DEPARTMENT OF ENERGY BIOMASS PROGRAM

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A Review of DOE Biofuels Program

4th International Conference on Biofuels Standards (ICBS-2012) - NIST

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November 13, 2012

Introduction

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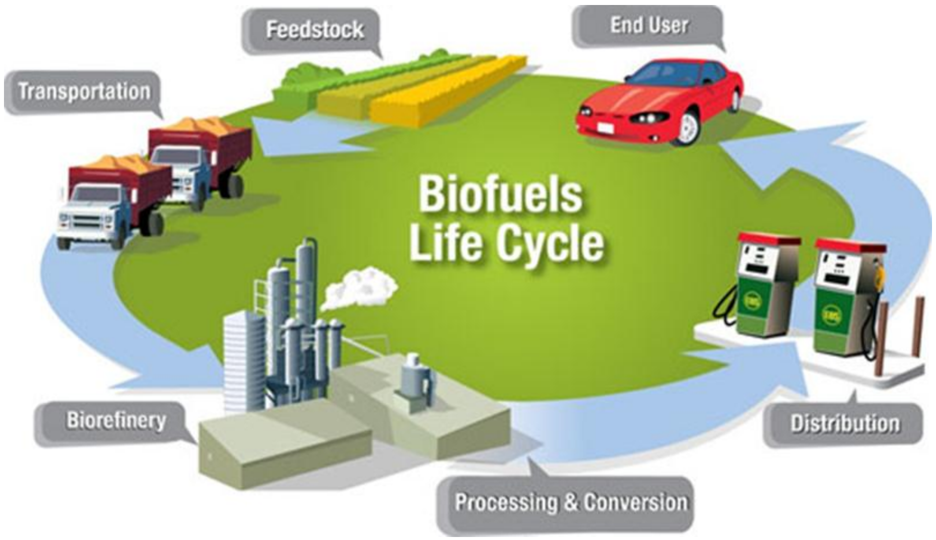
- Develop and deploy integrated biorefineries
- Research and develop advanced biofuels technologies
- Navy/USDA/DOE Advanced Biofuels Initiative
- Resource assessment – do we have enough biomass?
- Techno-economic analysis – can biofuels be produced at competitive prices?
- Sustainability – What are the greenhouse gas emissions?



Energy Price Volatility

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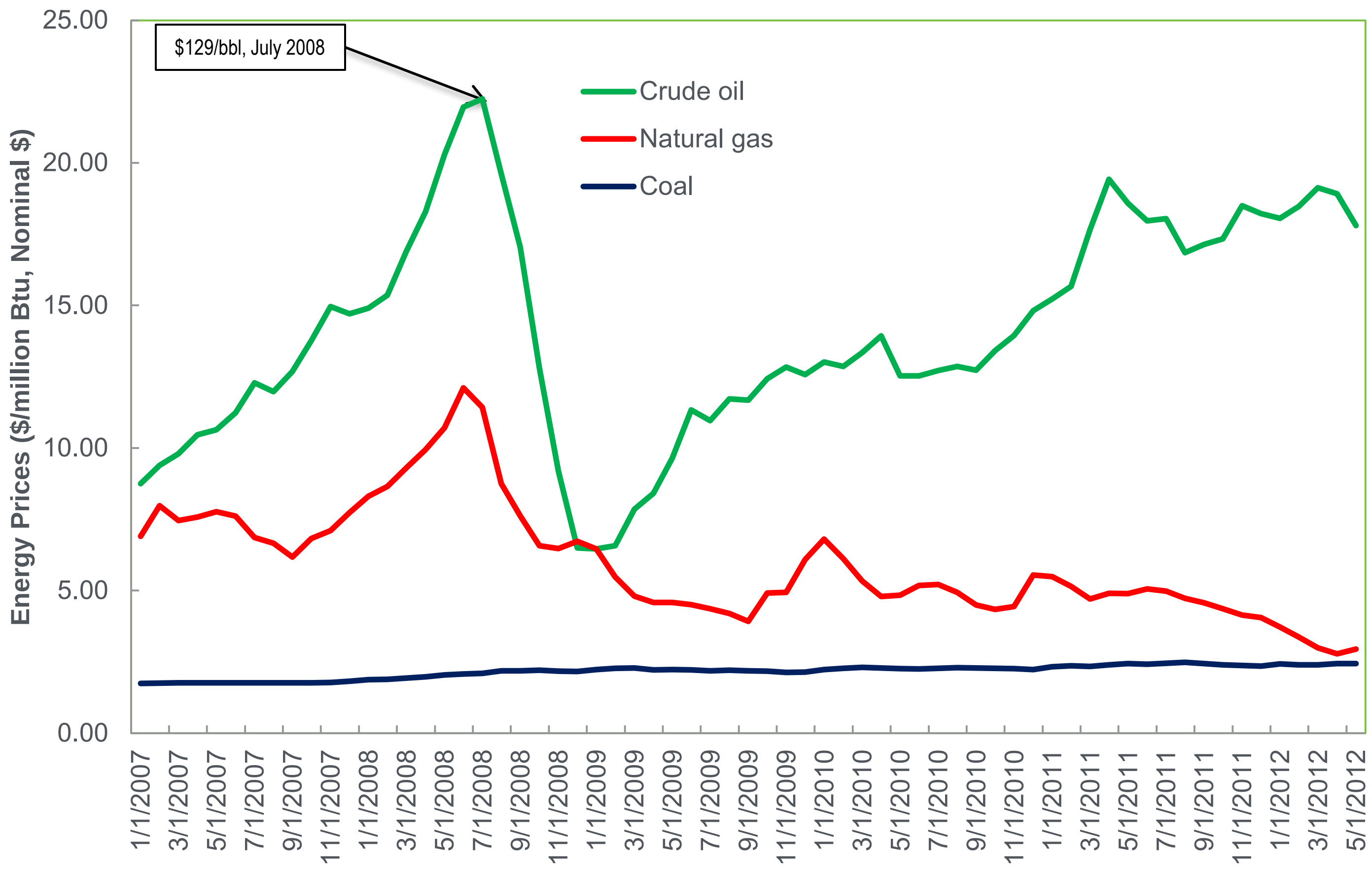

