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DOE Bioenergy Technologies Office - IBR Project Peer Review March 24, 2015

Ed Legere, Founder, Executive Vice President and Principle Investigator

Algenol Integrated Biorefinery (IBR)

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Goal Statement

- The goal of the Algenol Integrated Biorefinery project is to prove the commercial viability of the bioconversion of industrial waste CO_2 into liquid transportation fuels in enclosed photobioreactor systems utilizing a proprietary metabolically enhanced algae as a biocatalyst using the sun as the primary energy source

- The Algenol IBR project provides the DOE with data to evaluate enclosed photobioreactor systems and metabolically enhanced algae for use in bioenergy production and Carbon Capture and Utilization

- The bioenergy industry needs a broad range of low carbon impact technologies that can utilize diverse feedstocks and operate in various climates in order to meet the energy demands of the marketplace

- Bioenergy is a high technology industry in which the U.S. holds an un-paralleled technological superiority in the world. Bioenergy can be a major factor in the reduction of CO_2 emissions while helping to provide energy independence for the United States. Algenol has supplied the DOE with extensive information about its advanced technology.

Quad Chart Overview

Timeline

- Project Dates:
- BP-1 start date: 01/2010
- BP-2 start date: 08/2011
- 95% Complete thru 02/2015
- BP-3 start date: Target 03/2015

Barriers

- Low productivity in horizontal oriented cultures
- Vertical PBR system design and manufacture
- Genetic stability of production organisms
- Contamination control in large cultures

Budget

	Total Costs FY 10 –FY 12	FY 13 Costs	FY 14 Costs	Total Planned Funding (FY 15-Project End Date
DOE Funded	$24,081,431			$250,000
Project Cost Share (Comp.)*	$6,141,130	$6,459,664	$5,284,108	$8,954,091

Partners

- PNNL – Hydrothermal Liquefaction
- DOE – Donated used Hydrothermal Liquefaction unit to Algenol for IBR
- Leading plastics manufacturers
- Plastics welding equipment manufacturers
  - [illegible]

1 - Project Overview

- Location: Southwest Florida Coast
  - IBR - Fort Myers, FL
- Feedstocks
  - CO2 – Purchased from local supplier (Industrial grade)
  - Saltwater – Well on site
  - Sunlight
- Conversion Technology – Direct to Ethanol®
  - Hybrid Algae – Metabolically enhanced cyanobacteria (blue-green algae)
  - Directly connecting photosynthetic (Calvin Cycle) sugar production with ethanol fermentation
- Product Purification
  - 1st stage – Proprietary Vapor Compression Steam Stripper (VCSS)
  - 2nd stage – Molecular sieve – and evaluation of MTR membrane system
- Scale
  - Up to 2 tonnes CO_2/Day
  - Up to 18,000 gallons fuel grade ethanol per year
  - Up to 3,000 gallons of greencrude per year

1 - Project Overview

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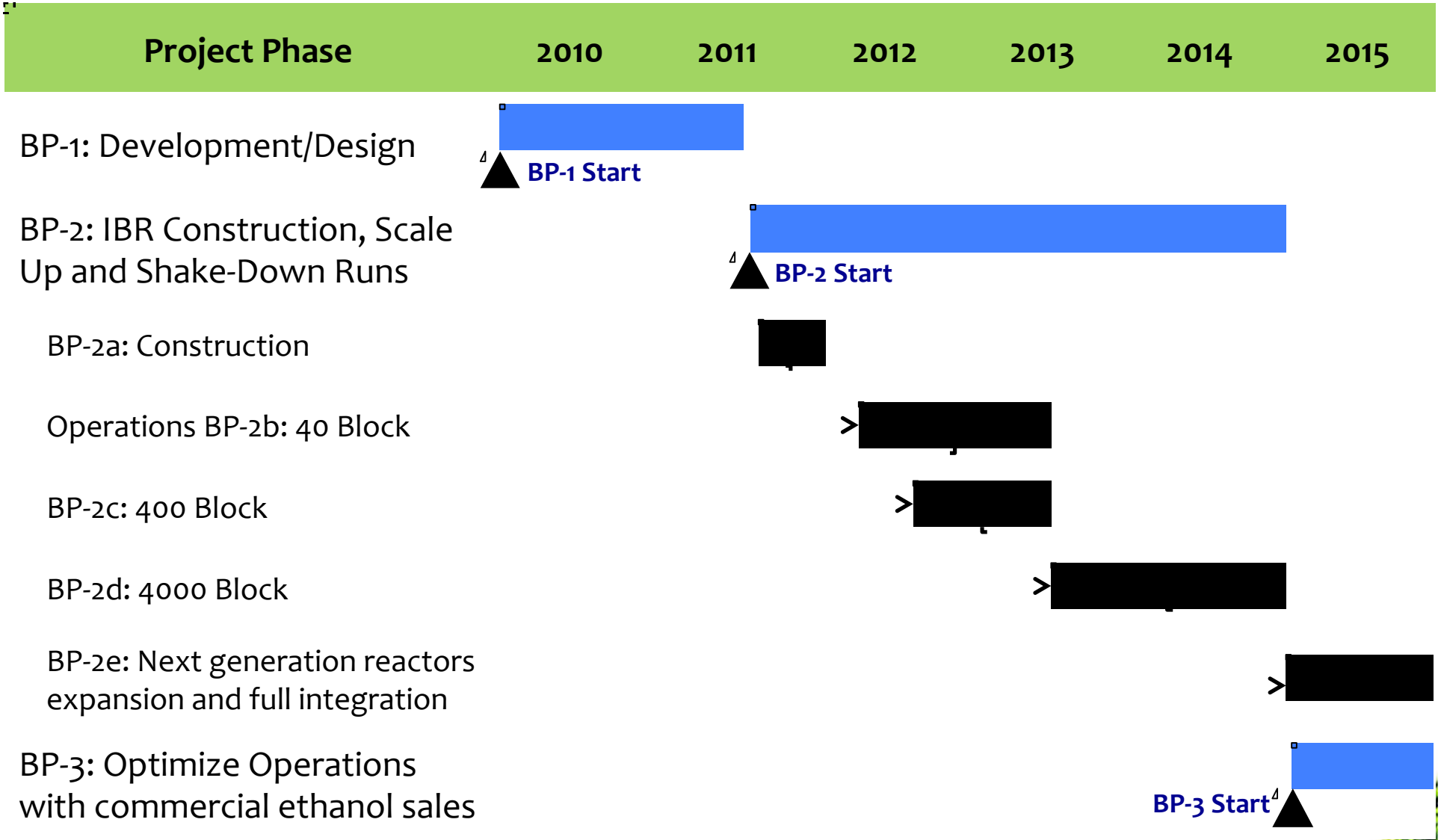

