Sapphire Energy

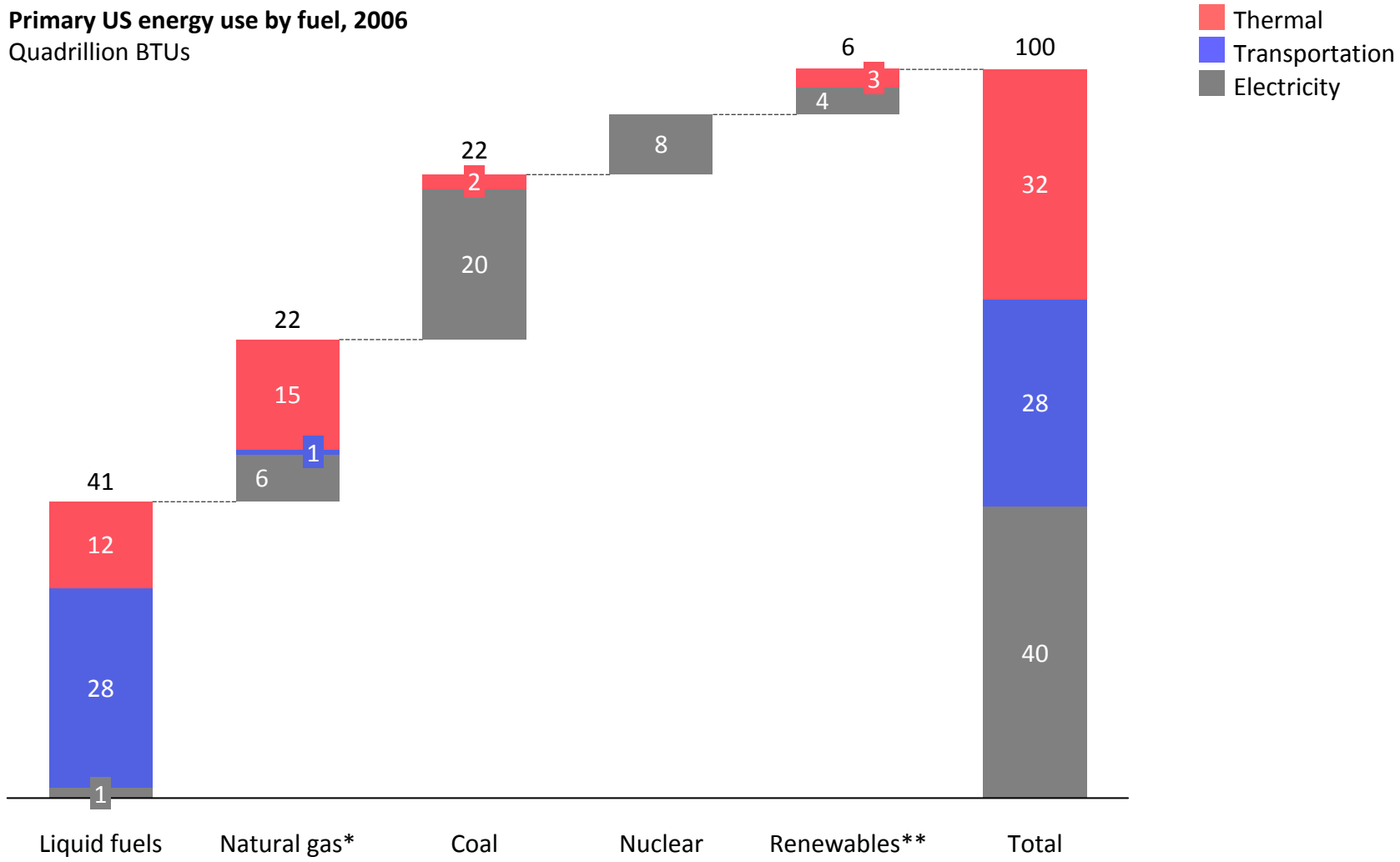
Creating the Potential for Fuels from Algae