- Biomass at $70/dry metric tonne = $3.69/million Btu
- Corn at $7/bushel = $324/dry metric tonne = $14.50/million Btu

Source: Energy Information Administration, Monthly Energy Review, August 2012

Oil Price Forecasts

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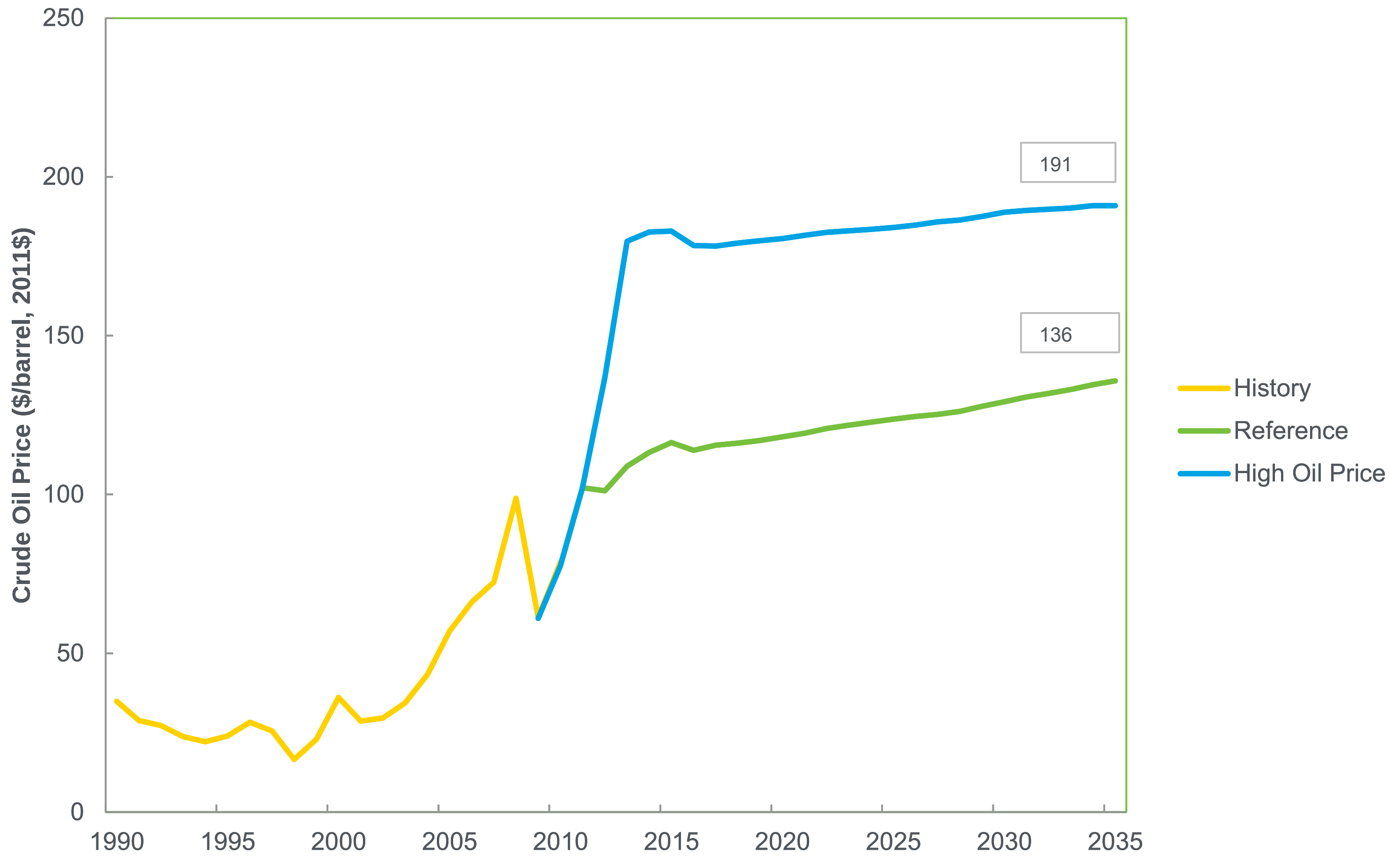

Source: Energy Information Administration, "Annual Energy Outlook 2012", DOE/EIA-0383(2012), available at http://www.eia.doe.gov, June 2012

Market Driver for Alternative Fuels

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- Military, aviation, marine, long-haul trucking, and long-distance rail have limited alternatives to liquid transportation fuels

- Biofuels as a mechanism for reduced price volatility

- Opportunity for innovative technologies incorporating natural gas and biomass
  - Will natural gas prices continue to decline and remain stable?
  - Can biomass and natural gas conversion processes be integrated?
  - What are the greenhouse gas emissions implications of biomass-natural gas technologies?

