U.S. DEPARTMENT OF ENERGY BIOMASS PROGRAM

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

Biomass Program

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ABO Algae Biomass Summit
September 25, 2012

Biomass Program Priorities

The Biomass Program supports the following national priorities:

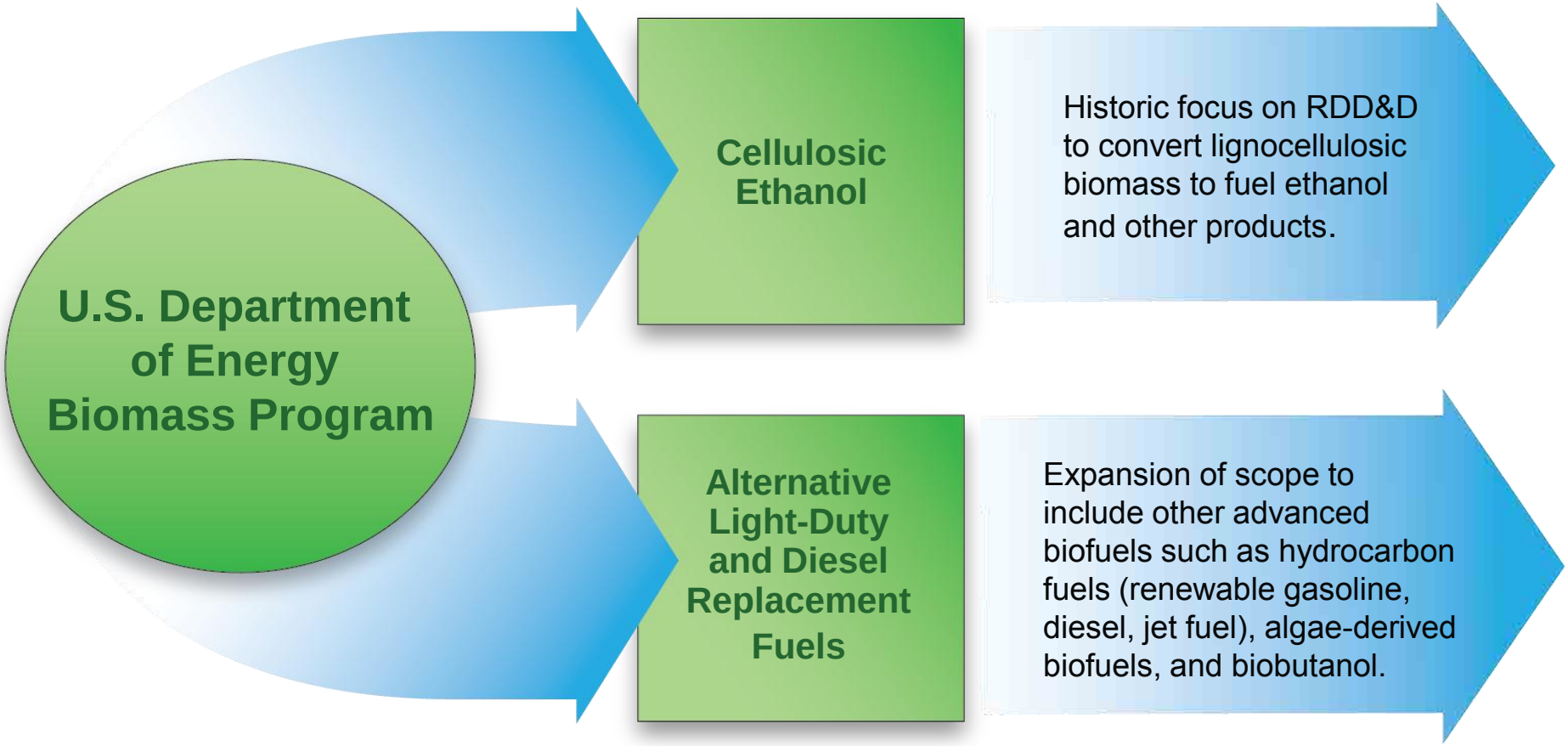
Dramatically reduce dependence on foreign oil

