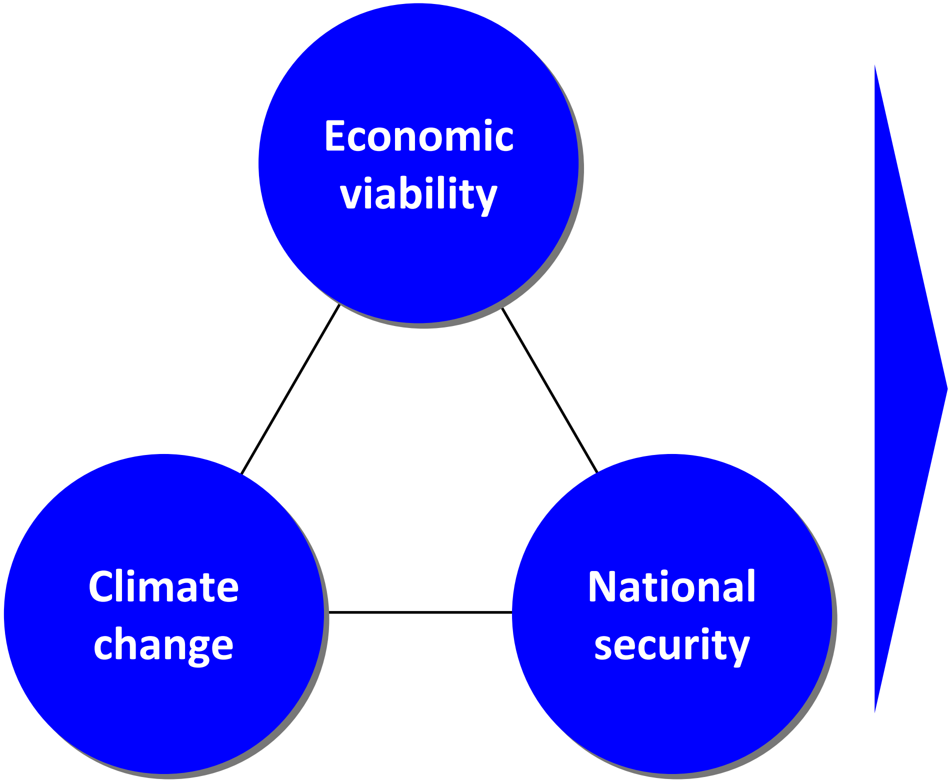
Renewable, Scalable, Algal-Derived Liquid Transportation Fuels

Houston, TX
October 21, 2009

Sapphire Energy

Sapphire Energy was founded under three guiding principles



Key principles

- **Scalable** and **sustainable** energy solutions require **robust economics** and must favorably address **climate change** and **national security**
- Projects failing to meet **all three principles** will not capture and maintain long-term value
- Sapphire concluded that **algae** was the best platform to most clearly meet these **three necessary** objectives

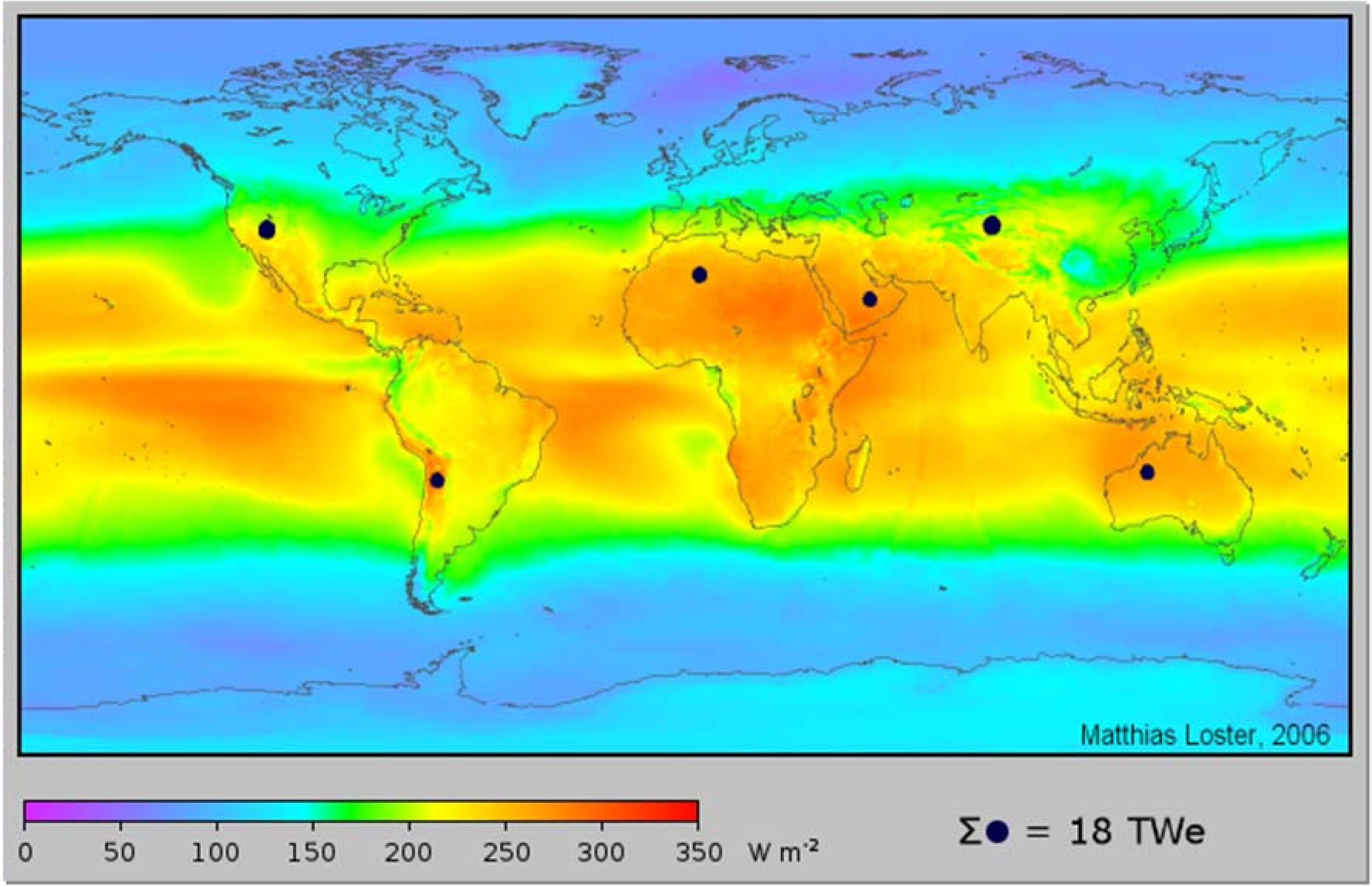
Why Green Crude?

