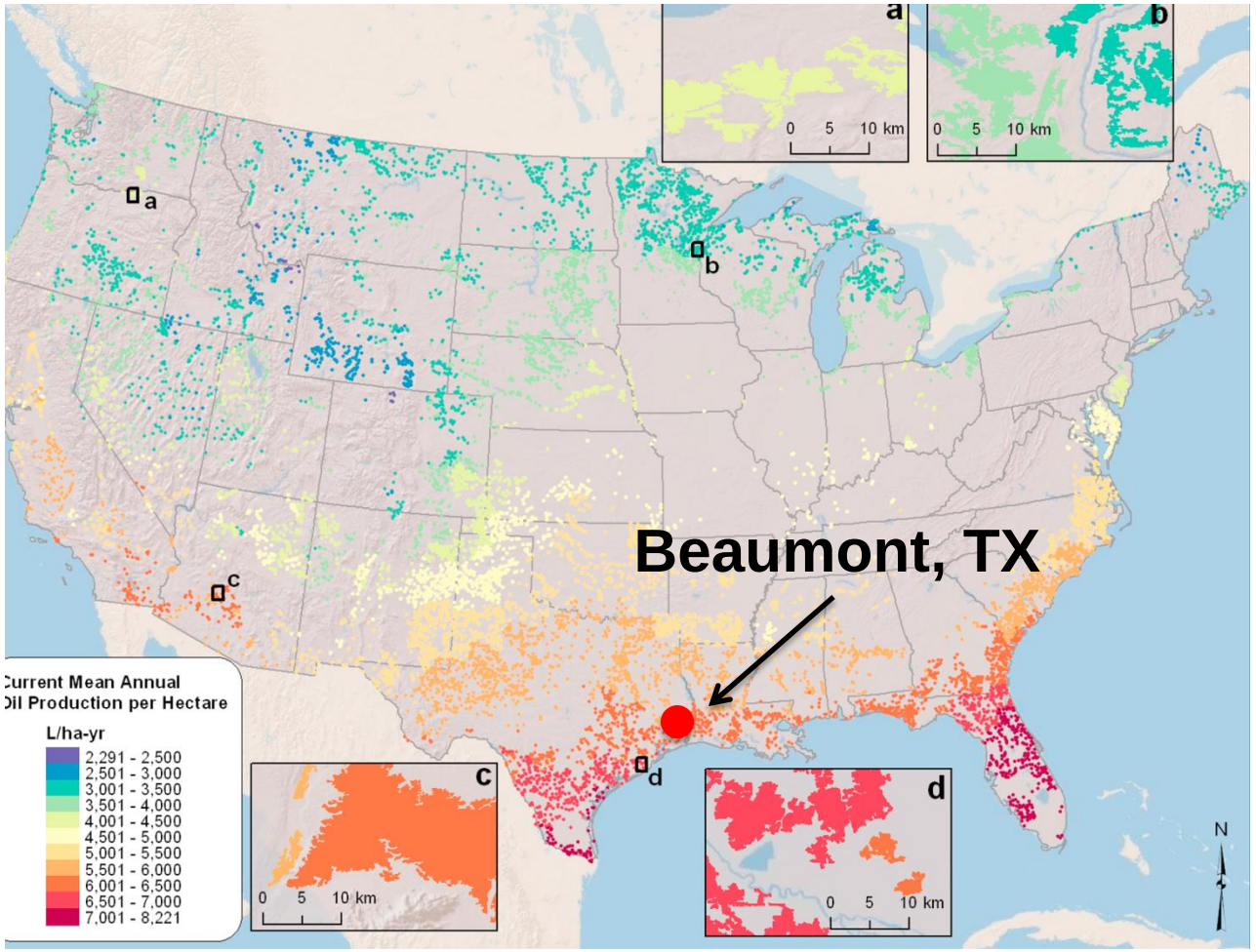
2 - Technical Accomplishments/ Progress/Results (cont'd)

- **Integrated Assessment Framework enables**
  - Identification of production, resource, and cost assessment of algal production systems
    - Assessment of various design configurations
    - Trade-off assessment of technologies and operation assumptions
  - Design of algal production system by site (determine appropriate processing scale to reduce cost)
  - Uncertainty analysis around annual productivity and resource requirements



2 - Technical Accomplishments/ Progress/Results (cont'd)

