BIOENERGY TECHNOLOGIES OFFICE (BETO)

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

Waste-to-Energy

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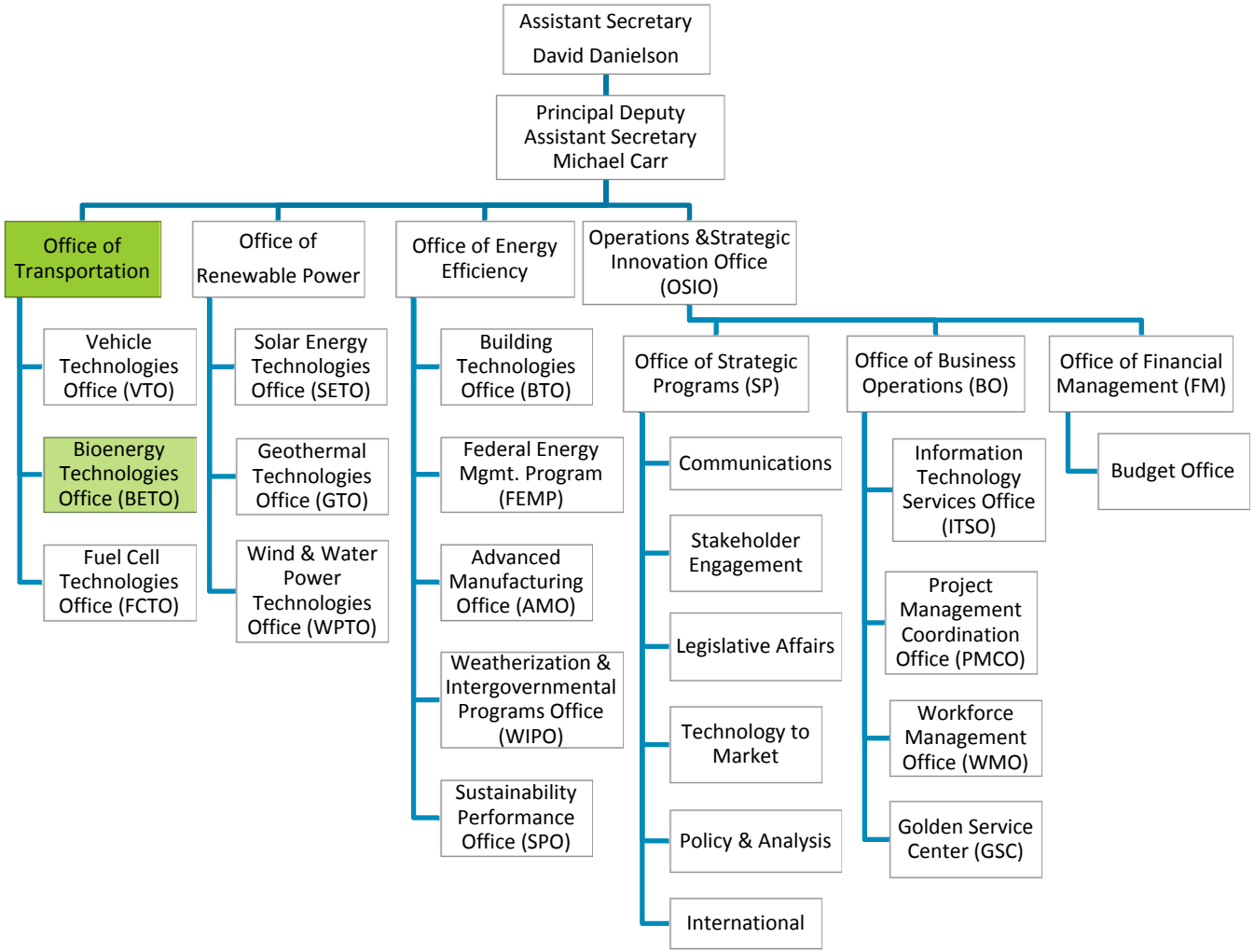
Outline

I. BETO Overview
II. Biosolids and Waste-to-Energy
III. Waste-to-Energy Technologies
IV. Waste-to-Energy Activities
V. Questions

EERE Organization Chart



Mission and Strategic Goal

Mission

Develop and transform our renewable biomass resources into commercially viable, high-performance biofuels, bioproducts, and biopower through targeted research, development, demonstration, and deployment supported through public and private partnerships.

