DEPARTMENT OF ENERGY BIOMASS PROGRAM

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AMERICA'S FIRST BIOFUELS CORRIDOR

BIOFUELS CORRIDOR I-65

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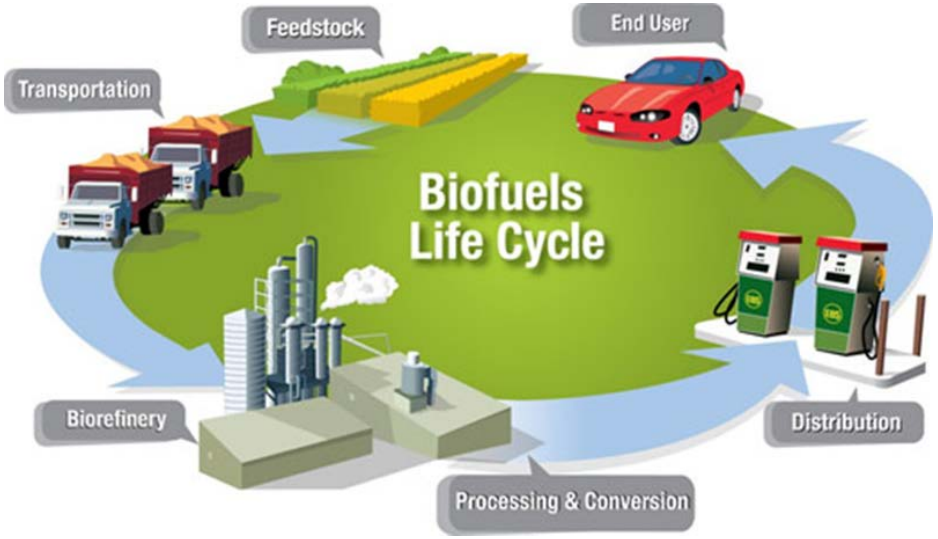
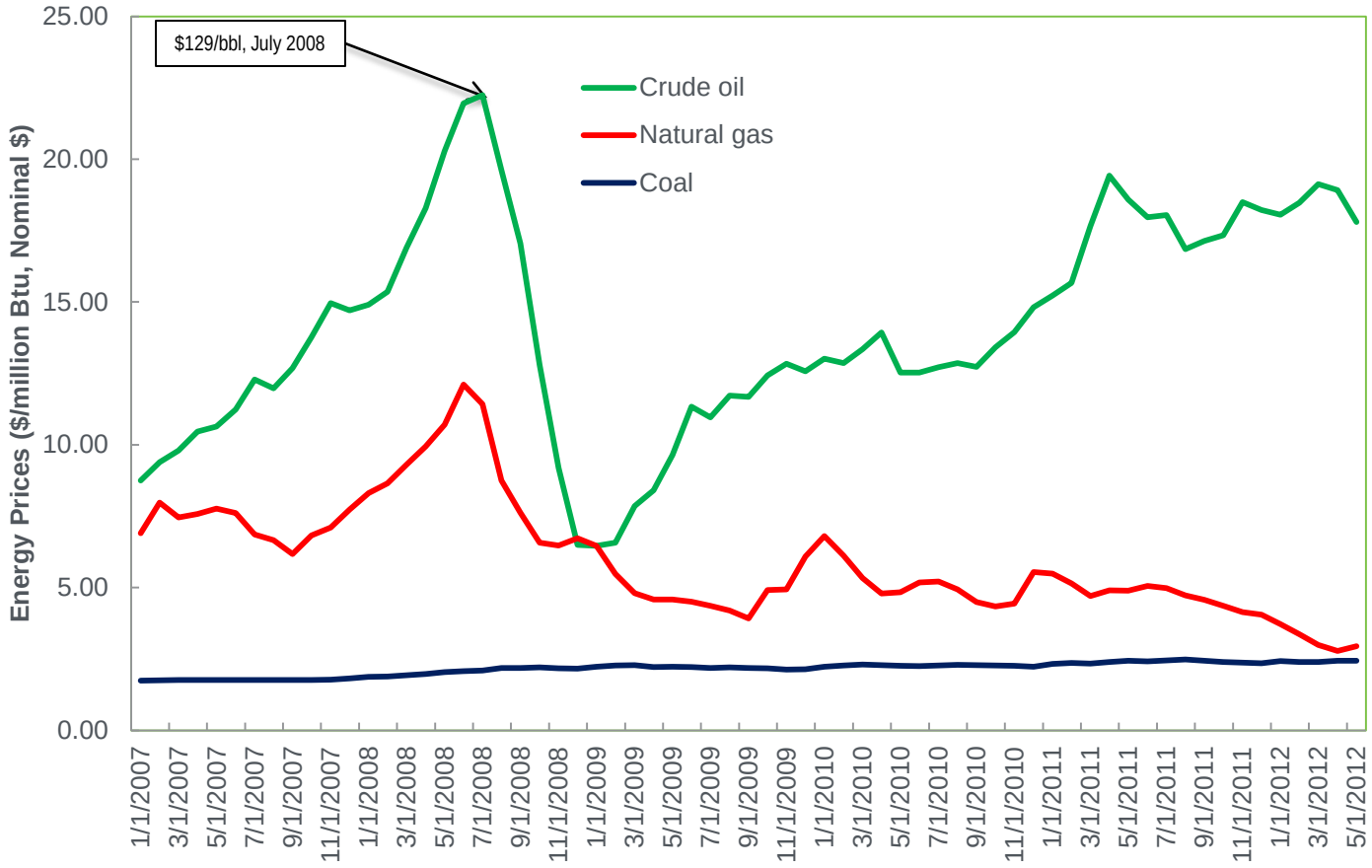
- Develop and deploy integrated biorefineries
- Research and develop advanced biofuels technologies
- Navy/USDA/DOE Advanced Biofuels Initiative
- Resource assessment – do we have enough biomass?
- Techno-economic analysis – can biofuels be produced at competitive prices?
- Sustainability – What are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