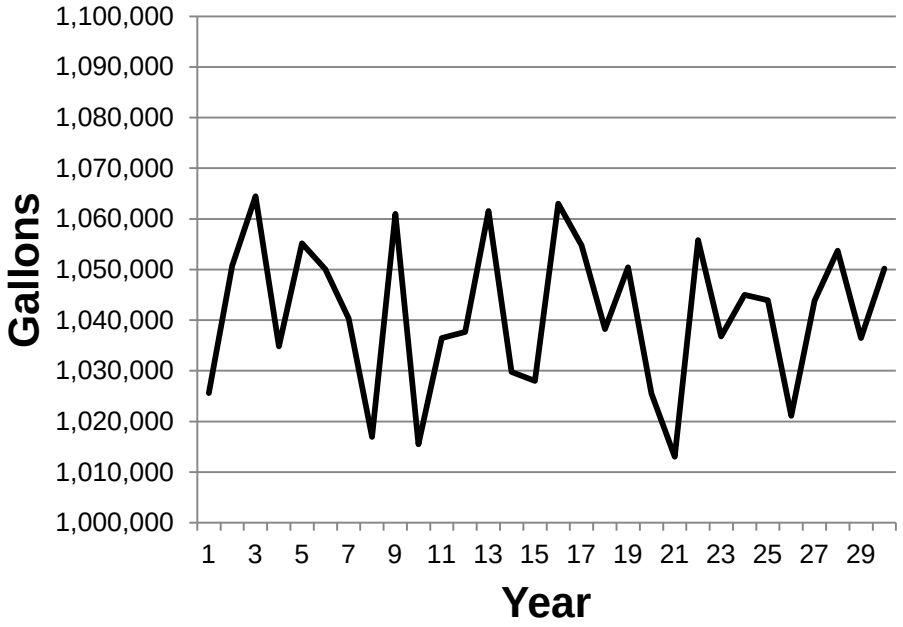
- **IAF assessment of Beaumont, TX site using harmonized algal production system design**
  - 30-year assessments

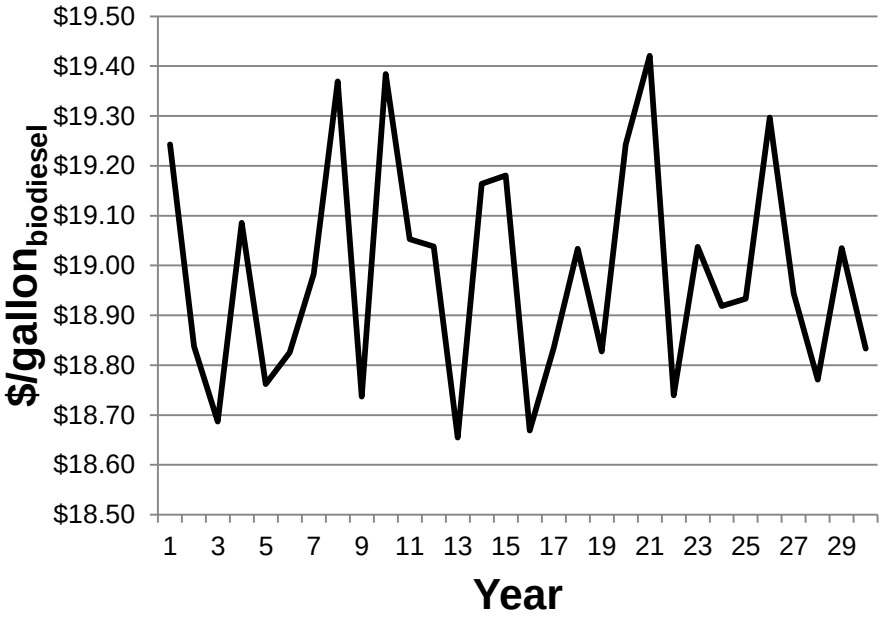


Wigmosta, M. S., A. M. Coleman, R. J. Skaggs, M. H. Huesemann, and L. J. Lane (2011), National microalgae biofuel production potential and resource demand, Water Resour. Res., 47, W00H04, doi:10.1029/2010WR009966.