- Higher value use of biomass as a fuel substitute instead of an electron substitute

Resource Assessment – "Billion Ton Update"

U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry

- Provides current and potential available biomass for 2012-2030
- Estimates are at the county level and for a range of costs to roadside
- Has scenarios based on crop yields and tillage practices
- Models land use for energy crops and ensures meet food, forage, and export commodity crop demands
- Includes sustainability criteria
- Report and data on the web

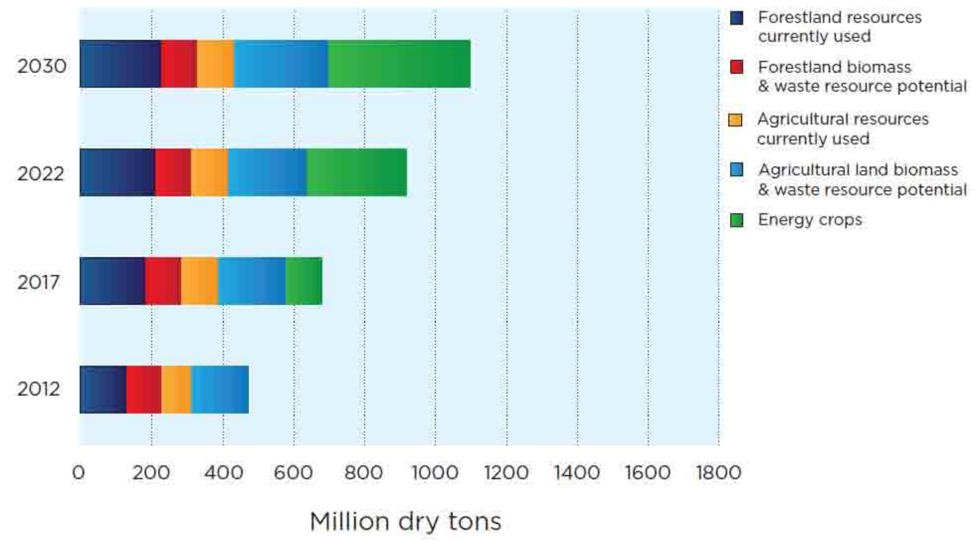
Data and analysis tools located on the Knowledge Discovery Framework: http://bioenergykdf.net

U.S. Billion-Ton Update: Findings

Baseline scenario

– Current combined resources from forests and agricultural lands total about 473 million dry tons at $60 per dry ton or less; <u>about 200 million dry tons from forestry</u>

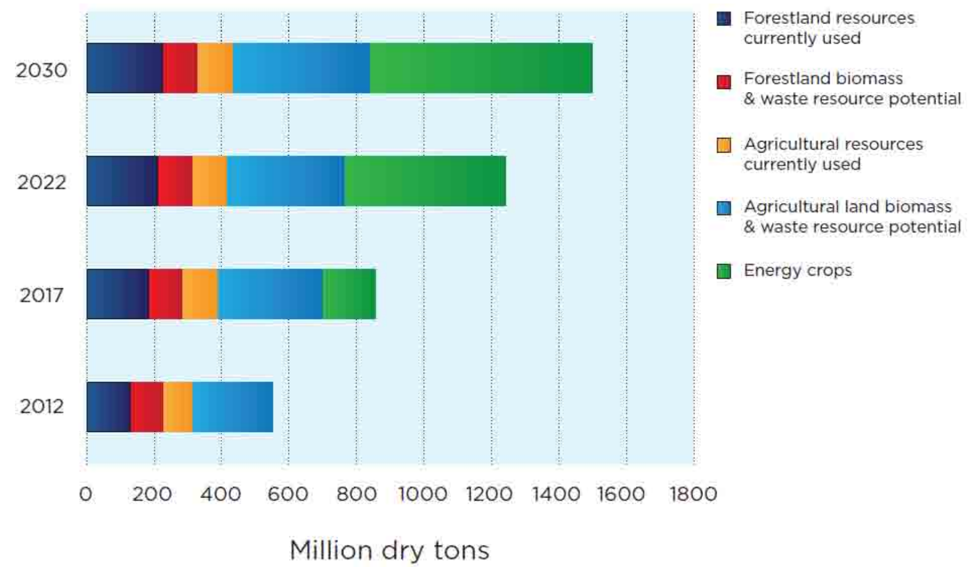
– By 2030, estimated resources increase to nearly 1.1 billion dry tons; <u>about 300 million dry tons from forestry</u>



High-yield scenario

– Total resource ranges from nearly 1.4 to over 1.6 billion dry tons annually of which 80% is potentially additional biomass;

– No high-yield scenario was evaluated for forest resources, except for the woody crops