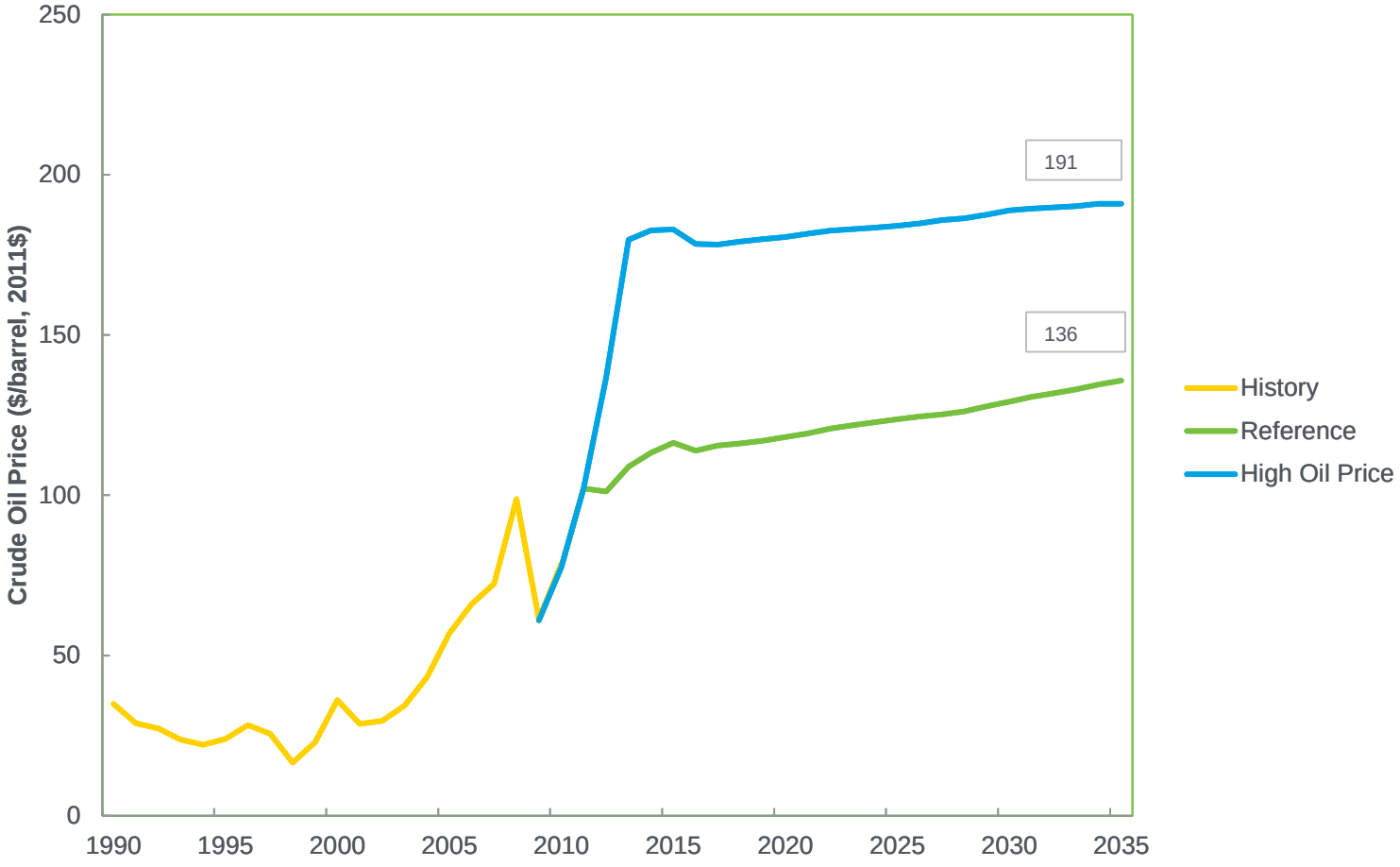
Energy Price Volatility



- 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



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

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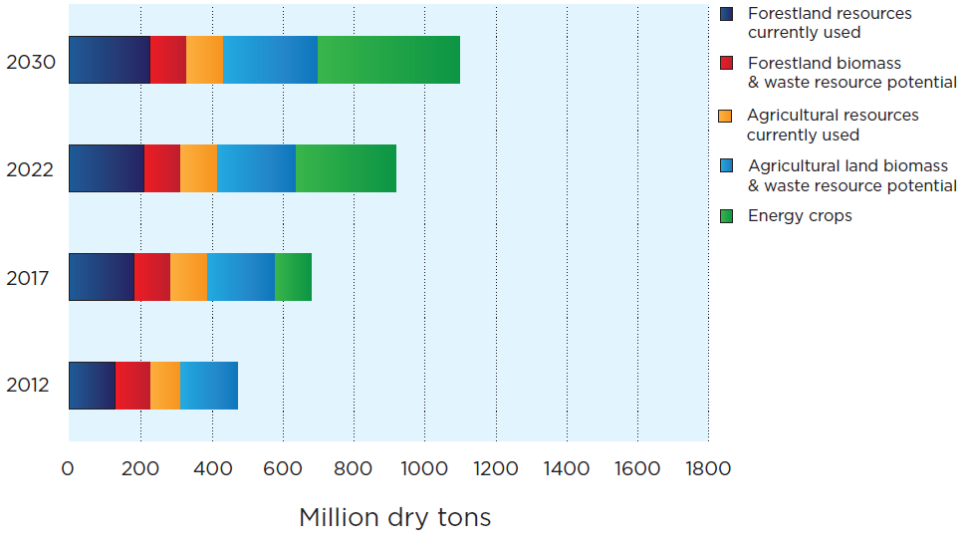
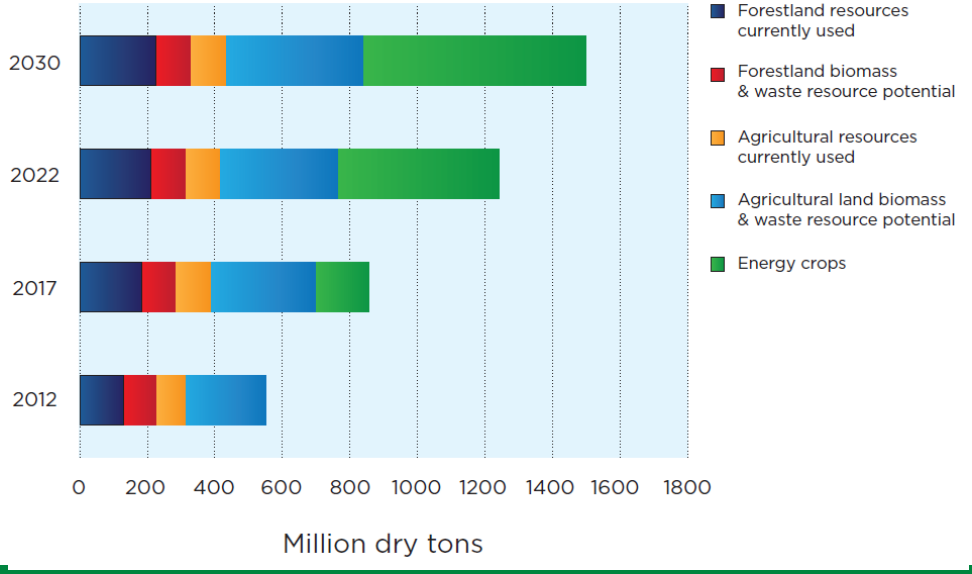
Baseline scenario