Strategic Goal

Develop commercially viable biomass utilization technologies to enable the sustainable, nationwide production of biofuels that are compatible with today's transportation infrastructure and can displace a share of petroleum-derived fuels to reduce U.S. dependence on oil and encourage the creation of a new domestic bioenergy industry.

Performance Goals

- By 2017, validate a $3/GGE hydrocarbon biofuel (with ≥50% reduction in GHG emissions relative to petroleum-derived fuel) for a mature modeled price for at least one hydrocarbon technology pathway at pilot scale.
- By 2022, validate hydrocarbon biofuels production at >1 ton/day from at least two additional technology pathways at pilot or demonstration scale.

BETO's Core Focus Areas

Program Portfolio Management

• Planning • Systems-Level Analysis • Performance Validation and Assessment
• MYPP • Peer Review • Merit Review • Quarterly Portfolio Review
• Competitive • Non-competitive • Lab Capabilities Matrix

Research, Development, Demonstration, & Market Transformation

Feedstock Supply & Logistics R&D

- Terrestrial
- Algae
- Product Logistics Preprocessing

Conversion R&D

- Biochemical
- Thermochemical
- Deconstruction
- Biointermediate
- Upgrading

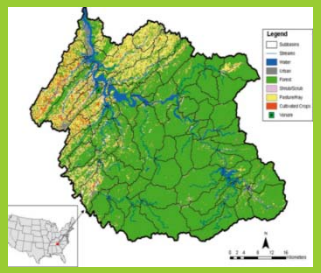
Demonstration & Market Transformation

- Integrated Biorefineries
- Biofuels Distribution Infrastructure

Cross Cutting

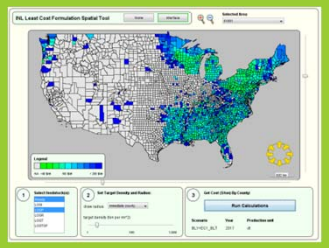
Sustainability

- Sustainability Analysis
- Sustainable System Design



Strategic Analysis

- Technology and Resource Assessment
- Market and Impact Analysis
- Model Development & Data compilation