Presented by Cynthia J Warner, President

Sapphire
Energy

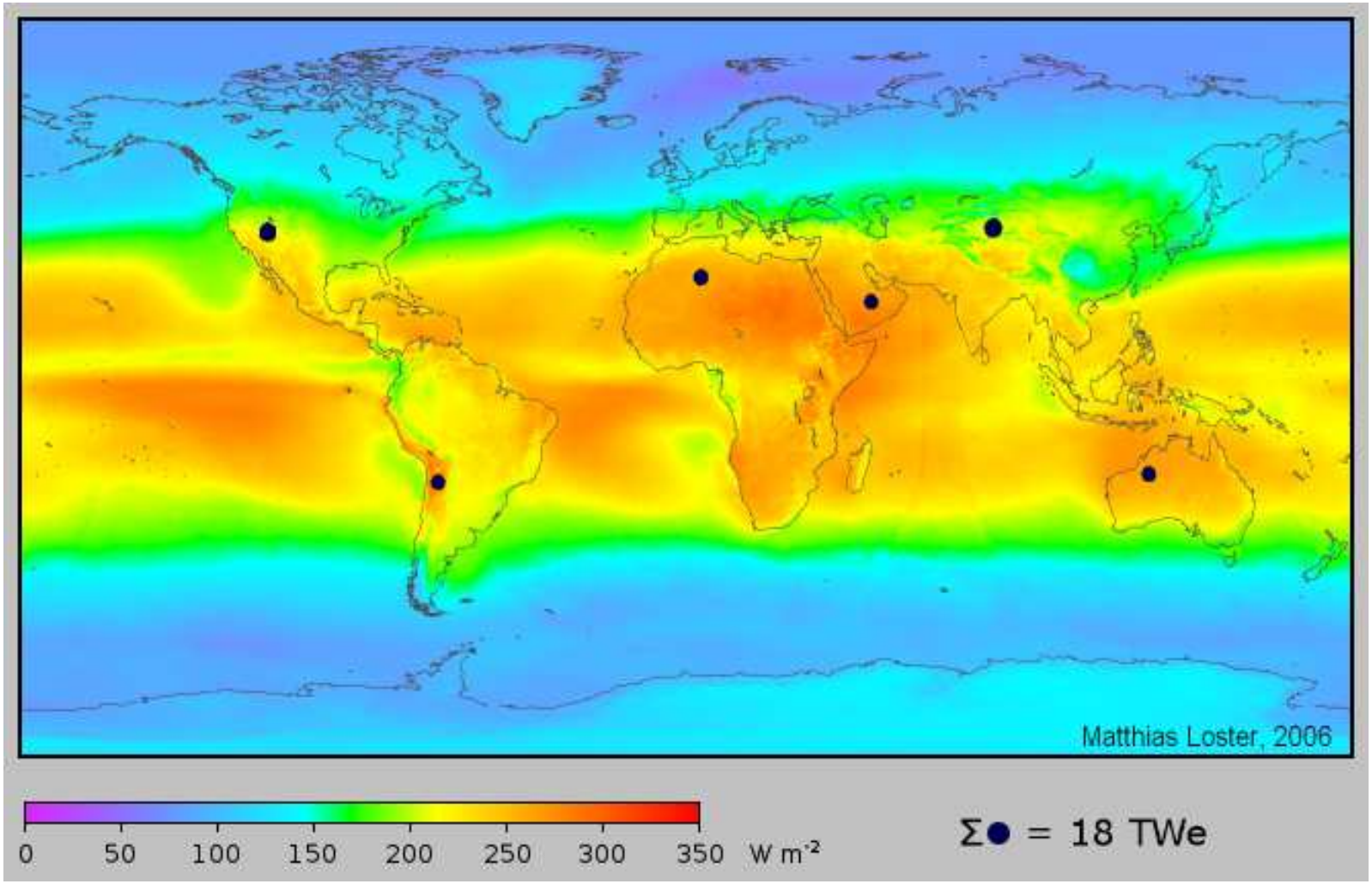
Liquid transportation fuels are a major source of energy use, though renewables make up a tiny fraction