2 - Technical Accomplishments/ Progress/Results (cont'd)

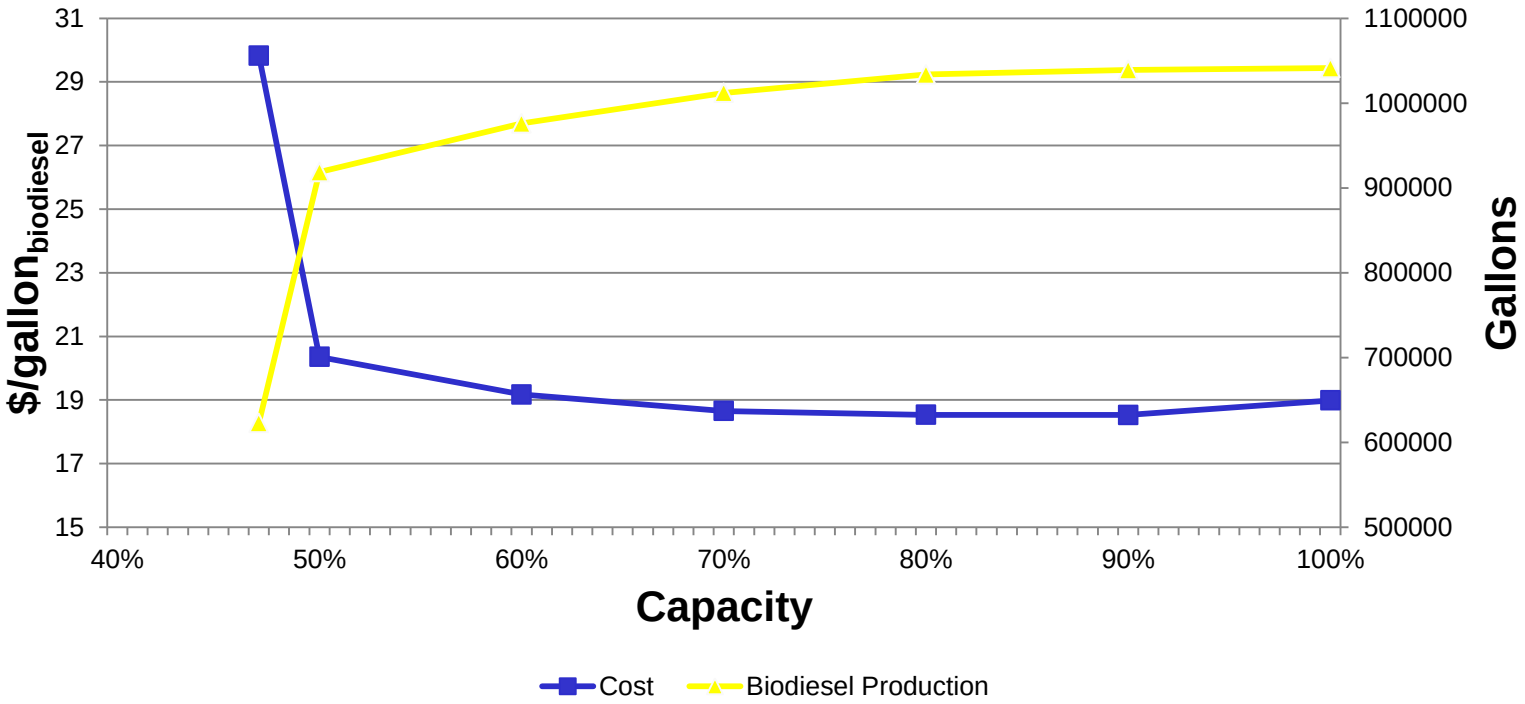
- **Annual production variability based on site productivity**
- **Downstream processing scaled to max production**
- **Results in**
  - Production and cost uncertainty
  - Underutilized processing equipment





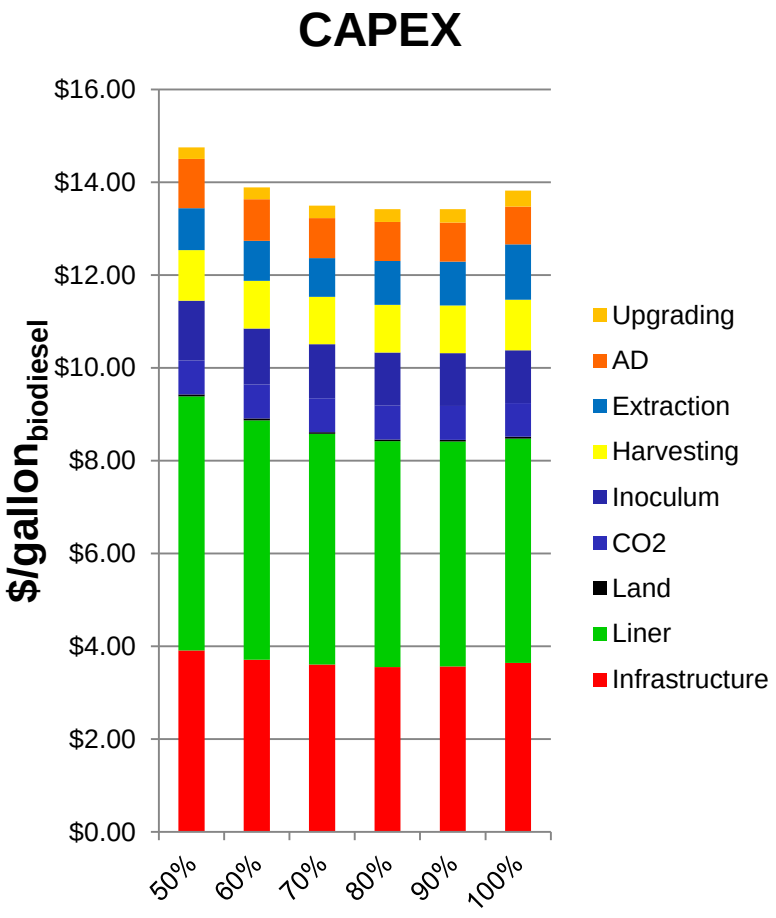
2 - Technical Accomplishments/ Progress/Results (cont'd)

