

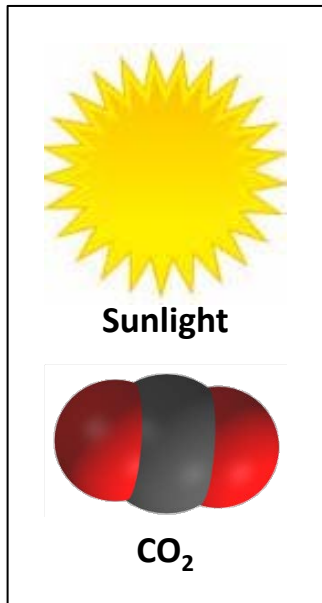
2013 DOE Bioenergy Technologies Office (BETO) Project Peer Review

Sapphire Integrated Algal Biorefinery (IABR)

Wednesday, May 22, 2013
Integrated Biorefineries

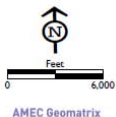
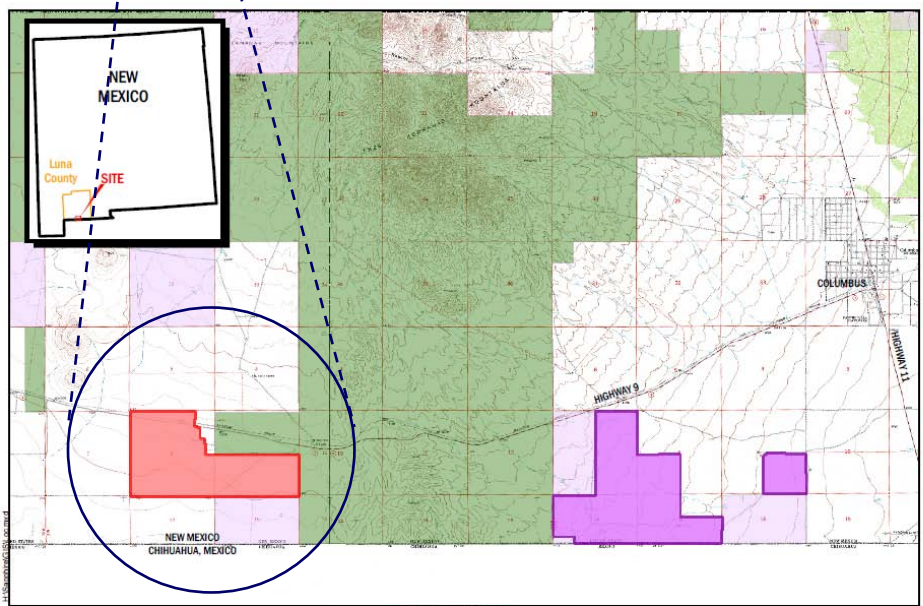
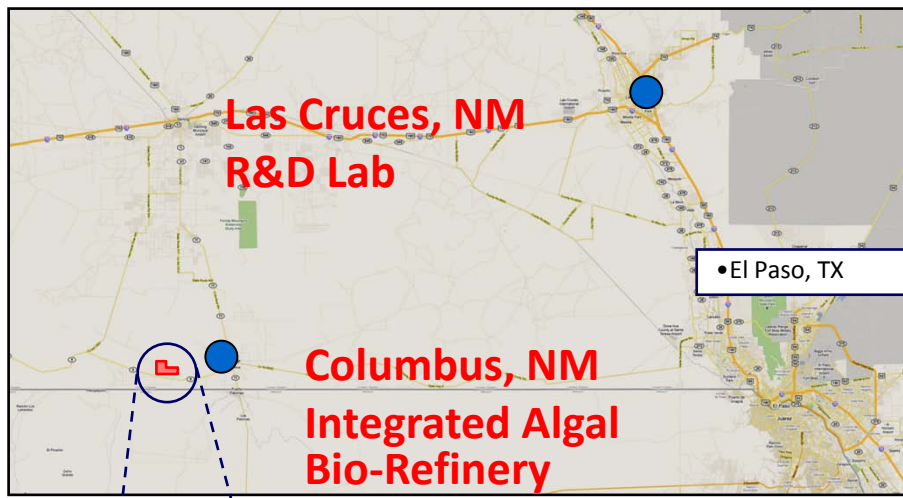
Jaime E. Moreno, P.E.
Sapphire Energy, Inc.

Sapphire produces drop-in crude oil from algae, sunlight, and CO₂ – in a scalable and sustainable process

Plentiful inputs**Scalable, open pond facilities****Green crude**

**Fossil crude came from algae and other plants living millions of years ago;
Sapphire radically accelerates a natural phenomenon**

Non-potable water • Non-arable land • Enhanced algae • Proprietary process



Western Parcels		Eastern Parcels		Land Ownership	
■	Total Irrigated - 819.8 ac.	■	Total Irrigated - 216.9 ac.	■	Bureau of Land Management
■	Total Volume - 2,459.4 ac/yr	■	Total Volume - 650.7 ac/yr	■	State Land
				■	Private Land