Promote the use of diverse, domestic, and sustainable energy resources

Establish an advanced bioindustry and stimulate economic growth

Reduce carbon emissions from energy production and consumption

Expansion of the Biomass Program's Scope



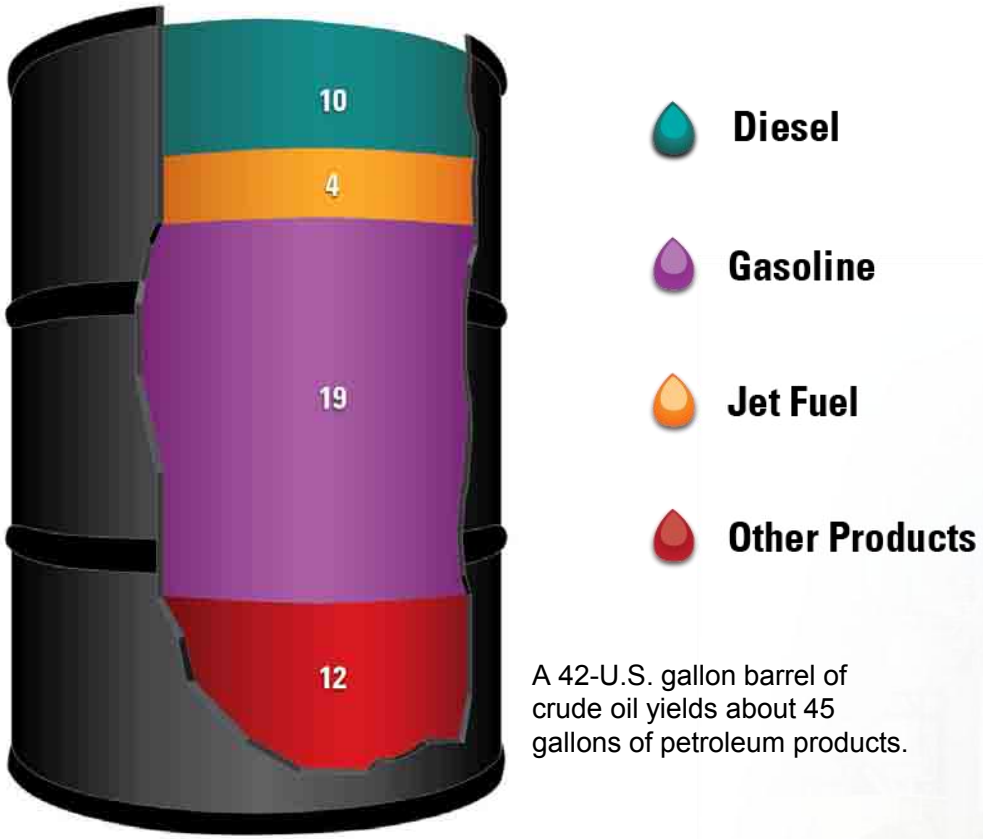
The Biomass Program forms cost-shared partnerships with key stakeholders to develop, demonstrate, and deploy technologies for advanced biofuels, bioproducts, and biopower from lignocellulosic and algal biomass.

Replacing the Whole Barrel

Greater focus needed on RDD&D for a range of technologies to displace the *entire* barrel of petroleum crude

- U.S. spends more about $1B each day on crude oil imports*
- Only about 40% of a barrel of crude oil is used to produce petroleum gasoline
- Cellulosic ethanol can displace gasoline fraction
- Reducing dependence on oil requires replacing diesel, jet, heavy distillates, and a range of other chemicals and products