- Fuels that are **completely fungible** (100% “drop-in solutions”) with
  - Existing oil and fuel movement infrastructure (e.g., pipelines, terminals)
  - Existing fleet of land and air vehicles (i.e., cars, trucks, jets)
  - Existing refining infrastructure
- Fuels that **do not compete** with agricultural products, agricultural land, or fresh water
- Fuels that have a **significantly favorable life cycle** with respect to CO_2 compared to conventional petroleum
- Fuels that **can be scaled** to over 1,000,000 barrels per days (>1 MBD) to meaningfully impact the widening gap between fuel production and consumption

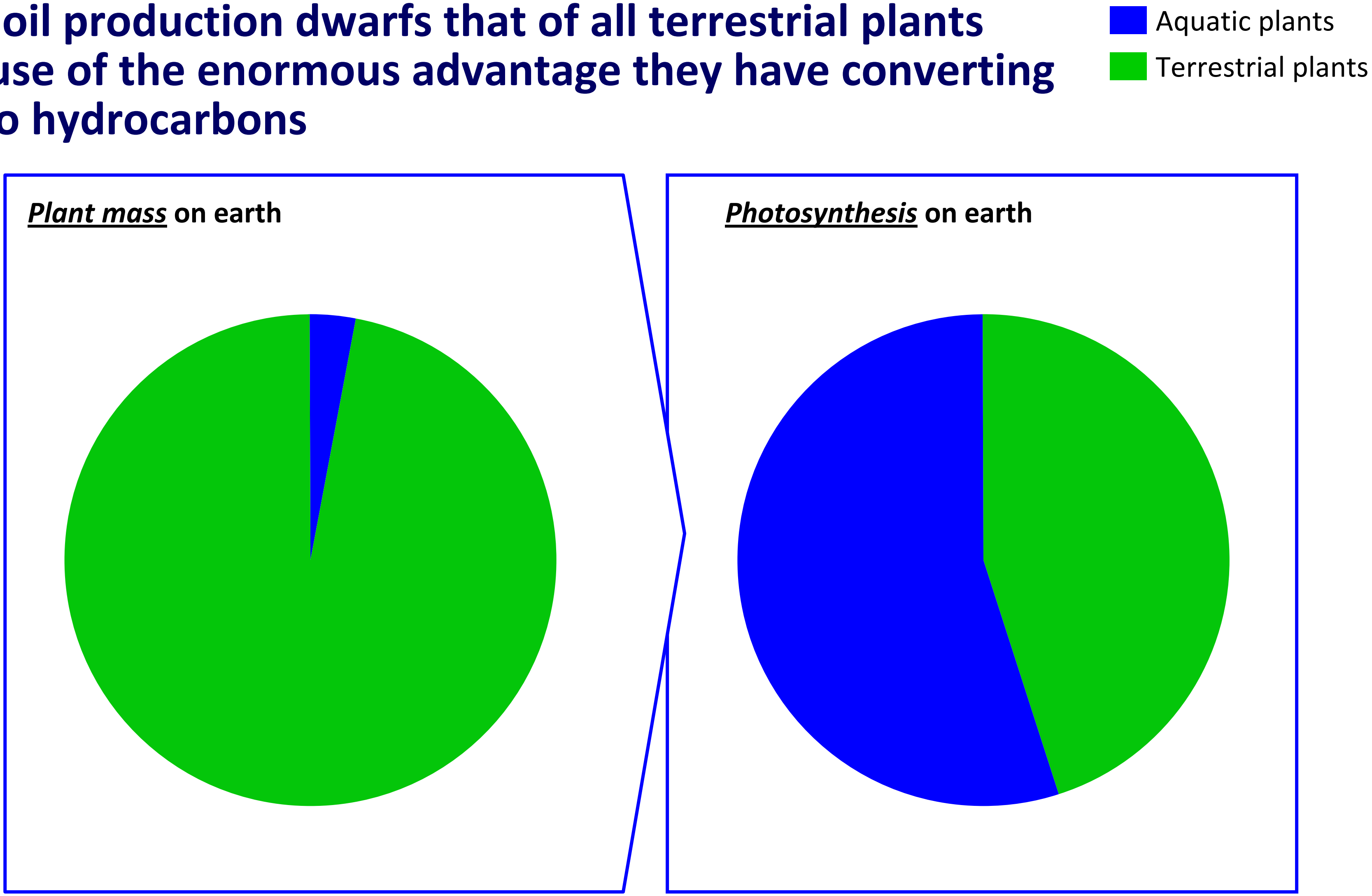
Thunder Horse platform: An example of how far we'll go to find oil – and at what cost

$1B =

There's only one free lunch



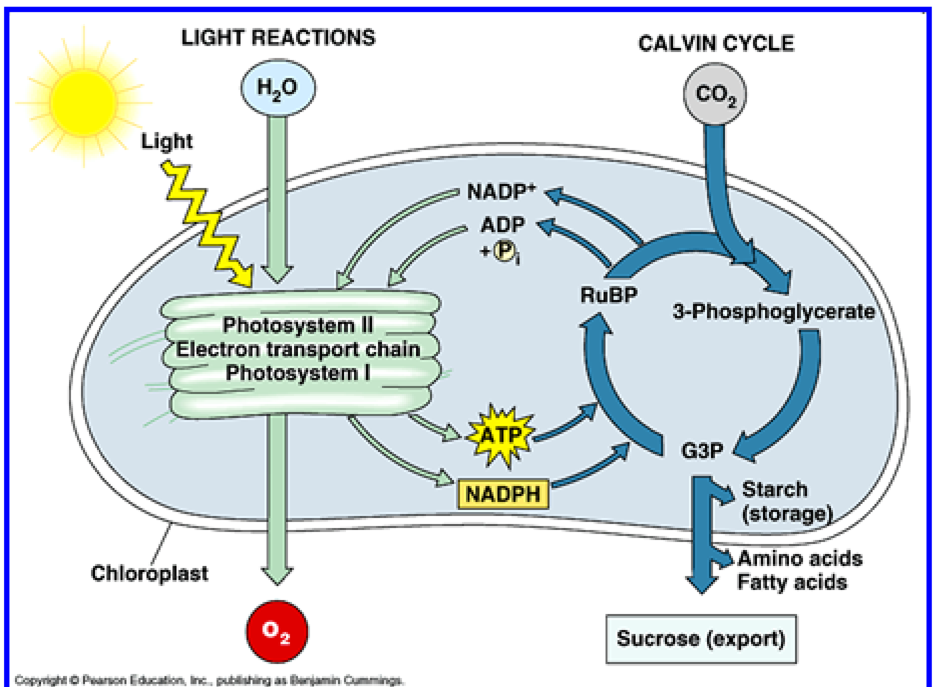
Algal oil production dwarfs that of all terrestrial plants because of the enormous advantage they have converting CO_2 to hydrocarbons



Algae are 40x more efficient at converting sunlight to hydrocarbon than terrestrial plants