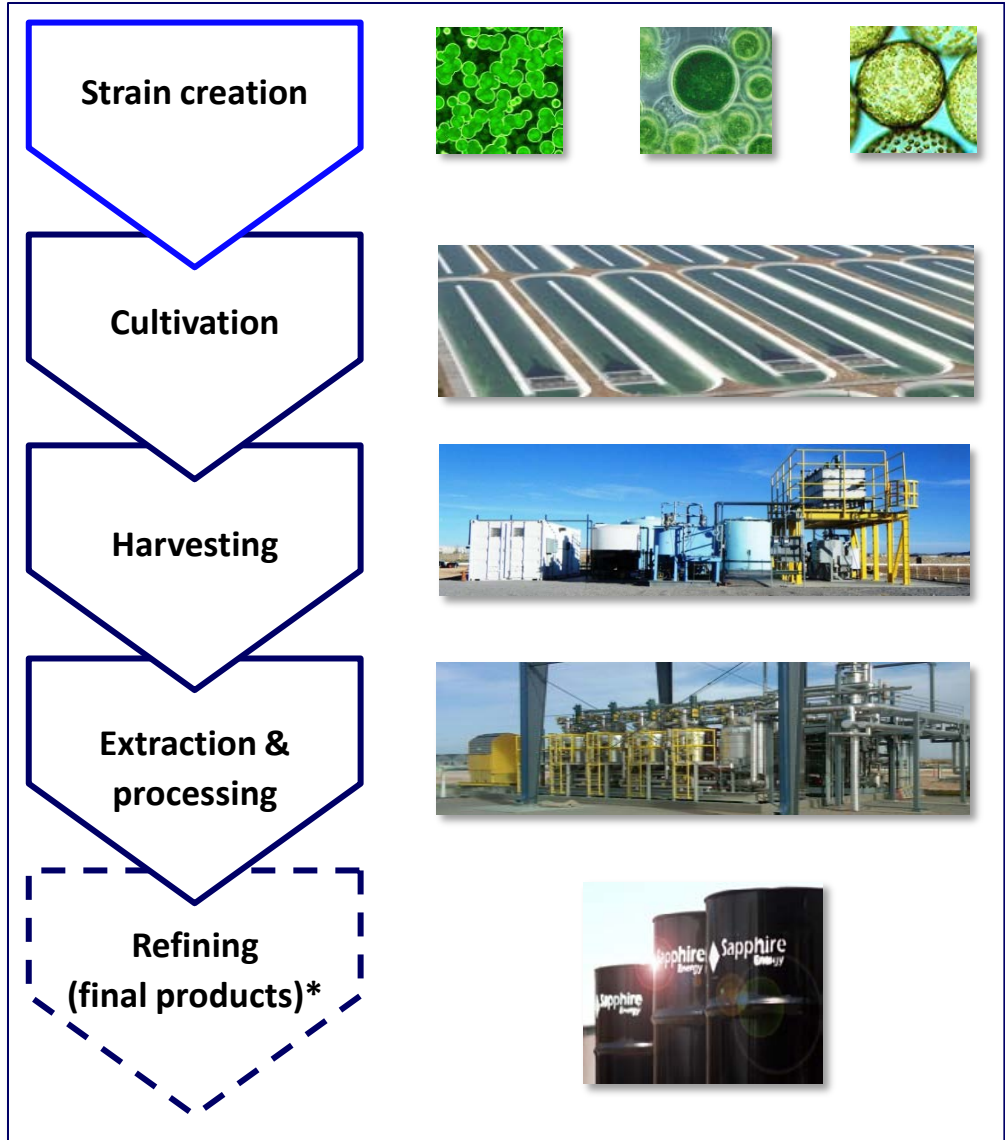
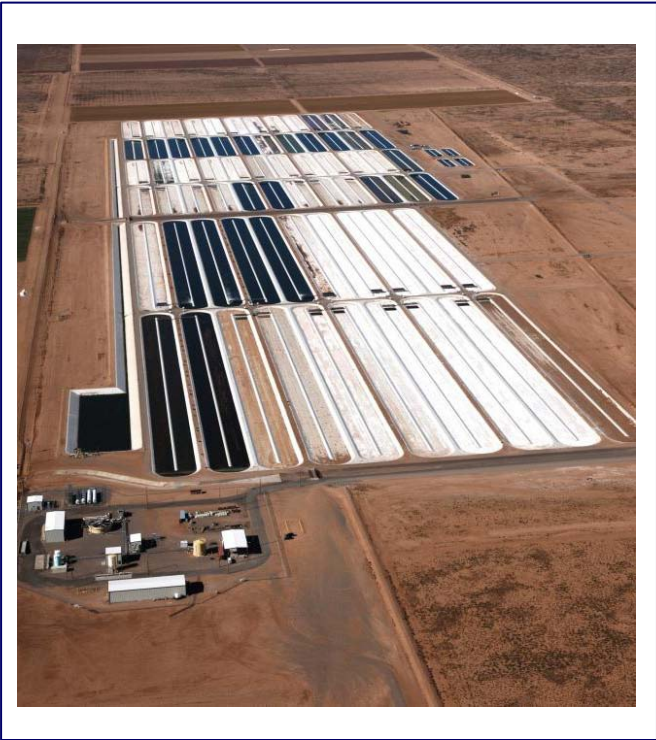
Location and Land Ownership Map
Columbus, New Mexico
FIGURE 1



- **At Completion – Proof of Commercial Demonstration for Large Scale Production of Transportation Fuels from Algae Feedstock**
- **Integrated Process:**
 - Biomass Growth
 - Biomass Harvesting
 - Oil Extraction
 - Water and Nutrient Recycle
 - Energy reuse and Optimization
 - Waste Stream Minimization
- **\$135 MM total project costs**



Sapphire has developed the most advanced large-scale algal oil system in the world

Algae facility in Columbus, NM



-  Advanced algae strain development
-  Algae-derived fuel process units

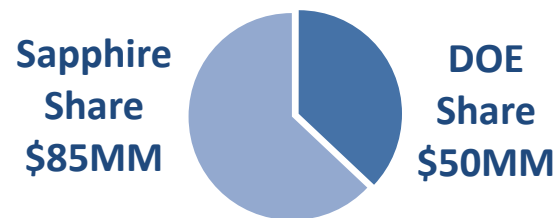
* Upgraded in a refinery or by a stand-alone processor; Sapphire’s oil quality enables processing in today’s refineries with no modifications

Project Timeline

- Start Phase I: Jan-2010
- Phase I Mech. Turnover: Jun-2012
- Final Phase Design Stage Gate: Sept-2013
- Final Phase Planned Completion: Jun-2014
- ~60% complete as of Jan-2013

Project Budget

TOTAL \$135MM



- DOE Funding Rec'd to Date: \$31MM

Project Development

- Phased Deployment
- Cost on track
- Schedule on track
- Technical Progress on track
- Completion in Sept-2014