Products Made from a Barrel of Crude Oil (Gallons) in 2010

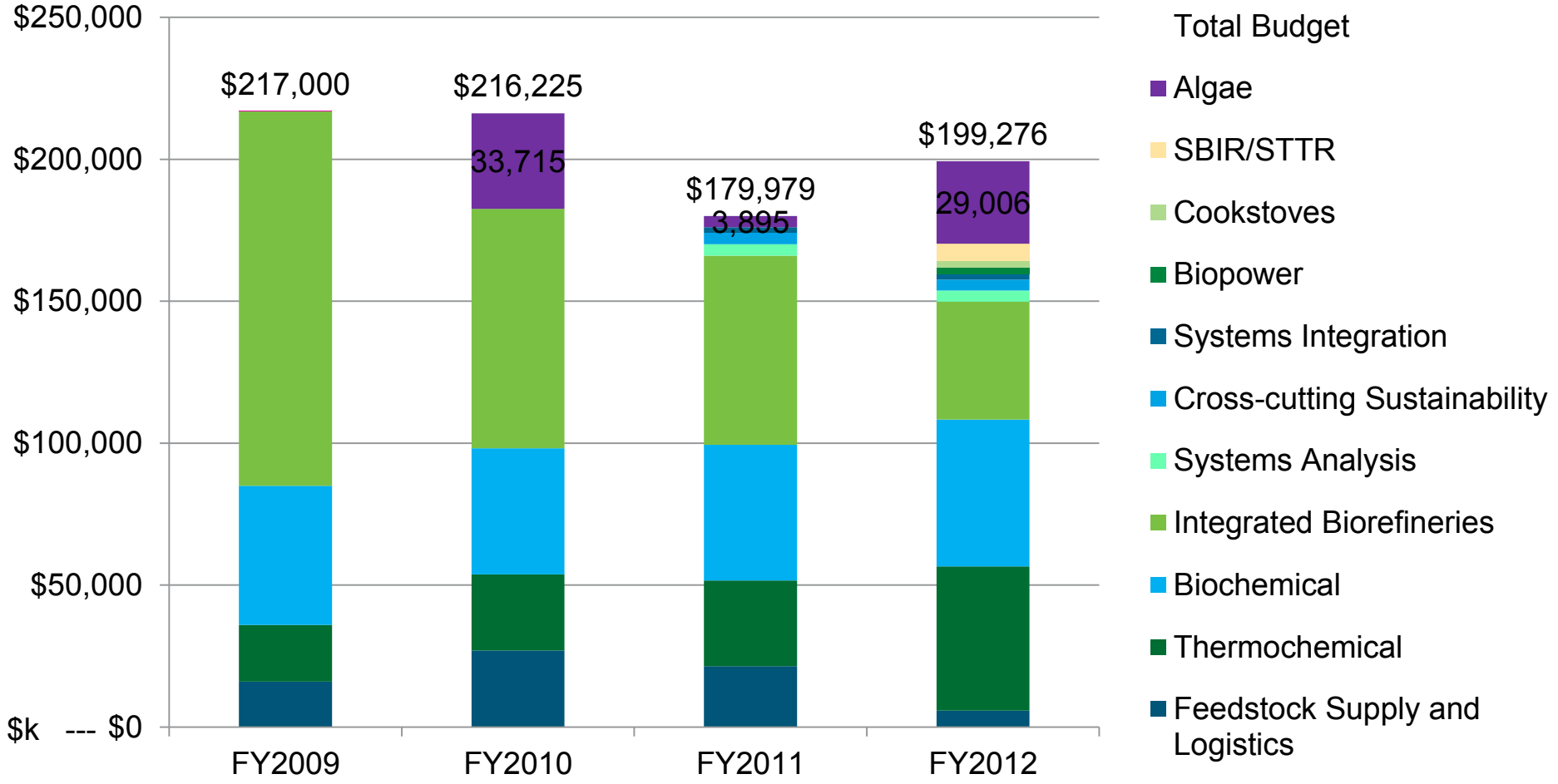


A 42-U.S. gallon barrel of crude oil yields about 45 gallons of petroleum products.