- 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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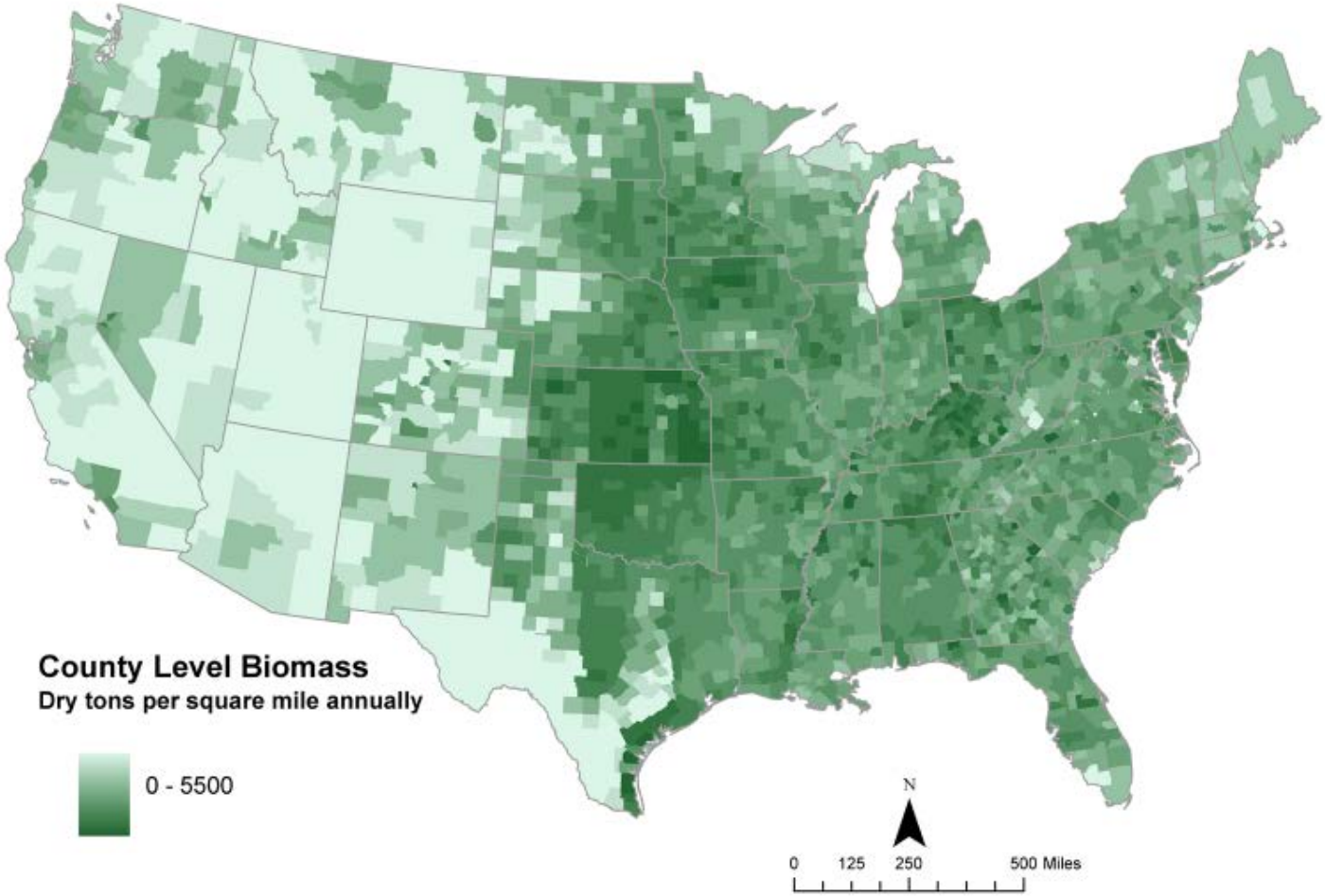
Under Baseline Assumptions