Potential County-level Resources at $60 Per Dry Ton or Less in 2030

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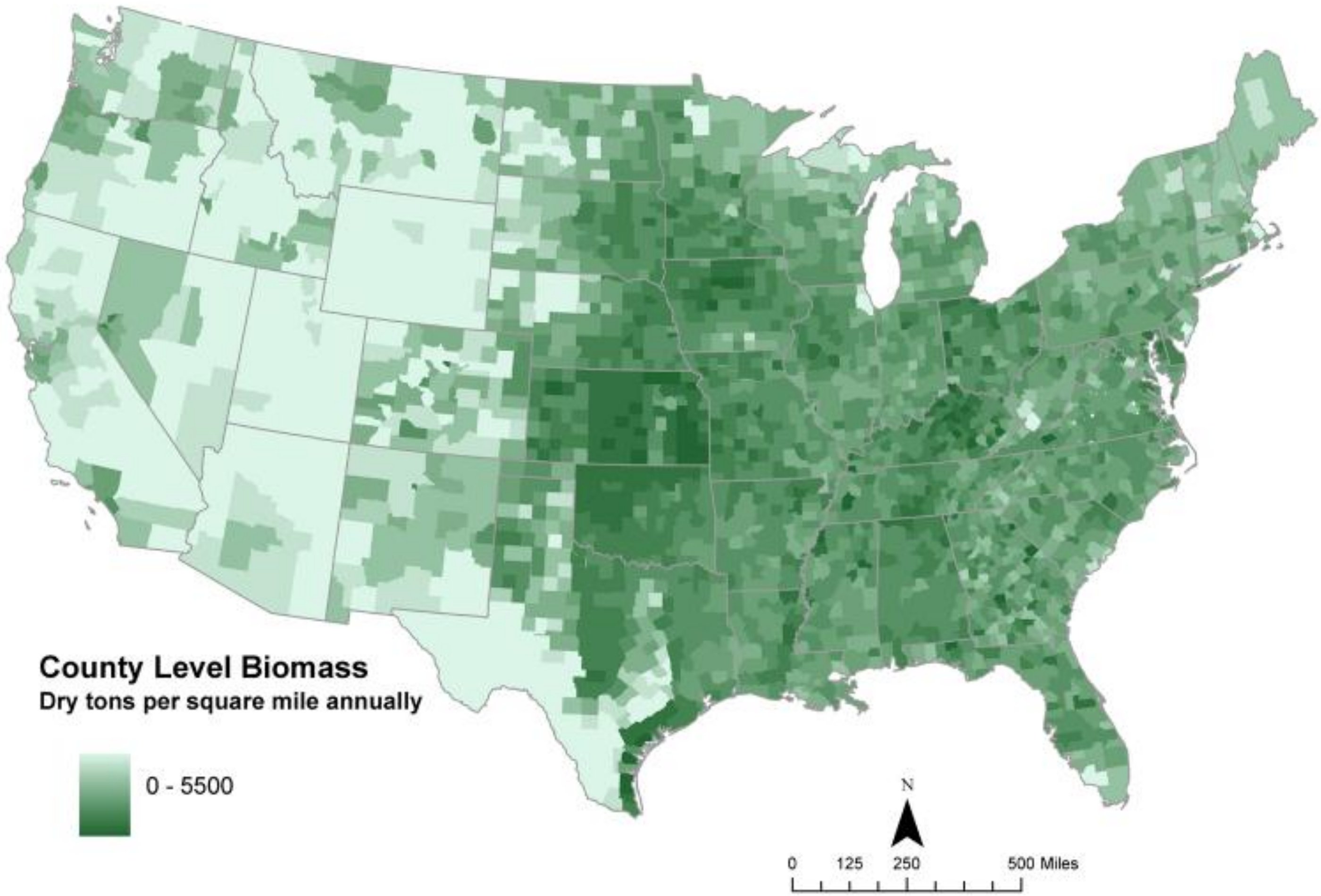
Under Baseline Assumptions



Micro-algae Resource Assessment

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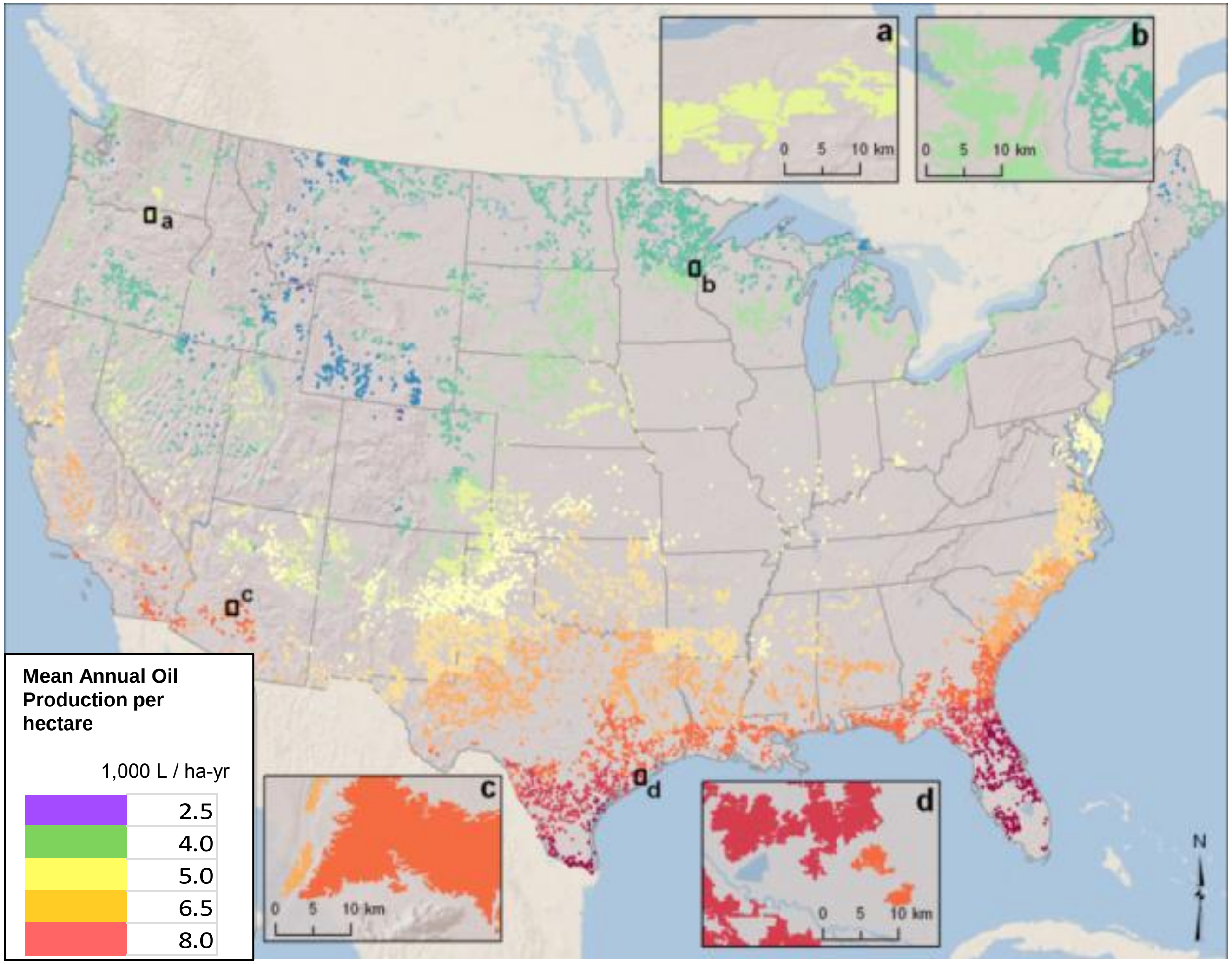