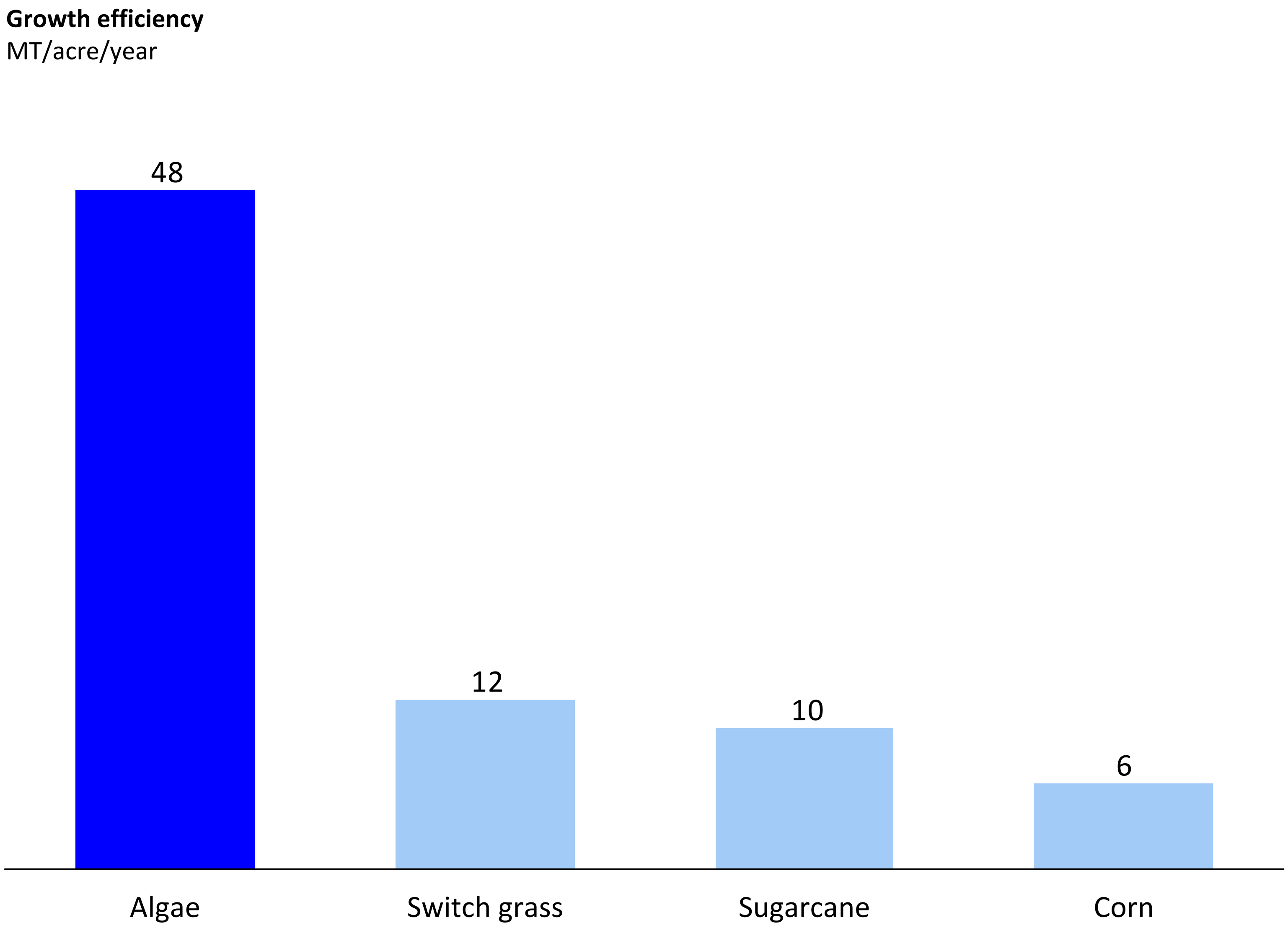
The most important chemical reaction on our planet was tailor made for algae

Ingredients			*Product*	
Sunlight + H_2O	+ CO_2	+ Nutrients →	"CH_2O"	+ O_2
Water	Carbon dioxide	Nitrate NO_3 Phosphate PO_4 Iron Silica	"Organic matter"	Oxygen

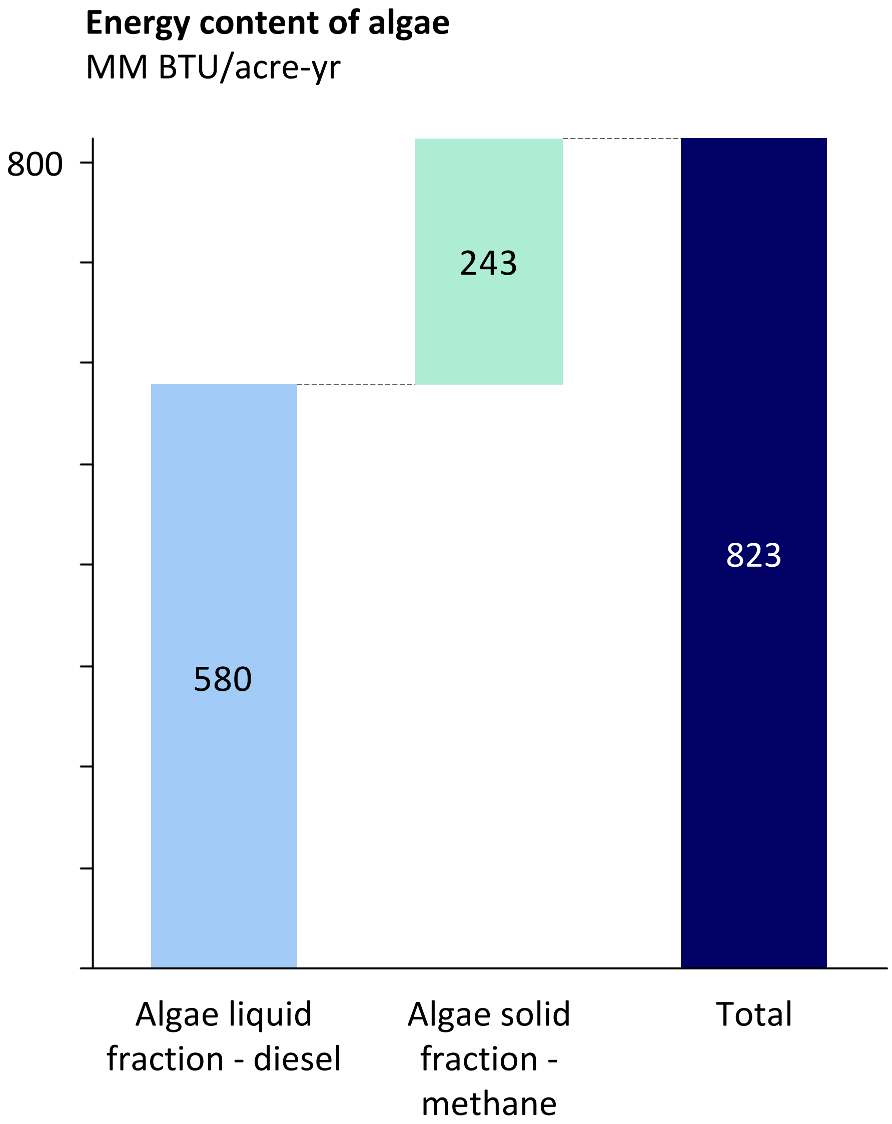


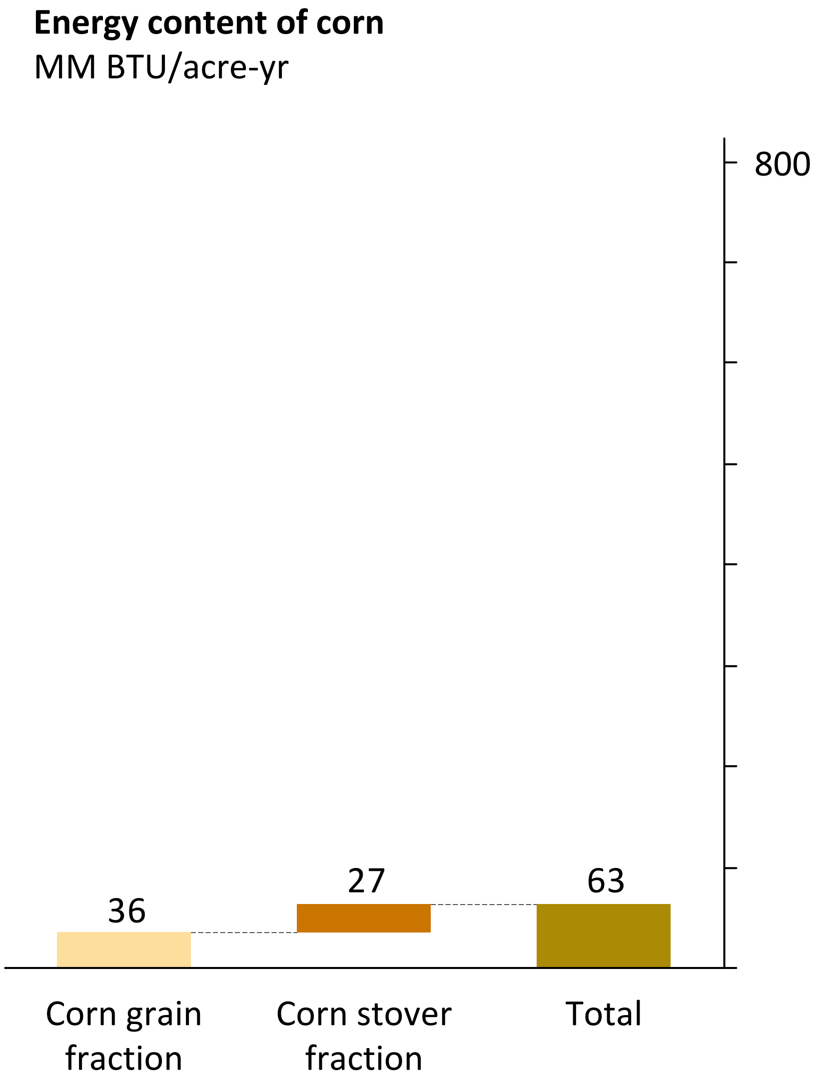
- Nearly all of the biomass of algae is concentrated in the chloroplast – the engine that turns sunlight and CO_2 into organic carbon (i.e., C-C and C-H bonds)
- Algae consume approximately 2 kg of CO_2 for each kg of oil produced
- Algae "waste" no time or energy making stalks, roots, leaves, or fruit in the way terrestrial plants do
- **The result is maximum hydrocarbon per unit area**