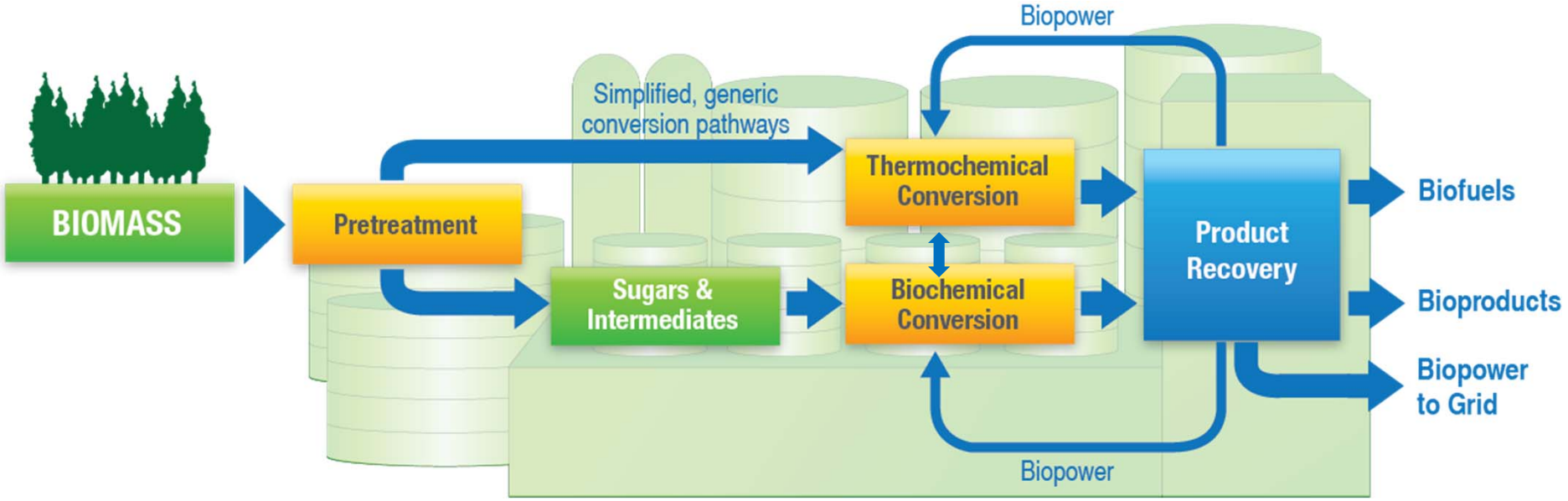
Strategic Communications

- New Communications Vehicles & Outlets
- Awareness and Support of Office
- Benefits of Bioenergy/Bioproducts

Key Challenge for Innovation Involves Lowering Risks

De-risking technologies is central to R&D through demonstration that addresses greater integration and scale:

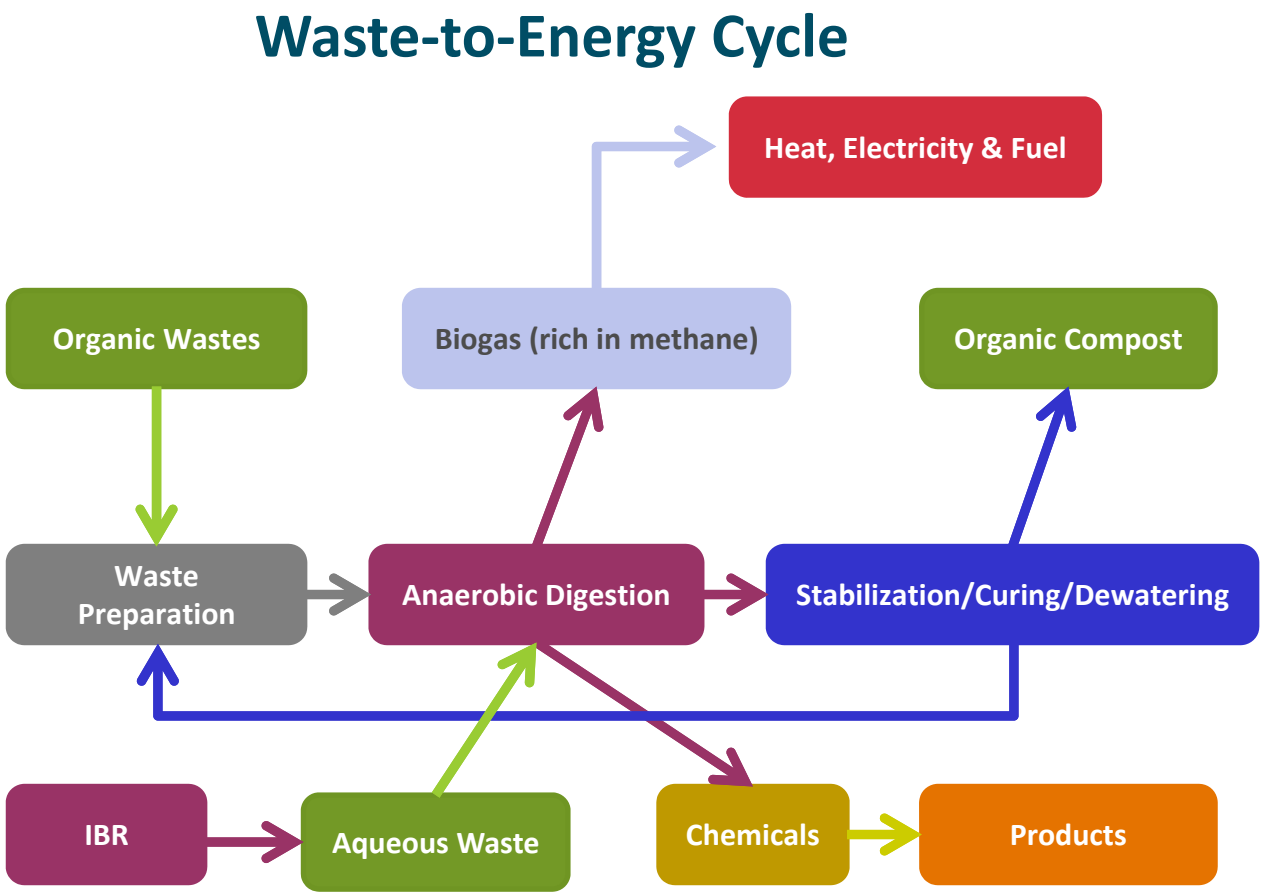
- BETO is focusing on advancing renewable gasoline, diesel, and jet fuels technologies.
- Technical, construction, operational and financial/market risks.