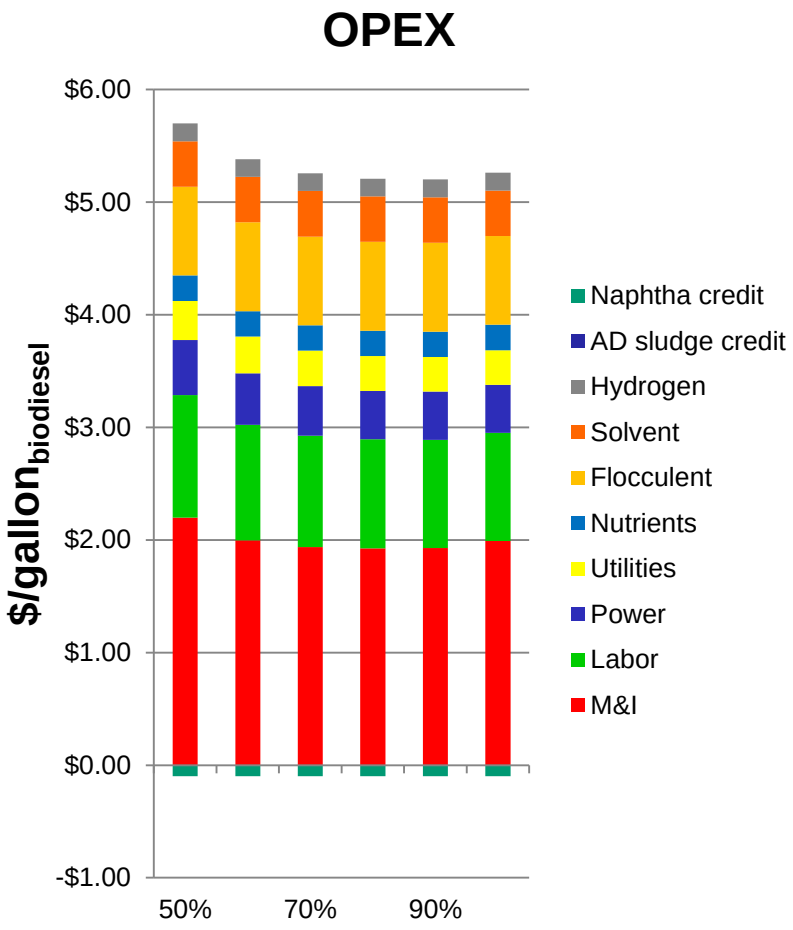
- **Production duration curve results**
  - Scaled to maximum capacity leads to underutilized processing equipment
  - Scaled to low capacity leads to loss in biomass
    - Majority of investment in productivity



2 - Technical Accomplishments/ Progress/Results (cont'd)