Source: Energy Information Administration

*American Petroleum Institute

Annual Appropriations



Conceptual Framework: Algae as Feedstocks

Sustainability and Analysis

Feedstock Production → Feedstock Logistics → Biofuels Production → Biofuels Distribution → Biofuels End Use

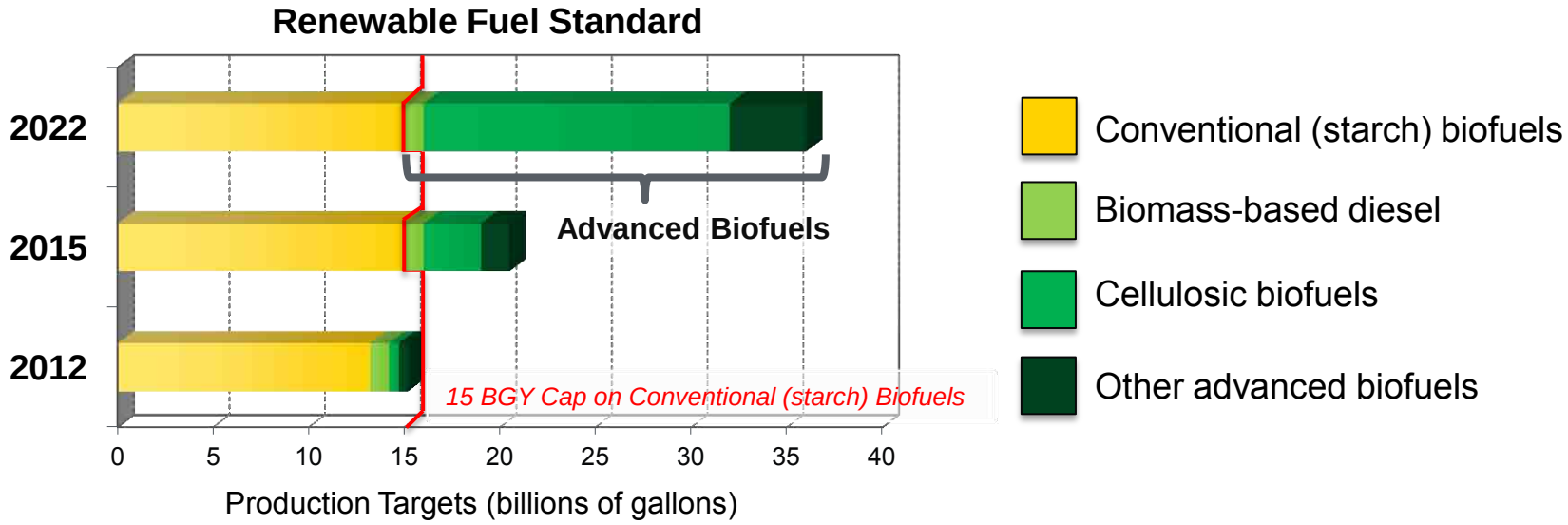
Key Policy Driver: Renewable Fuel Standard Program

The Energy Independence and Security Act (EISA) of 2007 sets aggressive goals:

- Move renewable fuels into the marketplace
- Reduce the nation's dependence on foreign sources of energy
- Reduce GHG emissions from the transportation sector.

EISA established production volumes for the Renewable Fuel Standard Program (RFS), increasing the supply of renewable fuels to 36 billion gallons by 2022.

The U.S. Department of Energy's (DOE) Biomass Program focuses on developing advanced biofuels to help meet the RFS goals.