1 - Project Overview

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2 – Approach (Technical)

- Use IBR construction and operation as a cost baseline
  - Used step wise scale up factors to gain operational experience at small scale before advancing to larger scale
  - We successfully scaled up to expected commercial scale
- Use Techno Economic Model to determine areas of highest importance for further research and development to lower capital and operating costs
  - Ethanol productivity
  - Photobioreactors (PBRs) and related costs
  - Longer batch durations – production organism genetic stability
  - Clean in Place procedures
- Research findings are validated at lab scale and at our outdoor Process Development Unit (PDU)
  - We have developed lab scale PBRs that accurately predict expected outdoor results
  - We have developed a process for collecting flue gas from anthropogenic sources to be tested in our labs
  - All process changes are vetted at scale at the PDU and detailed SOPs are developed prior to being transferred to the IBR

2 – Approach (Management)

- Algenol's DOE program is managed using multi-functional project teams
- Internal Technical Committee (ITC) has overall project responsibility and authority
  - Project teams have specific goals and objectives for each budget period that are approved by the ITC
  - Goals and Objectives are reviewed bi-weekly and tracked monthly
- The Project is managed using a Gate Review Process for each budget period
  - The ITC reviews pre-specified goals for each budget period
- The Algenol project is broken down into phases separated by evaluations at major decision points
  - ITC reviews have been and will continue to be conducted at key project phases
- Overall project and technology risk is managed by deploying the project in stepwise expansions and summarized in the risk management plan (RMP)
  - Technology is stepwise de-risked by modular deployment of capacity
  - Opportunity for demonstration of improved technology and yield in subsequent phases is assumed

3 – Technical Accomplishments

- Construction of commercial scale 2 acre PBR system approaching completion
  - 6120 PBRs
  - Full integration of all processes
    - Ethanol dehydration
    - Greencrude production
- Operated 4000 photobioreactor system for over 500 days
  - Developed low cost CO_2 delivery method suitable for commercial production
  - Developed robust Clean in Place (CIP) process that allows batch to batch consistency
- Next generation PBR production system developed
- Lower cost system is 3x larger than prior generation reactors
  - Commercial PBR manufacturing system has been developed and is now in operation at our production facilities
- Significant improvements in manufacturing quality, brought in house all photobioreactor manufacturing
  - Reduced failure rate to under 1%
  - Dramatically lowered costs

3 – Technical Accomplishments

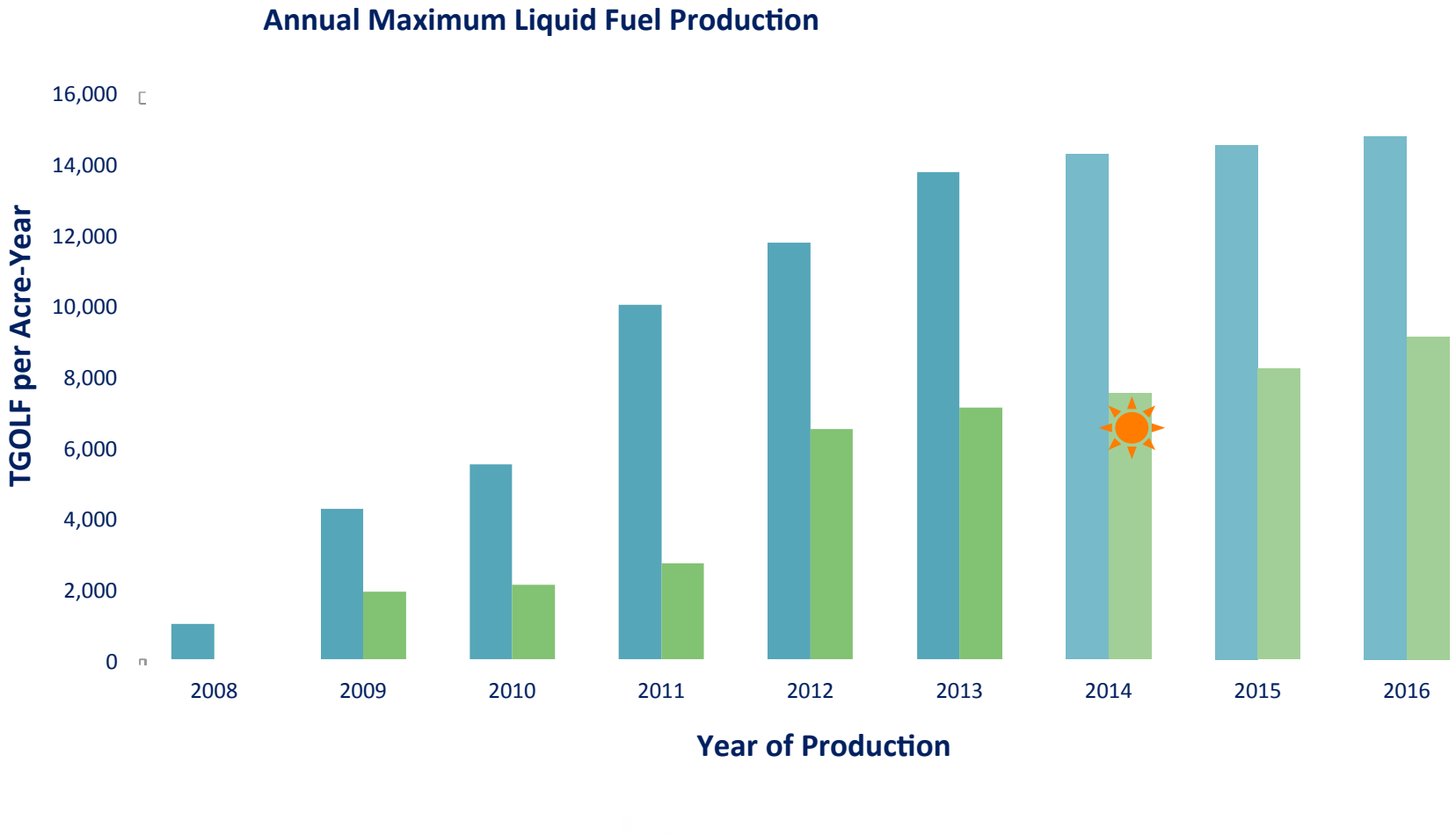
- Increased genetic stability of commercial production strain
  - Demonstrated genetic stability for over 120 days of production
  - Permits more efficient algae culture operations
- Commercial production strain converts extraordinary amount of carbon into fuel
  - +80% carbon branching into ethanol
- Successful creation of antibiotic resistance-free ethanologenic AB1 strains