Key Challenges			
Biomass	**Pretreatment**	**Conversion**	**Product**
• Reliable supply • Consistent quality • Affordable delivery	• Biomass feeding, sizing and moisture • Solids handling • Construction materials	• Products Yields • Construction materials • Catalysts • Fermentation organisms	• Separations • Catalytic upgrading • Recycle loops

BETO's Waste-to-Energy (WTE) Efforts

There is a significant near-term market entry opportunity to deploy WTE technologies in the U.S., specifically with regard to anaerobic digestion at landfills to recycle organic waste biomass into renewable energy, thereby enabling a national network of distributed power and biofuel production sites.



Waste streams that could be considered for use include:

- Municipal solid waste
- Landfill gas
- Waste streams from waste water treatment plants (WWTPs)
- Bio-solids (from thermochemical or biochemical biofuel pathways)

The DOE Loan Guarantee Office released a Renewable Energy and Energy Efficiency Solicitation for a public comment period. The solicitation is expected to provide as much as $2.5 billion in loan guarantees for commercial financing of technologies that avoid, reduce, or sequester GHG emissions. "Waste-to-Energy" is included in the list of eligible project types to be considered.

Image courtesy of Iona Capital

Biogas and Biosolids

Biogas

- Biogas can be used to produce electricity and can often offset all electricity needed to run the processing facility, especially in WWTPs, where the waste stream has high energy content.
- Process provides useful methane source for CHP, which would otherwise be flared or released into the atmosphere, and remaining bio-solids can be used as valued-added soil amendment.
- Producing energy from biogas expands the suite of products from biorefineries, municipalities, and agricultural operations and has the potential to increase revenue and reduce GHG emissions.
- Biogas can be an input to conversion processes to produce other chemicals of higher value.

Biosolids

- Biosolids are the nutrient-rich organic materials resulting from the treatment of sewage sludge (EPA).
- Biosolids, which are rich in nitrogen and phosphorous, are readily used as soil amendments.
- Approximately 7.1 million dry tons generated annually in the U.S.
- Successful technology development could open the door to conversion of other waste materials, e.g., dairy waste, to value-added products.
- Current management options: landfilling, combustion/incineration, and soil amendment.
- New options could: address environmental issues, provide value-added products (fuels, chemical intermediates), improve biorefinery economics (low cost or “tipping” fee), reduced potential for water contamination.

