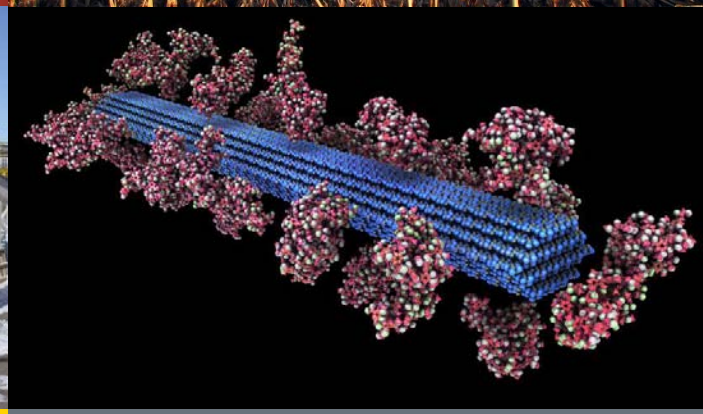
U.S. DEPARTMENT OF ENERGY
BIOENERGY TECHNOLOGIES OFFICE

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy





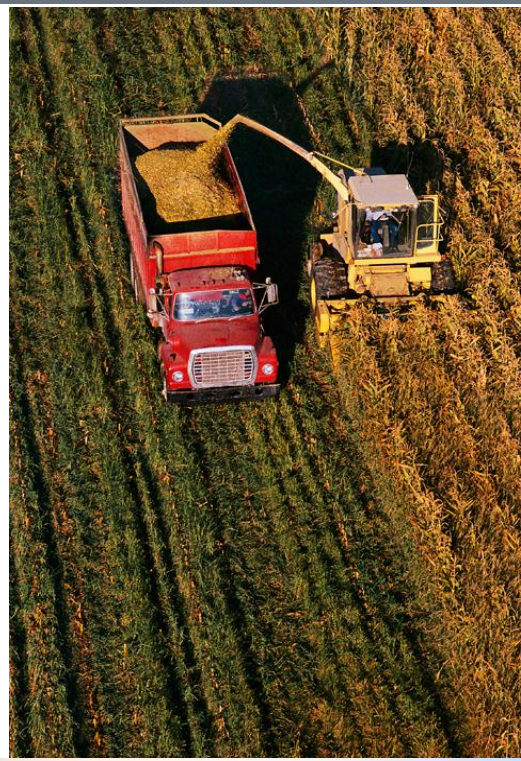
John Ferrell

Feedstocks Peer Review
Overview Presentation

May 20, 2013

Introduction:
Terrestrial and Algal Feedstocks

Feedstock supply efforts focus on RD&D to develop and optimize cost-effective and sustainable integrated systems for growing, harvesting, collecting, storing, preprocessing, handling, and transporting quality feedstock to biorefineries.



Courtesy Sapphire Energy, LLC

Introduction: Terrestrial and Algal Feedstocks

The Office works in partnership with national laboratories, universities, industry, and other key stakeholders to identify and develop economically, environmentally, and socially sustainable terrestrial and algal feedstocks for the production of energy, including transportation fuels, electrical power and heat, and other bioproducts.

RD&D on feedstock production and logistics is critical to developing a reliable and sustainable supply of high quality and low cost feedstock necessary for the expansion of the U.S. advanced biofuels industry.

Objectives

Terrestrial Feedstocks:

- **Production**: Support the sustainable production of a variety of types of biomass
- **Logistics**: Support research on economic, sustainable feedstock logistics systems to reliably supply an on-spec feedstock to future biorefineries
- Focus on cost, quality, quantity

Algal Feedstocks:

- **Resource:** Identify adequate U.S. resources to sustainably produce the equivalent of over one billion gallons of algal biofuels.
- **Performance:** Develop, demonstrate, and integrate high performance algal biofuel technologies that maximize energy return on investment and minimize costs.

Feedstocks Research Approach: Partnerships

- National Laboratories
- Universities
- ARPA-E
- Other EERE offices
- Office of Science and Technology Policy
- Biomass Research & Development Board