3 – Technical Accomplishments

- Evaluated processes for conversion of algae biomass to greencrude
  - Hydrothermal liquefaction (HTL) process developed by Pacific Northwest National Labs (PNNL)
  - DOE donated used HTL skid to Algenol
  - Completely refurbished unit and it is being brought on line
- Evaluated numerous algae separation technologies for commercial viability
  - Commercial centrifuge system is best option
  - Also evaluating membrane dewatering pre-step for commercial viability
- Refurbished proprietary Vapor Compression Steam Stripper (VCSS) unit for saltwater feeds
  - Saltwater supernatant from PBRs can be fed directly from the centrifuge into the system
  - Operations have begun on the system

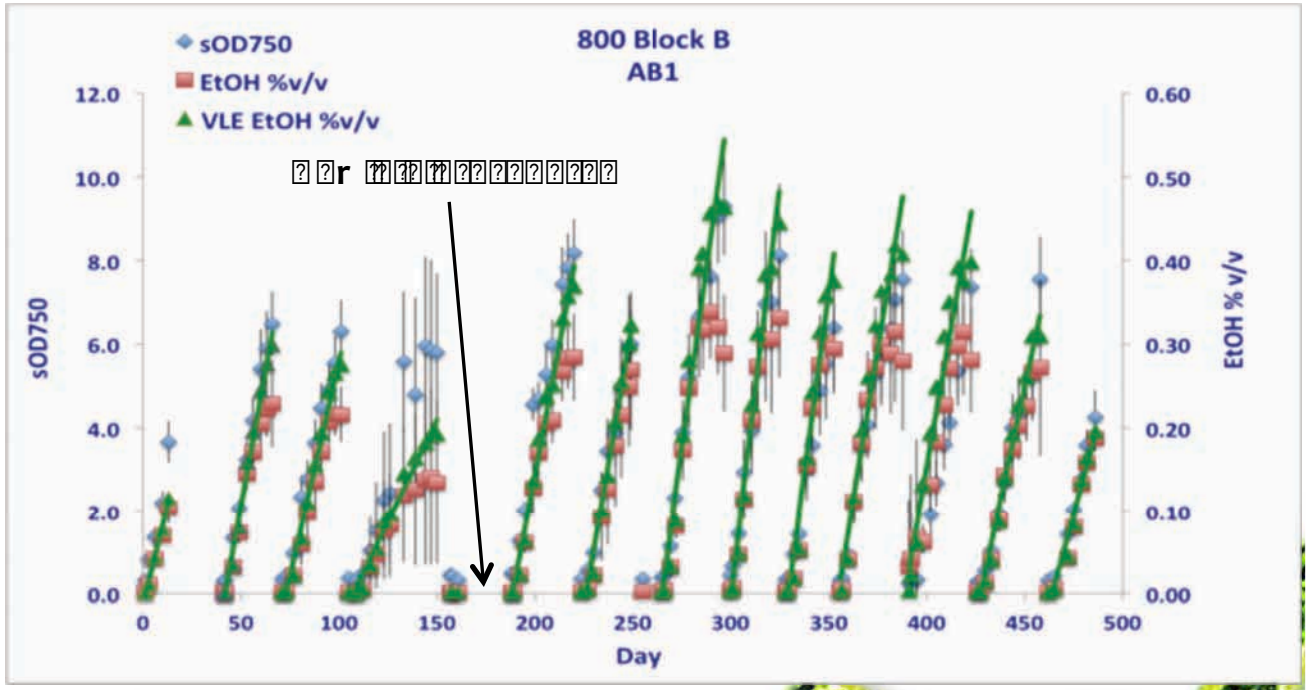
3 – Technical Accomplishments

- Enhanced Algae - Increasing Productivity



3 – Technical Accomplishments

- IBR Accomplishments
  - >500 days of operation - 69 inoculations, 65 CIPs
  - Demonstrated ability to recover from system upsets
    - [illegible]
  - Provided feedstock for centrifuge selection, VCSS efficiency confirmation and HTL evaluation
  - Processes development and lessons-learned to inform design and operation of next generation deployments