Primary US energy use by fuel, 2006
Quadrillion BTUs

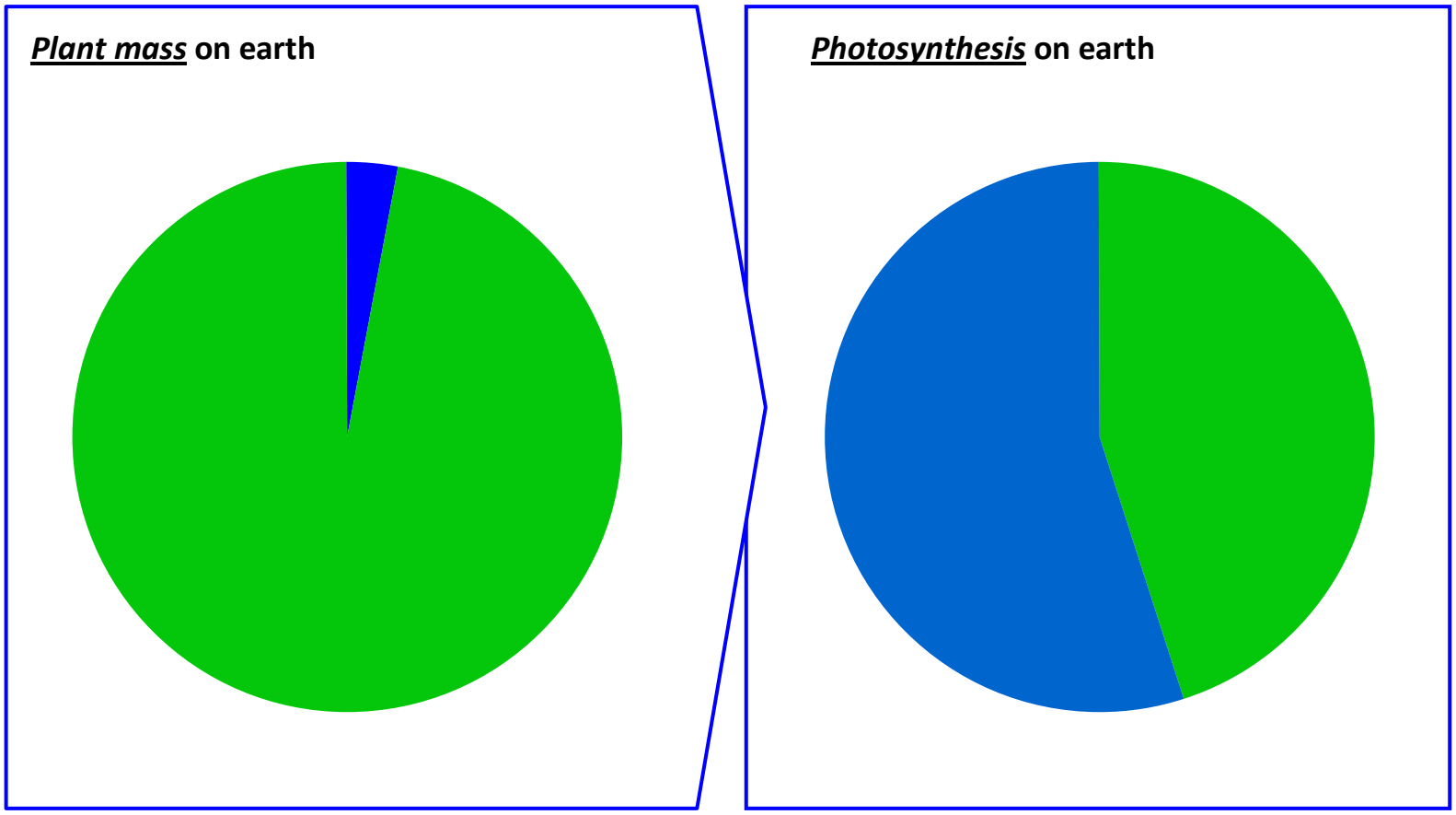


* Natural gas for transportation is composed largely of compressed natural gas and pipeline fuel.
** Includes geothermal, wood and wood waste, biogenic municipal waste, other biomass, wind, photovoltaic and solar thermal sources. Includes petroleum coke used in the electric power sector.
Source: DOE, "Annual Energy Outlook 2008," June 2008.

Why photosynthesis? 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

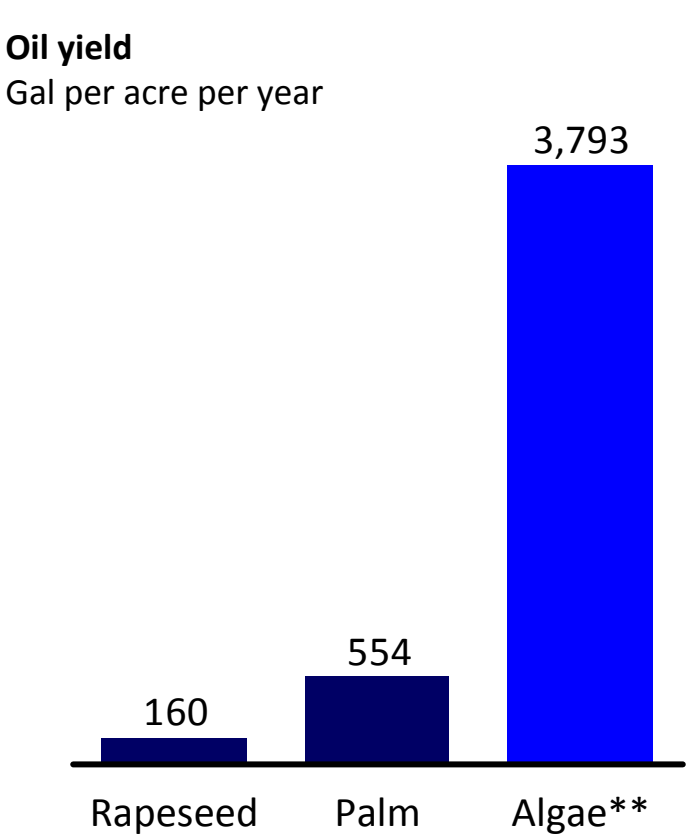
Even with the most conservative estimates, algae provide extraordinary yields