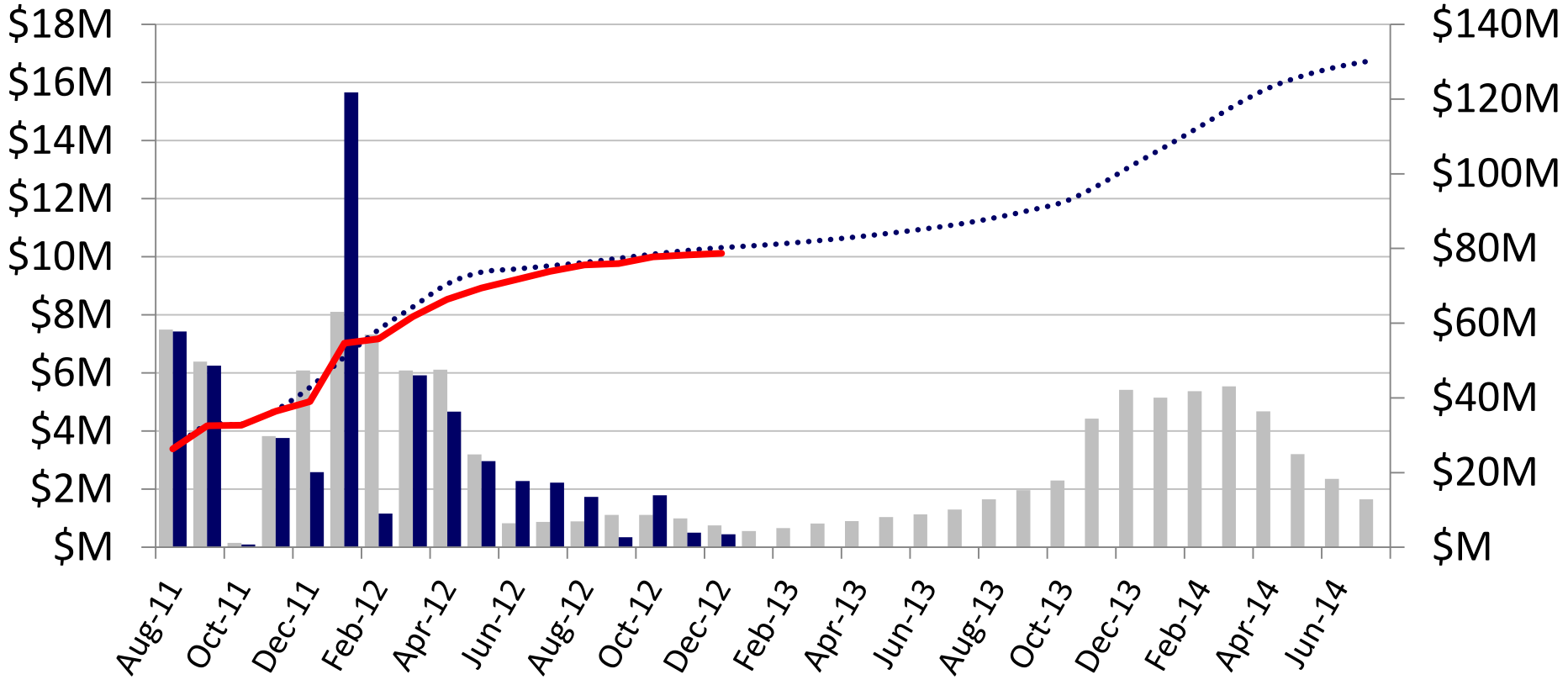
Project Participants



Spend Plan

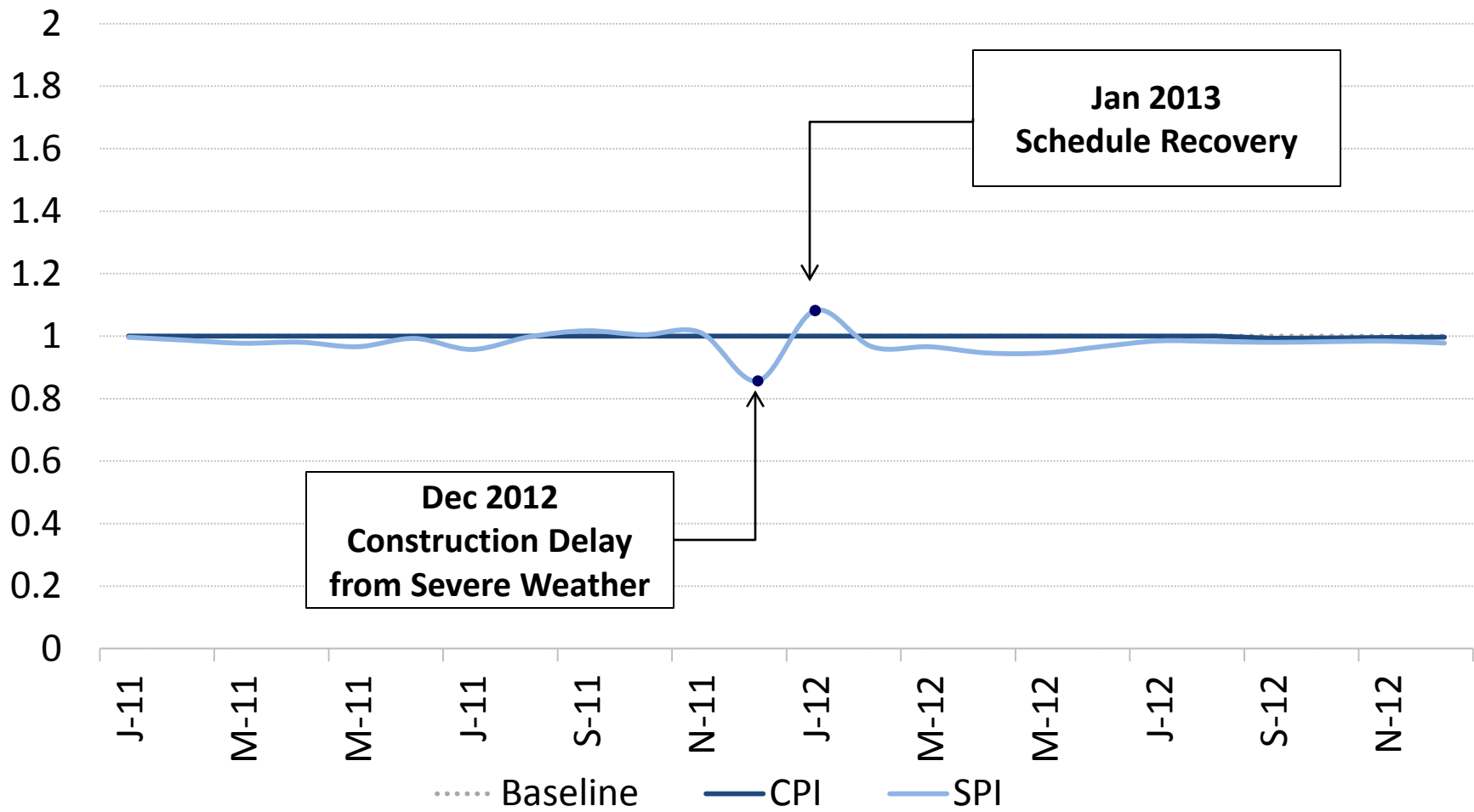
Monthly Costs

Cumulative Costs

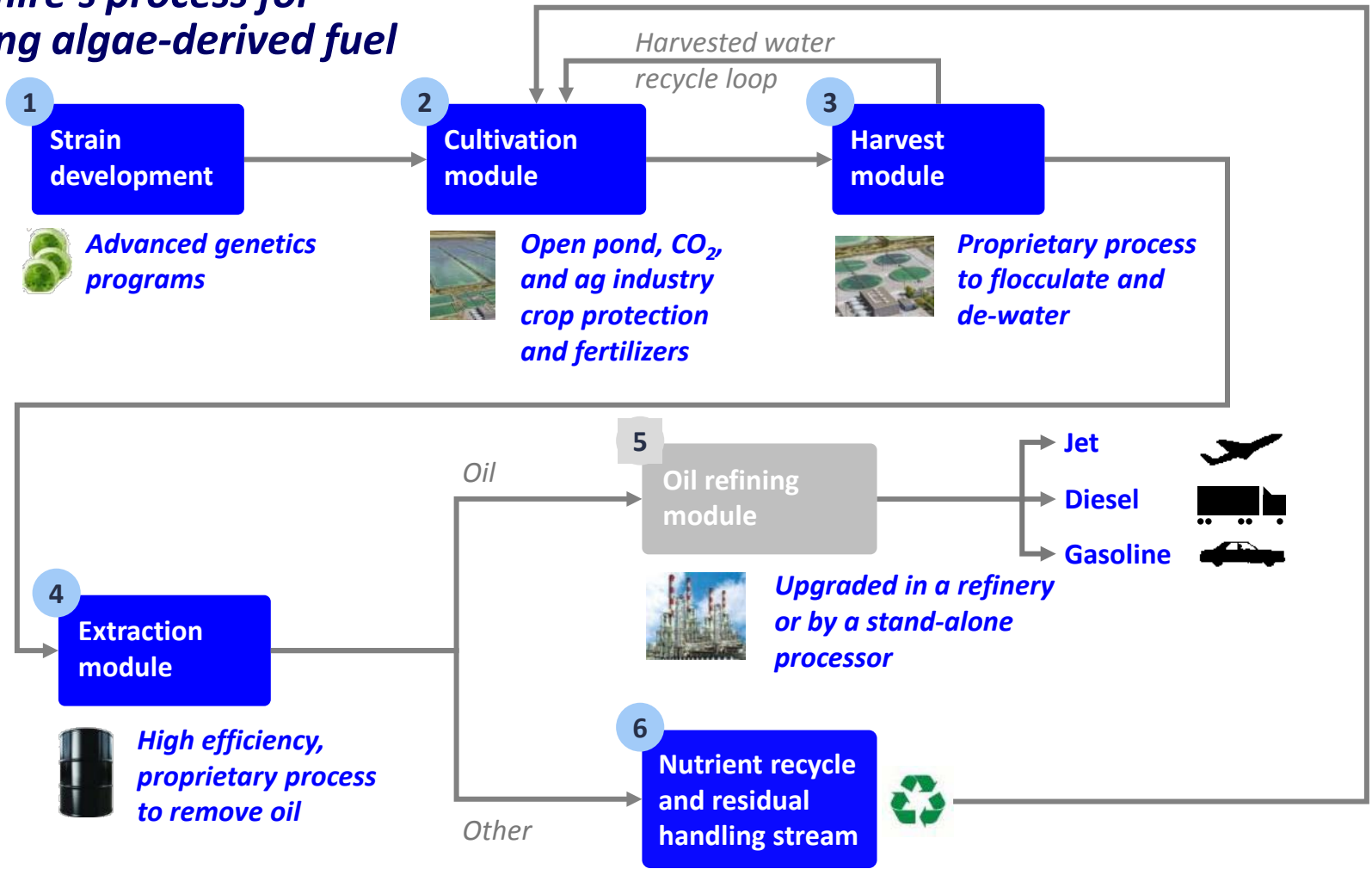


Planned Monthly Actual Monthly Planned Cumulative Actual Cumulative

Earned Value



Sapphire's process for making algae-derived fuel



Sapphire Energy is providing barrels of oil to be refined for market use



TESORO

- Tesoro recently signed an agreement to purchase crude oil from Sapphire Energy's Green Crude Farm in Columbus, New Mexico
- This begins the first step of a commercial relationship to process Green Crude oil from Sapphire's future commercial facilities

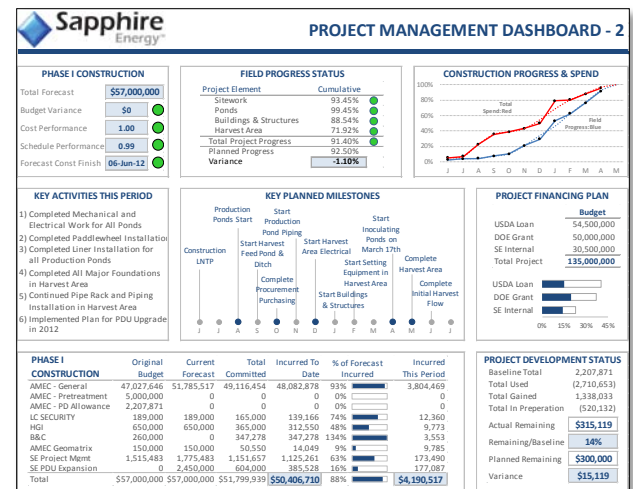
- In initial testing by Sapphire Energy, Green Crude oil was refined into **on-spec ASTM 975 diesel fuel**, proving its compatibility with the existing network of pipelines, refineries and transport systems
- Sapphire Energy will grow production significantly to further expand its commercial demonstration and begin the transition towards commercial-scale production



Rationale & Drivers for Prioritization of Project Objectives

- Purposeful and targeted technology and biology program development
- Data and piloting based
- Stage Gate decision making / spending approval
- Maximize Project Success Criteria
 - Integrated process
 - Commercial demonstration scales
 - Commercial demonstration economies
 - Budget control
 - Schedule constraints
 - Stakeholder interests

- Establish dedicated PMO
- Utilize personnel with a proven track record of developing and executing complex projects
- On-site Sapphire personnel to provide owner oversight during construction
- Baseline focused project execution
- Utilize industry standard tools and management practices
 - Stage gate process
 - Primavera CPM schedules
 - Establish baseline metrics and measure on regular basis
 - Robust project reporting systems