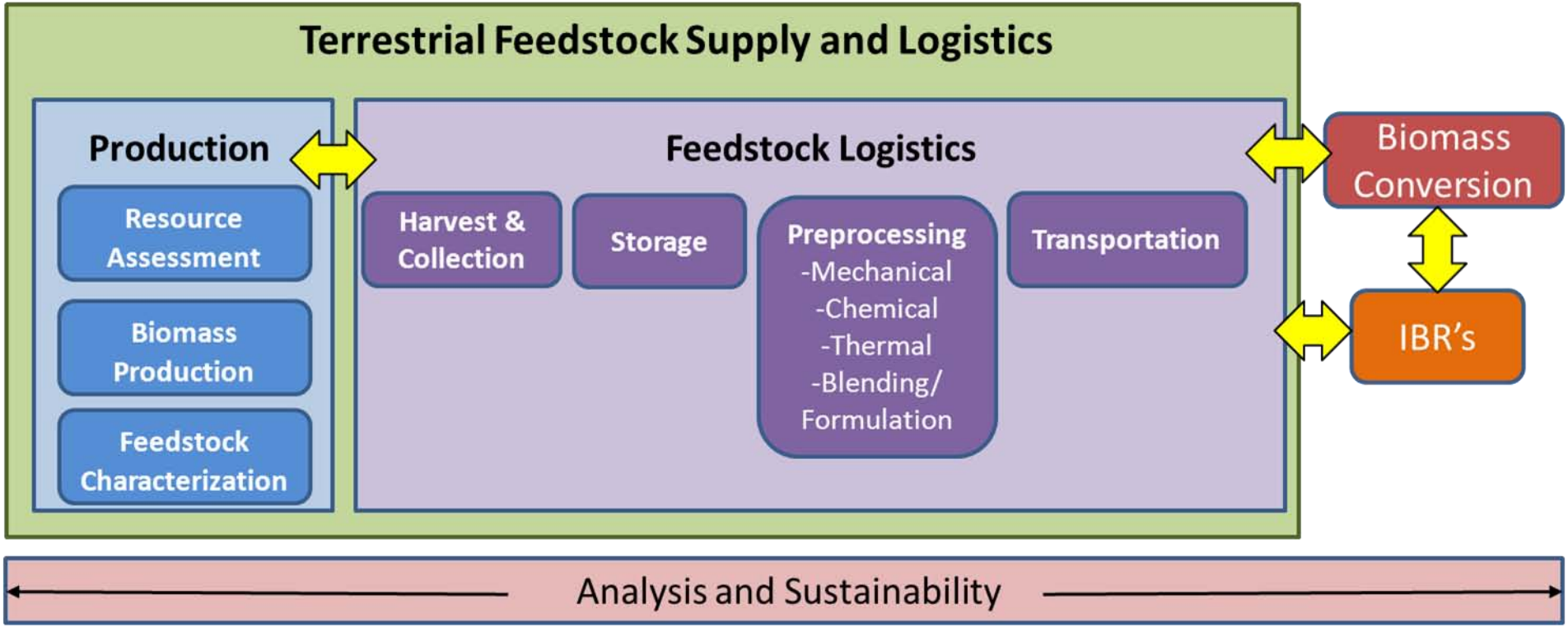
Offices and programs within the following:

- USDA
- DoD
- DoI
- DoT
- EPA
- NASA
- NSF

Coordination: Interfaces within BETO

- ***Resource Assessments (Production, Analysis, and Sustainability Interface) -*** determine if and where there is sufficient quality feedstock in the US to meet needs of future biorefineries
- ***Feedstock Quality Analysis & Formatting (Conversion Interface) -*** study physical and chemical characteristics of feedstocks, and its impact on conversion yield; formatting a variety of feedstock types for testing in conversion systems
- ***Improved Logistics Systems (Integrated Biorefinery Interface) -*** design logistics systems that deliver an affordable, on-spec feedstock to biorefineries

Terrestrial Feedstocks



Goals: Terrestrial Feedstocks

Production

- Update national resource assessments based on results from Regional Partnership and published literature by 2014
- Field-scale targeted scale-up demonstration for emerging energy crops linked to IBR's by 2017
- Validate feedstock cost, volume and quality requirements for all BETO technology pathways by 2022

Logistics

- National feedstock quality data collected and analyzed through the Biomass R&D Library using Regional Partnership data and industry partnership physical samples collected during FY11-FY13 by 2014
- Demonstrate $80/dry ton feedstock cost at conversion reactor throat (including grower payment and logistics cost) by 2017
- Demonstrate industrial-scale integrated advanced feedstock production and logistics systems, in conjunction with IBR program and/or industry by 2022

Terrestrial Feedstocks History at DOE

- Legacy: Biofuels Feedstock Production Program at ORNL (1984 – 2002)
- Billion Ton Report and Update: (2004 – 2011)
  - Knowledge Discovery Framework (2008)
- Regional Feedstock Partnership (2007 – 2014)
- Feedstock Logistics as Main Focus
  - Road Map Workshop (2003)
  - High tonnage logistics projects (2009 – present)
  - Densification Workshop (2011)
  - Operation of INL PDU (2011)
  - INL Environmental Science Laboratory (2013)
- $35/DM ton stover (2012)

State of Technology: Feedstock Logistics

- Improving on logistics systems originally designed for the agricultural and pulpwood industry
  - Modifying these systems to meet the various needs of the bioenergy industry

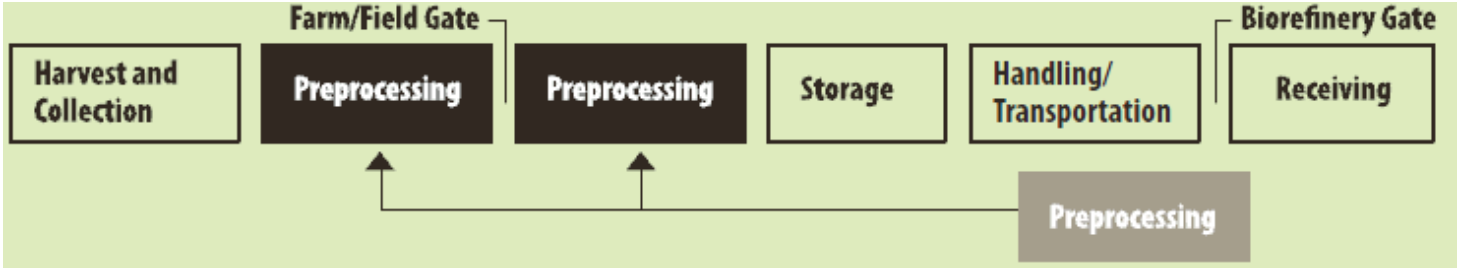
- Some challenges associated with biomass:
  - Bulky, heterogeneous, and often unstable
  - Quality (for example, biomass can be high in ash and other problematic components)
  - Poor flowability
  - Dispersed resource