Algae are fast growers…



No crop can match the energy density and yield of algae





The implications of (even conservative) oil yields are dramatic

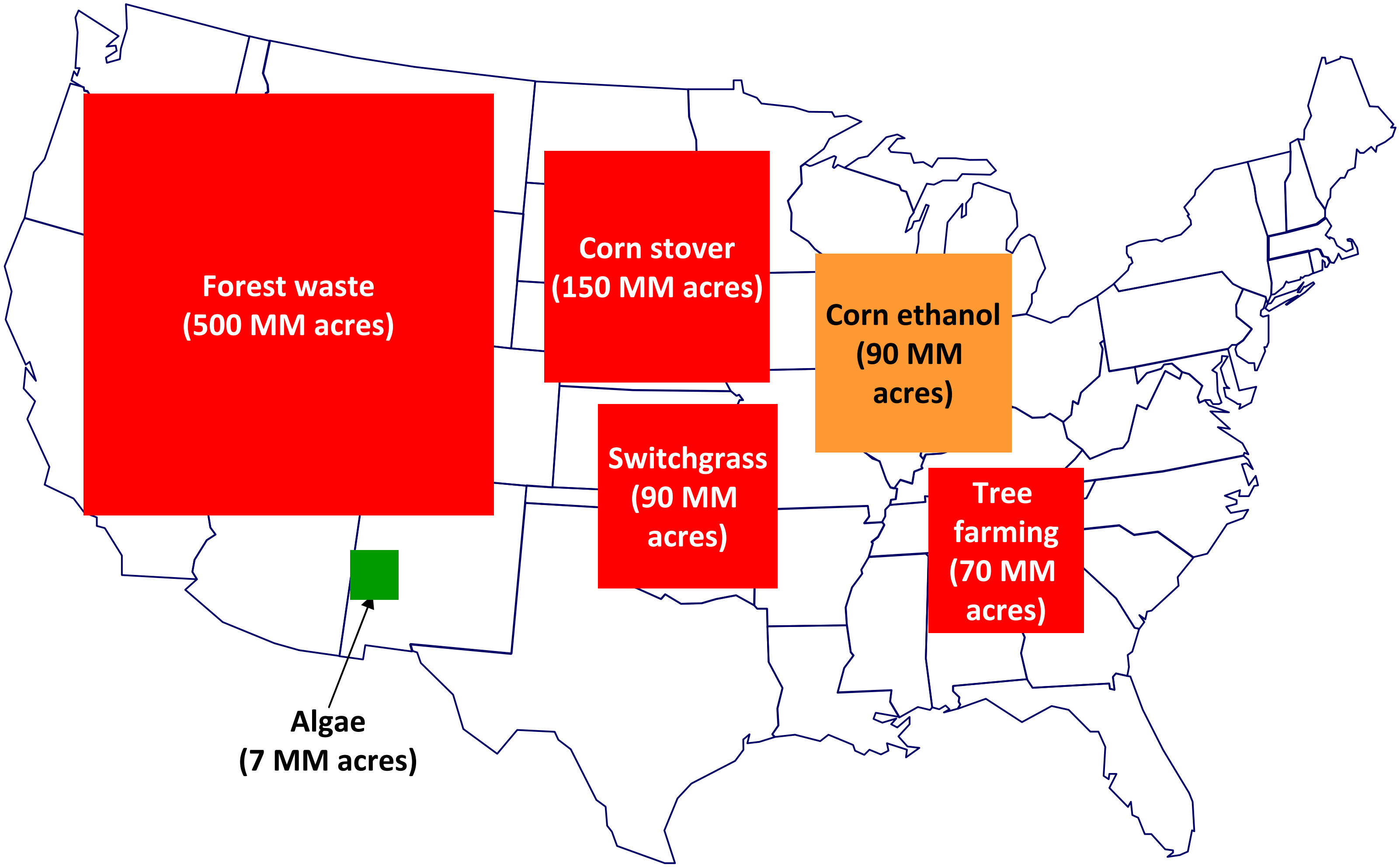
	Current trajectory	Base case, 2020	Best case, 2020	
	5,000	**6,000**	**7,800**	***Gallons of oil per acre per year***
Entire USAF jet fuel consumption 8MM gal/day	0.7 MM acres 33 x 33 miles	0.6 MM acres 30 x 30 miles	0.4 MM acres 26 x 26 miles	
5% of US fuel consumption 29MM gal/day	2.3 MM acres 60 x 60 miles	1.9 MM acres 55 x 55 miles	1.5 MM acres 48 x 48 miles	
10% of US fuel consumption 58MM gal/day	4.7 MM acres 85 x 85 miles	3.9 MM acres 78 x 78 miles	3.0 MM acres 68 x 68 miles	
25% of US fuel consumption **144MM gal/day**	11.7 MM acres 135 x 135 miles	9.7 MM acres 123 x 123 miles	7.5 MM acres 108 x 108 miles	

…by comparison

4% of US consumption by volume* *(23MM gal/day equivalent)*	*23 MM acres* *190 x 190 miles*	***Productivity of corn for ethanol*** *– 25% of growing land used for ethanol to displace 4% of US fuel*

* 3.5% Based on energy content. Numbers based on 2007 production figures from USDA, Greencarcongress

The land required for algae to displace 15% of US transportation fuel usage is a fraction of that of other feedstocks

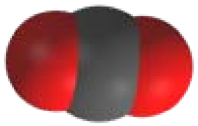


Note: Calculated on a BTU basis. Assumes all algae is used to produced diesel and all cellulosic processes produce ethanol.