3 – Technical Accomplishments

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- **VCSS Operation**
- Design specification of 10x enhancement met
  - 0.38% → 4.9% (v/v) [12.8x]
- 98% EtOH recovery, >90% heat recovery
  - 0.09 MJ/MJ EtOH energy demand
- Performance meets expectations based on modeling, lab scale unit
- 2.89 MMgal/year feed capacity

3 – Technical Accomplishments

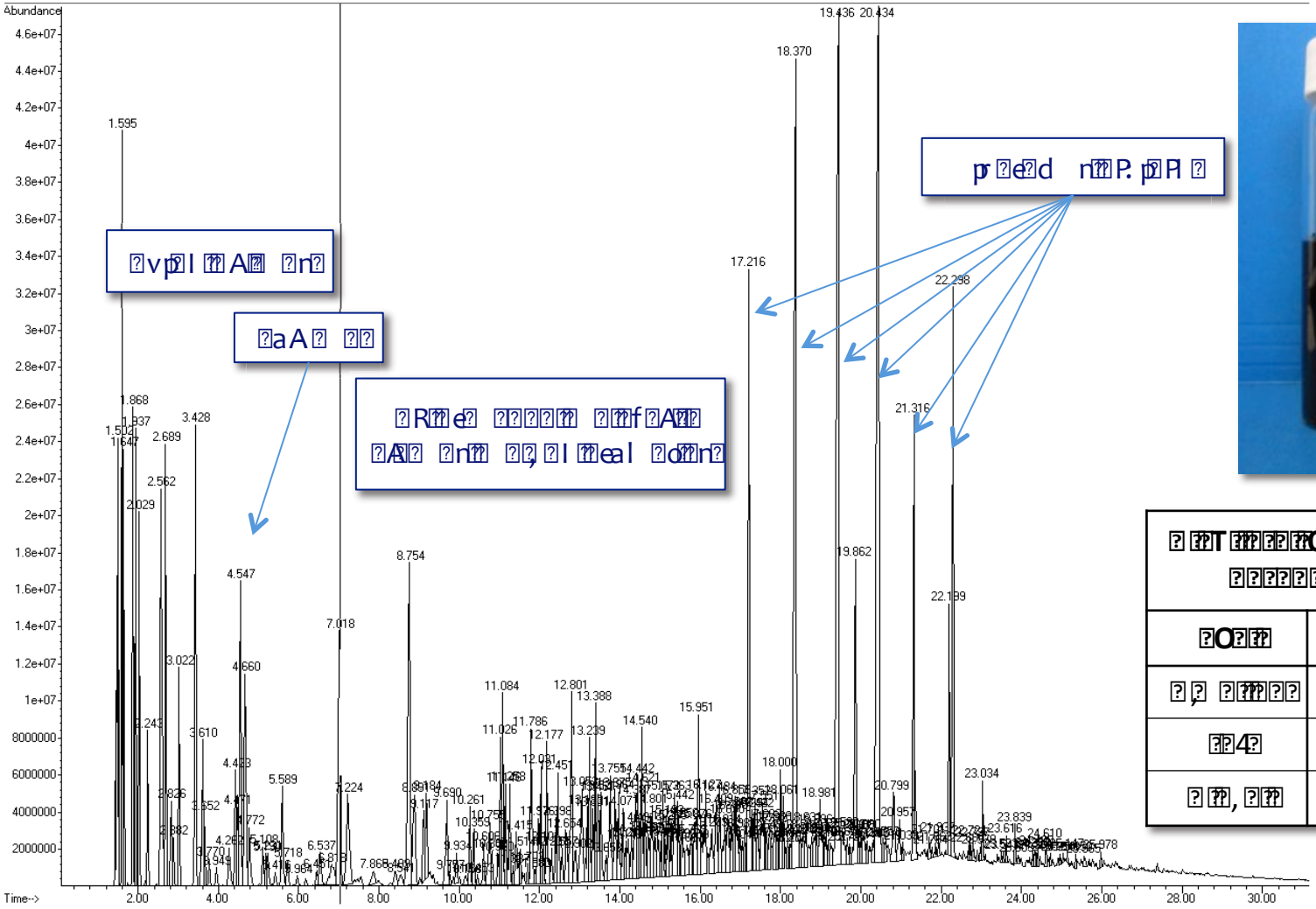
- **HydroThermal Liquefaction at PNNL**
- In May 2013 Algenol began a program with Pacific Northwest National Laboratory to investigate the use of hydrothermal liquefaction (HTL) to produce mid-distillate range liquids from wet algal biomass
- Tests showed ~35 wt% conversion of hybrid algal biomass to bio-oil
- HTL oil was successfully upgraded – products show low sulfur, nitrogen and oxygen by GC/MS analysis

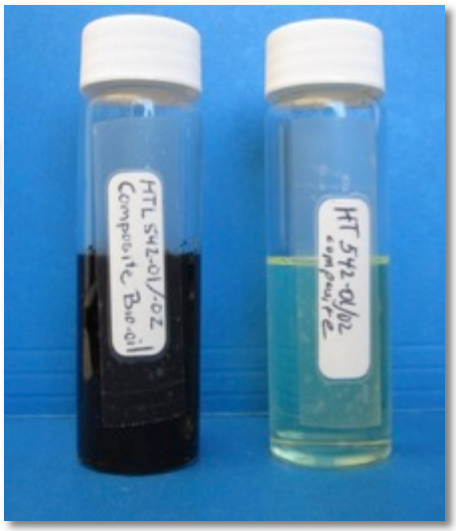
Run No.	Unit	542-01	542-02A	542-02B	542-02C
LHSV	L/L/h	2.2	4.6	6.8	9.1
Mass Balance	%	97%	99%	98%	98%
Oil Yield, Mass (N)	g_{oil}/g_{fd}	34%	44%	35%	34%
Gas Yield, Mass (N)	g_{solid}/g_{fd}	4%	4%	3%	2%
Solid Yield, Mass (N)	g_{gas}/g_{fd}	5%	6%	4%	4%