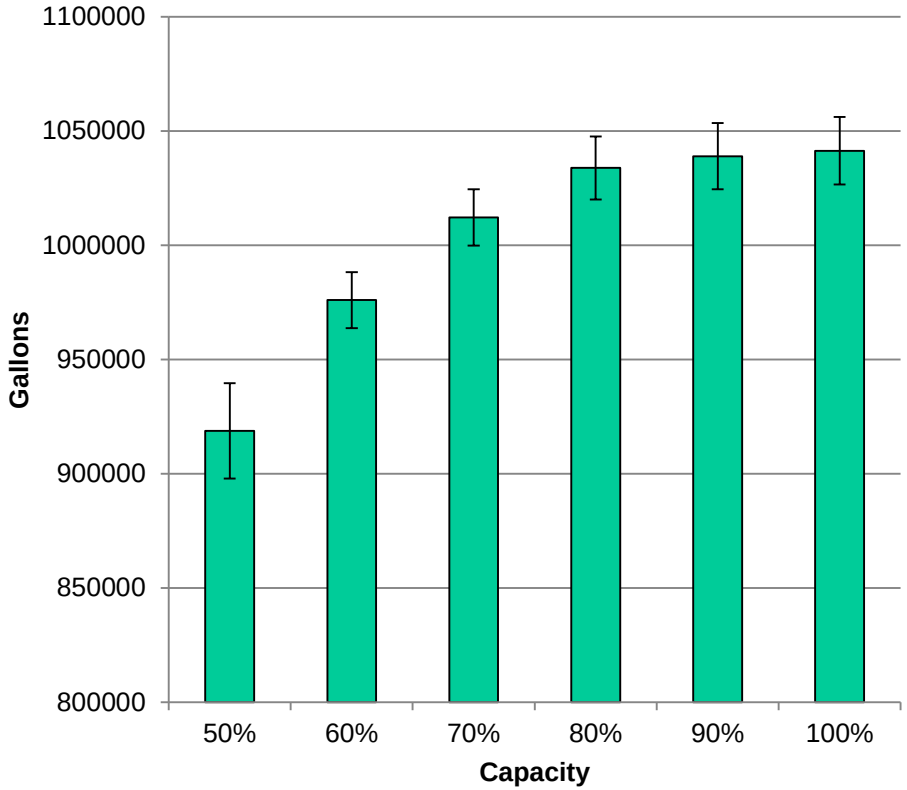
- **Cost breakdown using production duration curve**

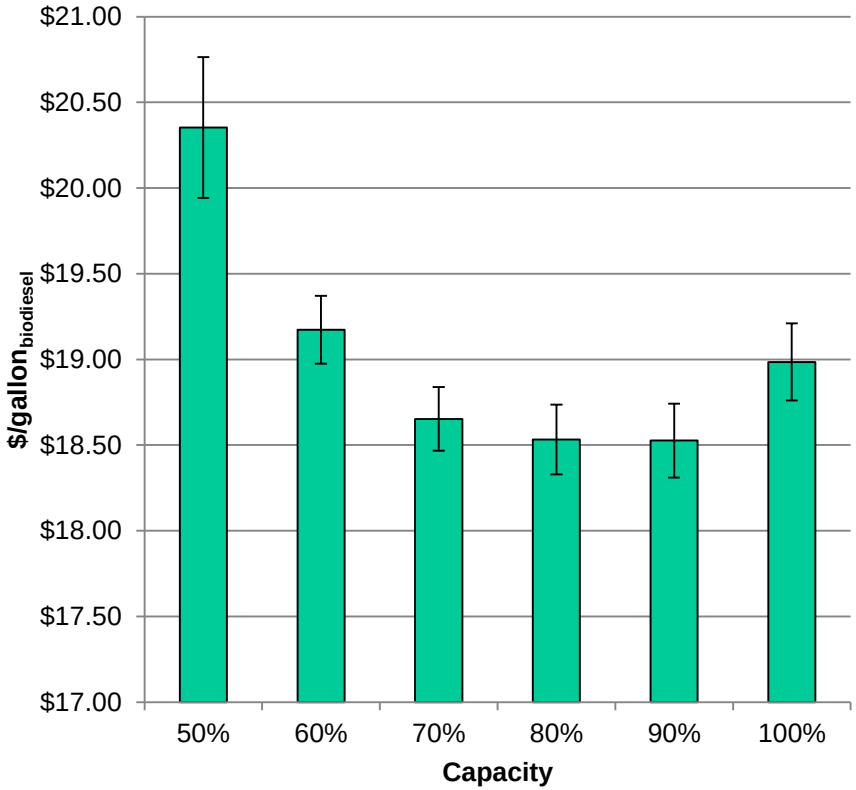




2 - Technical Accomplishments/ Progress/Results (cont'd)