State of Technology: Feedstocks

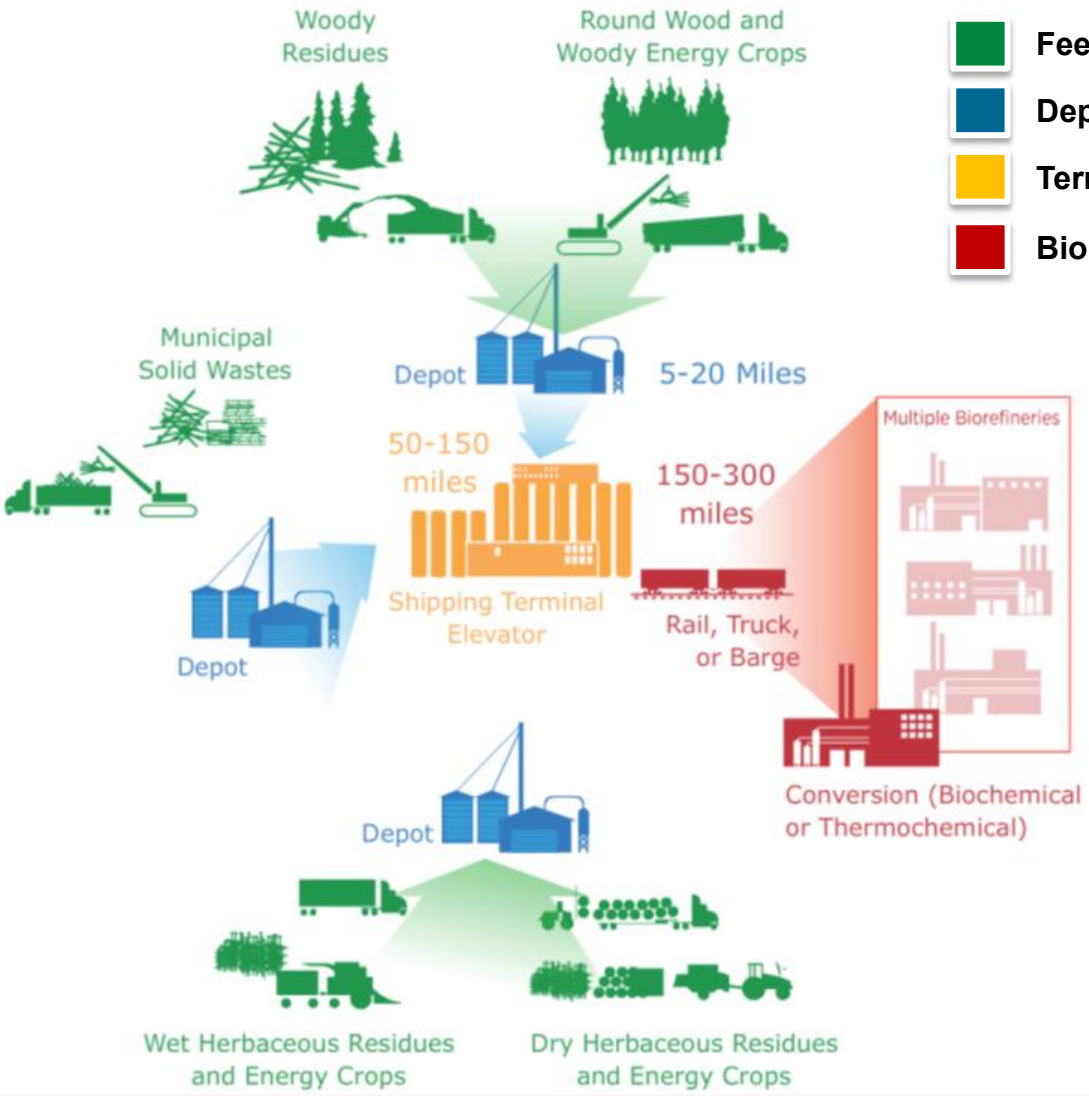
- Shift from Conventional to Advanced: moving preprocessing operations to earlier in the supply chain