Integrated Biorefinery Projects

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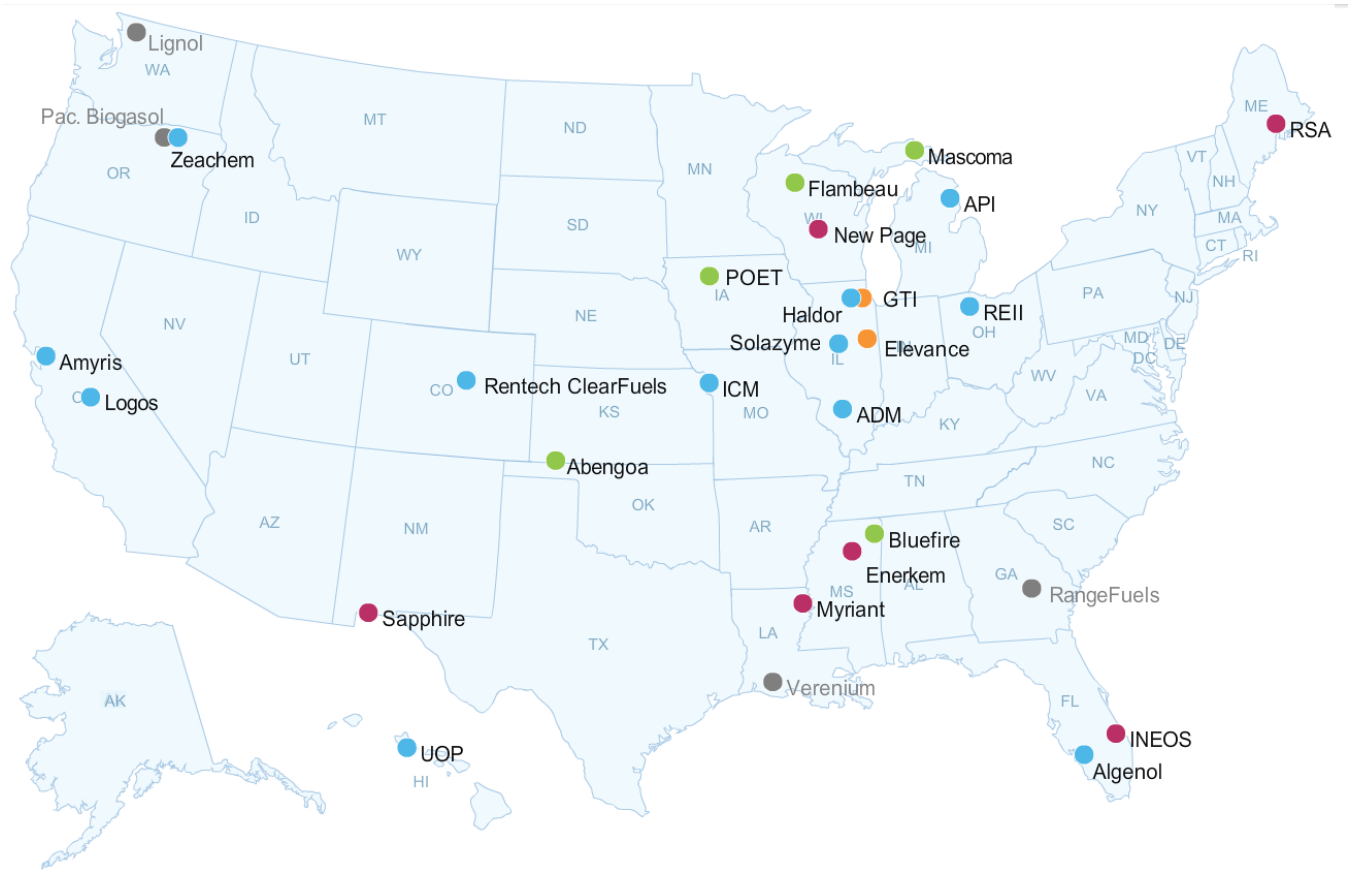
- 11 IBRs will produce hydrocarbons from biomass
- 12 IBRs will produce cellulosic ethanol from biomass



Project Scale Key

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

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

Biochemical Conversion

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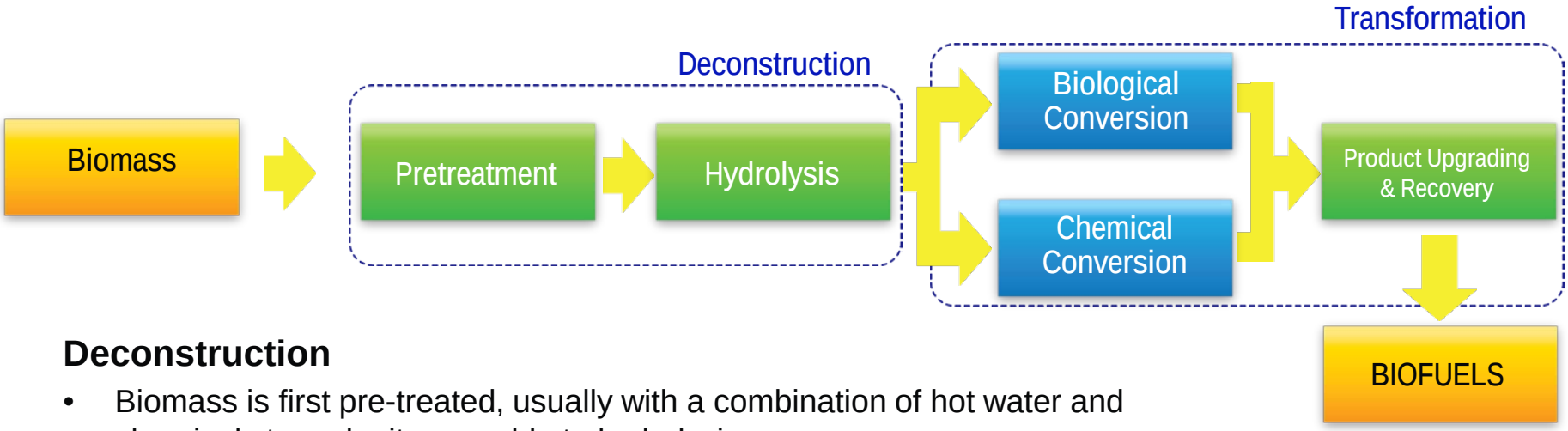
RD&D projects are improving the biochemical conversion of cellulosic biomass to biofuels and chemicals. These processing routes entail breaking down biomass to make the carbohydrates available for conversion into sugars, which microorganisms and other catalysts can use to create biofuels and bioproducts.



Deconstruction

- Biomass is first pre-treated, usually with a combination of hot water and chemicals to make it amenable to hydrolysis
- The pre-treated biomass slurry is then exposed to enzymes, which unlock and release (hydrolyze) the biomass sugars

Transformation

- The sugar-rich media is then fed to organisms, like yeast and E. Coli, which transform the sugars into biofuels and chemicals
- Chemical catalysis can also be employed to transform the sugars into biofuels and chemicals

An enzyme that turns cellulose into sugar (image courtesy of NREL)