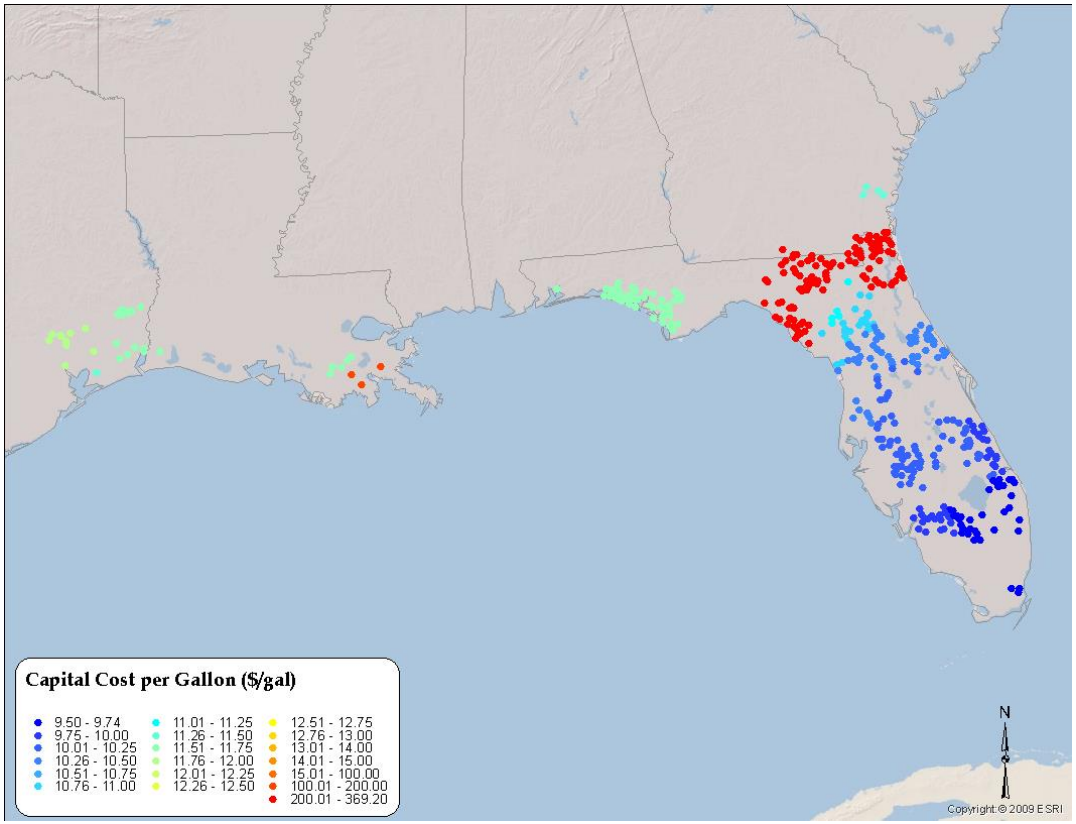
- **Uncertainty assessment considering the temporal impacts of productivity**
  - 30 years of hourly productivity data
  - Capability to capture uncertainty at various scales





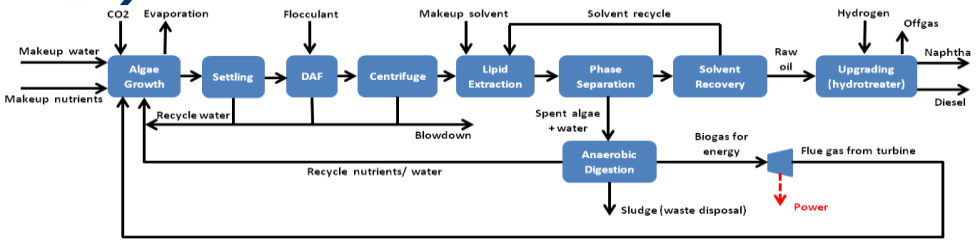
2 - Technical Accomplishments/ Progress/Results (cont'd)

- **Impact on cost using site specific data for the Southeast Region**
  - Significant production and cost variability within a region
  - Ability to simultaneously run thousands of sites

