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Advanced Biofuels Cost of Production

Aviation Biofuels Conference

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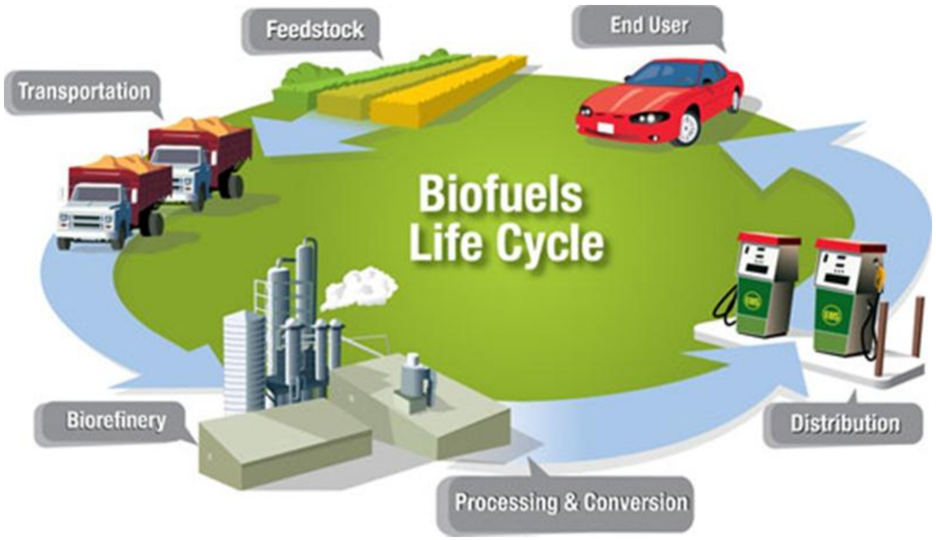
Introduction

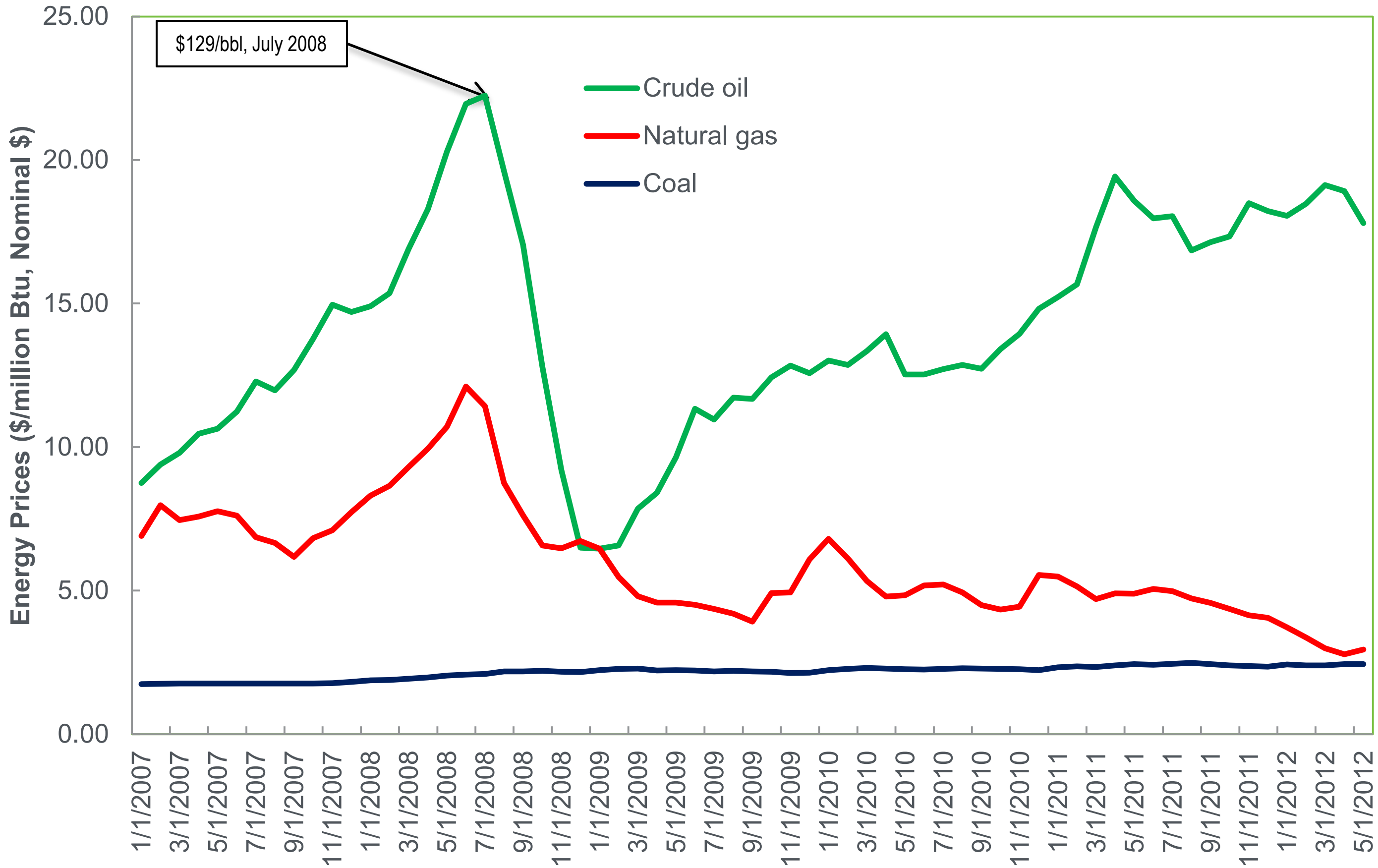
- Resource assessment – do we have enough biomass?
- Techno-economic analysis – can biofuels be produced at competitive prices?
- Sustainability – What are the greenhouse gas emissions?
- Integrated biorefineries – what is being funded at DOE and what are future plans?