Thermochemical Conversion

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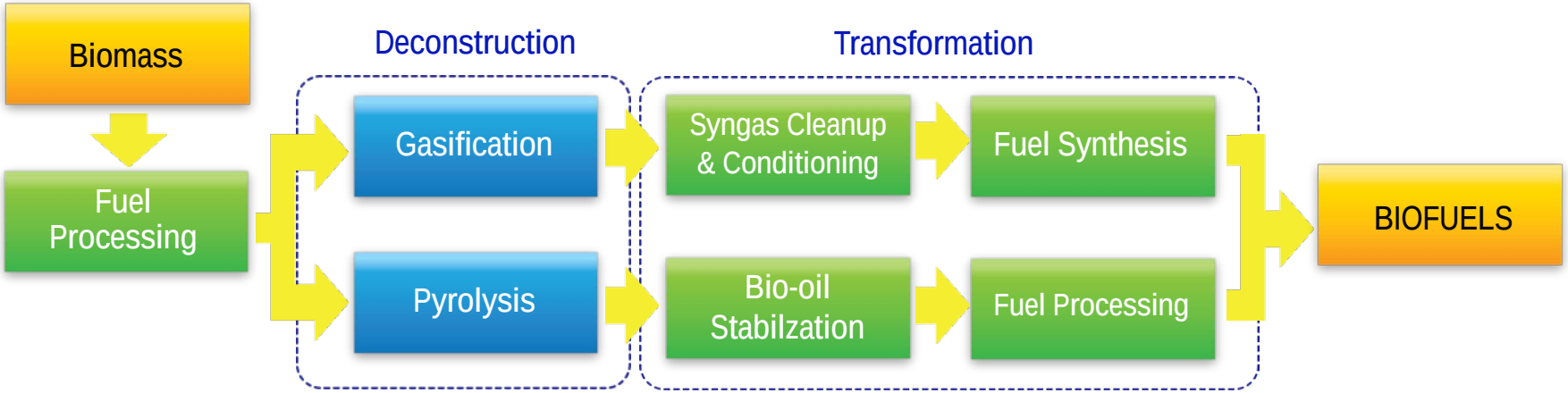
RD&D projects are improving the thermochemical conversion of cellulosic biomass. These processing routes use heat and chemistry to convert biomass into a liquid or gaseous intermediate, such as syngas or bio-oil. Customized processing of intermediates produces biopower or biofuels such as gasoline, diesel, and jet fuel.



Deconstruction

- Pre-processed biomass is heated in reactors (in some cases with a catalyst) to produce gas and liquid intermediates

Transformation

- Synthesis gas (aka syngas) is then scrubbed for impurities and converted into biofuels and chemicals
- Liquid (aka pyrolysis oil) is stabilized and upgraded to produce biofuels and chemicals

An F/A-18 Green Hornet Fighter plane operating on a 50/50 biofuels blend. Photo courtesy of the U.S. Navy.

Algae Feedstocks

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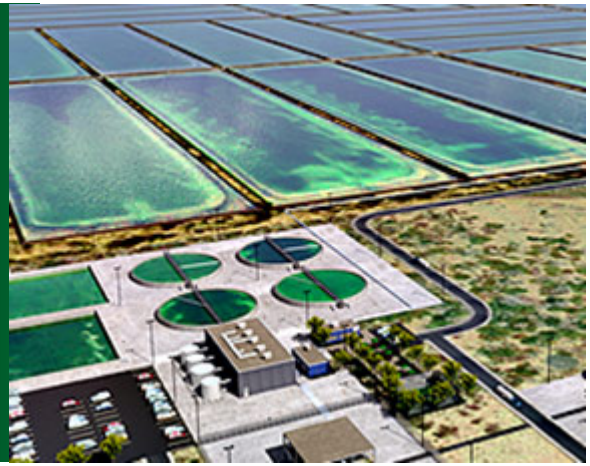
Activities include R&D on algal feedstocks and issues related to the sustainable production of algae-derived biofuels.

Benefits	Challenges
High productivity	Affordable and scalable algal biomass production
Reduced competition with agriculture	Feedstock production and crop protection
Ability to use waste and salt water	Energy-efficient harvesting and drying
Recycling of carbon dioxide	Extraction, conversion, and product purification
Integrated production of fuels and co-products	Siting and sustainability of resources

The goal of creating abundant, cost-effective, and sustainable algal biomass supplies in the United States involves algal genetics, strain development, and algal cultivation strategies. R&D activities also factor in the economic and environmental sustainability of various routes and technologies to produce algal biofuels and bioproducts.



Micro-algae Resource Assessment

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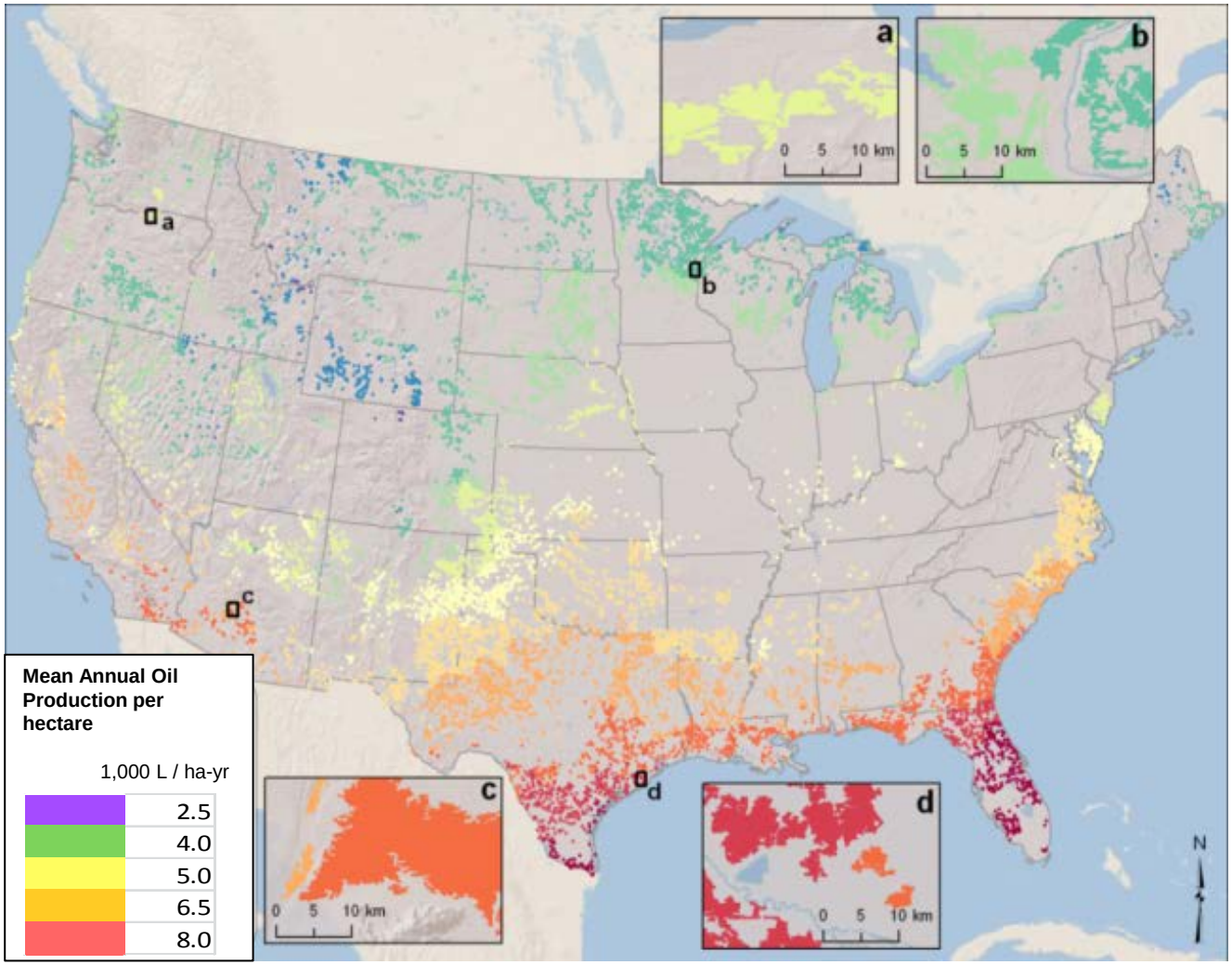

