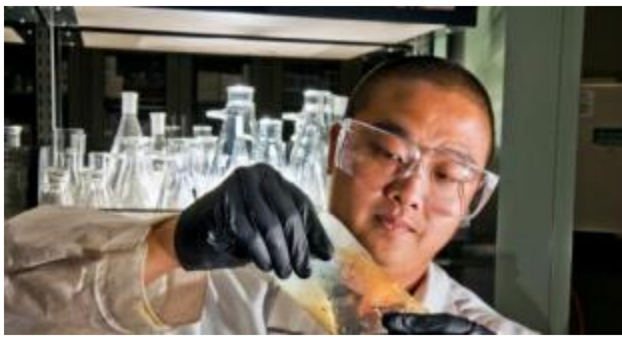
SAND2014-16000PE

Exceptional service in the national interest

Sandia National Laboratories



Algae biofuels potential impact

Ben Wu, PhD

Sandia National Laboratories

U.S. Department of Energy NNSA National Nuclear Security Administration

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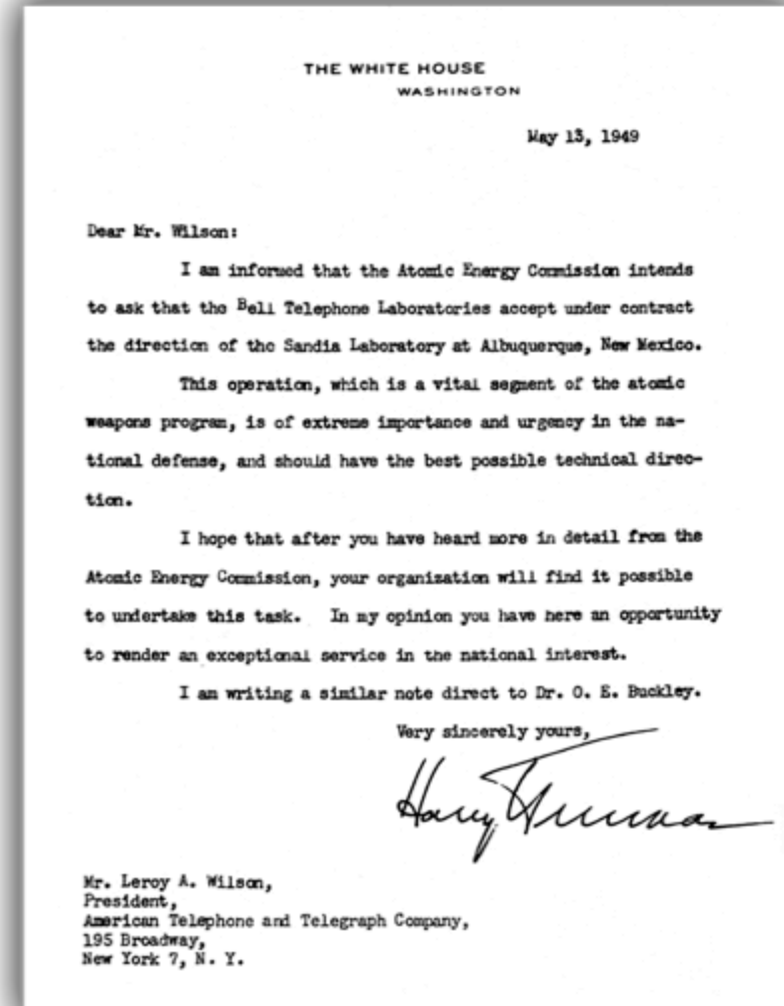
Sandia's History



THE WHITE HOUSE
WASHINGTON

May 13, 1949

Dear Mr. Wilson:

I am informed that the Atomic Energy Commission intends to ask that the Bell Telephone Laboratories accept under contract the direction of the Sandia Laboratory at Albuquerque, New Mexico.

This operation, which is a vital segment of the atomic weapons program, is of extreme importance and urgency in the national defense, and should have the best possible technical direction.

I hope that after you have heard more in detail from the Atomic Energy Commission, your organization will find it possible to undertake this task. In my opinion you have here an opportunity to render an exceptional service in the national interest.

I am writing a similar note direct to Dr. O. E. Buckley.

Very sincerely yours,

Harry Truman

Mr. Leroy A. Wilson,
President,
American Telephone and Telegraph Company,
195 Broadway,
New York 7, N. Y.