Techno-Economic Analysis

- Citable source for budget justification
- 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?

Market Driver for Alternative Fuels – Energy Price Volatility



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

- Long term price trends indicate significantly higher value and price volatility for crude oil compared to natural gas or coal
- Military, aviation, marine, long-haul trucking, and long-distance rail have limited alternatives to liquid transportation fuels

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

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

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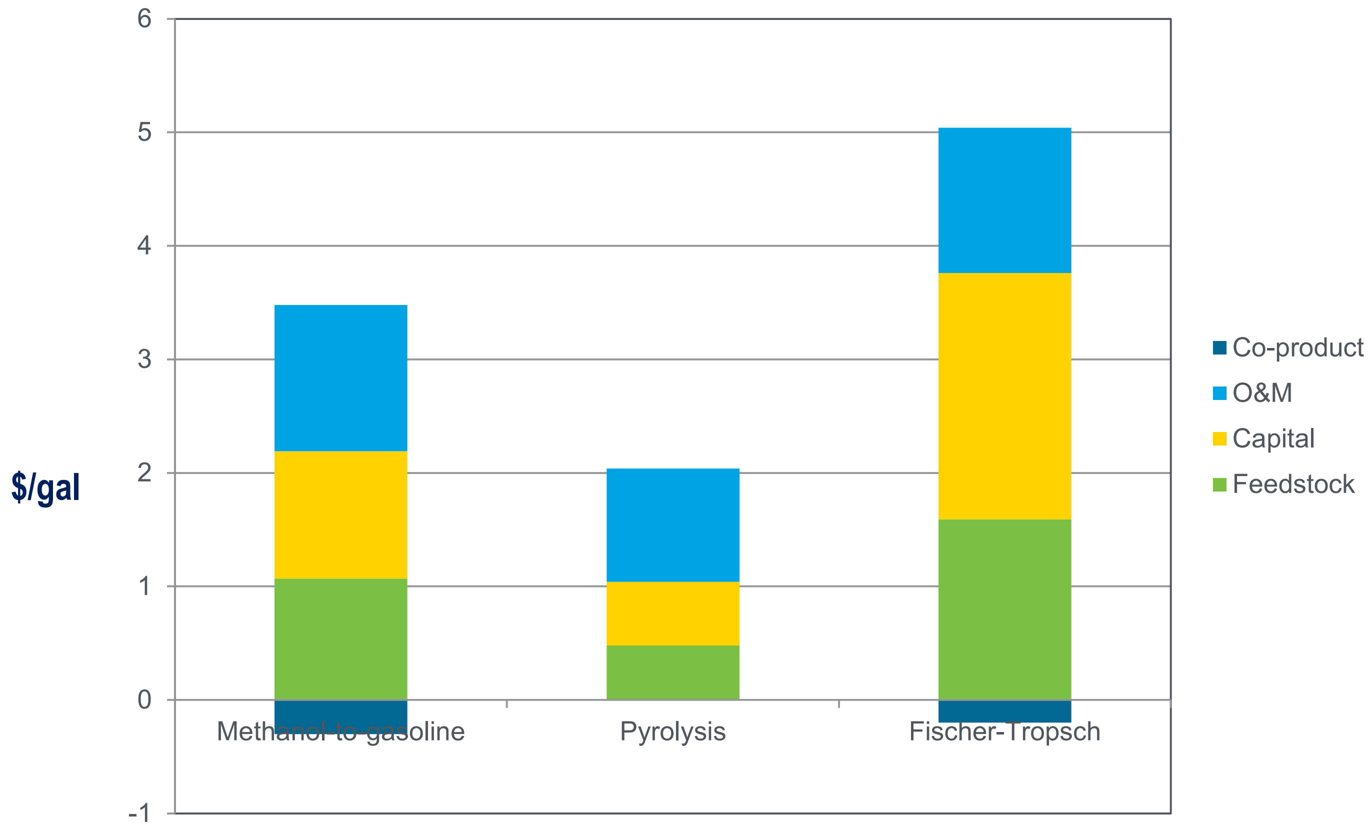