Wigmosta, M. S., A. M. Coleman, R. J. Skaggs, M. H. Huesemann, and L. J. Lane, 2011, National microalgae biofuel production potential and resource demand, Water Resour. Res., 47, W00H04

- A National resource assessment identified ~430,000 km^2 of suitable land for algae cultivation with potential for 58 BGY of algal oil production
- Optimizing to maximize productivity and minimize water use identifies 10,000 km^2, or about 3.7M acres, mainly around the Southwest and Gulf Coast
- These optimized sites would support production of 5 BGY

Integrated Biorefinery Projects

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- 11 IBRs will produce hydrocarbons from biomass
- 12 IBRs will produce cellulosic ethanol from biomass

Project Scale Key

- Research and Development
- Pilot
- Demonstration
- Commercial
- Complete/Inactive

For more information visit:
http://www.eere.energy.gov/biomass/integrated_biorefineries.html

Techno-Economic Analysis

- Setting R&D priorities
- Benchmarking
- Informing multi-sectoral analytical activities
- Track Program R&D progress against goals
- Identify technology process routes and prioritize funding
- Program direction decisions:
  - Are we spending our money on the right technology pathways?
  - Within a pathway: Are we focusing our funding on the highest priority activities?

Terminology and Concepts

- Nth plant economics
  - Costs represent the case where several biorefineries with this technology have been built, which assumes lower contingency and other cost escalation factors
  - Assumes no risk premiums, no early-stage R&D, or start-up costs
- Pioneer plant
  - Costs represent a first-of-a-kind construction, where added cost factors are included for contingency and risk
  - Most closely represented by IBR projects
  - Few estimates available in the public domain
- Design Case:
  - Detailed, peer reviewed process simulation based on ASPEN or Chemcad
  - Establishes cost of production at biorefinery boundary
  - Provides estimate of nth plant capital and operating costs
  - Based on best available information at date of design case
  - Scope: feedstock cost (harvest, collection, storage, grower payment), feedstock logistics (handling, size reduction, moisture control), conversion cost, profit for biorefinery
  - Excludes: taxes, distribution costs, tax credits or other incentives

Cost of Production for Hydrocarbon Biofuels

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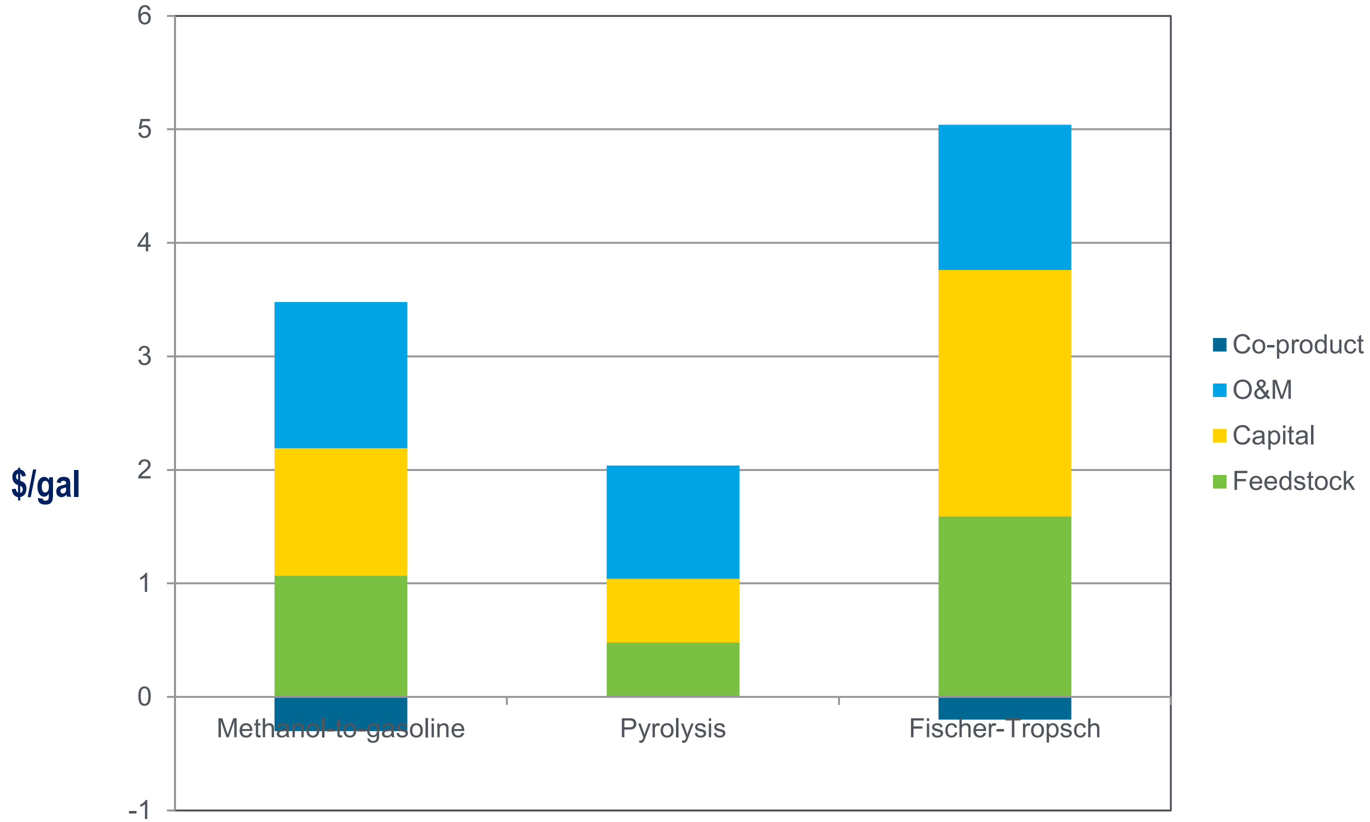