Waste to Energy

BETO's Interest in Waste to Energy

- Key Wet Waste Streams to Target in the U.S. would include:
  - Food Scraps: 35.2 million tons wasted in 2014

    2014 Opportunity: 71.4 TBtu

    2030 Opportunity: 80.5 TBtu
  - Biosolids: 3.9 million dry tons wasted in 2014

    2014 Opportunity: 27.3 TBtu

    2030 Opportunity: 30.8 TBtu
- BETO is interested in potentially supporting technologies that can handle diverse wet waste streams, complementing ongoing work in other agencies and teams focused on dry and single source waste streams.
- A key outcome of this research would be a technically and economically validated WTE conversion processes ready for pilot scale testing.

Biogas Roadmap From the White House

The *Biogas Opportunities Roadmap* identifies voluntary actions that can be taken to reduce methane emissions through the use of biogas systems and outlines strategies to overcome barriers to a robust biogas industry in the United States. In order to realize these opportunities, the Federal government will take the following actions:

- Promote biogas utilization through existing agency programs by ensuring that existing criteria for technical and financial assistance considers the benefits of biogas systems.
- Foster investment in biogas systems by improving the collection and analysis of industry financial and technical data.
- Strengthen markets for biogas systems and system products by reviewing opportunities to overcome barriers to integrating biogas into electricity and renewable natural gas markets.
- Improve communication and coordination across federal agencies by establishing a Biogas Opportunities Roadmap Working Group.

BCU Selection Announcement

On October 9th, DOE announced up to $13.4 million for five projects to develop advanced biofuels and bioproducts that will help drive down the cost of producing gasoline, diesel, and jet fuel from biomass.

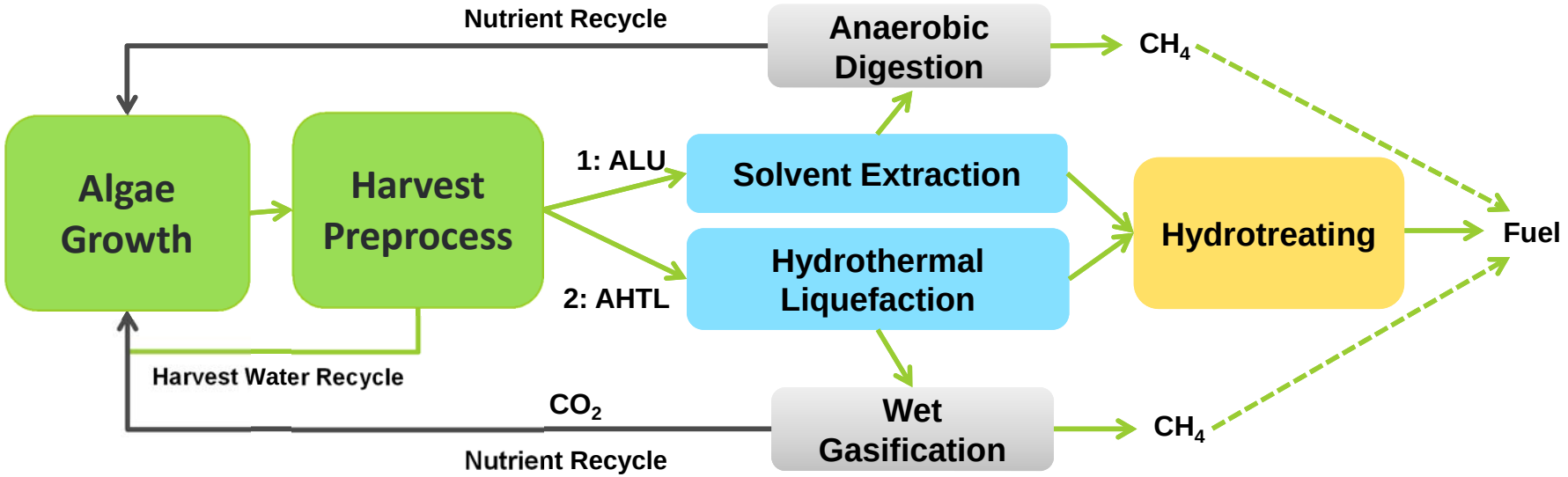
- **The University of Wisconsin** of Madison, Wisconsin will receive up to $3.3 million to develop a process to produce high value chemicals from biomass, which can be used as plasticizers (an additive in certain plastics) and in the production of industrial chemicals and resins.
- **American Process, Inc.** of Atlanta, Georgia will receive up to $3.1 million to develop and demonstrate processes to upgrade cellulosic sugars to solvents in their demonstration facility.
- **The National Renewable Energy Laboratory** of Golden, Colorado will receive up to $2.5 million to develop a conversion process demonstrating the production of muconic acid from biogas. This acid can be converted into an array of bioproducts, including fuel, plasticizers, and lubricants.
- **Natureworks, LLC** of Minnetonka, Minnesota will receive up to $2.5 million to develop a fermentation process, using biogas and bacteria, for the production of lactic acid. This process could be used for the commercialization of biomethane to fuels.
- **Vertimass LLC** of Irvine, California will receive up to $2 million to commercialize technology to convert ethanol into diesel fuel, gasoline, and jet fuel blend stocks compatible with the current transportation fuel infrastructure.