Wigmosta, M. S., A. M. Coleman, R. J. Skaggs, M. H. Huesemann, and L. J. Lane, 2011, National microalgae biofuel production potential and resource demand, Water Resour. Res., 47, W00H04

- 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

Techno-Economic Analysis

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- 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

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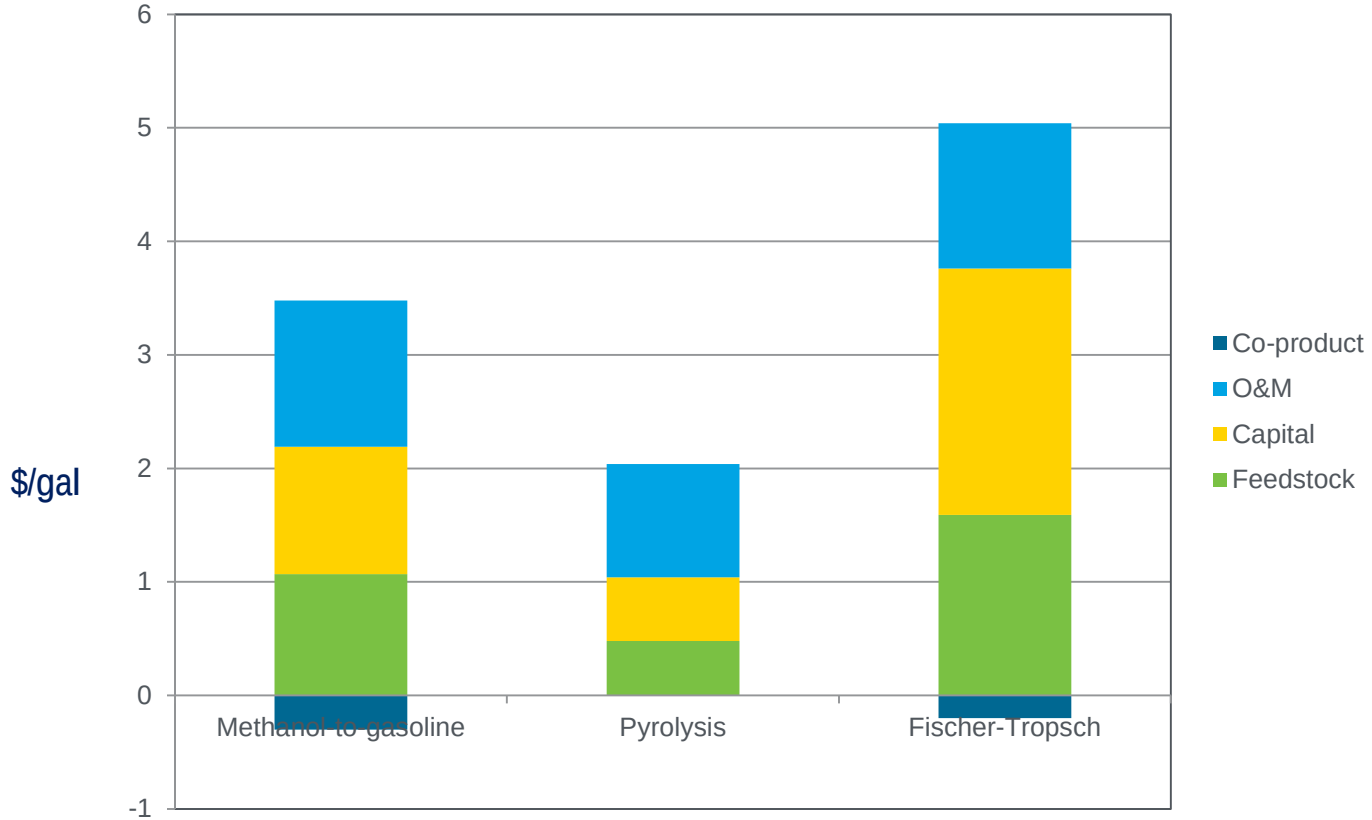
- Nth plant economics
  - Costs represent the case where several biorefineries with this technology have been built, which assumes lower contingency and other cost escalation factors
  - Assumes no risk premiums, no early-stage R&D, or start-up costs
- Pioneer plant
  - Costs represent a first-of-a-kind 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