- Other economically viable technology routes for hydrocarbon biofuels exist, such as conversion of waste and plant oils, and sugar-to-hydrocarbons
- These costs are projected for the Nth Biorefinery Plant, after operation of initial commercial-scale Pioneer Plants

Sources:

1. Sue Jones et. al., "Production of Gasoline and Diesel from Biomass via Fast Pyrolysis, Hydrotreating and Hydrocracking: A Design Case", Pacific Northwest National Laboratory, PNNL-18284, available from http:/www.pnl.govFebruary 2009.
2. Sue Jones et. al., "Techno-Economic Analysis for the Conversion of Lignocellulosic Biomass to Gasoline via the Methanol-to-Gasoline (MTG) Process", Pacific Northwest National Laboratory, PNNL-18481, available from http://www.www.pnl.gov, February 2009.
3. Anex, R. A., et. al., "Techno-Economic Comparison of Biomass-to-Transportation Fuels via Pyrolysis, Gasification, and Biochemical Pathways", Fuel, July 2010.

Biofuel Production Costs
Example of renewable fuels via pyrolysis

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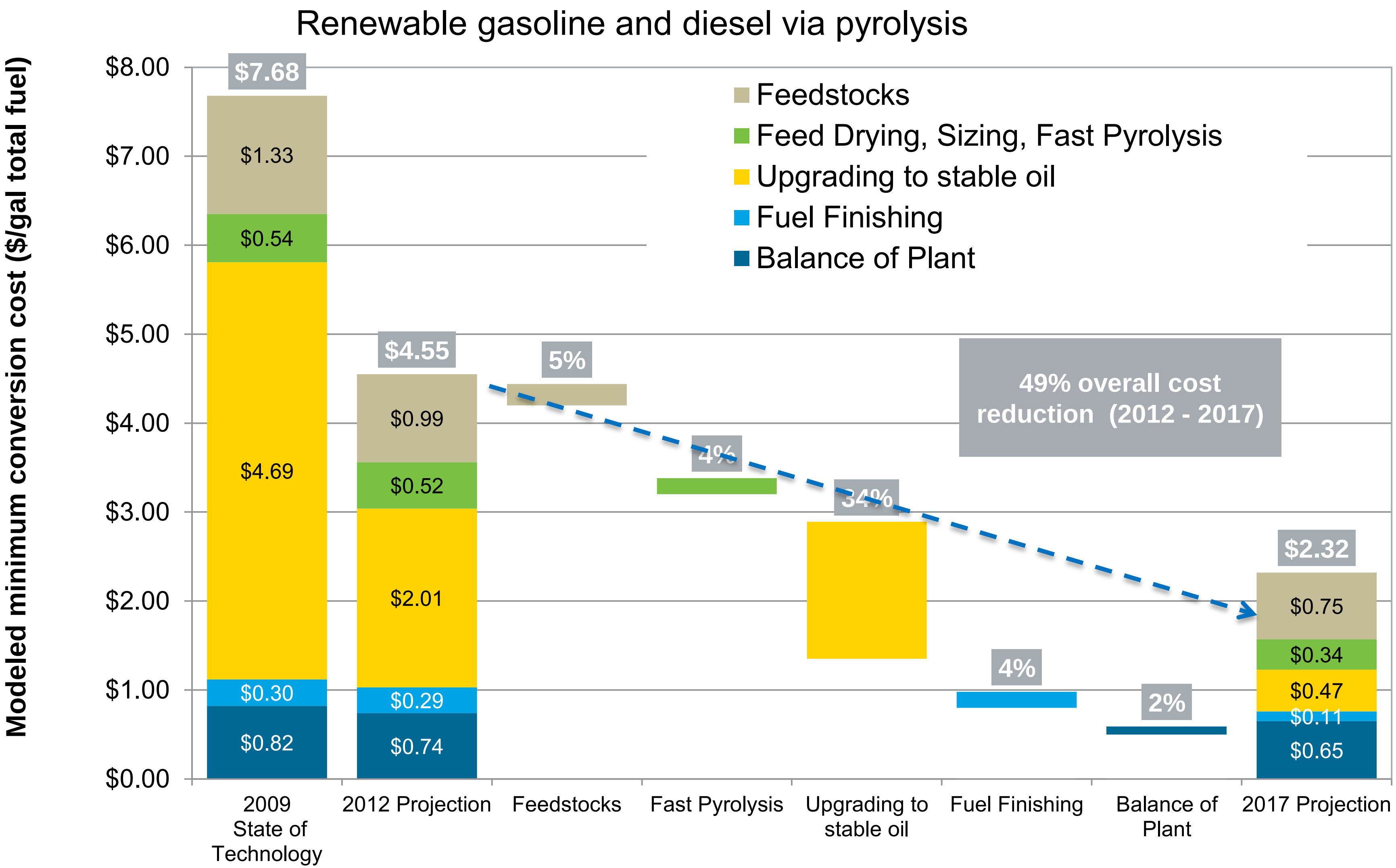