- Establish open reporting to all stakeholders
- Hold regular status reviews with stakeholders
- Early identification of project deviations
 - Develop mitigation plans
 - Identify variances



Site details: the project is located on land that was previously used for farming, but no longer is fertile

The site prior to Sapphire's ownership



- Land was used for farming until 1973
- Land was abandoned for farming use because the underlying water source became too saline
- Few other productive uses until Sapphire started developing the current project

Construction: the first phase of the project was constructed over the 2011/2012 timeframe and has proceeded on-schedule and on-budget

December 2011

May 2012



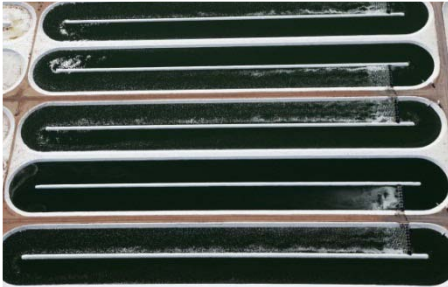
Startup and commissioning: construction is completed and the facility has been in continuous integrated operation since June 2012



From the air (looking east to west) – late November 2012



The phase one shakedown for the Green Crude Farm is designed to demonstrate the viability of all unit processes and operations



Cultivation

Open pond, CO₂, and ag industry fertilizers and crop protection methods



Harvest

Proprietary process to flocculate and de-water
Dissolved Air Flotation unit allows us to skim algae from the water

Algae slurry is transported to the extraction unit



Extraction

Sapphire uses a proprietary, innovative, solvent-based extraction system to process oil and nutrients
Slurry undergoes chemical reactions with heat, pressure and solvents to create refinable crude oil

A few IABR production metrics to date

523 MT CO2 consumed

Cultivation module

67 million gallons of culture harvested and returned to ponds

Harvest module

123 MT dry biomass recovered

Continuous cultivation of 20 wet acres (summer and winter strains) since 2ndQ 2012



PDU debottlenecked & commissioned in October 2012

Extraction module (PDU)