A highly efficient conversion of solar energy…

Solar irradiation	100%
Photosynthetic active radiation (PAR)	40%
Entering the water body	75%
Max efficiency of photosynthesis	25%

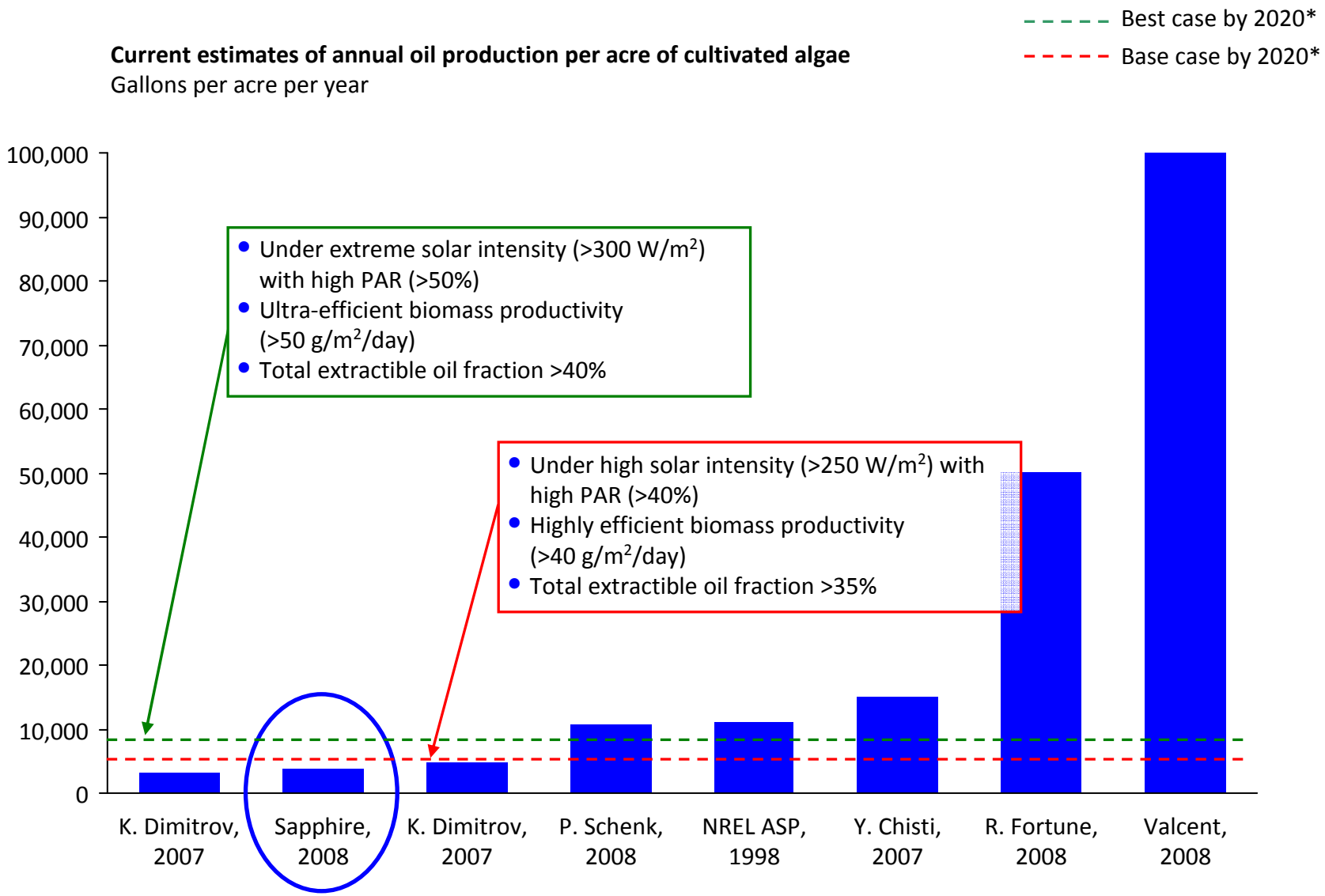
Theoretically maximum PE	**8% of total irradiation**
Target PE for conversion of sunlight to hydrocarbon*	**1.9 – 3.8% of total irradiation**