Example of Conventional Logistics System

Example of "Advanced" Logistics System



Feedstocks: Vision for the Future



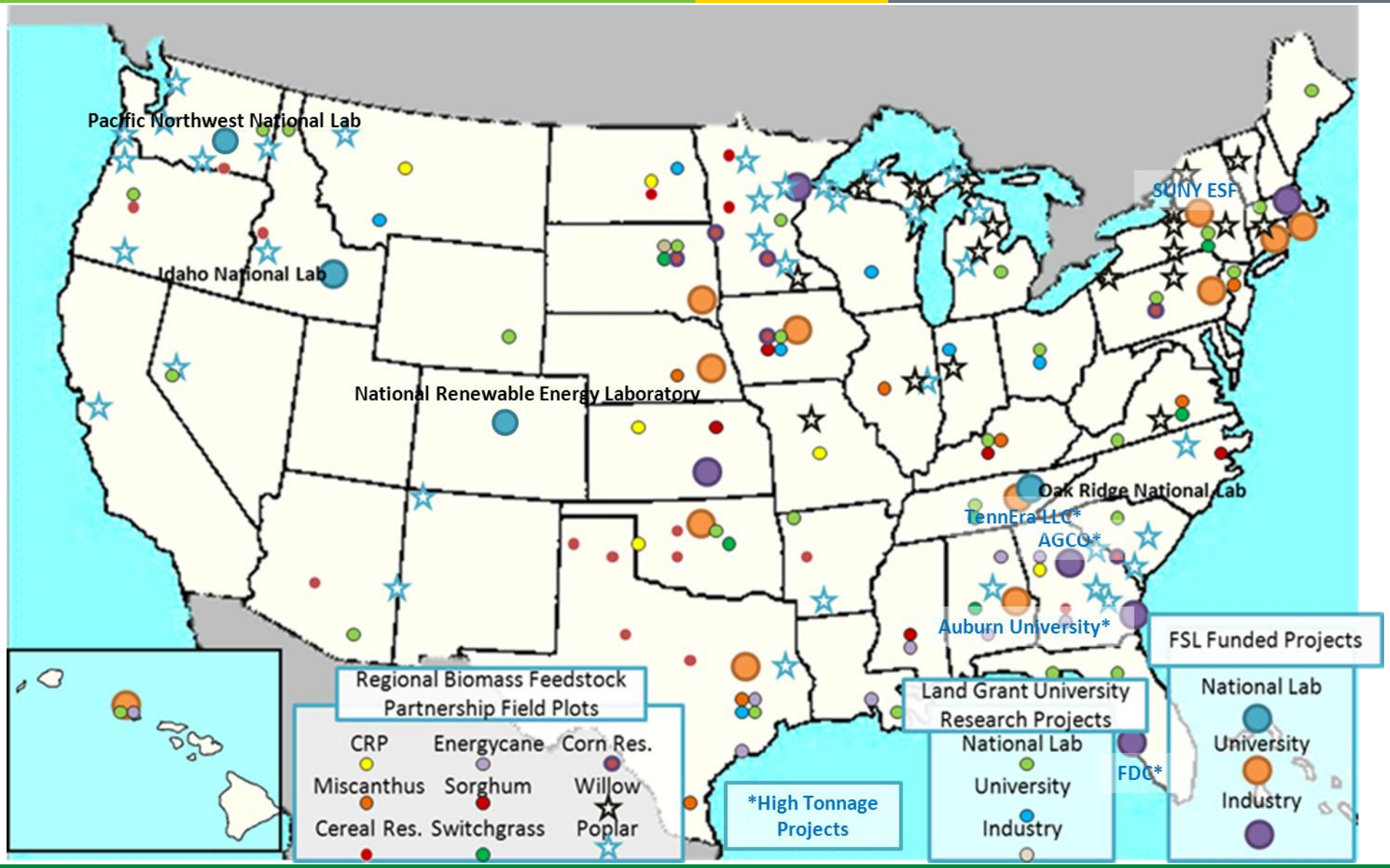
Commodity feedstock supply system supports an expanding bioenergy industry by sustainably and economically supplying an on-spec feedstock to future biorefineries

DOE USDA Feedstock Coordination Group

- ***GOAL***: Identify common issues and barriers to full biomass feedstocks deployment and understand what the Departments were doing to overcome these barriers through the various RDD&D activities.
- Major emerging themes:
  - lack of quality plant material
  - insufficient production systems, technologies, and management practices
  - invasive species
  - high production and logistics costs
  - institutional barriers
- On-going discussion of barriers and individual agency approaches to overcoming them; identify opportunities for enhancing coordination together.

Terrestrial Feedstock Projects

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



The ***Advanced Biomass Feedstock Logistics Systems II*** focuses on developing and demonstrating strategies, equipment, and rapid analytical methods to manage terrestrial feedstock quality within economic constraints throughout the feedstock supply chain.

Addresses 2 technical barriers identified at BETO Feedstock workshops:

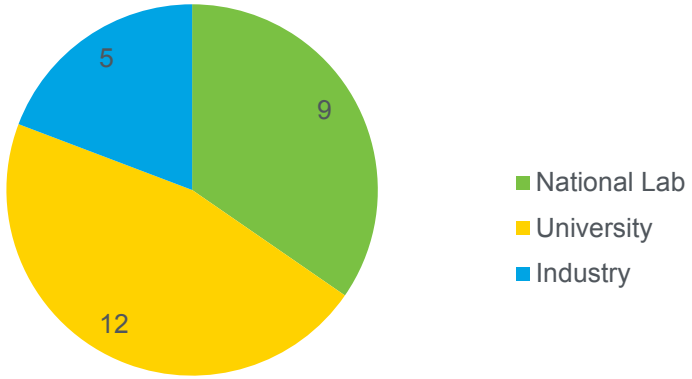
1. Feedstock Logistics Costs – Moving towards a target of $80/DT, or less, for all cumulative logistics costs and grower payment
2. Feedstock Quality – Improve quality parameters for physical, chemical, and conversion performance characteristics