Algae Platform: Two Goals

Identify sufficient national resources to sustainably produce at least **0.5 quads** of algae energy (equivalent to 5 billion gallons of "non-cellulosic advanced biofuels") as mandated by EISA Renewable Fuel Standards by 2022

- Sunlight
- Land
- Water
- Nutrient
- Siting

By 2022, develop, demonstrate and integrate algal biofuels technologies that are projected to be cost-competitive with conventional fuels (n^{th} plant modeled minimum fuel selling price)

- Scalability
- Productivity
- Sustainability

Algae History at DOE

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Aquatic Species Program (ASP) Legacy

- 1996: ASP closed out after 20 year research program. Demonstrated pathway to algal biodiesel at 2-3x cost of regular diesel

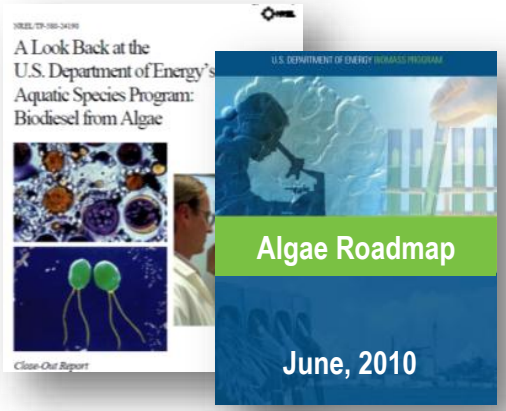
Biomass Program Algae Platform Development 2009-2012

- 2010: **Released** roadmap; **selected $74M** DOE value in R&D (Consortia Initiative) and **$100M** in D&D (IBRs) projects; **convened** National Academies to develop a Algal Biofuels Sustainability report
- 2012: **Selected for negotiation $15M** Advancements in Sustainable Algal Production (ASAP) FOA to establish algae user facilities; gather long-term, regionally specific cultivation data; and develop nutrient, water, and CO2 technology; **released $20M** Innovative Piloting FOA to support construction and operation of integrated pilot processes to create military-spec biofuels.

Ongoing Algae Strategic Planning efforts

- **Integrated baseline**: Technical Report "Renewable Diesel from Algal Lipids: An Integrated Baseline for Cost, Emissions, and Resource Potential from a Harmonized Model"
- **RFI** on establishing research plans for enhancing algae biomass yields through advanced biology and downstream processing

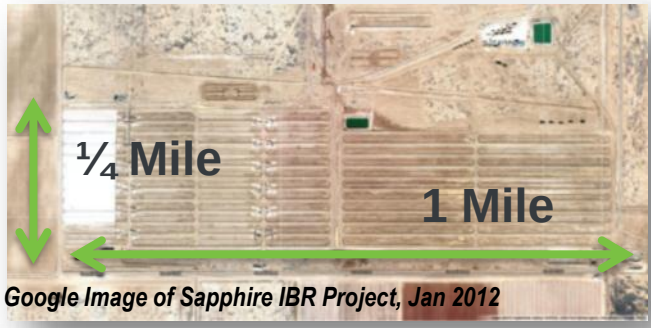
Roadmaps: ASP; Algae Roadmap Workshop



R&D: NAABB Consortium Kicks Off (2010)

(left to right: R. Sayre, W. Danforth, S. Chu)