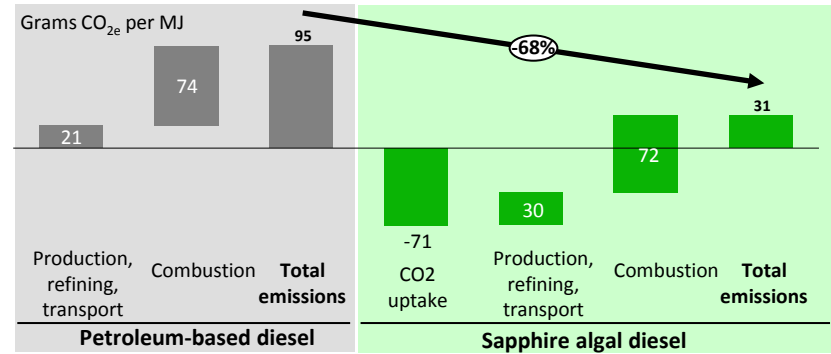
378 gallons of oil



Superior attributes of algae

- Scalable to millions of barrels per day
- Cost competitive with marginal crude oil production
- Completely fungible with infrastructure and fleet
- Favorable life cycle with respect to CO₂
- Does not compete with agricultural products, land, or water

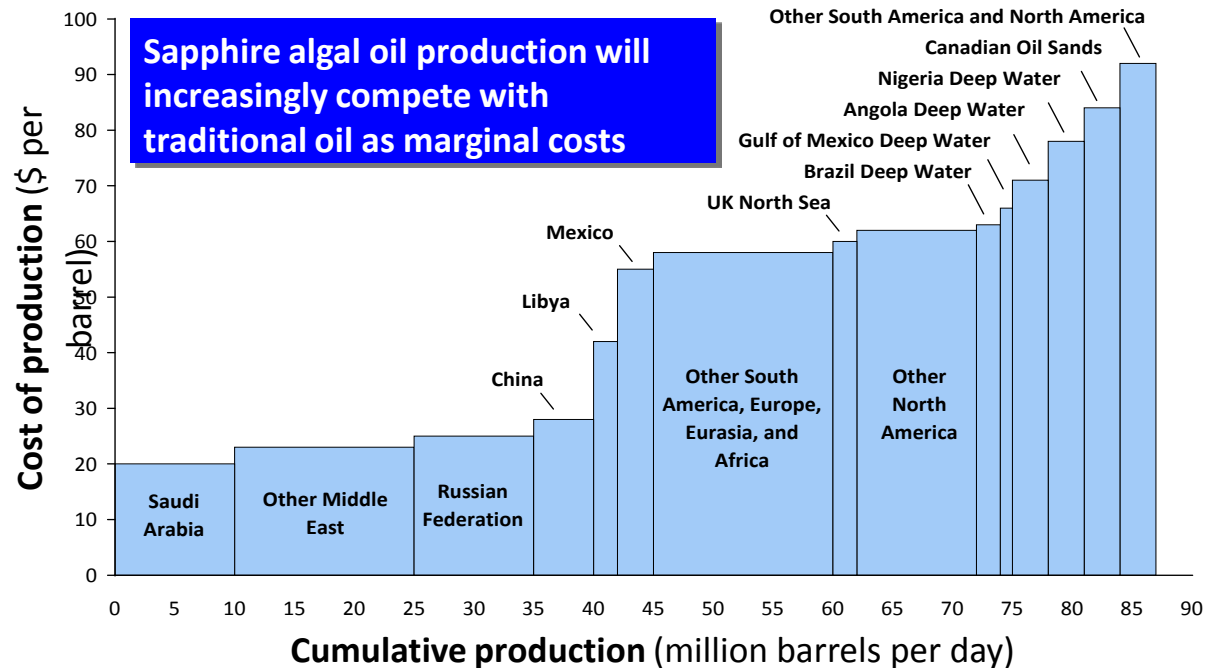
Algae is a superior renewable feedstock



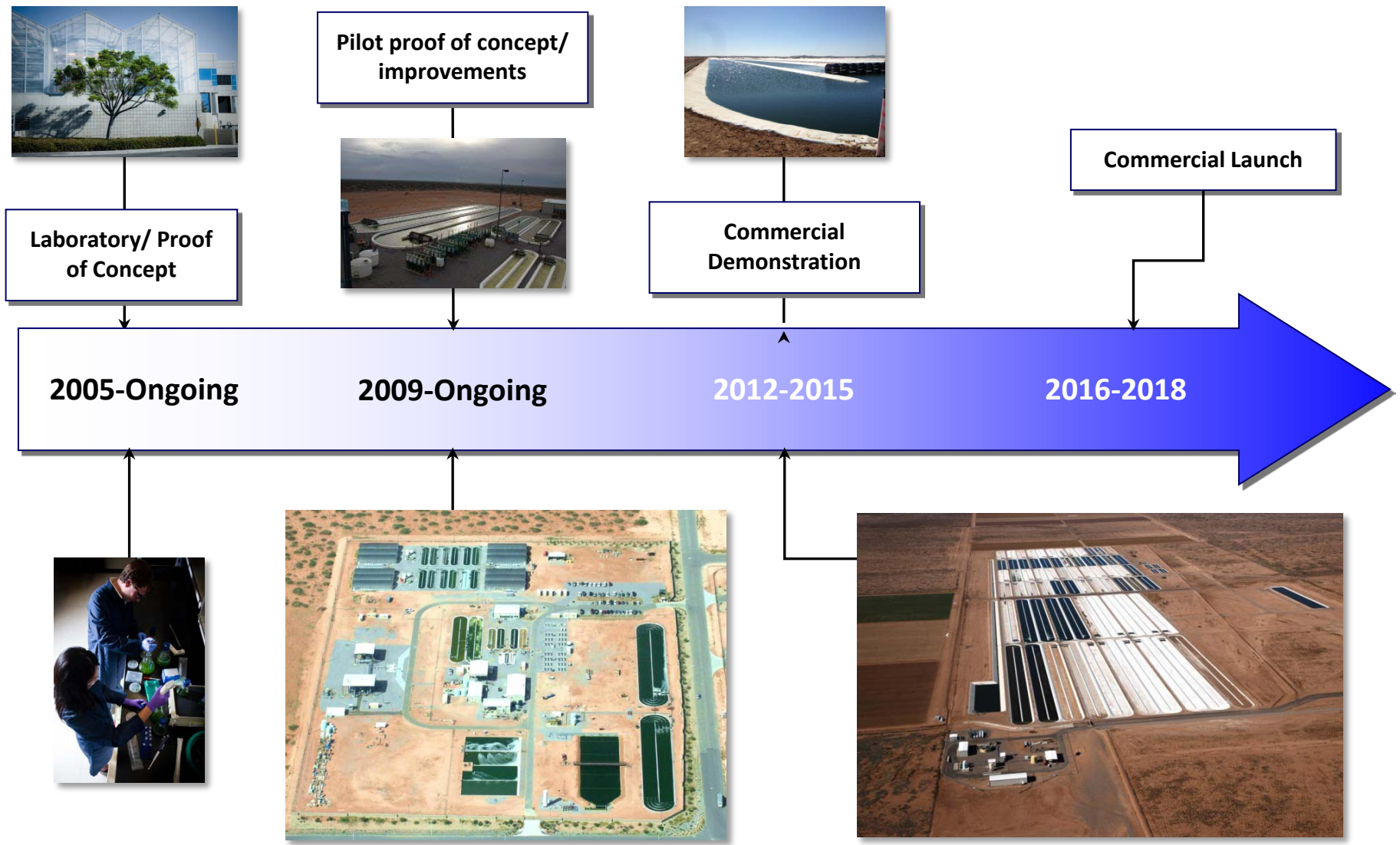
Algae fuel can be grown on marginal land with saline water