Benchmarking Progress: Algae Technology Pathway Baselines

High Priority Pathways

- Advanced algal lipid extraction and upgrading (ALU).
- Whole algae hydrothermal liquefaction and upgrading (AHTL).

Pathways analysis will result in national laboratory-led design case studies for the BETO to benchmark progress towards $3/gallon algal biofuel.



Hydrothermal Liquefaction of Whole Algae

HTL of whole algae results in high yield of biomass to bio-oil which can be upgraded using commercial HT catalysts. Potential to use fast growing, low lipid accumulating algae.

Description	%
Lipid content of whole algae	33%
Bio-oil from HTL as % algae AFDW*	64%
% of algae carbon in HTL oil	69%

Description	C%	H%	O%	N%	S%	Ash
Whole Algae	55.9	8.3	23.7	4.1	0.6	7.4
HTL oil	77.9	10.2	5.0	*4.6*	*0.42*	*0.10*
Upgraded HTL	84.5	14.1	0.8	*<500ppm*	*<50ppm*	*nd*

Elliott, D. and Oyler, J. (2012). Hydrothermal processing: Efficient production of high-quality fuels from algae. *2nd International Conference on Algal Biomass, Biofuels and Bioproducts*, San Diego, CA, June 2012.

Baseline and Projections: HTL Pathway

- A major NAABB Consortium breakthrough is a new technology pathway which implements the hydrothermal liquefaction (HTL) of whole wet algae biomass.
- HTL avoids the steps of biomass drying and solvent extraction of lipids, and is ideal for lower lipid content strains as well as algae cultures of more than one strain.
- The Pacific Northwest National Lab HTL Design Case shows pathway to high-impact algal biofuel, projecting a $4.49 per gallon gasoline equivalent price by 2022.

Whole Algae HTL

- 40-70% of the carbon in algae captured in oil.
- Carbon retained during hydrotreating (70-90 wt%)
- Waste-water cleanup captures additional carbon as biogas.