…Leads to high yields of oil



* Assuming 25-50% of theoretical maximum PE is achievable
** Yield at 30 g/m^2/day (Medium irradiation); 30% oil content

There is no shortage of estimates for how much oil an acre of algae can yield per year



* Based on internal estimates

The implications of (even conservative) oil yields are dramatic

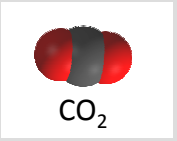
	Current trajectory	Base case, 2020	Best case, 2020	
	3,800	**5,170**	**7,800**	← ***Gallons oil per acre per year***
	4:1	**3:1**	**2:1**	← ***Acres per barrel oil per day***
	10.5	**14**	**21**	← ***Liquid biomass gm per m^2 per day***
Entire USAF jet fuel consumption (200,000 bpd)	800,000 acres 35x35 miles	600,000 acres 31x31 miles	400,000 acres 25x25 miles	
5% of US consumption (1,000,000 bpd, 1 MBD)	4 MM acres 80x80 miles	3 MM acres 70x70 miles	2 MM acres 55x55 miles	
10% of US consumption (2,000,000 bpd, 2 MBD)	8 MM acres 112x112 miles	6 MM acres 97x97 miles	4 MM acres 80x80 miles	
25% of US consumption (5,000,000 bpd, 5 MBD)	24 MM acres 190x190 miles	18 MM acres 165x165 miles	12 MM acres 135x135 miles	} ***Total US oil production**, including off-shore and arctic is ~5 MBD*
50% of US consumption (10,000,000 bpd, 10 MBD)	40 MM acres 250x250 miles	30 MM acres 215x215 miles	20 MM acres 175x175 miles	
4% of US consumption by volume* (800,000 bpd equivalent)		23 MM acres 190x190 miles		} ***Productivity of corn for ethanol** – 25% of corn growing land was used to make ethanol to displace 4% of US fuel*

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

Why Green Crude?

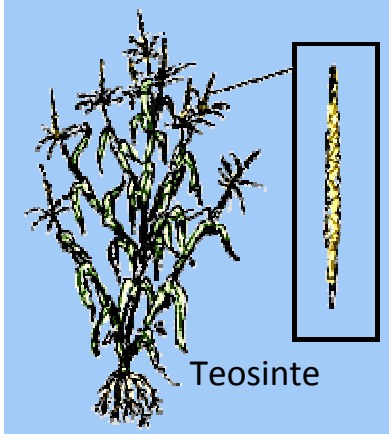
- Fuels that are **completely fungible** (100% “drop in solutions”) with
  - Existing oil and fuel movement infrastructure (e.g., pipelines, terminals)
  - Existing fleet of land and air vehicles (i.e., cars, trucks, jets)
  - Existing refining infrastructure
- Fuels that **do not compete** with agricultural 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 well over 1,000,000 barrels per days (>1 MBD) to meaningfully impact the widening gap between fuel production and consumption

Transportation fuels need to have characteristics to match upcoming policy and infrastructure

	 Infrastructure compliant	 Fleet compliant	 Growth potential	 Domestic	 Renewable	 GHG compliant
Sapphire fuels	●	●	●	●	●	●
Petroleum fuels	●	●	●	●	●	●
Alcohols	●	●	●	●	●	●
Bio-diesel	●	●	●	●	●	●
Hydrogen	●	●	●	●	●	●
Electricity	●	●	●	●	●	●

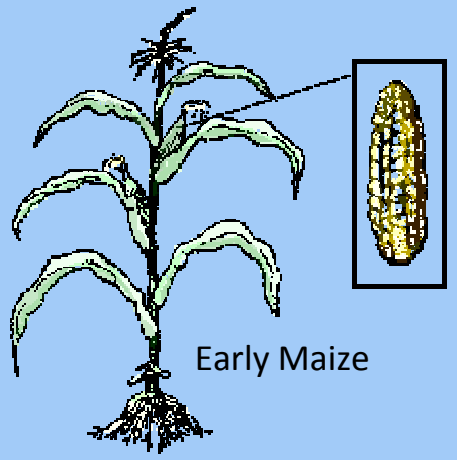
Why is directed evolution necessary?

- Crop domestication required thousands of years of human ingenuity and, ultimately, directed evolution



Teosinte

~7,000 years ago



Early Maize

~1,000 years ago

Today

- Why should algae be any different?
- Algae can be domesticated in 5 – 10 years using systems biology and synthetic biology

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

PRELIMINARY

Commercialization timeline - *overview*