Oil supply marginal cost curve for 2008 WTI equivalent



From the very beginning Sapphire's focus has been to create a drop-in replacement for crude oil from algae



**OPEN POND CULTIVATION—
*BREAKTHROUGHS IN THE FIELD***

Large-scale production of photosynthetic algae

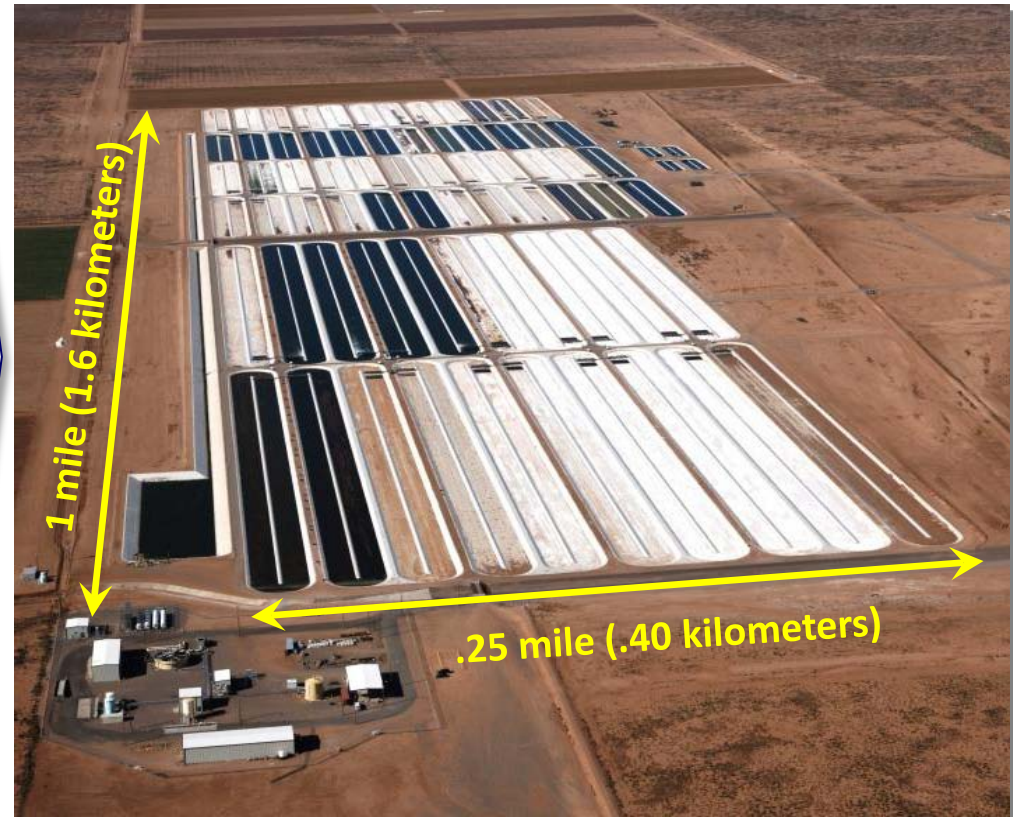
Pilot technology facility

- **22-acre pilot facility** operated since 2009
- Over **180,000 hours** of large pond cultivation piloting

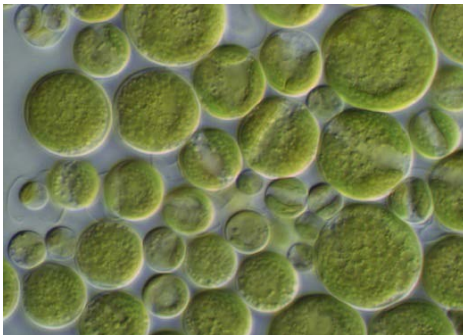


Commercial demonstration facility

- Sapphire is operating the **world's first integrated algal-oil production facility**
- Operations began in Q3 2012



Cultivation: Sapphire grows algae in a proven, scalable, growing system, while continually reducing cost



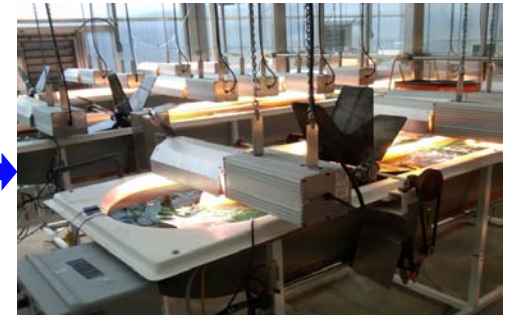
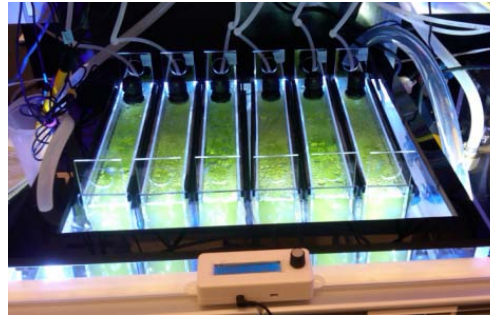
Algae grow rapidly and continuously, all year

- Ponds are harvested daily and some of the biomass is removed for processing
- The remaining algae quickly replicate and replace the harvested portion
- The result is a consistent biomass density, set for optimal growth

Sapphire has a fully integrated R&D asset pipeline, enabling creation and testing of strains from the laboratory to the field

Laboratory (SD)

- Screening
- Columns
- Pond simulators
- Greenhouse mini-ponds



Pilot facility (NM)

- Outdoor mini-ponds
- Large Ponds
- Harvest
- Extraction



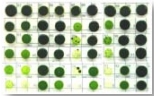
Comm. Demo. (NM)

- Inoculation Ponds
- 1.1 Acre & 2.2 Acre ponds
- Harvest Channel & Pond
- Large Scale Harvest
- Water Return Pond

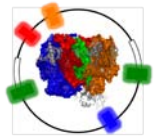


Sapphire has advanced biotech and oil production systems

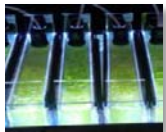
Molecular and biochemical innovation, enhancement, control, and oil production



High throughput screening and selection
(not previously demonstrated with algae)



Novel genetic enhancements and manipulations
(not previously possible with algae)