Preliminary - June 16, 2013

3 – Technical Accomplishments

Upgraded Product Analysis





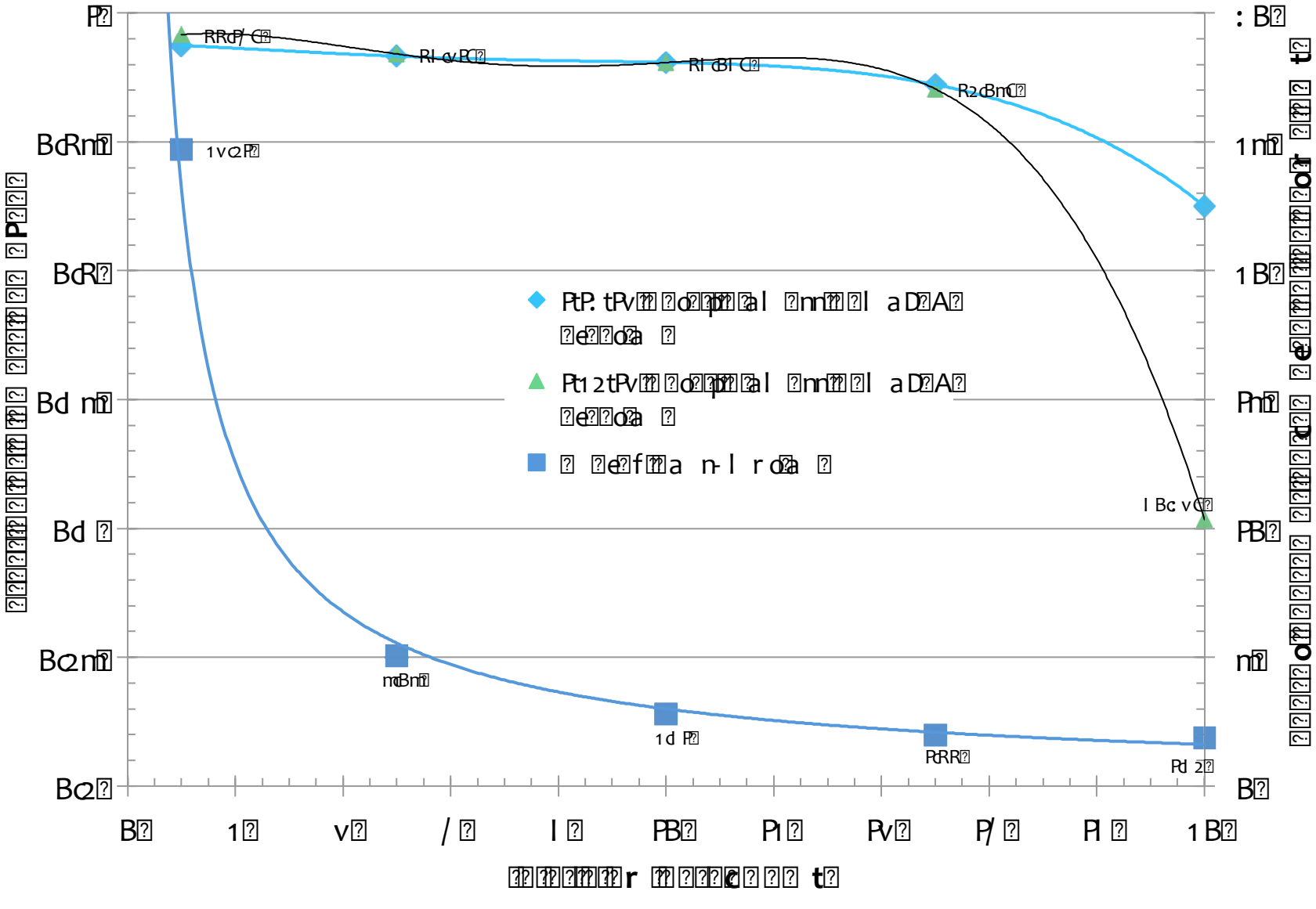
3 – Technical Accomplishments

- **HydroThermal Liquefaction Unit**

- Unit designed with significant input from PNNL scientists
- Scaled to process targeted HTL oil output: 6 gal/day
- All HP lines tested
- Final assembly and start up this month