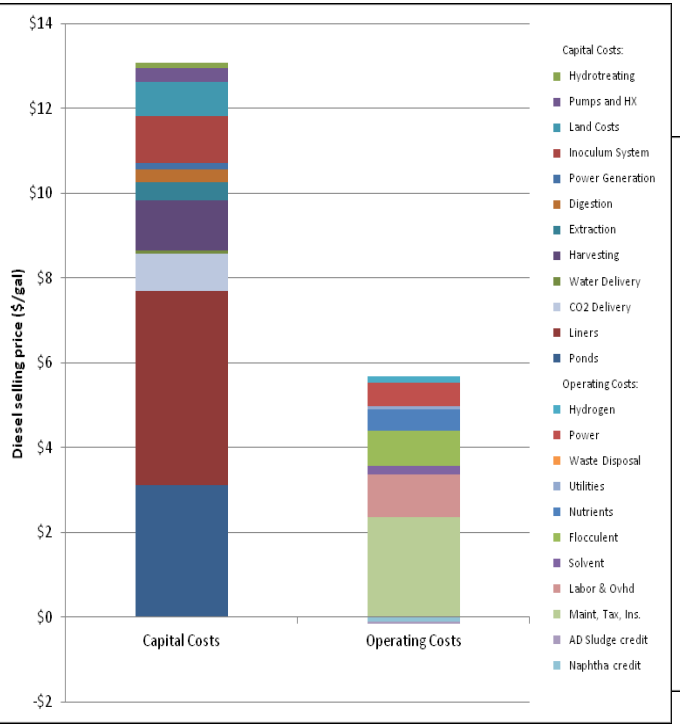


2 - Technical Accomplishments/ Progress/Results (cont'd)

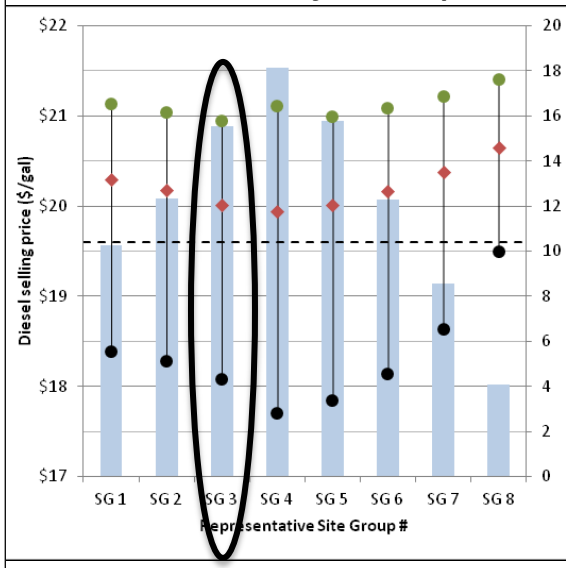
- **IAF validation against harmonized baseline design and analysis**



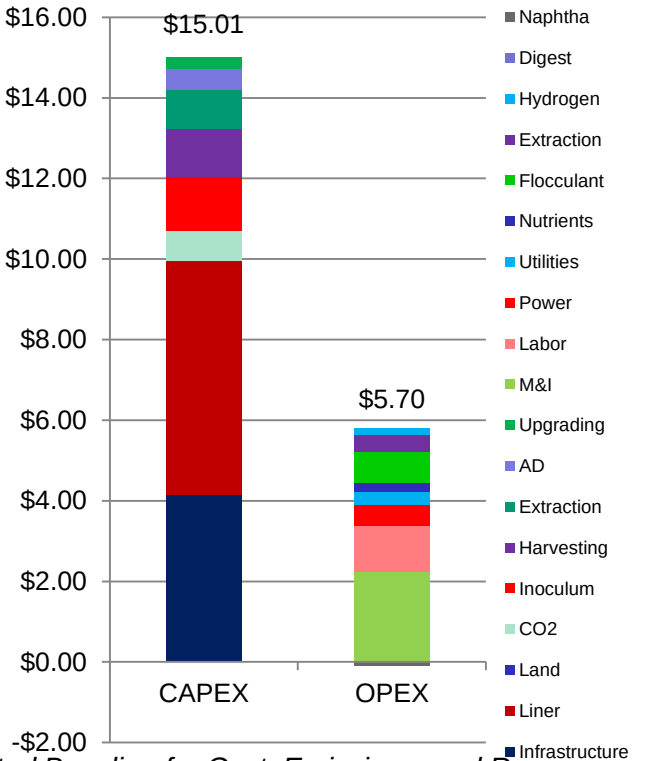
Harmonization Cost Assessment*



Harmonization Cost Assessment by Group*



IAF Cost Assessment for Group 3



*ANL; NREL; PNNL. (June 2012). *Renewable Diesel from Algal Lipids: An Integrated Baseline for Cost, Emissions, and Resource Potential from a Harmonized Model. ANL/ESD/12-4; NREL/TP-5100-55431; PNNL-21437. Argonne, IL: Argonne National Laboratory; Golden, CO: National Renewable Energy Laboratory; Richland, WA: Pacific Northwest National Laboratory.*

2 - Technical Accomplishments/ Progress/Results (cont'd)