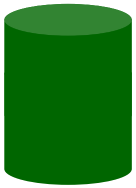
CA Air Resources Board, GREET model, 2009; Walters, Yang, "Corn stover removed without compromising soil quality", Dept. Agronomy & Horticulture, UNL ; Vinod Khosla, Khosla Ventures; Pimentel, Patzeck, "Ethanol Production Using Corn, Switchgrass, and Wood", 2005; McLaughlin, S.B., Kzos, "L.A. Development of switchgrass (Panicum virgatum) as a bioenergy feedstock in the United States"; Purdue University, "Fast-Growing Trees Could Take Root as Future Energy Source"

The feedstock for algal oil production is CO_2

- For every gallon of algal oil produced, approximately 12-15 kg of CO_2 are captured
- Every barrel of algal oil therefore consumes approximately 600 kg of CO_2



CO_2
~600 kg



Algal oil
1 barrel

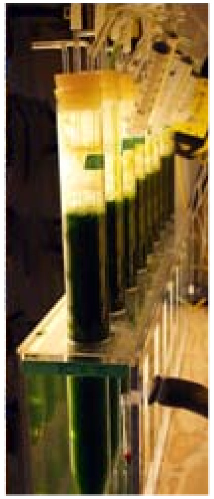
- A 1,000 MW power station emits enough CO_2 to produce over 20,000 barrels of algal oil per day

Power station
1,000 MW

Algal oil facility
20,000 bbl/day

Sapphire's Cultivation R&D testing & development progression in Las Cruces, NM

Column reactors



Bag reactors

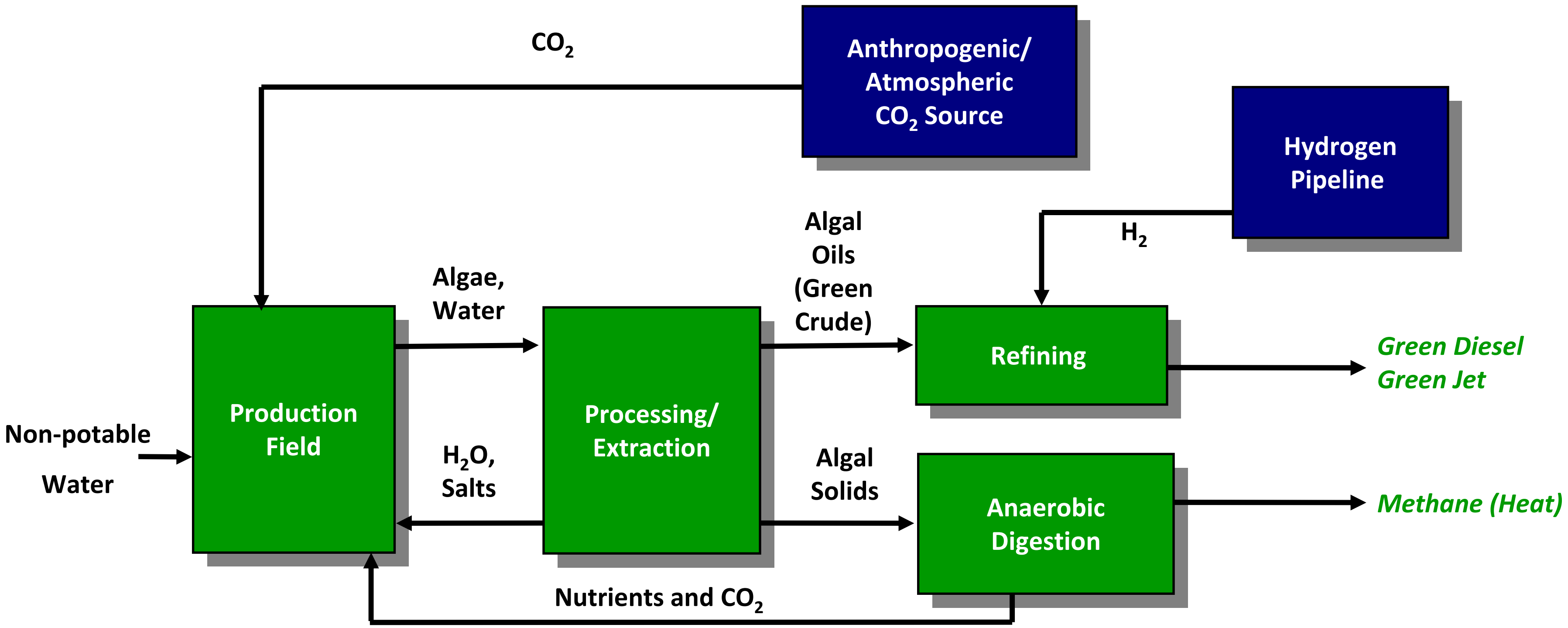
Pre-fabricated ponds

40' raceway ponds

100' raceway ponds

200' and 400' raceway ponds

Integrated Algal Bio-Refinery (IABR) – Our current project



INPUTS

CO_2 capture approx. 35,000 MT/yr
Brackish water input approx. 2,100 acre-ft/yr
300 acres non-arable land
210 tonnes/yr Hydrogen

OUTPUTS

100bpd – green crude
30 MT/day – solids
Minimum 60 bpd – green jet fuel and green diesel

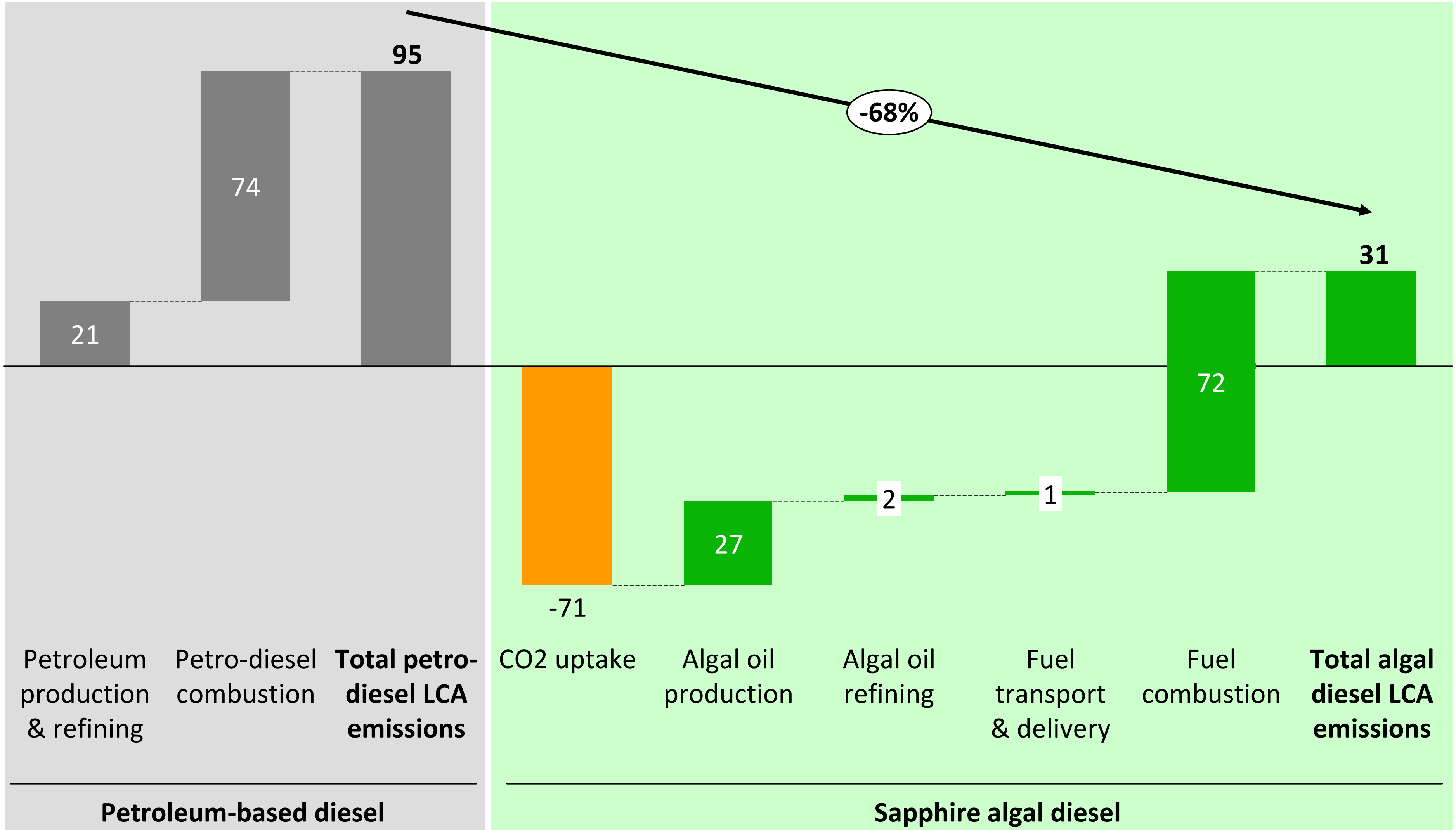
Life Cycle Analysis (LCA): Base case – *Sapphire Algal diesel*