Sandia's Sites


Albuquerque, New Mexico


Livermore, California


Kauai, Hawaii

Waste Isolation Pilot Plant, Carlsbad, New Mexico

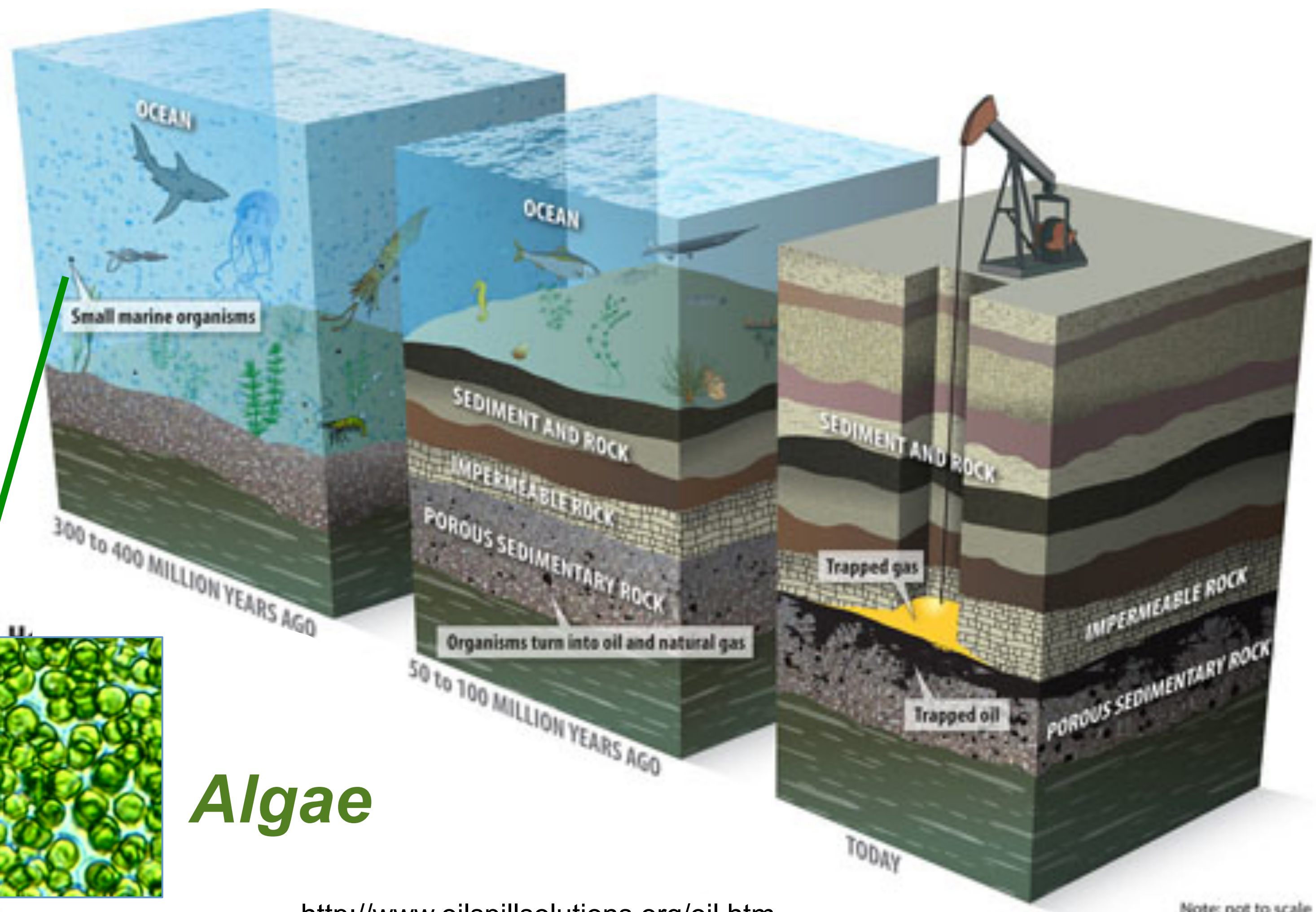

Pantex Plant, Amarillo, Texas

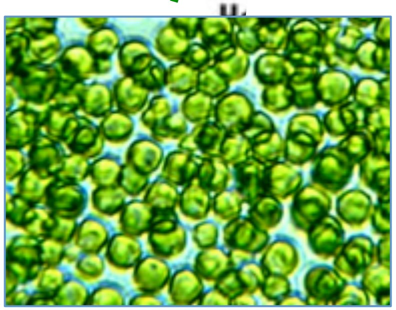

Tonopah, Nevada

SNL energy strategy targets national security missions

- *Reduce our dependence on foreign oil*
- *Increase deployment of low carbon stationary power generation*
- *Understand risks and enable mitigation of climate change impacts*
- *Increase security and resiliency of critical infrastructures*
- *Strengthen the nation's S&T base in energy, climate, and infrastructure*