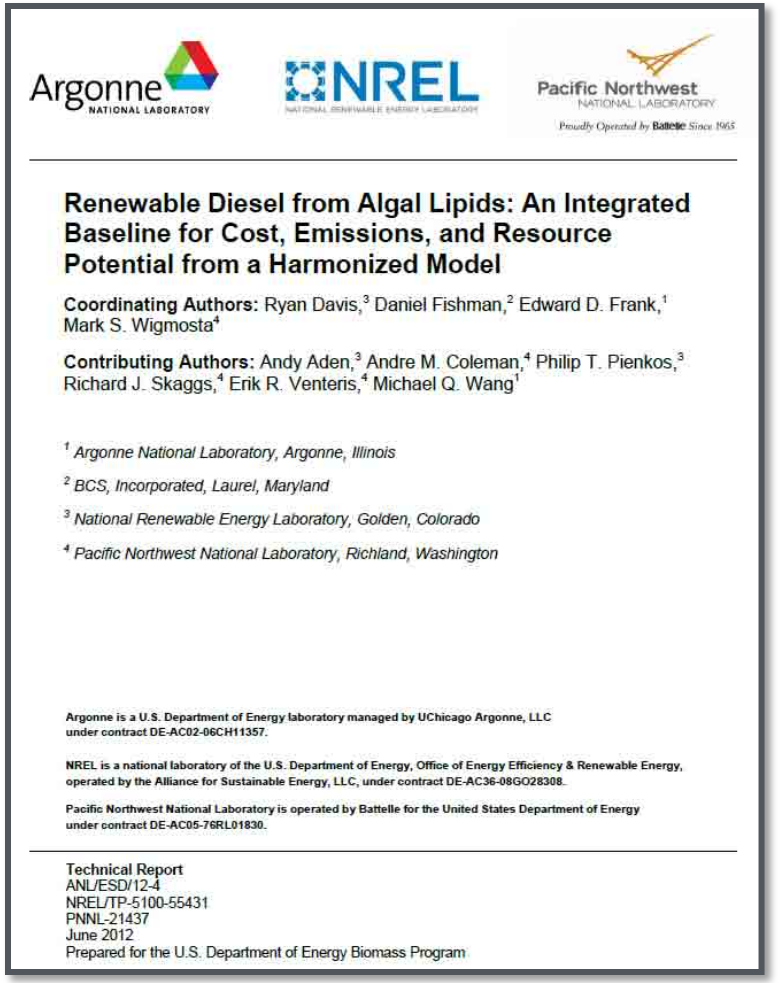
D&D: Sapphire IBR Scale-Up (2012)



Google Image of Sapphire IBR Project, Jan 2012

Algae Model Harmonization Initiative

- 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 | Pacific Northwest NATIONAL LABORATORY

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

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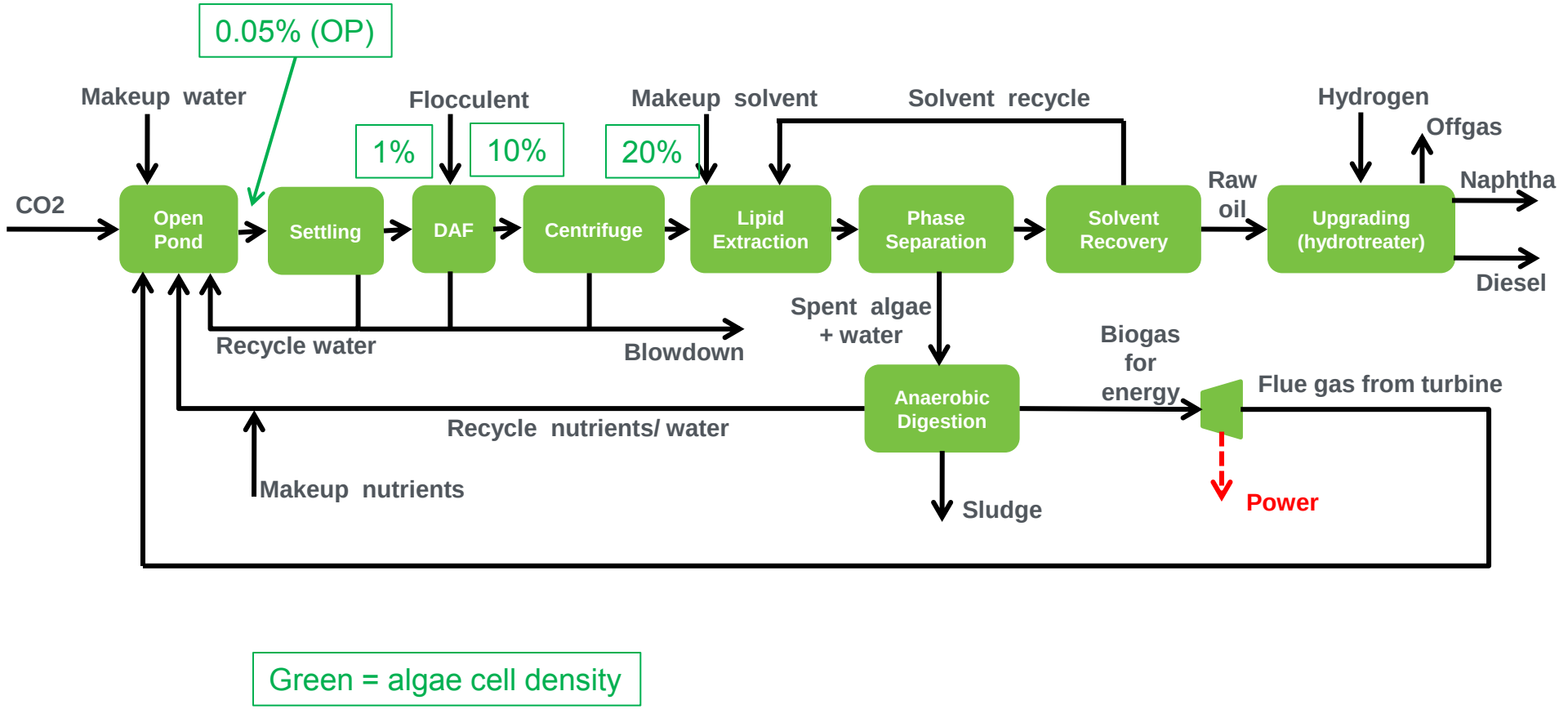
Argonne is a U.S. Department of Energy laboratory managed by UChicago Argonne, LLC under contract DE-AC02-06CH11357.