- Other economically viable technology routes for hydrocarbon biofuels exist, such as conversion of waste and plant oils, and sugar-to-hydrocarbons
- These costs are projected for the Nth Biorefinery Plant, after operation of initial commercial-scale Pioneer Plants

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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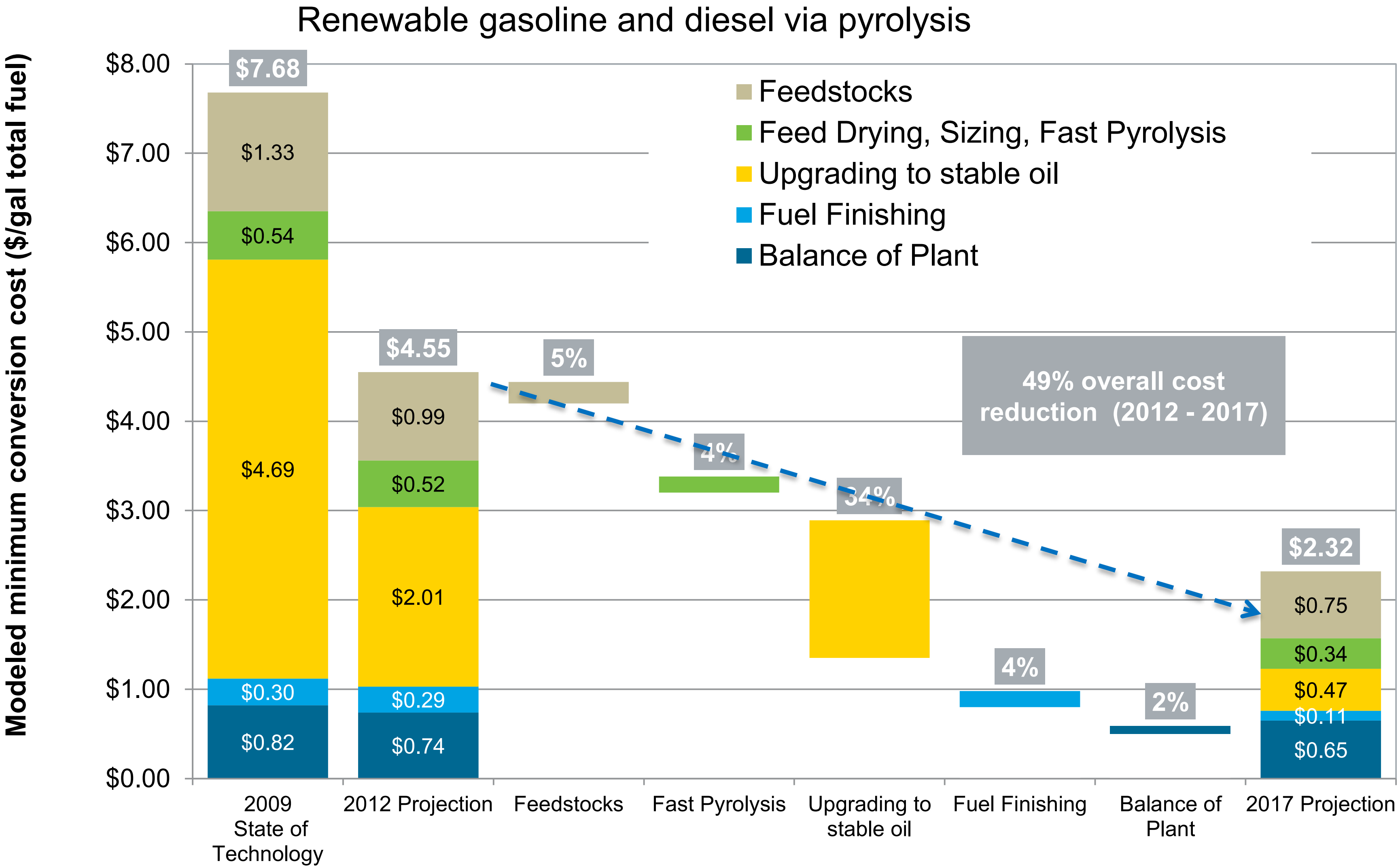