(Sapphire Energy LCA, model v49, r01)

PRELIMINARY

Sapphire fuel GHG impact per MJ of fuel consumed

Grams CO_2 per MJ



Source: Draft values from California Air Resources Board; Life Cycle Associates, LLC

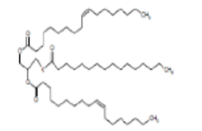
What is Green Crude?

	Fossil Crude	Algae Oil
C	84-87%	77-78%
H	11-14%	11-12%
S	<0.1-8%	<<0.1%
N	<0.1-1.5%	~0.5-4%
O	<0.1%	10-12%
P	<<0.1%	0.3-1%
Olefins	<1%	?
Metals	<0.01-0.15%	~0.05%

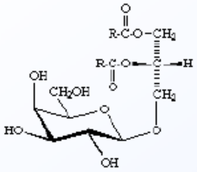
At commercial scale:

How can we make Green Crude fungible (like the final fuels)?

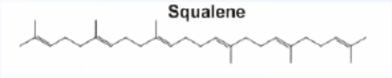
Can it be transported by pipeline?



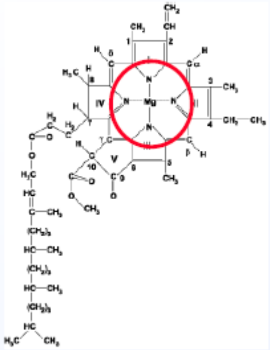
Triglycerides (and FFA's)



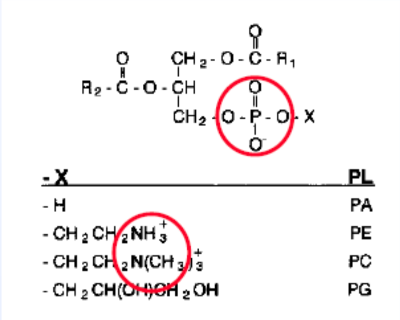
Glycolipids



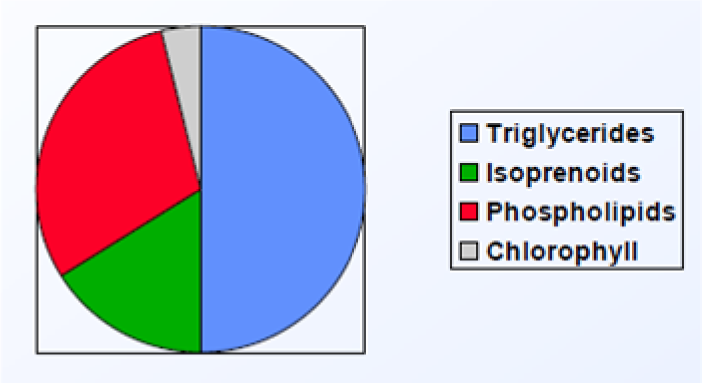
Isoprenoids

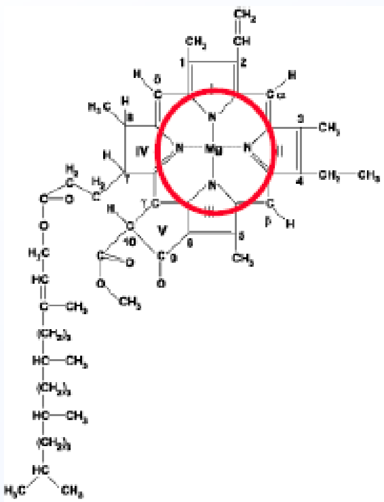


Chlorophyll

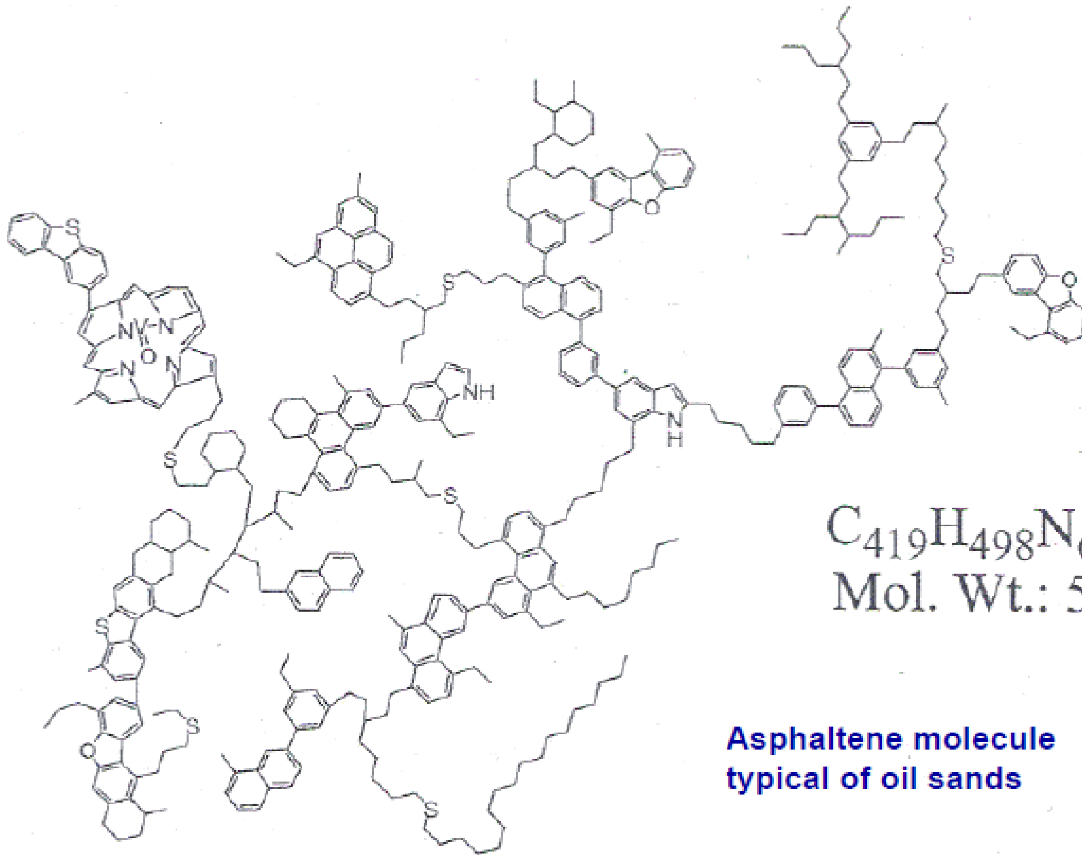


Phospholipids





Chlorophyll



$C_{419}H_{498}N_6O_4S_8V$

Mol. Wt.: 5989.94

Asphaltene molecule typical of oil sands

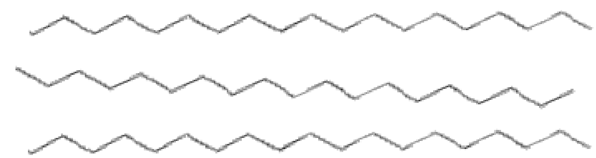
Downstream Processing of Algal Oils to Fuels