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



Green = algae cell density

Integrated Baseline - Process Performance and Sensitivity

The integrated baseline makes conservative assumptions on productivity, processing, and co-products:

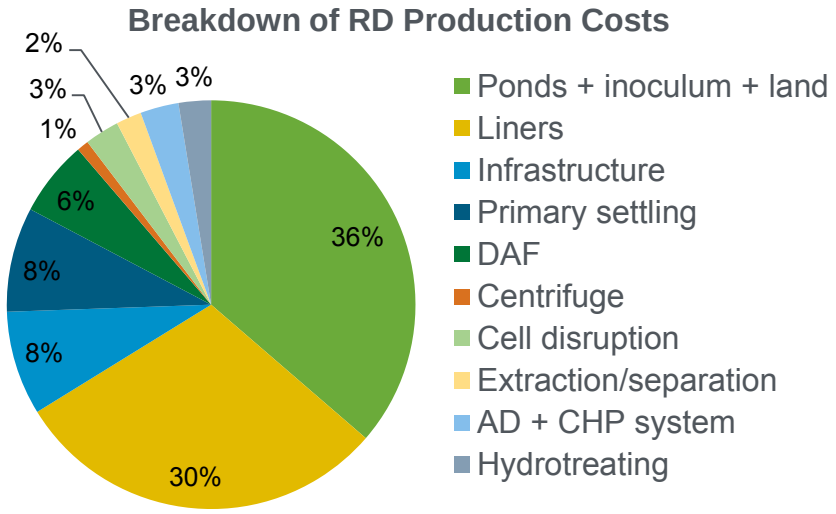
- Annual average productivity 13.2 g/m2/d
- 80% processing efficiency
- No high-value co-products