Pyrolysis costs by unit and projected cost reductions through R&D

Algae Model Harmonization Initiative

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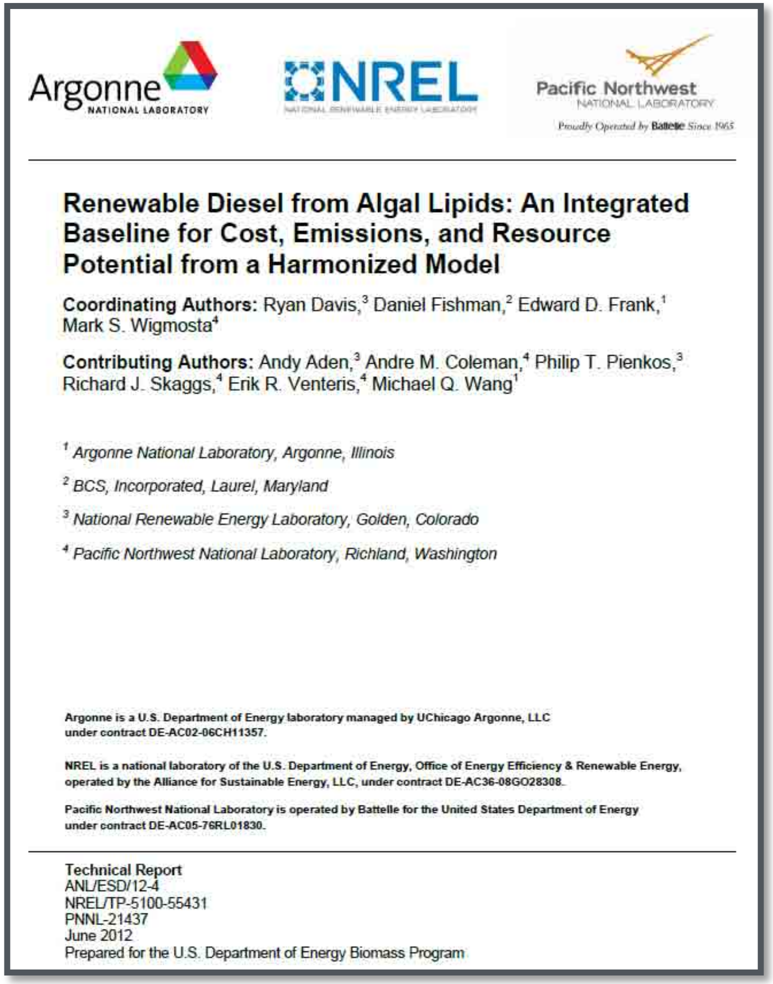
- The Biomass Program uses a baseline algal production scenario with model-based **quantitative metrics** to inform strategic planning
- Preliminary work on resource, techno-economic, and life cycle assessments **integrated with external stakeholder** input during Harmonization Workshop (Dec, 2011)
- ANL, PNL, NREL joint technical report "Renewable Diesel from Algal Lipids" (June, 2012), describes the **<u>conservative</u>** harmonized pathway
- Renewable diesel from extracted algal lipids pathway is the Biomass Program's **baseline** to measure progress
- Subsequent workshops will be held to further the Initiative and consider **whole algae processing** and other innovative pathways


Argonne NATIONAL LABORATORY | NREL NATIONAL RENEWABLE ENERGY LABORATORY | Pacific Northwest NATIONAL LABORATORY Proudly Operated by Battelle Since 1965

Renewable Diesel from Algal Lipids: An Integrated Baseline for Cost, Emissions, and Resource Potential from a Harmonized Model

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Argonne is a U.S. Department of Energy laboratory managed by UChicago Argonne, LLC under contract DE-AC02-06CH11357.

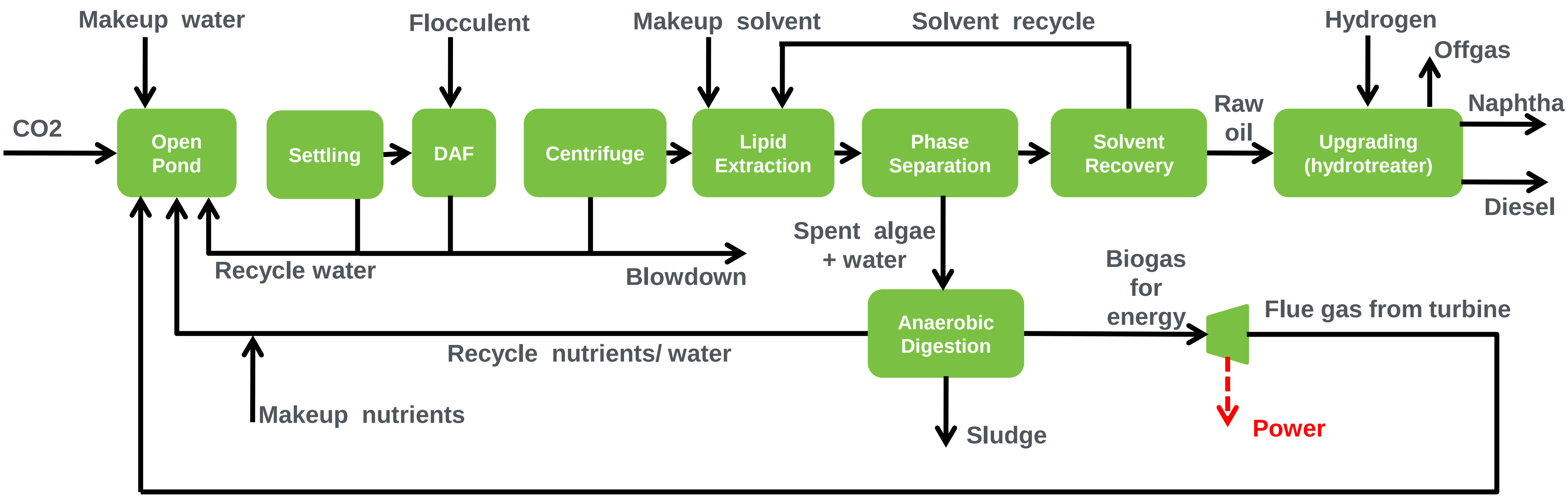
NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, operated by the Alliance for Sustainable Energy, LLC, under contract DE-AC36-08GO28308.