Pyrolysis costs by unit and projected cost reductions through R&D

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

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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

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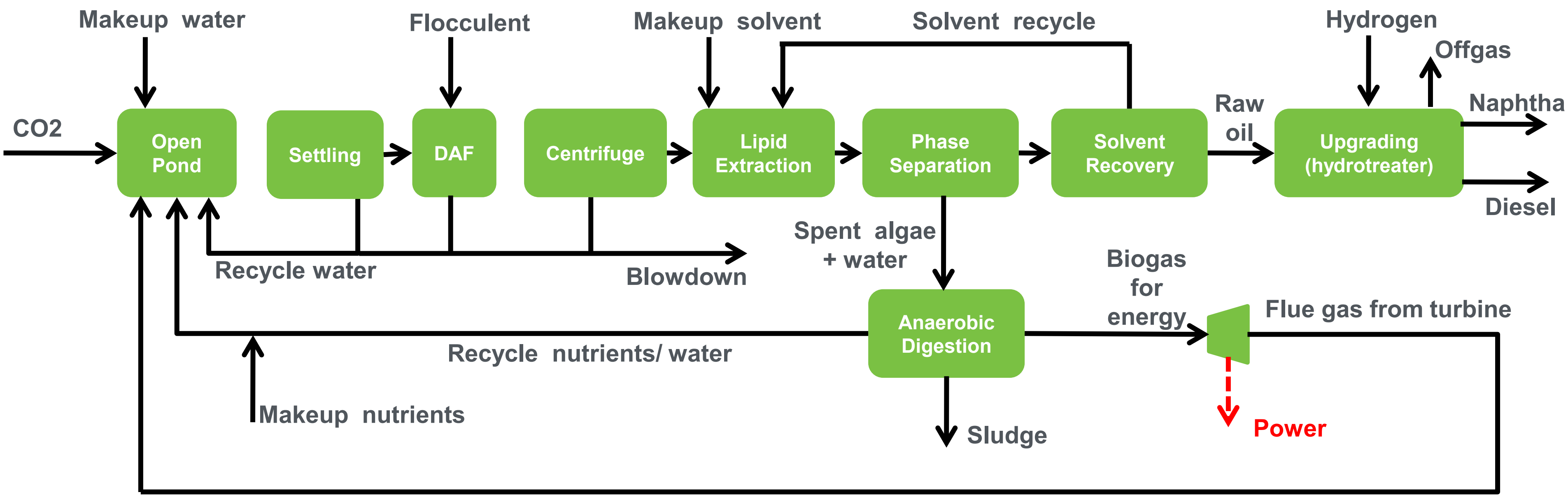

Green = algae cell density

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.