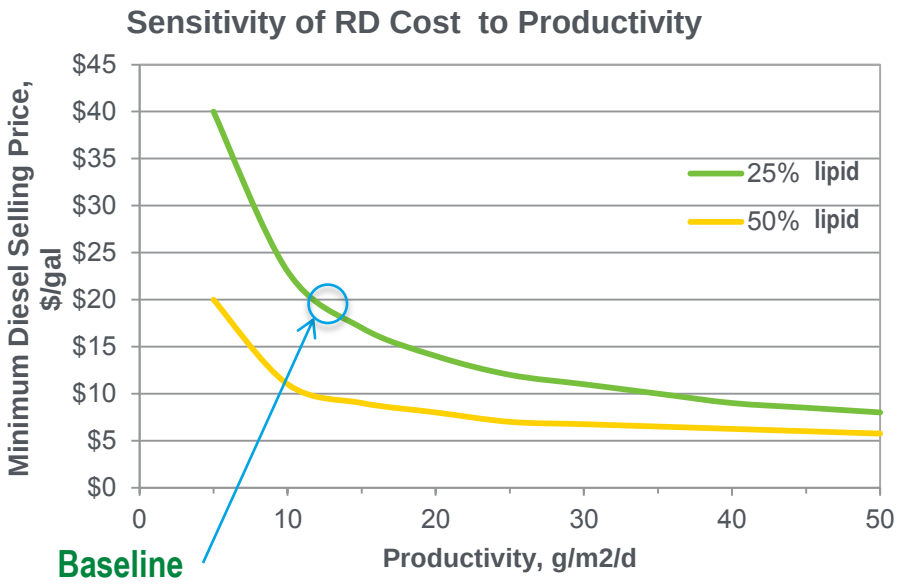
The baseline performance is highly uncertain and small changes in productivity have big impacts

Baseline assumption results:

- Minimum Selling Price: ~$20/gallon
- Emissions: 67,400 g cO2e/MMBTU RD
- Water: 195 gal / gal RD

Innovative work across the value chain is showing promise in reducing costs.





Algae R&D Consortia and ARRA IBR Projects

National Alliance for Advanced Biofuels and Bioproducts (NAABB)

Sustainable Algal Biofuels Consortium (SABC)

Consortium for Algal Biofuels Commercialization (CAB-Comm)

Cornell/Cellana Consortium

Sapphire Energy

Algenol Biofuels

Solazyme Inc.

2012 Project Selections: Up to $21M

Projects have been selected for negotiation under the FY12 Advancements in Sustainable Algal Production (ASAP) FOA

Nutrients & Water

- California Polytechnical Institute – up to $1.3M
  - "Recycling of Nutrients and Water in Algal Biofuels Production"
  - PI: Dr. Tryg Lundquist. Partners: MicroBio Engineering, Inc.
- University of Toledo – up to $3M
  - "Integration of Nutrient and Water Recycling for Sustainable Algal Biorefineries"
  - PI: Dr. Sridhar Viamajala. Partners: Montana State University; University of North Carolina; Logan City, UT; AAS LLC
- Sandia National Laboratories – up to $2.1M
  - "Major Nutrient Recycling for Sustained Algal Production" -
  - PI: Dr. Todd Lane. Partners: Texas Agrilife; OpenAlgae LLC

Testbed

- Arizona State University (AzCATI) – up to $8.3M for years 1&2 and $15M total
  - "Algae Testbed Public-Private Partnership (ATP3)"
  - PI: Dr. Gary Dirks.
  - Testbeds Locations: Arizona State University, CalPoly, Georgia Tech, Touchstone Research Laboratory (OH), Cellana (HI).

Enhanced Yields RFI & FY13 Plans

Algae plans to continue addressing challenges in biology, processing, and systems integration. Competitive FOAs encouraging integrated, scalable systems will continue to be a focus.

- Aggressive technical targets on biological and downstream processing yields:
  - 35 g / m2 / day biomass production in outdoor cultivation systems at commercially relevant scales
  - 40% reductions in operating and capital costs for downstream processing unit operation to harvest, dewater, and process algae biomass into intermediate products suitable for conversion to biofuel.

- Request for Information (RFI) issued this summer to gather stakeholder input on targets
  - 33 responses are being evaluated to help craft future research plans
  - RFI is closed, but OBP is still gathering input

- Budget situation uncertain, however the Biomass Program anticipates releasing a FOA in this area early in FY13

Thank You!

Questions?

Watch our news feed at www.eere.energy.gov/biomass for information of RFIs, funding, and conferences