- 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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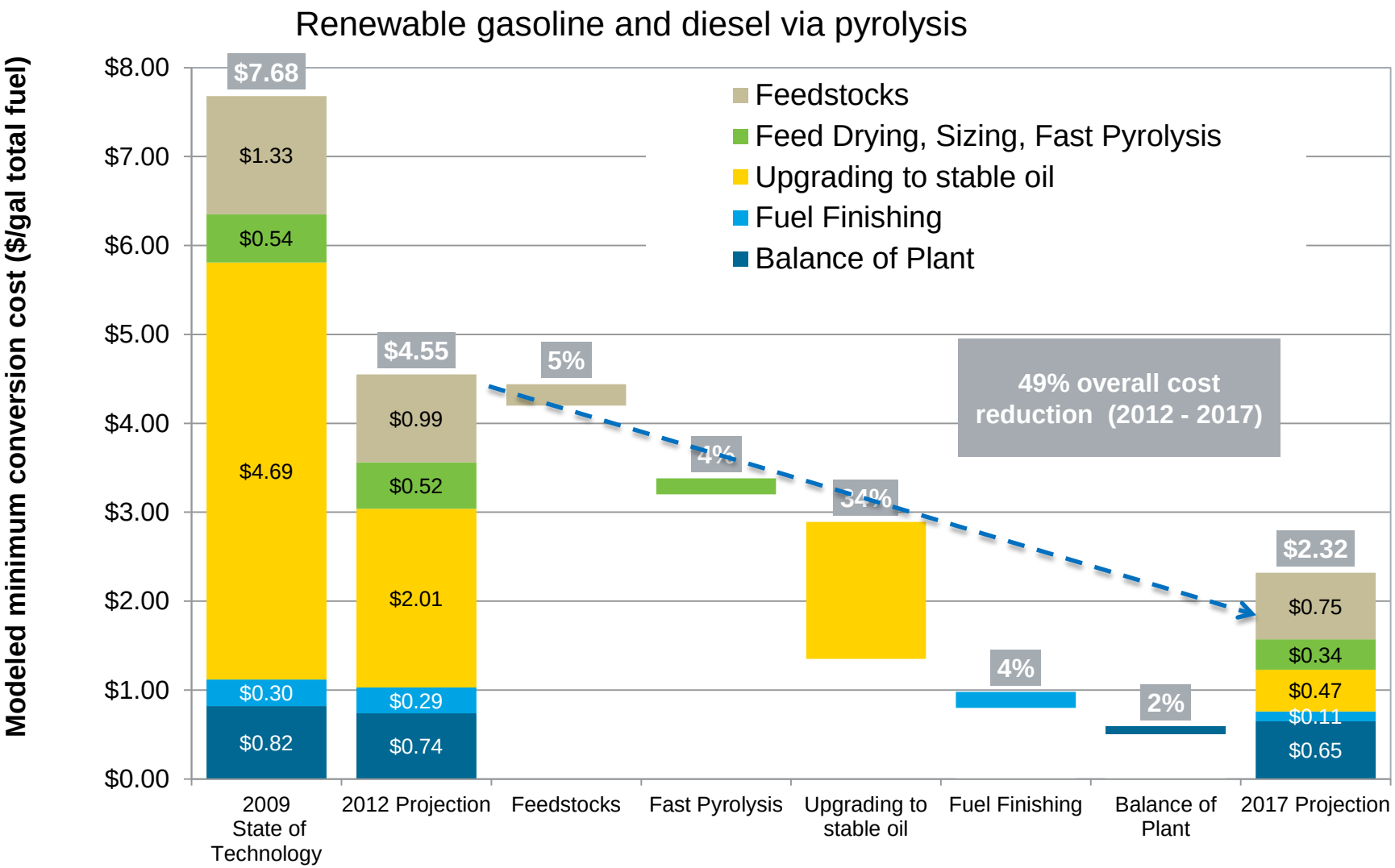

Pyrolysis costs by unit and projected cost reductions through R&D

Algae Model Harmonization Initiative

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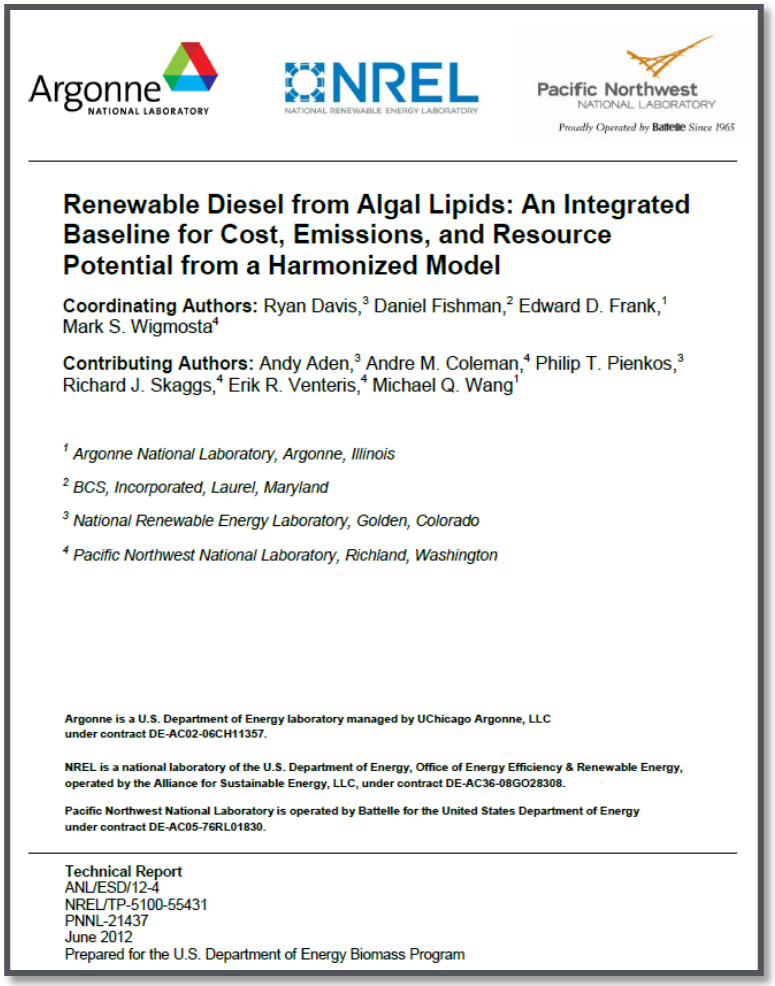
- The Biomass Program uses a baseline algal production scenario with model-based **quantitative metrics** to inform strategic planning
- Preliminary work on resource, techno-economic, and life cycle assessments **integrated with external stakeholder** input during Harmonization Workshop (Dec, 2011)
- ANL, PNL, NREL joint technical report "Renewable Diesel from Algal Lipids" (June, 2012), describes the **conservative** 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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Contributing Authors: Andy Aden,[3] Andre M. Coleman,[4] Philip T. Pienkos,[3] Richard J. Skaggs,[4] Erik R. Venteris,[4] Michael Q. Wang[1]