Hydroprocessing of Algal Oil

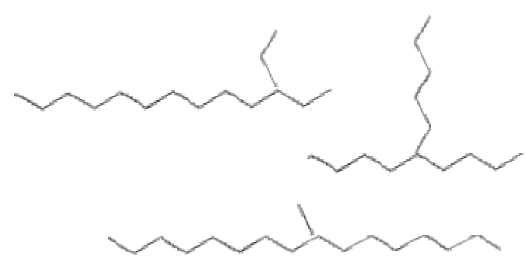
Triglycerides and FFA's

Hydrotreating (HDO)

***n*-alkanes**



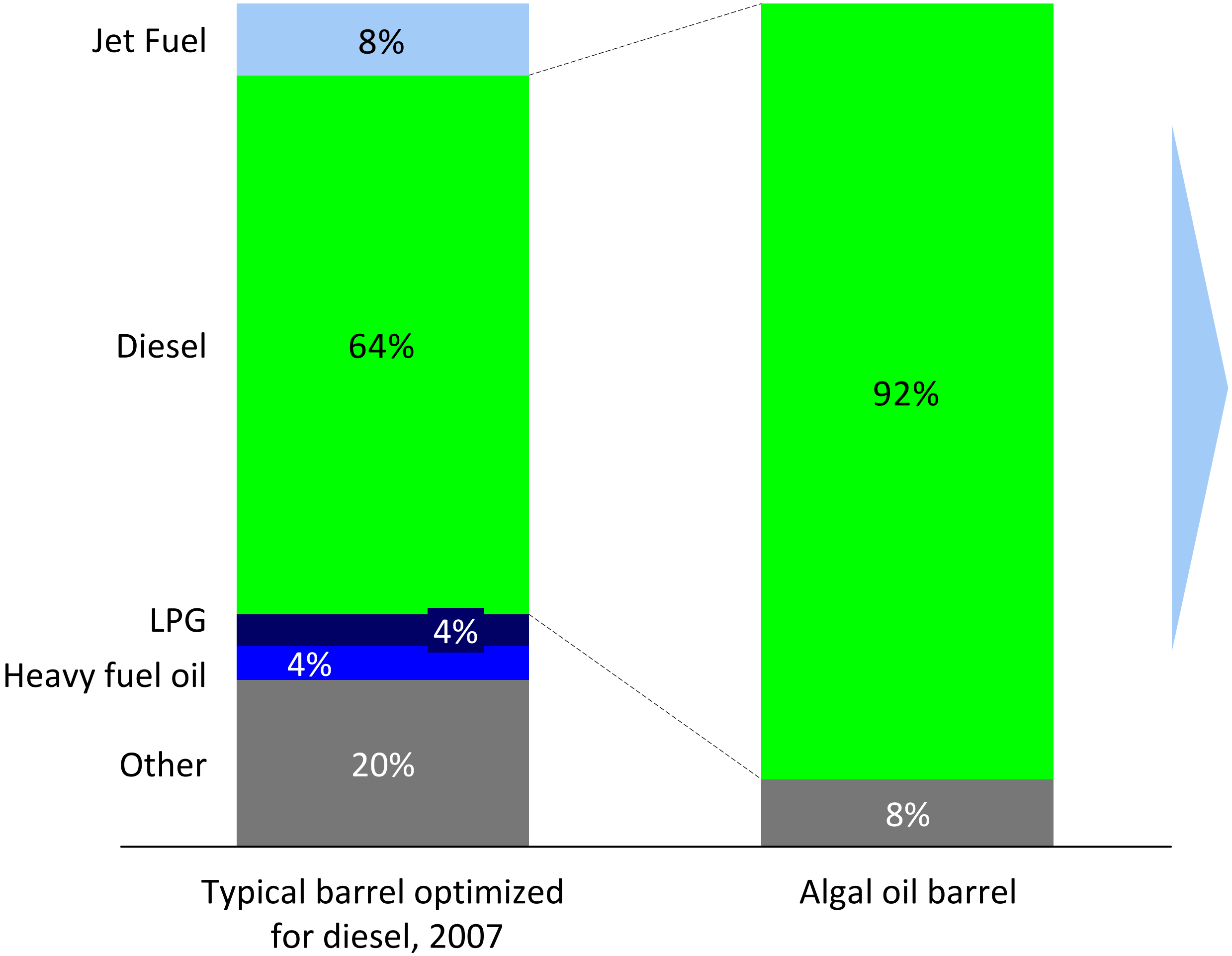
Isomerization/ Cracking



SPK/IPK

***iso* (and cyclic) -alkanes**

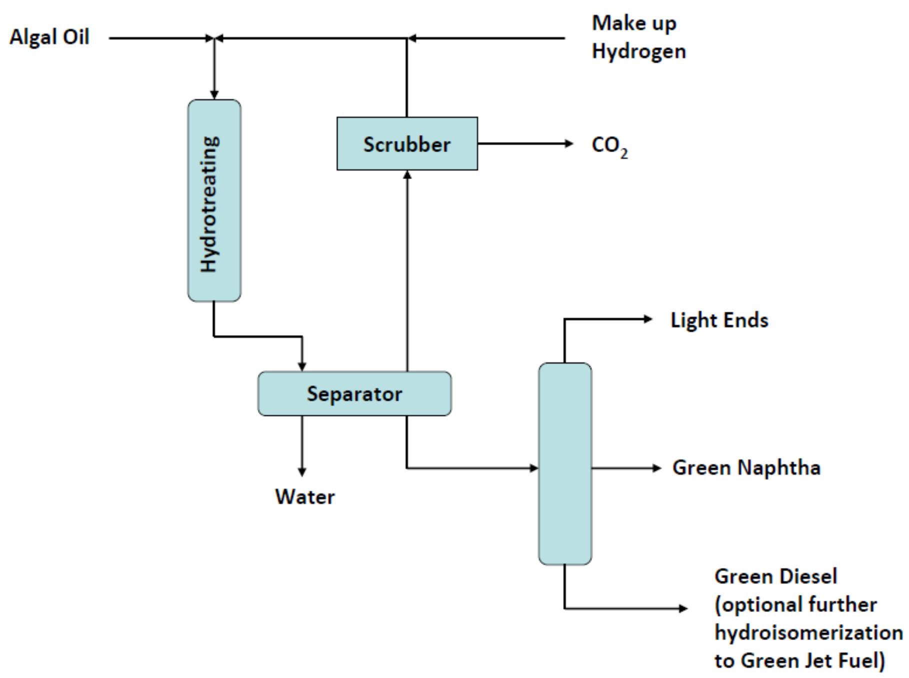
Each barrel of algal crude has a much higher yield of transportation fuels than a barrel of conventional petroleum