Terrestrial Feedstocks Project Portfolio

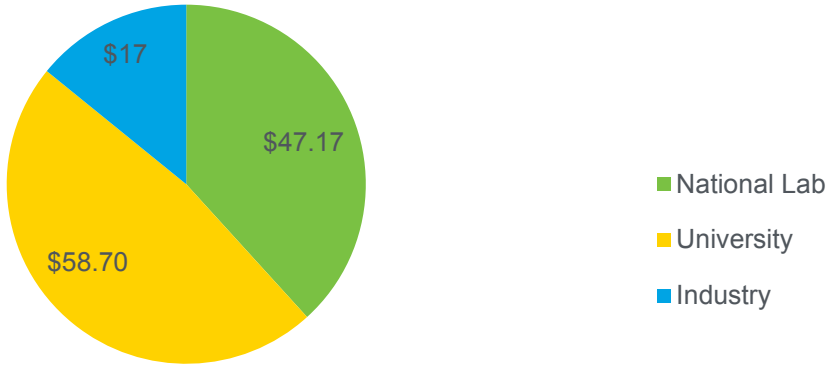
26 projects will be reviewed in the Terrestrial Feedstocks Technology Area, covering a diversity of research topics including:

- Consortia
- National Labs
- Universities
- Industry

Portfolio Performers Reviewed

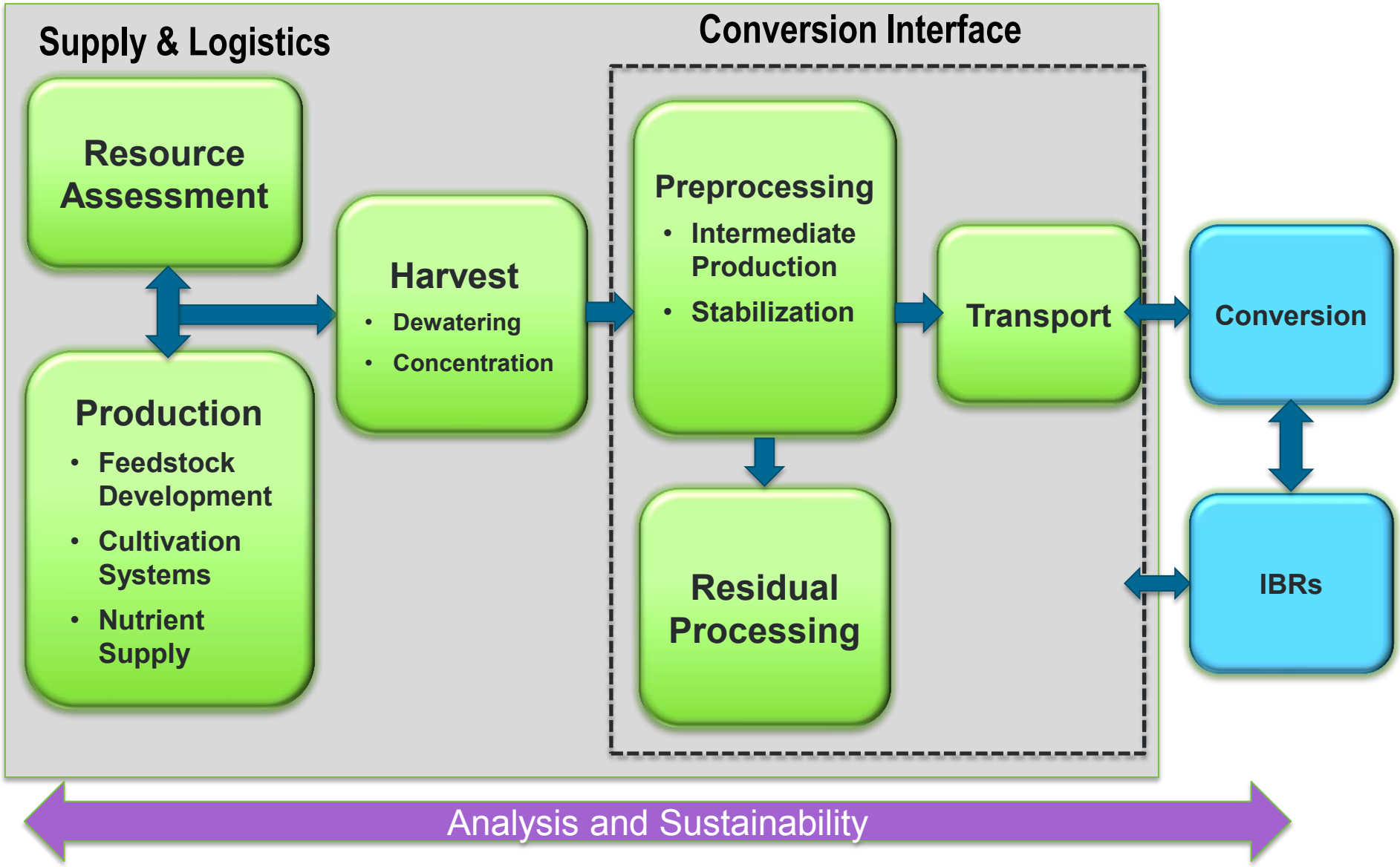


DOE Value of Projects Reviewed
(in millions)



Total: $123 Million

Algal Feedstocks

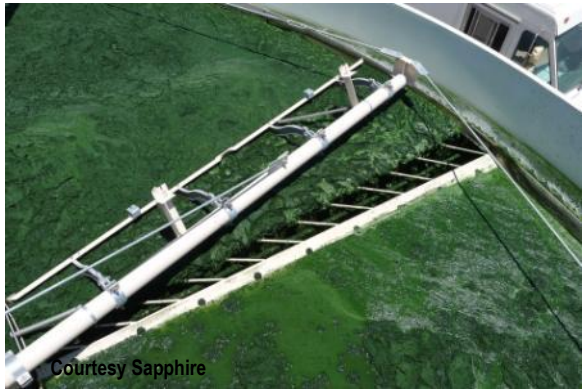


Algae: Challenges and Barriers

Activities include R&D on algal feedstocks and issues related to the sustainable production of algae-derived biofuels.