Advanced, industrial-class crop evaluation systems



Breakthrough, novel chemical engineering and oil production systems

Sapphire's technology improves strain robustness

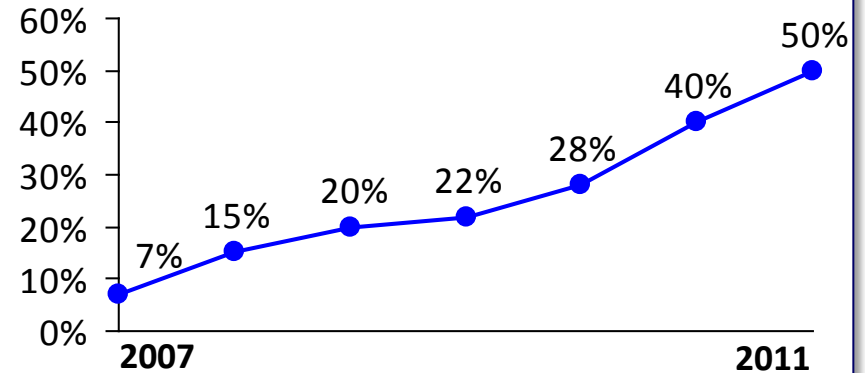


Unhealthy base strain

Healthy Sapphire improved strain

Sapphire has steadily increased oil extraction yield and decreased cost

Percentage of biomass extracted as hydrocarbon



**WET EXTRACTION—
*BREAKTHROUGHS IN THE FIELD***

Harvesting: algae and water are separated to prepare algae for extraction

Sapphire uses a Dissolved Air Flotation (DAF) system to concentrate algae



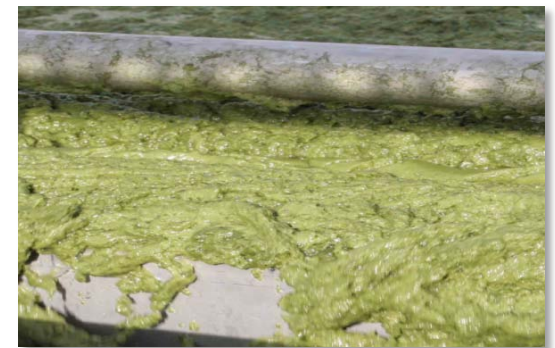
Solution enters the DAF in dilute concentration



DAF technology adapted for algae

1. **Cluster**: chemicals are applied which make the algae stick together
2. **Float**: air bubbles float algae to the surface
3. **Skim**: floating algae harvested with a skimmer

After the DAF, the algae is concentrated



Extraction: the harvested algae slurry is processed using proprietary technology to extract oil and nutrients

Sapphire uses a proprietary, innovative, solvent-based extraction system



Concentrated algae enters the extractor as a slurry



Slurry undergoes chemical reactions

1. **Heat and pressure**: the slurry is exposed to heat and pressure, causing separation of materials
2. **Chemicals**: solvents are added to complete separation process

Extraction process creates refinable crude oil



Extraction breakthrough: Sapphire has substantially increased the amount of oil which can be recovered from biomass

Sapphire uses a proprietary, innovative, solvent-based extraction system



Strain	Extracted oil yield (% ash free dry weight)	
	Prior Methods	Sapphire Process v2
Strain A	15%	50%
Strain B	15%	43%
Strain C	10%	48%
Strain D	10%	38%
Strain E	5%	38%
Strain F	5%	36%
Strain G	5%	41%
Strain H	5%	39%

- Advantages:**
- Algae can be processed wet
 - High yield boost
 - Enables broad range of algae strains

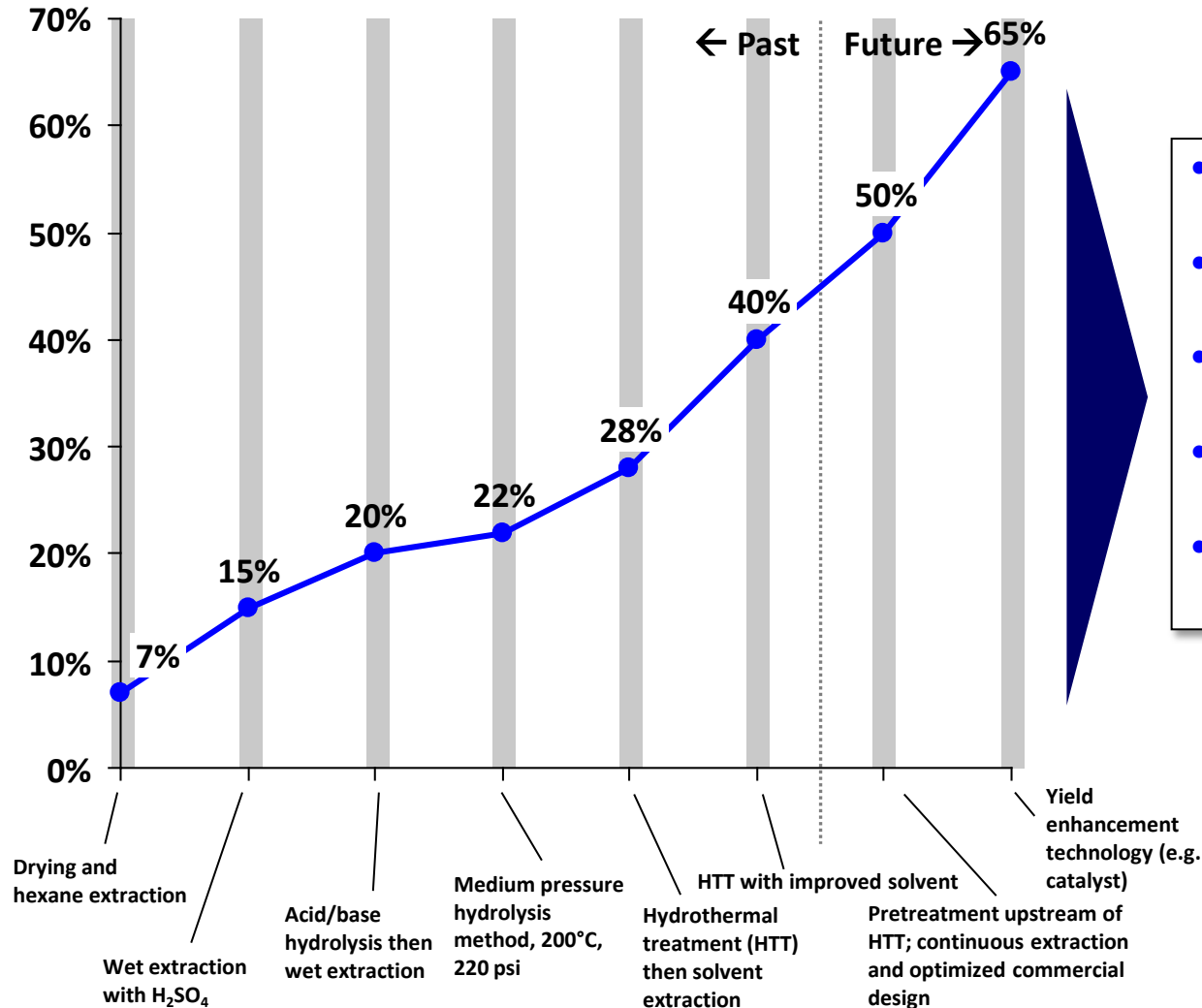
Extraction: Renewable Green Crude oil leaves the extractor