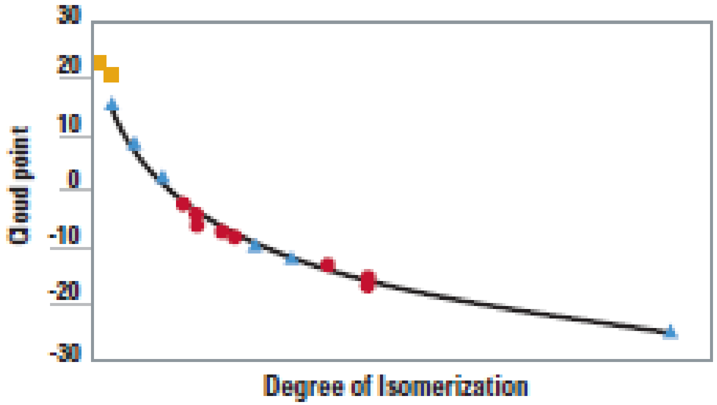
Hence a barrel of algal crude – *based solely on chemical composition and product profile* – could be expected to fetch a premium of 30-40% of 'conventional' crude

Sapphire's algal oil can be hydrotreated to create green diesel and green jet fuel (SPK); degree of isomerization determines yield and rates

Flow diagram for hydrotreating to green diesel and jet



Degree of isomerization critical in determining product properties



- Summer diesel abound 92% yield (+ naphtha)
- Winter diesel around 88% yield (+ naphtha)
- Green jet 65-70% yield (+ diesel and naphtha)

Sapphire has processed biomass grown in Las Cruces, NM to produce on-spec summer and winter diesel, and green jet

Summer and winter diesel

Lightly isomerized to summer diesel and winter diesel (cloud point -10°C)

Green jet (SPK)

Heavily isomerized and distilled to yield colorless Green Jet Fuel (SPK/IPK)

Sapphire has been involved in half of the successful biofuel test flights

	Virgin Atlantic LHR-AMS	Air New Zealand AKL	Continental IAH	Japan Airlines NRT
Date	Feb 24, 2008	Dec 30, 2008	Jan 7, 2009	Jan 29, 2009
Airplane model	Boeing 747-400	Boeing 747-400	Boeing 737-800	Boeing 747-300
Consortium		Terasol	Terasol, **Sapphire**	Sustainable Oils, Terasol, **Sapphire**
Feedstock	Coconut, Babassu	Jatropha	Jatropha, **Algae**	Camelina, Jatropha, **Algae**
Refiner	Imperium	UOP	UOP	UOP
Product	Tailored biodiesel	HRJ ("drop in")	HRJ ("drop in")	HRJ ("drop in")

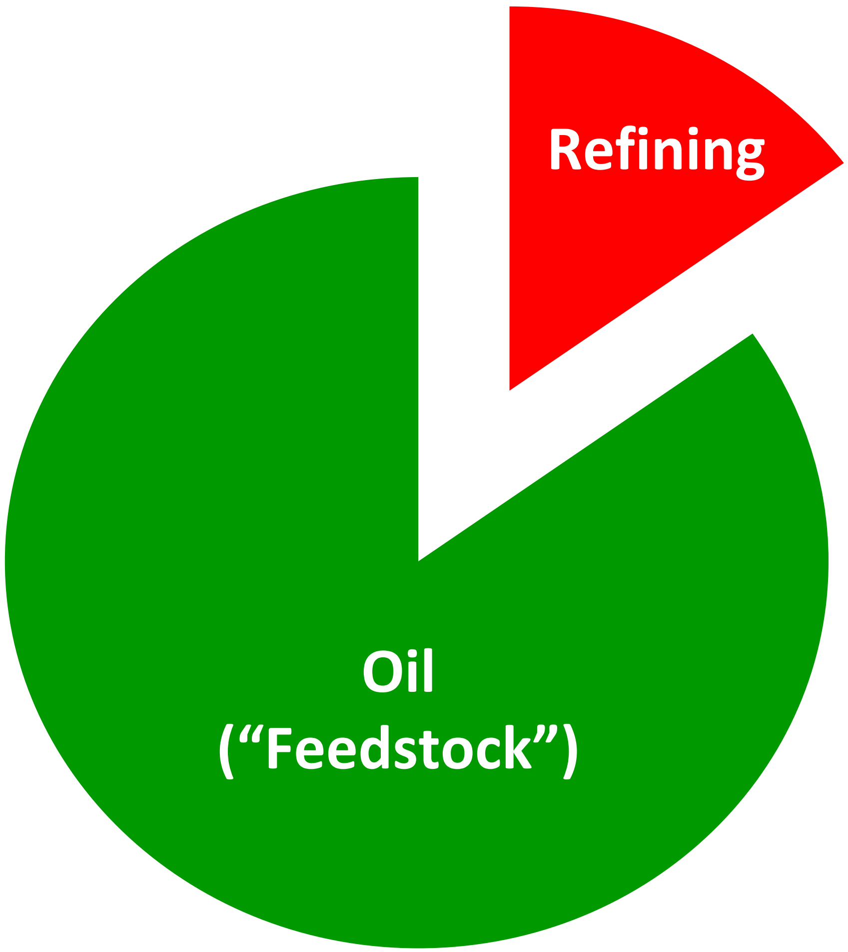
Lessons learned in addition to critical aviation-technical data:

- Hydrotreated Renewable Jet (HRJ) represents a "drop in" option
- Hydrotreating technology is familiar to refiners and technology providers
- Key issues are availability of viable oils and cost of HRJ

Sapphire participated in the first flight ever using synthetic jet fuel made from algae – *January 7, 2009*

- Two-hour test flight with 2-engine 737-800
  - Engine 1: Conventional petroleum-based jet fuel
  - Engine 2: 50% conventional, 50% synthetic jet fuel (blend of algae- and jatropha-derived spec jet fuel)
- “The airplane performed perfectly,” test pilot Rich Jankowski said. “There were no problems. It was textbook.”
- The plane burned 3,600 pounds of the 50-50 jet fuel-biofuel mix in engine 2 and roughly 3,700 pounds of traditional fuel in engine 2, implying the test batch was somewhat more efficient

Cost of manufacturing HRJ is primarily in the feedstock



Typical green diesel properties

Attribute	Units	ASTM D 975	Green Diesel - Typical Summer Grade	Green Diesel - Typical Winter Grade
Flash point	°C	52 min	**59**	**60**
Copper strip corrosion rating	-	No. 3 max	**No. 1a**	**No. 1a**
Ramsbottom carbon residue	wt %	0.35 max	**0.04**	**TBD**
Viscosity @ 40°C	cSt	1.9-4.1	**2.4**	**2.5**
Specific gravity @ 15°C	g/ml	Not specified	**0.774**	**0.776**
Distillation 90%	°C	282-338	**286**	**282**
Cloud point	°C	0 to -26 (seasonal max values)	**-13 (9°F)**	**-26 (-15°F)**
Sulfur*	ppm	15 (ULSD max)	**0.8**	**0.8**
Ash	wt %	0.01 (max)	**<0.005**	**<0.005**
Cetane**	-	40 min	**80-90**	**80-90**
Aromaticity	% vol.	**35 max**	**<1**	**<1**

* Just as with ULSD, Green Diesel requires a lubricity additive – various options available

** Heating value: Petrodiesel 43 MJ/kg, Green Diesel 44 MJ/kg

Summary

Performance

- Sapphire technology delivers **algal-derived green jet** and **green diesel** that **meets** or **exceeds** all current specifications
- Sapphire delivered the **only algal-derived green jet fuel** to fly on a commercial jet (January 7 2009, Continental Airlines)
- Sapphire green diesel **outperforms petrodiesel** in terms of both **energy content** (by around 3%) and **cetane** (by over 100%)

Environmental

- Sapphire green diesel affords **major benefits** in reduced **emissions** of all types, NO_x, SO_x, and the increasingly important **polyaromatics** and **particulate matter**

Cost

- Sapphire green diesel will be **cost-competitive with petrodiesel**
- Sapphire green diesel (by virtue of it's high cetane value) can be **beneficially blended** with lower value refinery streams such as LCO (light cycle oil)