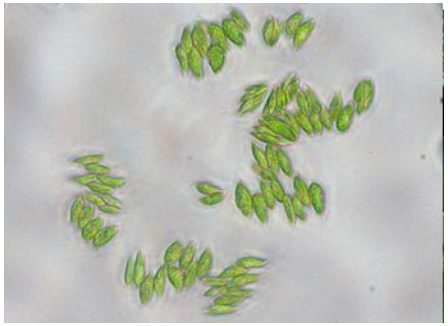
Benefits	Challenges
High productivity expands domestic biomass potential	Affordable and scalable algal biomass production
Adds value to unproductive or marginal lands	Feedstock production and crop protection
Ability to use waste and salt water	Energy-efficient harvesting and drying
Potential recycling of carbon dioxide	Extraction, conversion, and product purification
Production of a range of biofuel feedstocks suitable for diesel and aviation fuels	Siting and sustainability of resources

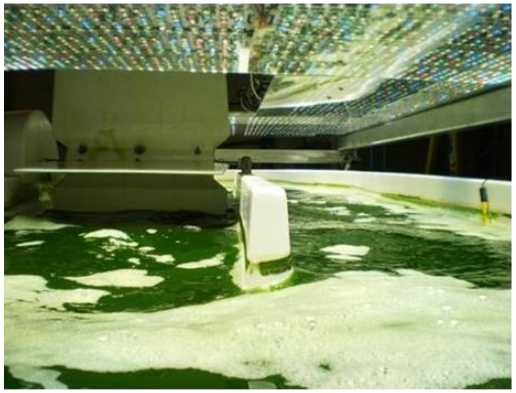

Courtesy University of Arizona


Courtesy Sapphire

Algae Pathway Focus

- Advanced Biofuels Technology Pathways analysis in 2013 resulted in two priority algae biofuel pathways:
  - **Algal Lipid Upgrading (ALU)**
  - **Whole Algae Hydrothermal Liquefaction (AHTL)**
- Pathways are the focus of national lab-led design case studies, serve as basis for resource, cost, and LCA analysis, and are benchmarks for progress towards $3/gallon algal biofuel.
- Pathways are not limiting factors for competitive R&D FOAs





PNNL Simulated Algae Pond

Goals: Feedstock Algae

Resource Assessment

- Model the sustainable production of algae to support cultivation of 1 million metric tons (dry weight) algae biomass by 2017, and 20 million metric tons by 2022.

Productivity and Yield

- By 2014, achieve, in outdoor environments, yields of more than 1,000 gallons algal oil per acre per year.
- By 2018, demonstrate, at a process demonstration unit scale, 2,500 gallons of biofuel feedstock per acre per year by 2018.
  - Validate the potential to produce 5,200 gallons by 2022.

Overall

- By 2022, $3/gallon algal based biofuel (nth plant modeled cost)

Algae History at DOE

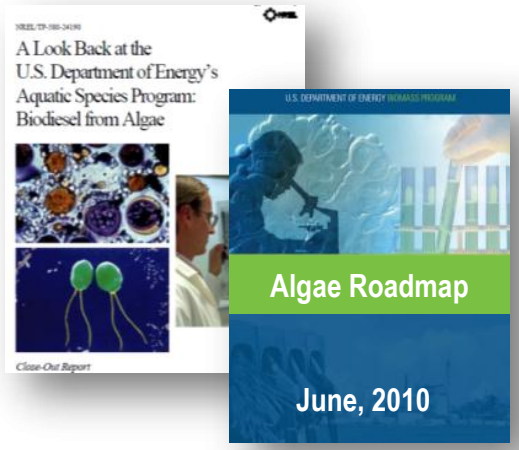
Aquatic Species Program (ASP) Legacy

- (1976 -1996): ASP produced final report. Research program. Demonstrated pathway to algal biodiesel at 2-3x cost of regular diesel

Algae Platform Development 2009-2013

- 2010:
  - Released the Algae Roadmap;
  - Selected $74M DOE value in R&D (**Consortia Initiative**) and $100M in D&D (**IBRs**) projects;
  - Convened **National Academies** to develop an Algal Biofuels Sustainability report
- 2012:
  - Selected $21M DOE value **Advancements in Sustainable Algal Production (ASAP) FOA**
  - Released the **Baseline Technical Report** "Renewable Diesel from Algal Lipids: An Integrated Baseline for Cost, Emissions, and Resource Potential from a Harmonized Model"
- 2013:
  - **Algal Biomass Yield (ABY) FOA** Selections

Roadmaps:
ASP; Algae Roadmap Workshop



Targeted R&D:
ATP3 Testbed ribbon cutting

FY12 Advancements in Sustainable Algal Production (ASAP)

Nutrients & Water

- **"Recycling of Nutrients and Water in Algal Biofuels Production"**

  California Polytechnical Institute – up to $1.3M
- **"Integration of Nutrient and Water Recycling for Sustainable Algal Biorefineries"**

  University of Toledo and University of Montana– up to $3M
- **"Major Nutrient Recycling for Sustained Algal Production"**

  Sandia National Laboratories, University of Texas, and Open Algae – up to $2.1M

Testbed

- **"Algae Testbed Public-Private Partnership (ATP3)"**

  Arizona State University – up to $15M total
  - Testbeds Locations: Arizona State University, CalPoly, Georgia Tech, Touchstone Research Laboratory (OH), Cellana (HI).