Photo courtesy of PNNL

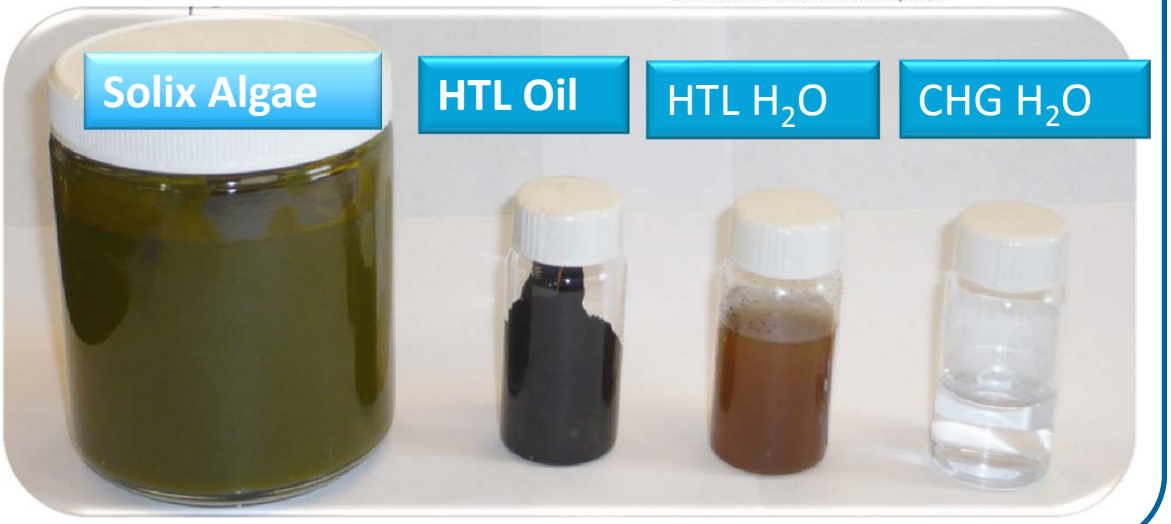
Source: Process Design and Economics for Conversion of Algal Biomass to Hydrocarbons: Whole Algae Hydrothermal Liquefaction and Upgrading, Pacific Northwest National Laboratory, March 2014. http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-23227.pdf

Catalytic Hydrothermal Gasification

Description of CHG

- "Sister technology" to Hydrothermal liquefaction (HTL)
- Can be used on any organic rich aqueous stream
- Produces methane gas rather than oil (catalytic action)
- Compact means to do "digestion" providing a high quality gas (CH_4/CO_2) without residual sludge
- Provides potential to recycle nutrients in biomass

Samples of Materials



PNNL Mobile Unit

Partners

Reliance Industries Limited

Genifuel

UOP A Honeywell Company

IBR in HI

Demonstration Portfolio – Selected Project

INEOS, Vero Beach, Florida

- Expected to produce 8 million gallons per year of cellulosic ethanol and 6 MW of power from wood and vegetative waste, including palm fronds.
- DOE Share = $50M; Cost share = $82M.
- Created 400 construction jobs; 65 permanent jobs are expected for operation.
- Major construction began in October 2010, commissioning was completed in June 2013, and the facility initiated commercial production of cellulosic ethanol in July 2013.
- First commercial production of cellulosic ethanol in the United States.
- A technology process to utilize the fermentation of syngas to alcohol.

Defense Production Act (DPA) Initiative

In July 2011, the Secretaries of Agriculture, Energy, and Navy signed a Memorandum of Understanding to commit $510 M ($170 M from each agency) to produce hydrocarbon jet and diesel biofuels in the near term. This initiative sought to achieve:

- Multiple, commercial-scale integrated biorefineries
- Cost-competitive biofuel with conventional petroleum (without subsidies).
- Domestically produced fuels from non-food feedstocks.
- Drop-in, fully compatible, MILSPEC fuels (F-76, JP-5, JP8).
- Help meet the Navy's demand for 1.26 billion gallons of fuel per year.
- Contribute to the Navy's goal of launching the "Great Green Fleet" in 2016.
- Demonstration of the production and use of more than 100 million gallons per year will dramatically reduce risk for drop-in biofuels production and adoption.

On September 19th, three projects were selected for construction and commissioning:

Company	Location	Feedstock	Conversion Pathway	Capacity (MMgpy)
Emerald Biofuels	Gulf Coast	Fats, Oils, and Greases	Hydroprocessed Esters and Fatty Acids (HEFA)	82.0
Fulcrum BioEnergy	McCarran, NV	Municipal Solid Waste	Gasification – Fischer Tröpsch (FT)	10.0
Red Rock Biofuels	Lakeview, OR	Woody Biomass	Gasification – Fischer Tröpsch (FT)	12.0

Questions?