Pacific Northwest National Laboratory is operated by Battelle for the United States Department of Energy under contract DE-AC05-76RL01830.

Technical Report
ANL/ESD/12-4
NREL/TP-5100-55431
PNNL-21437
June 2012
Prepared for the U.S. Department of Energy Biomass Program

Integrated Baseline Design Configuration

0.05% (OP)



Green = algae cell density

Integrated Baseline - Process Performance and Sensitivity

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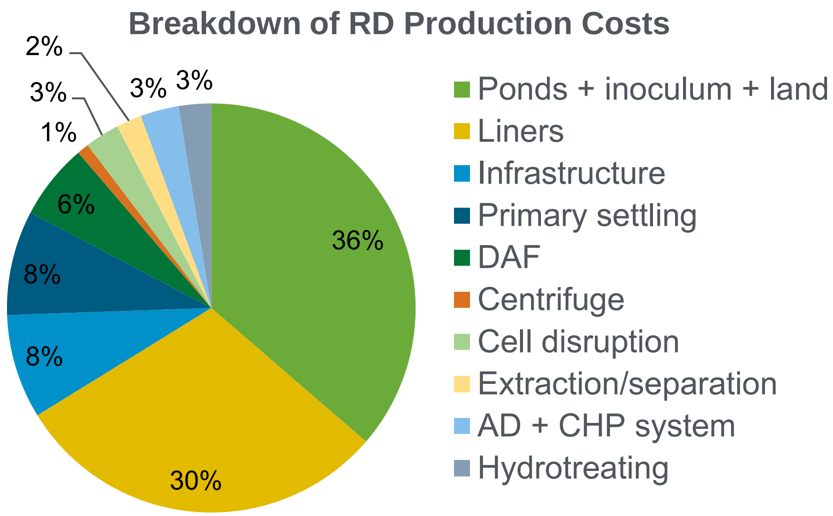
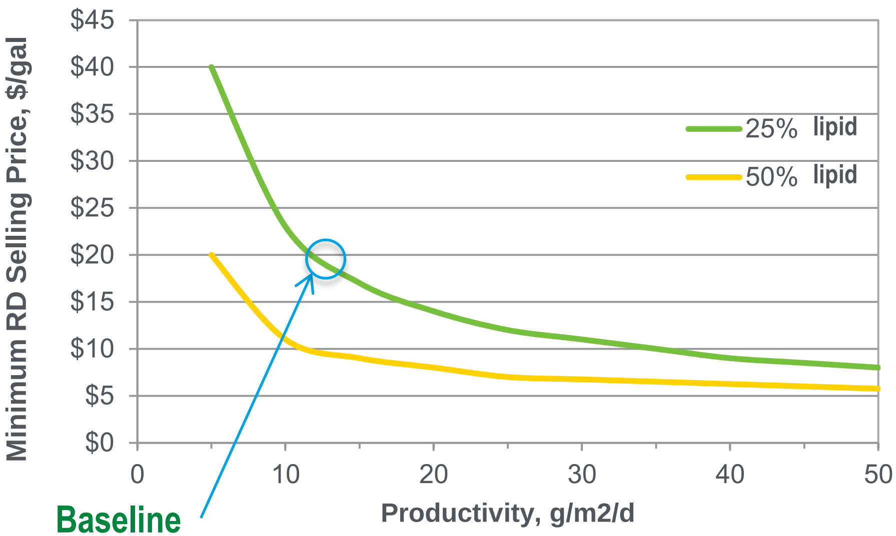
- The integrated baseline makes conservative assumptions on productivity, processing, and co-products:
  - Annual average productivity 13 grams/m2/day
  - 80% processing efficiency
  - No high-value co-products
- The baseline performance is highly uncertain and small changes in productivity have big impacts
- Baseline assumption results:
  - Unit Scale: 10 MGY renewable diesel
  - Minimum Selling Price: ~$20/gallon
  - Emissions: 67.4 kg cO2e/MMBTU renewable diesel
- Innovative work across the value chain is showing promise in reducing costs.





New Pathways Being Considered

- Feedstocks – integrate herbaceous and woody feedstocks into a uniform format that is transportable over long distances
- Biochemical – Biological conversion (bacterial, fungal, heterotrophic algae) of ligno-cellulosic sugars to hydrocarbons
- Biochemical - Catalytic upgrading of sugars or sugar derivatives (furfural) to hydrocarbons
- Thermochemical - Catalytic fast pyrolysis with vapor phase upgrading (two liquefaction reactors)
- Thermochemical – In-situ catalytic fast pyrolysis (one liquefaction reactor)
- Thermochemical – Gasification, catalytic conversion or fermentation of synthesis gas to hydrocarbons
- Algae – open pond, solvent extraction, algal lipid upgrading, anaerobic digestion of spent biomass
- Algae – open pond, whole algae hydrothermal liquid upgrading, wet catalytic gasification