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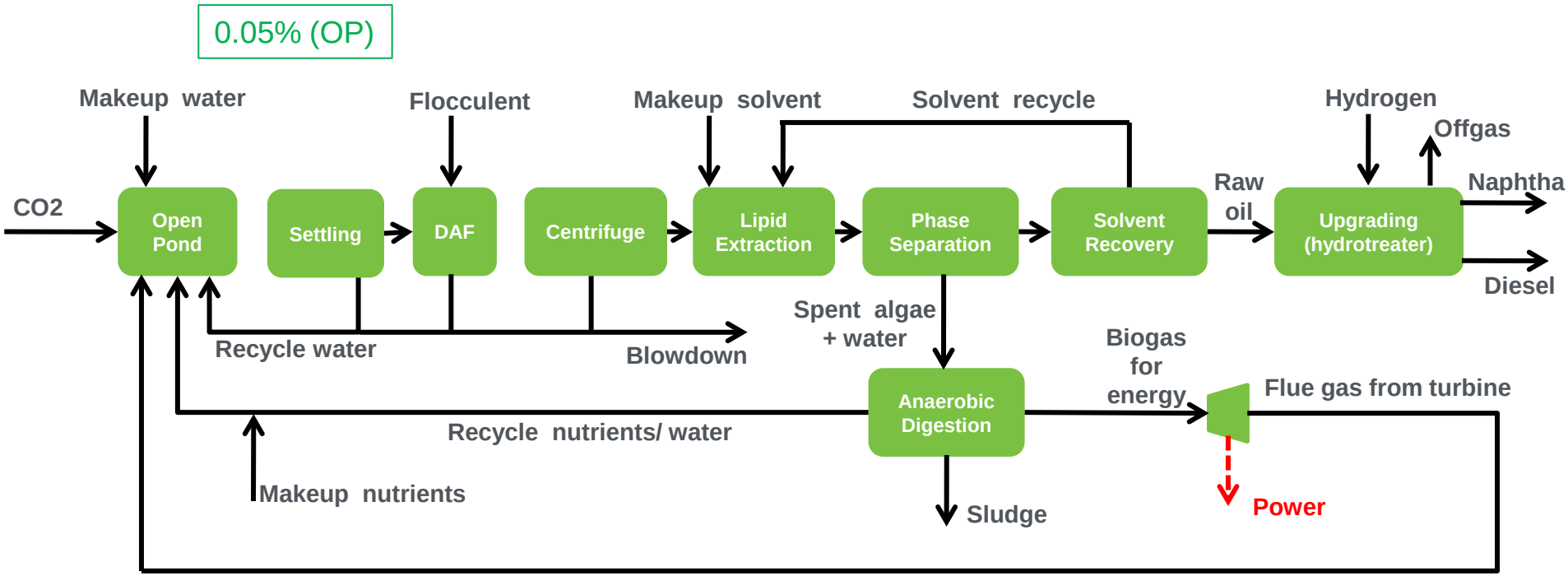
Argonne is a U.S. Department of Energy laboratory managed by UChicago Argonne, LLC under contract DE-AC02-06CH11357.

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



Green = algae cell density

Integrated Baseline - Process Performance and Sensitivity

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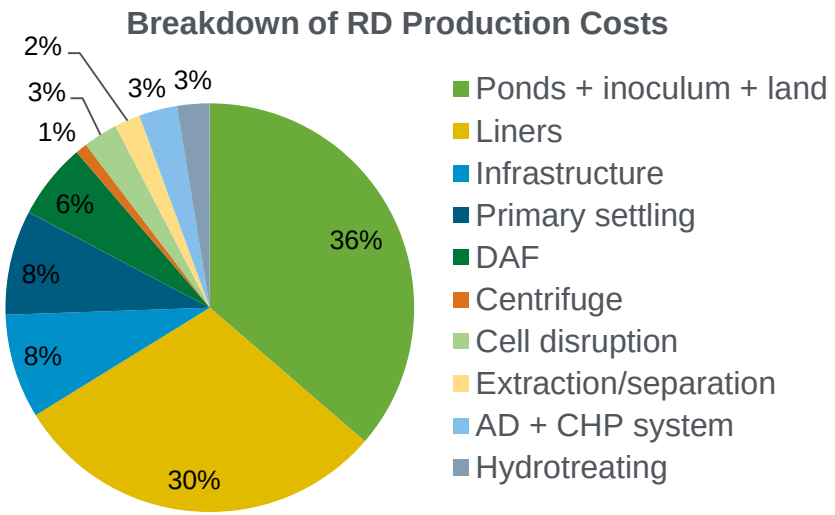
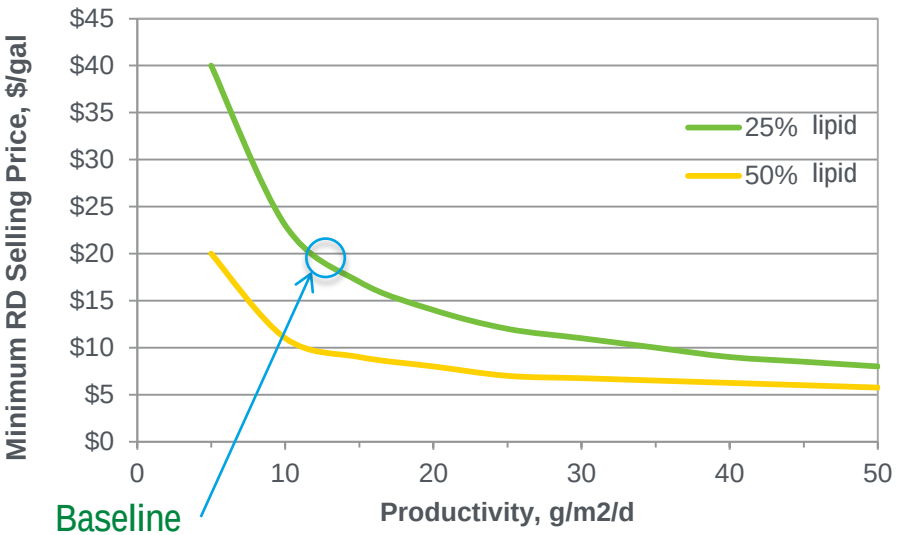
- The integrated baseline makes conservative assumptions on productivity, processing, and co-products:
  - Annual average productivity 13 grams/m2/day
  - 80% processing efficiency
  - No high-value co-products
- The baseline performance is highly uncertain and small changes in productivity have big 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

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- 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