Milestone	Due Date	Status
Advanced uniform algae supply system design completed	12/31/11	Completed
Complete integration of logistics model and Biomass Assessment Tool	3/31/12	Completed
Design and analysis completed for advanced uniform algae supply system including cost, performance, and efficiency	6/30/12	Completed
Submit manuscript on algae logistics model	9/30/12	Completed (In Review)
Submit joint manuscript with PNNL on Integrated Assessment Framework	5/31/13	95% Complete
Published Algae Supply System Design Report	3/31/13	Completed

3 - Relevance

- **Builds off previous harmonization effort to address DOE goals and objectives in the BETO 2012 MYPP targets by providing a dynamic and modular framework:**
  - "By 2013, establish cost goals … and complete techno-economic analysis for one additional algal-production-to-finished-fuel technology pathway, including feasibility and trade-off analysis with higher value co-products"
  - "By 2022, validate the potential for algae supply and logistics systems to product 5,200 gallons oil … per acre of cultivation per year, achieving a modeled nth plant minimum selling price of $3.27/GGE ($2011) of raw biofuel intermediate …"
- **Leverages feedstock logistics efforts at the INL and production and resource assessment efforts at PNNL to enable comprehensive local, regional, and national assessments of algal production systems**

4 - Critical Success Factors

- **Technical success:**
  - A model integration framework that enables disparate models and datasets that represent production, resources, and feedstock logistics to be coupled
  - Sustainably and cost-effectively manage the use of land, water, and nutrients
  - Assess each technology option in terms of overall system compatibility and sustainability
  - Optimize energy and costs in the context of facility siting and scaling
  - Understand the technologies and operation assumptions that impact cost
  - Mitigate uncertainty in algal production systems
- **Technical challenges:**
  - Integration of new scientific data and technologies
  - Utilizing disparate models and datasets for assessing algal production systems

5 - Future Work

- **Application of IAF to address existing and evolving needs**
  - What alternative methods exist for handling “excess” biomass that exceed processing capacity?
  - How do the interdependencies between algal feedstock production and supply systems help reduce the cost of producing algal oil?
  - What is the viability of small scale algal production systems for use in formulated feedstocks?
  - What impacts does economies of scale have on cost?
- **Broaden portfolio of technologies and conversion pathways (e.g. HTL)**
- **Integrate additional toolsets and datasets (LCA)**

Summary

- **Approach:**
  - Provide DOE with a framework to enable comprehensive assessments of algal production systems to reduce cost and uncertainty
- **Technical Accomplishments:**
  - Development of a dynamic and modular algae supply and logistics model in conjunction with the Integrated Assessment Framework
- **Success factors and challenges:**
  - Identified potential opportunites to decrease cost and uncertainty through appropriate scaling of algal production systems.
  - A model integration framework that enables comprehensive assessments of algal production systems
- **Future work:**
  - Use IAF to investigate relationships between microalgae feedstock production and feedstock logistics systems.
  - Incorporate additional technologies and conversion pathways.

Acknowledgements

INL:

- Deborah Newby
- Daniel Stevens
- Allison Ray

PNNL:

- Richard Skaggs
- Andre Coleman
- Mark Wigmosta

Questions

- **Biomass Assessment Tool (BAT) – PNNL**
- **Algae Logistics Module (ALM) – INL**
- **Integrated Assessment Framework (IAF) – BAT and ALM interface**

Responses to Previous Reviewers' Comments

- **Distinguish differences between ALM and IAF effort from NREL's techno-economic approach**
  - Uses high-fidelity datasets
  - Uses dynamic approach to process data
    - Model composed of technology modules
    - Quickly assess technology and operation assumption trade-offs
  - Uses modular approach
- **Obtain better data to populate model**
  - Developed relationship with NAABB consortium
  - Have had discussion with ATP3 to gain access to data
  - New industry partnership formed with BKS Energy, access to novel pond designs, operations, cost and performance metrics
  - CRADA with OriginOil

Publications and Presentations

- J.M. Abodeely, D.J. Muth, D.M. Stevens. Ray, and D.T. Newby "Integrated Modeling Framework for Algae Logistic Systems," Presentation, Algal Biomass, Biofuels, and Bioproducts, St. Louis, MO July 17-20, 2011.
- J.M. Abodeely, D.M. Stevens, A.E. Ray, and D.T. Newby. "An Integrated Modeling Framework Approach for Algal Supply Chain Assessments," Poster presentation, Algal Biomass Summit 2012, Denver, CO, September 23-27, 2012.
- J.M. Abodeely, D.M. Stevens, A.E. Ray, and D.T. Newby. "Assessment of Algal Farm Designs using a Dynamic, Modular Approach," Algal Research (In Review)

General Presentation Guidelines

(not to be included in your presentation)