3 – Technical Accomplishments

- Centrifuge Efficiency Study - GEA Westfalia Centrifuge



3 – Technical Accomplishments

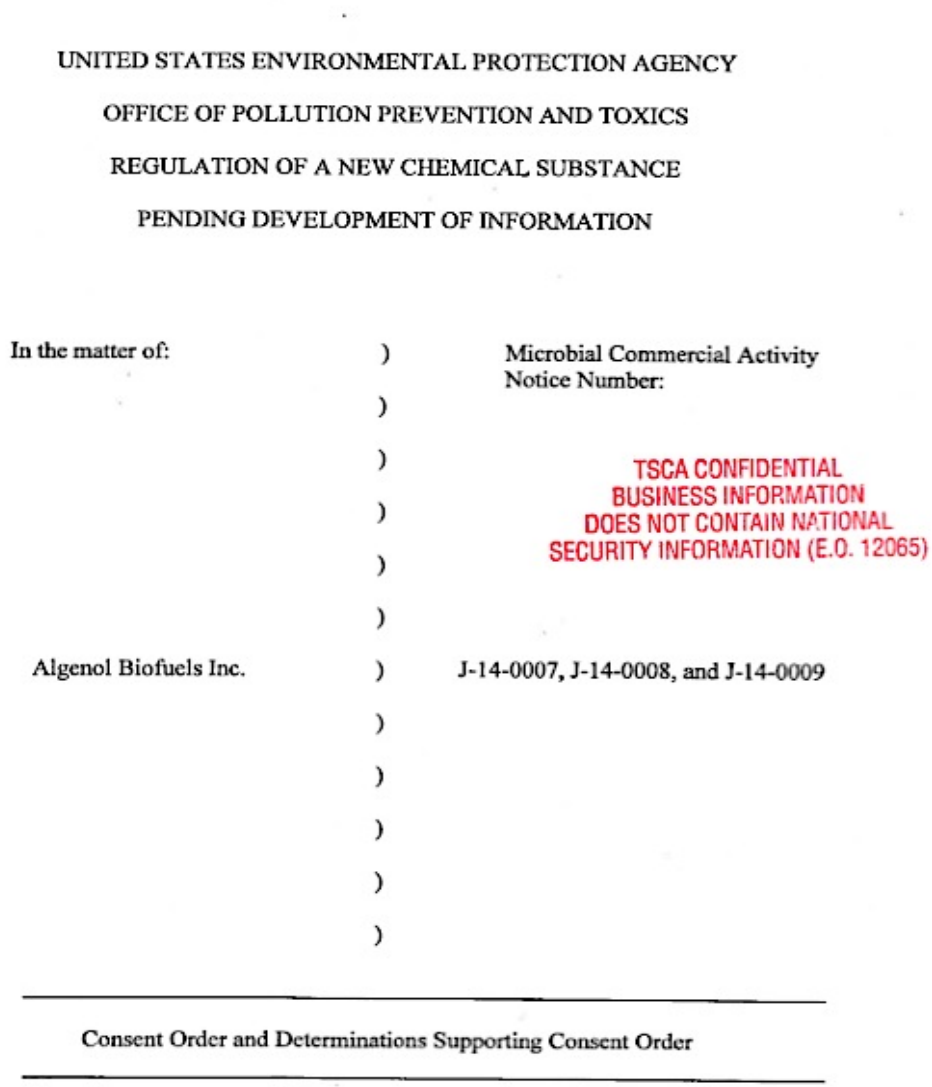
- **Flue Gas Testing**

- Designed and built flue gas capture unit
- Flue gas can be taken from any source and bottled
- Algae growth tests conducted on site at Algenol
- Facilitates flue gas source testing without the need to set up culture systems at remote sites

3 – Technical Accomplishments

Microbial Commercial Activity Notice (MCAN)

- Enhanced organisms used in industrial biotechnology are regulated by EPA under the Toxic Substances and Control Act
- Algenol submitted an MCAN for 3 strains of AB1
- Established consent decree allows, as requested, the ability to conduct commercial operations on the current Ft. Myers site
- Consent decree also identifies a roadmap for commercial scale approvals



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

OFFICE OF POLLUTION PREVENTION AND TOXICS

REGULATION OF A NEW CHEMICAL SUBSTANCE

PENDING DEVELOPMENT OF INFORMATION

In the matter of:	)	Microbial Commercial Activity Notice Number:
	)	
	)	TSCA CONFIDENTIAL BUSINESS INFORMATION DOES NOT CONTAIN NATIONAL SECURITY INFORMATION (E.O. 12065)
	)	
	)	
	)	
Algenol Biofuels Inc.	)	J-14-0007, J-14-0008, and J-14-0009
	)	
	)	
	)	
	)	
	)	

Consent Order and Determinations Supporting Consent Order

3 – Technical Accomplishments

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AB1 Exemption from Florida Non-Native Species Special Permitting

- Culmination of years of collaboration with FL Department of Agriculture and Consumer Services.
- Thorough environmental studies support timely approvals and exemptions.
- Statutory requirements for exemptions:
- Based on scientific data, FL regulators determined that that the enhanced algae does not pose an environmental or human threat
- Non-invasive
- History of safe use

Codified exemption in FL Rule 5B-57.011(5)

(5) A Non-Native Species Planting Permit, FDACS 08382 (Rev. 01/13), is not required if the Department, after consultation with the University of Florida, Institute of Food and Agricultural Sciences (IFAS), determines, based on experience or research data, that the non-native species does not pose a threat of becoming an invasive species or pest of plants or native fauna under Florida conditions. The following are specifically exempted from the requirements of this rule:

(a) Any plant that is commonly grown in Florida for purposes of human food consumption.

(b) Any plant that is commonly grown in Florida for commercial feed, feedstuff, or forage for livestock, nursery stock, or silviculture.

(c) Aquatic plants, algae, or blue-green algae grown in compliance with Aquaculture Best Management Practices and certified by the Division of Aquaculture pursuant to Section 597.004, F.S.

(d) *Cyanobacterium* sp. (Strain ABI)

(e) Energy cane (complex hybrid of *Saccharum officinarum, S. spontaneum, S. barberi* and *S. sinense*)

(f) *Eucalyptus amplifolia*

(g) *Eucalyptus benthamii*

(h) *Eucalyptus dorrigoensis*

(i) *Eucalyptus dunnii*

(j) *Eucalyptus grandis*

(k) *Eucalyptus gunni*

(l) *Eucalyptus nitens*

(m) *Eucalyptus smithii*

(n) *Eucalyptus urograndis - E. grandis* X *E. urophylla*

(o) *Hibiscus canabinus L*

(p) *Miscanthus giganteus - M. sacchariflorus*X *M. sinensis*

(q) *Pinus* spp.