ASAP Testbeds:
Algae Testbed Public-Private Partnership (ATP3)

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

ATP3 Testbed Facility at ASU

Testbed Partnership Sites (5)

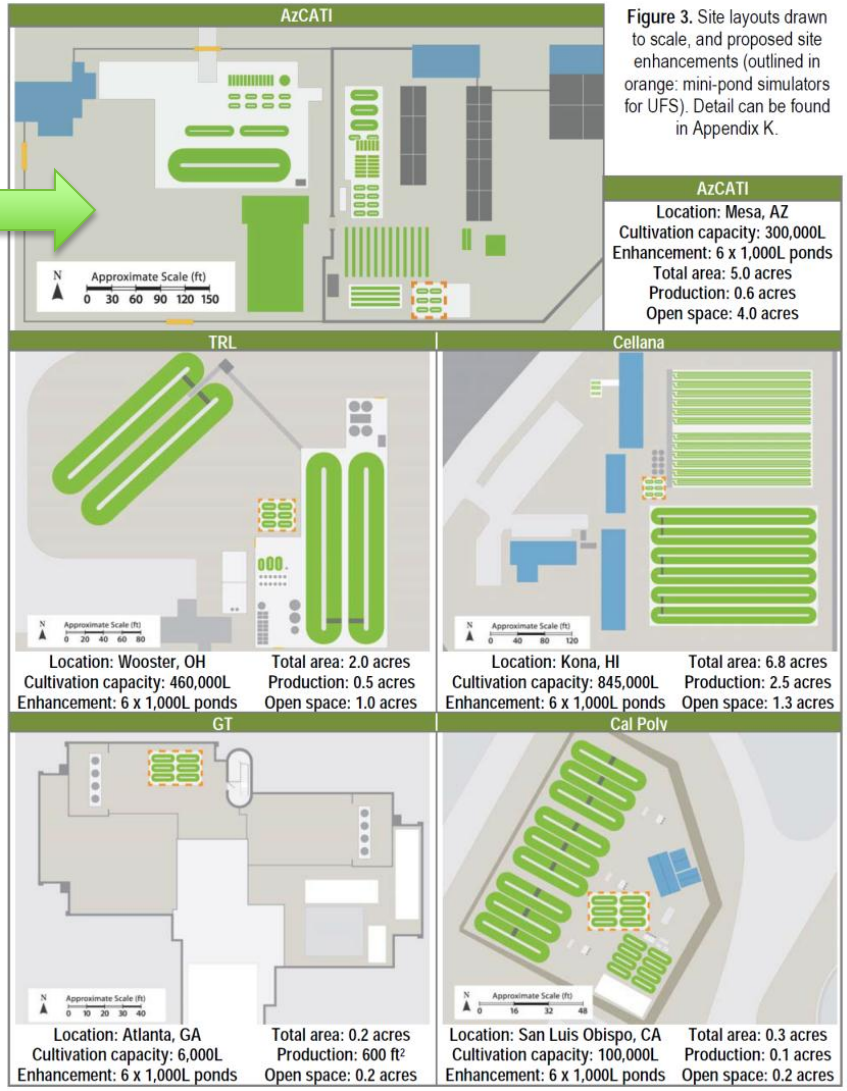


Figure 3. Site layouts drawn to scale, and proposed site enhancements (outlined in orange: mini-pond simulators for UFS). Detail can be found in Appendix K.

FY13 ABY FOA

- The Algae Biofuel Yield (ABY) FOA focuses on:
  - Improving algae productivity,
  - Enhancing algae cultivation systems to maximize yields,
  - Advancing preprocessing technologies, and
  - Integrating these improvements into complete processing systems for algae biofuel intermediates.
- With the goals of:
  - Lowering capital and operating costs
  - Enhancing the environmental sustainability of algal biofuels.

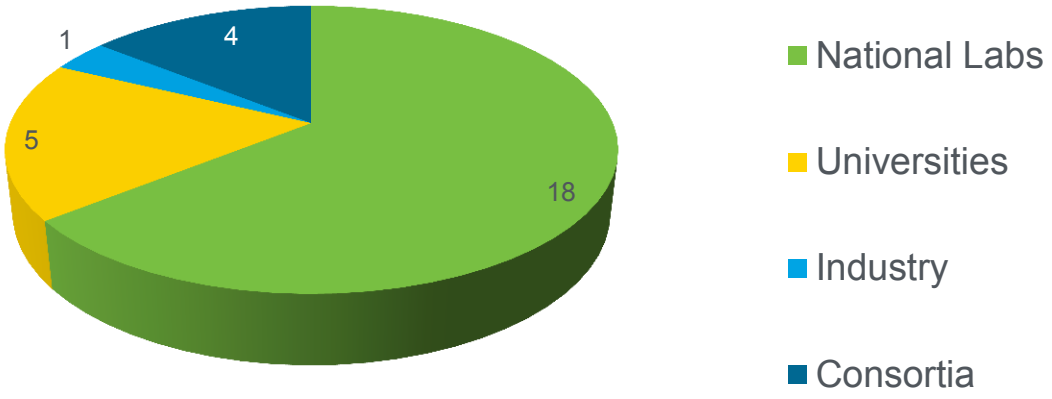
- Total DOE FY13: $20M
- Awards by September 2013