**COMPATIBLE CRUDE OIL—
*BREAKTHROUGHS IN THE FIELD***

Extraction R&D projects have substantially increased the amount of oil which can be recovered from biomass

Extractable oil fraction
Mass of oil per mass of algae



- Past and future yield benefits are absent biological improvement
- Patent issued for conversion and extraction process on June 5, 2012
- Operating demonstration scale HTT since October 2011
- Plan to convert demonstration scale HTT and extraction to improved solvent in 2014
- Lab, pilot and demonstration scale facilities for R&D



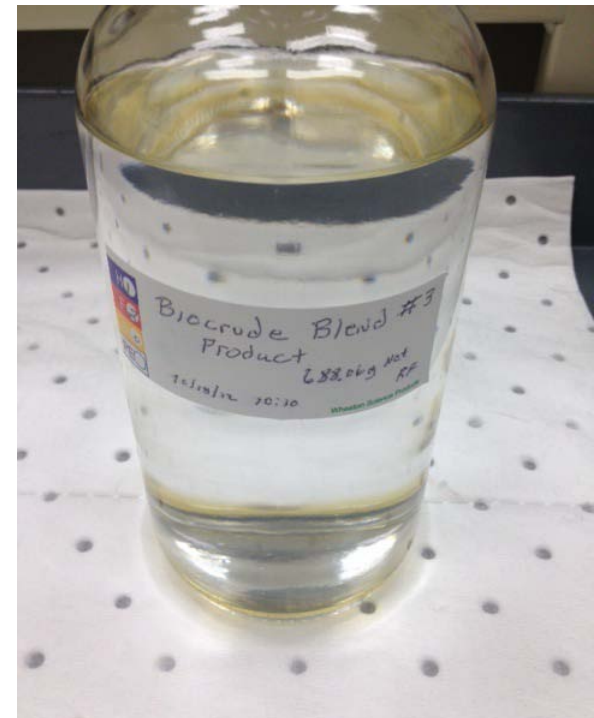
Algae bio-crude has been successfully upgraded at typical refinery hydrotreating conditions

10% Sapphire bio-crude balance solvent and inerts

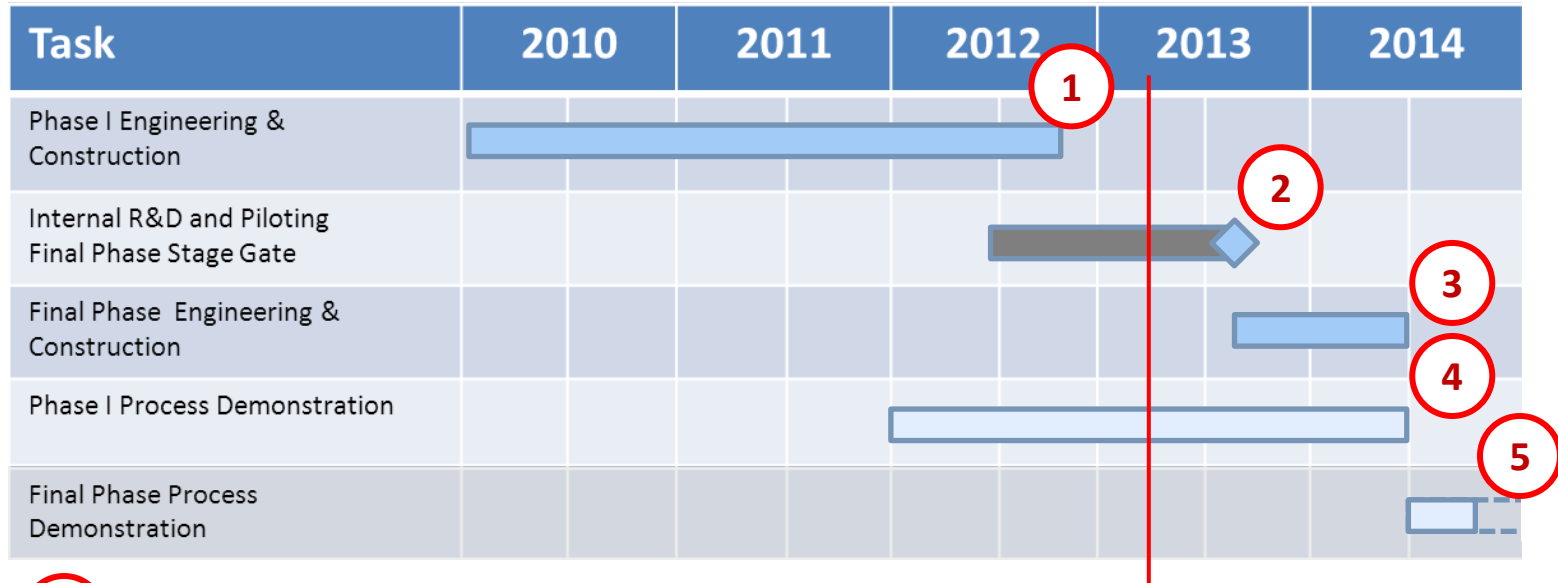


d = g/ml	0.7932	0.7795	0.7798	0.7793	0.7803
S = ppm	466	7*	12.1*	12.9*	12.6*
N = ppm	3537	3	13.7	23.3	48.4
TOS = hour	0	36	60	108	192

10% Sapphire bio-crude with petroleum feedstock (6 day test run)



Diesel product meets all requirements of ASTM D975



- 1 Phase I Facilities Complete
- 2 Final Phase Design Basis Stage Gate
- 3 Planned Final Phase Design & Construction
- 4 Phase I Startup & Process Demonstration Ongoing
- 5 Planned Final Phase Startup & Process Demonstration

Challenges and Success

Corn Husks



Tumbleweeds



PDU Filter



Black Oil



Relevance

The IABR is a key step in the development of commercial scale drop-in crude from algae, sunlight and CO2

Approach

Purposeful and targeted technology development that is data driven and maximized for project success

**Technical
Accomplishments**

Large scale outdoor production of drop-in crude to be refined for market use

**Success Factors
and Challenges**

Need to continue with project balance to deliver final goals and maintain momentum and policy support

Future Work

Build out and deployment of Next Generation Technologies

Sapphire's intellectual property program has produced a robust portfolio

Extensive portfolio

- **Over 303 active patent cases***
- ~50 patent families
- Average of 25 filings annually
- Filings and grants are worldwide

Freedom to operate and barrier to entry

Includes patents on all key platform technologies

- Molecular biology
- Cultivation / harvesting
- Extraction
- Upgrading
- Analytics

Claims limit competitors' freedom to operate

- Sequences
- Organisms
- Oils and products

Sapphire is currently producing barrels of Green Crude Oil