3 – Technical Accomplishments

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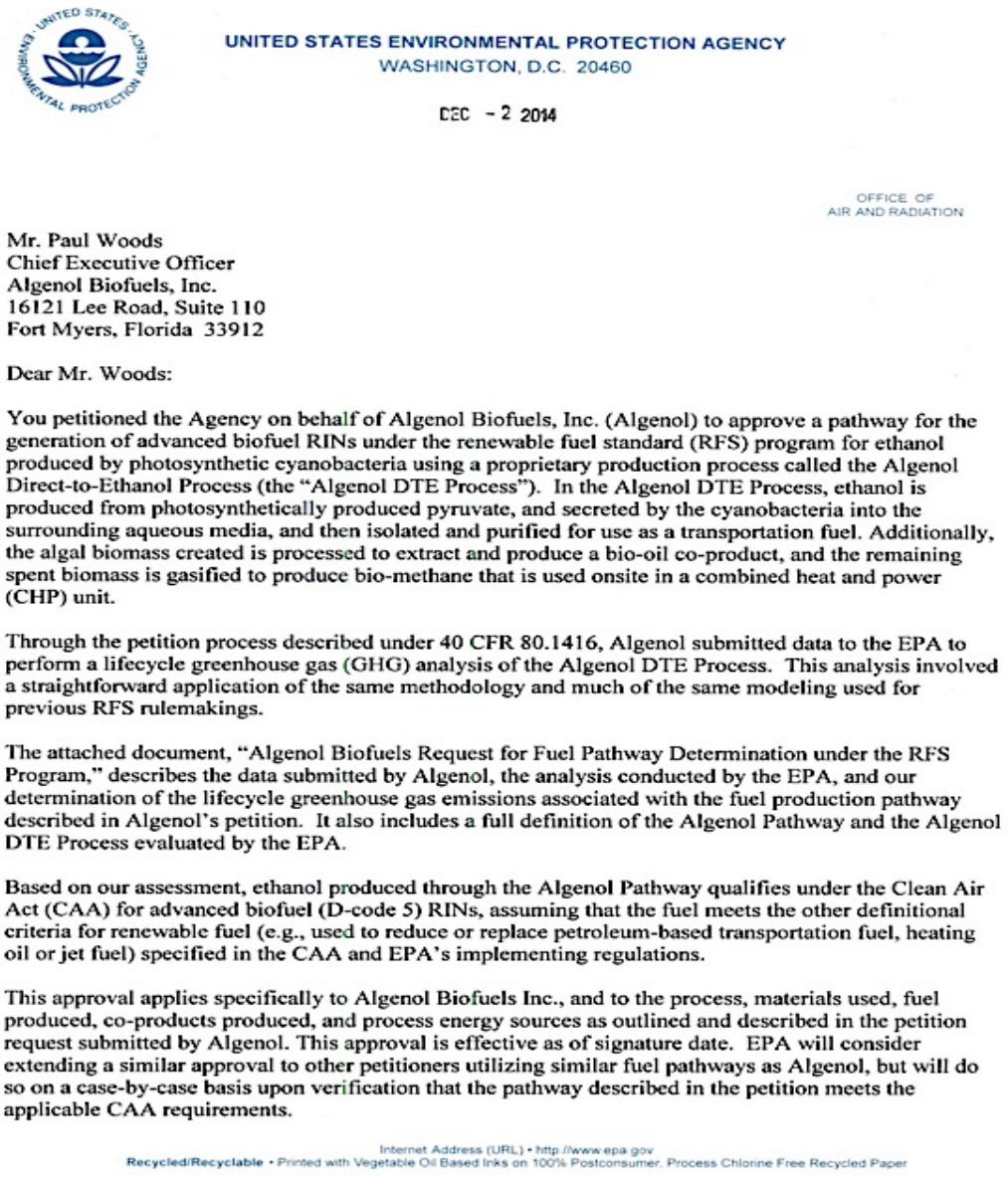
Pathway Approval

- December 2, 2014: EPA approved Algenol's pathway for ethanol produced by photosynthetic cyanobacteria using Direct-to-Ethanol® technology.
- Approval also confirms that Algenol's bio-crude qualifies for existing pathway.
- EPA's lifecycle analysis shows a reduction of GHG emissions compared to the statutory petroleum baseline of 69%.
- D-code 5 RINs to be produced at commercial scale.



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

DEC - 2 2014

OFFICE OF
AIR AND RADIATION

Mr. Paul Woods
Chief Executive Officer
Algenol Biofuels, Inc.
16121 Lee Road, Suite 110
Fort Myers, Florida 33912

Dear Mr. Woods:

You petitioned the Agency on behalf of Algenol Biofuels, Inc. (Algenol) to approve a pathway for the generation of advanced biofuel RINs under the renewable fuel standard (RFS) program for ethanol produced by photosynthetic cyanobacteria using a proprietary production process called the Algenol Direct-to-Ethanol Process (the "Algenol DTE Process"). In the Algenol DTE Process, ethanol is produced from photosynthetically produced pyruvate, and secreted by the cyanobacteria into the surrounding aqueous media, and then isolated and purified for use as a transportation fuel. Additionally, the algal biomass created is processed to extract and produce a bio-oil co-product, and the remaining spent biomass is gasified to produce bio-methane that is used onsite in a combined heat and power (CHP) unit.

Through the petition process described under 40 CFR 80.1416, Algenol submitted data to the EPA to perform a lifecycle greenhouse gas (GHG) analysis of the Algenol DTE Process. This analysis involved a straightforward application of the same methodology and much of the same modeling used for previous RFS rulemakings.

The attached document, "Algenol Biofuels Request for Fuel Pathway Determination under the RFS Program," describes the data submitted by Algenol, the analysis conducted by the EPA, and our determination of the lifecycle greenhouse gas emissions associated with the fuel production pathway described in Algenol's petition. It also includes a full definition of the Algenol Pathway and the Algenol DTE Process evaluated by the EPA.