The Algae Portfolio

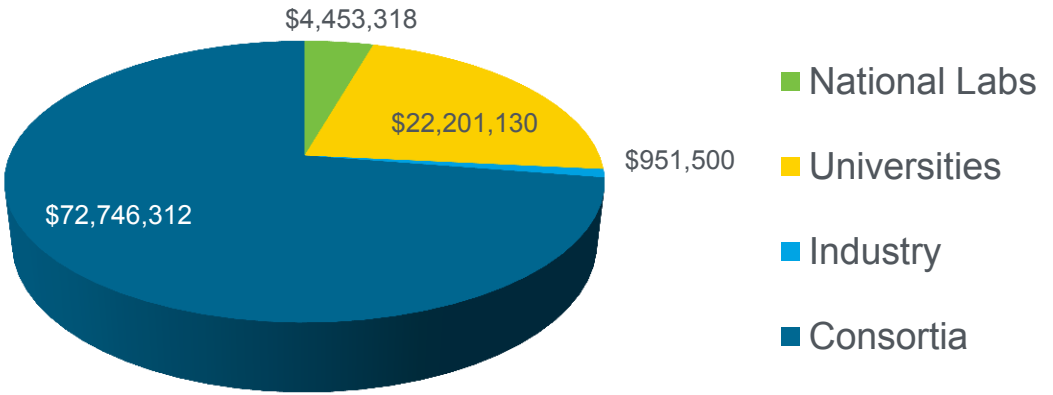
28 projects will be reviewed in the Algae technology area, covering a diversity of research topics including:

- algal biology
- algal cultivation, harvest, and processing logistics
- conversion interfaces and conversion technologies
- high value co-products, techno-economic, sustainability, and resource analyses.

28 Portfolio Performers Reviewed



DOE Value of Projects Reviewed



Total: $100,352,260

Algae Peer Review Performers

Key Accomplishments include the Algae Consortia

National Alliance for Advanced Biofuels and Bioproducts (NAABB)

Sustainable Algal Biofuels Consortium (SABC)

Consortium for Algal Biofuels Commercialization (CAB-Comm)

Future Directions: Algae

- Manage applied R&D in commercially-relevant scales in realistic, outdoor production environments (via ASAP and ABY)
- Support Lab Core R&D in:
  - Resource assessment modeling
  - Algal biomass characterization
  - Algal feedstock characterization and blending
  - Cultivation, harvest, and conversion process modeling
  - Organism development
  - Life-cycle assessments.

New Potential Areas of Focus:

- Feedstock Production - Enabling Co-products and Advanced Biology
- Reductions in Capital Expenditures – Advanced Materials, Integrated Systems, CO2 Delivery and Utilization

Future Directions: Terrestrial Feedstocks

Sustainable Production: In concert with Sustainability Technology Area

- Laboratories develop concept approaches on long-term watershed research/ feedstock demonstration projects:
  - Incorporate new or existing cropping systems on a small watershed to balance/optimize food and energy production with economic and environmental impacts (water, GHG, and wildlife impacts); Include a series of side-by-side comparisons of field studies
  - Explore opportunities on lab sites, IBR sites, private land sites, USDA project sites, or land grant sites (e.g. Century Farm)

Logistics:

- Select one or more alternate proposals to FY13 FOA to advance feedstock logistics
- Use full capabilities of DOE/INL user facility to procure materials for testing (utilize flexible user agreements)
- Use Biomass R&D Library
- Continue inter-laboratory blending/formulation strategies

Integration of Feedback from Peer Review 2011

Based on reviewer comments from the 2011 Peer Review, Feedstocks (both terrestrial and algal), have:

- Increased emphasis on sustainability
- Incorporated techno-economic, life-cycle, and resource assessment analyses
- Ensured research funding levels for large efforts are high and sustained
- Instituted Active Project Management to ensure the formulation of and adherence to concrete project milestones and deliverables

BETO Staff

Terrestrial Feedstocks

- John Ferrell (Program Manager)
- Sam Tagore
- Mark Elless
- Steve Thomas*
- Art Wiselogel
- Erin Searcy (M&O)
- Bryce Stokes (CNJV)
- Max Broad (BCS)

Algae

- John Ferrell (Acting Program Manager)
- Roxanne Dempsey
- Daniel Fishman*
- Christy Sterner
- Christine English (CNJV)
- Jessica Phillips (CNJV)
- Will Shrode (CNJV)
- Colleen Ruddick (BCS)

*Peer review lead

Reviewers

Feedstocks

- Lyle Stephens (Lead Reviewer, Deere & Company (Retired))
- Marilyn Buford (US Forest Service)
- Jami Nettles (Weyerhaeuser Company)
- Tom Richard (Pennsylvania State University)
- Steve Searcy (Texas A&M University)
- Mike Tumbleson (University of Illinois)

Algae

- Brent Massmann (Lead Reviewer, Monsanto)
- Chris Cassidy (USDA)
- David Hazlebeck (General Atomics)
- Philip Marrone (SAIC)
- Tasios Melis (UC Berkeley)
- Emilie Slaby (The Scoular Company)

Key Take Away Messages

Additional Info