Based on our assessment, ethanol produced through the Algenol Pathway qualifies under the Clean Air Act (CAA) for advanced biofuel (D-code 5) RINs, assuming that the fuel meets the other definitional criteria for renewable fuel (e.g., used to reduce or replace petroleum-based transportation fuel, heating oil or jet fuel) specified in the CAA and EPA's implementing regulations.

This approval applies specifically to Algenol Biofuels Inc., and to the process, materials used, fuel produced, co-products produced, and process energy sources as outlined and described in the petition request submitted by Algenol. This approval is effective as of signature date. EPA will consider extending a similar approval to other petitioners utilizing similar fuel pathways as Algenol, but will do so on a case-by-case basis upon verification that the pathway described in the petition meets the applicable CAA requirements.

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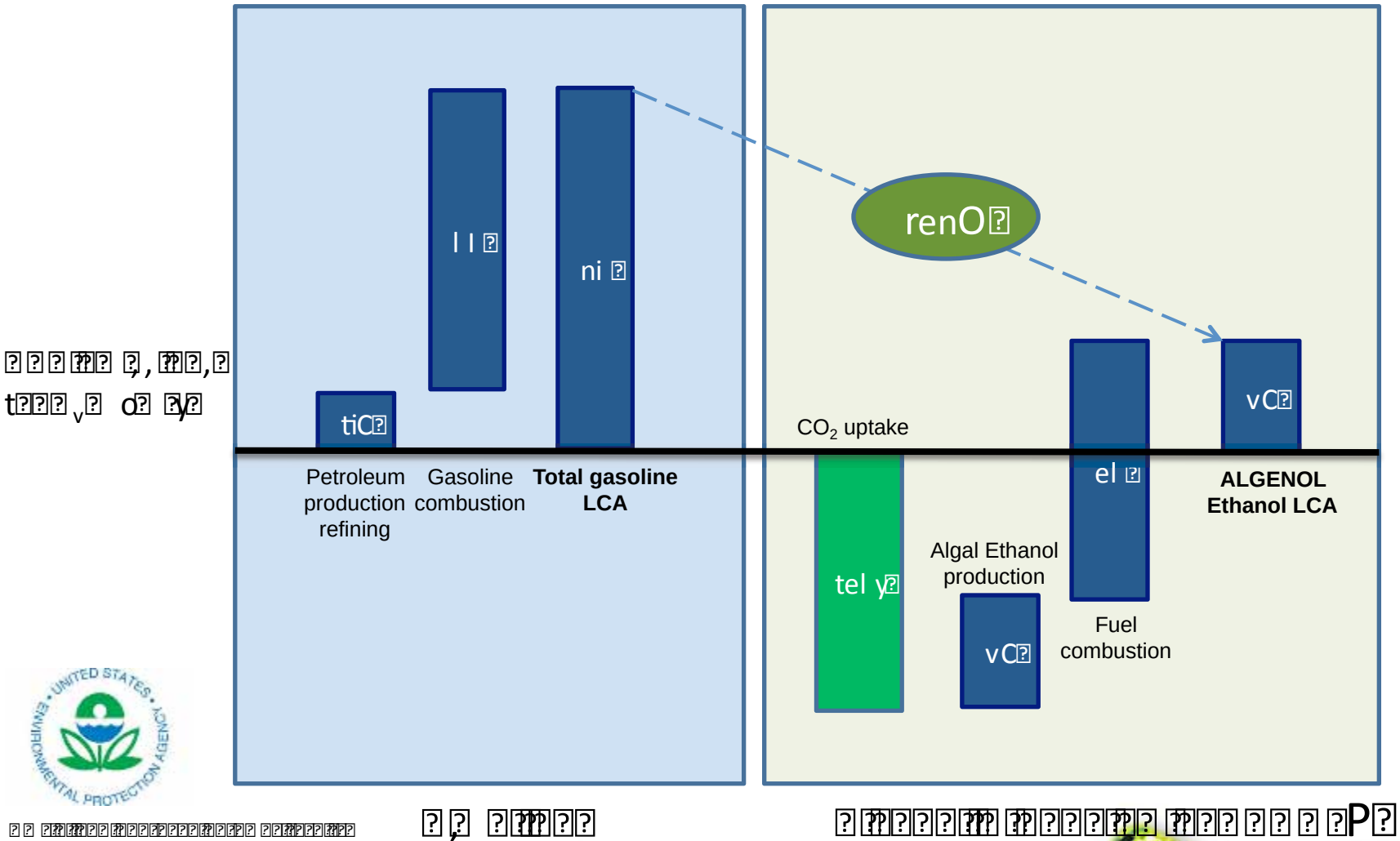
3 – Technical Accomplishments



4 – Relevance

- The Algenol IBR project provides the DOE with data to evaluate enclosed photobioreactor systems and metabolically enhanced algae for use in bioenergy production and Carbon Capture and Utilization

- The bioenergy industry needs a broad range of low carbon impact technologies that can utilize diverse feedstocks and operate in various climates in order to meet the energy demands of the marketplace

- When successful, the Algenol technology can provide a means to use abundant feedstocks, saltwater, industrial waste CO_2 and sunlight, to make low carbon footprint transportation fuels

- Algenol has constructed a small pilot plant in India next to the world's largest point source of CO_2 and we are proving that our technology can be successfully transferred and operated by third parties

Summary

- Algenol has made extensive progress in the development of its technology
- Algenol now has all applicable licenses to commercially produce and sell ethanol
- Commercial ethanol sales will happen in 2Q2015 from the IBR facility
- Algenol is on a path to commercialization
- Algenol's technology can be an important part of the carbon capture and utilization efforts for greenhouse gas reduction allowing industrial CO_2 emitters to monetize their pollution

Additional Slides

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#3

Industry Leader

Commercial Operations Developments

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