Petroleum started as algae 300 million years ago

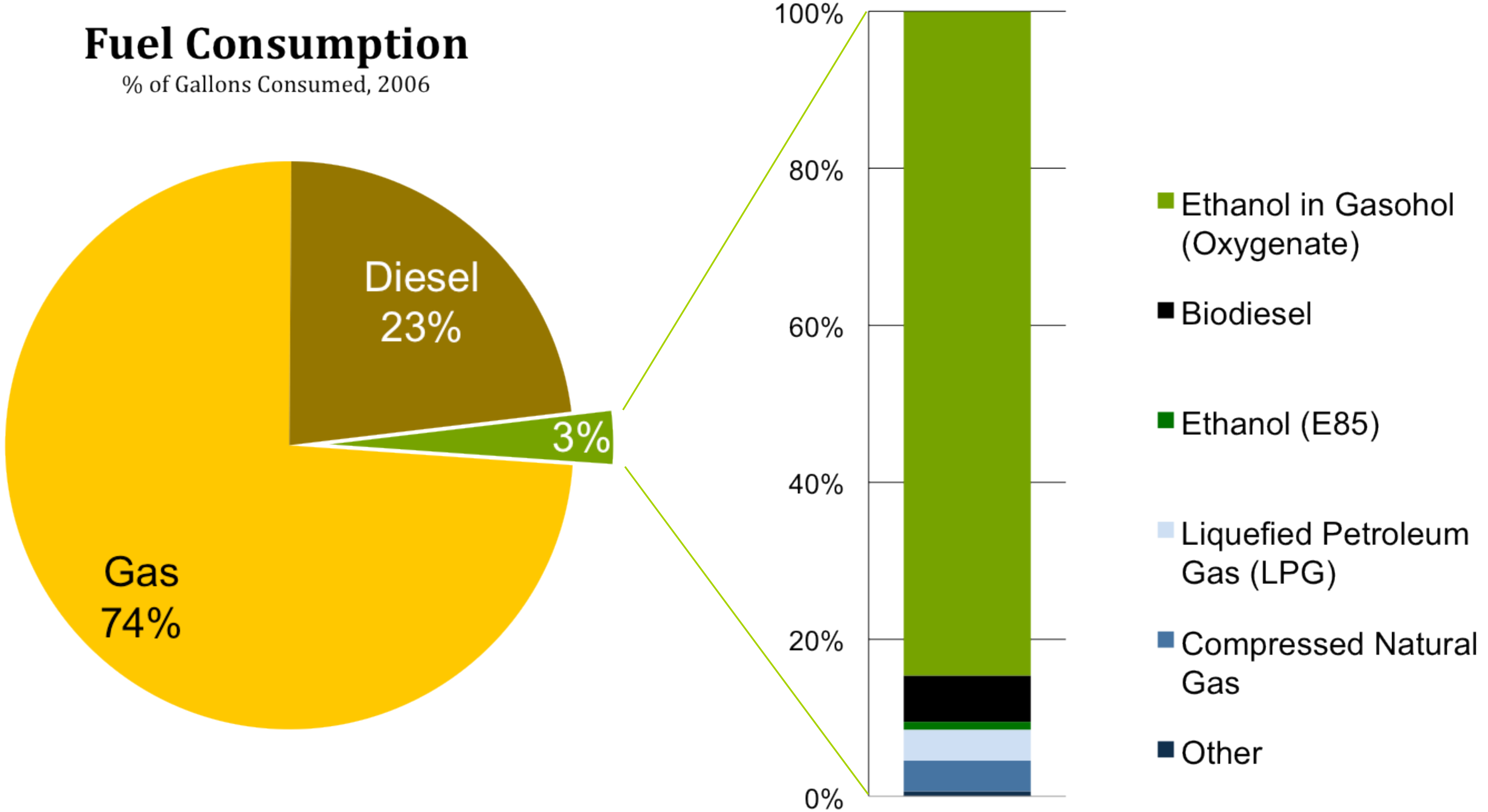




Algae

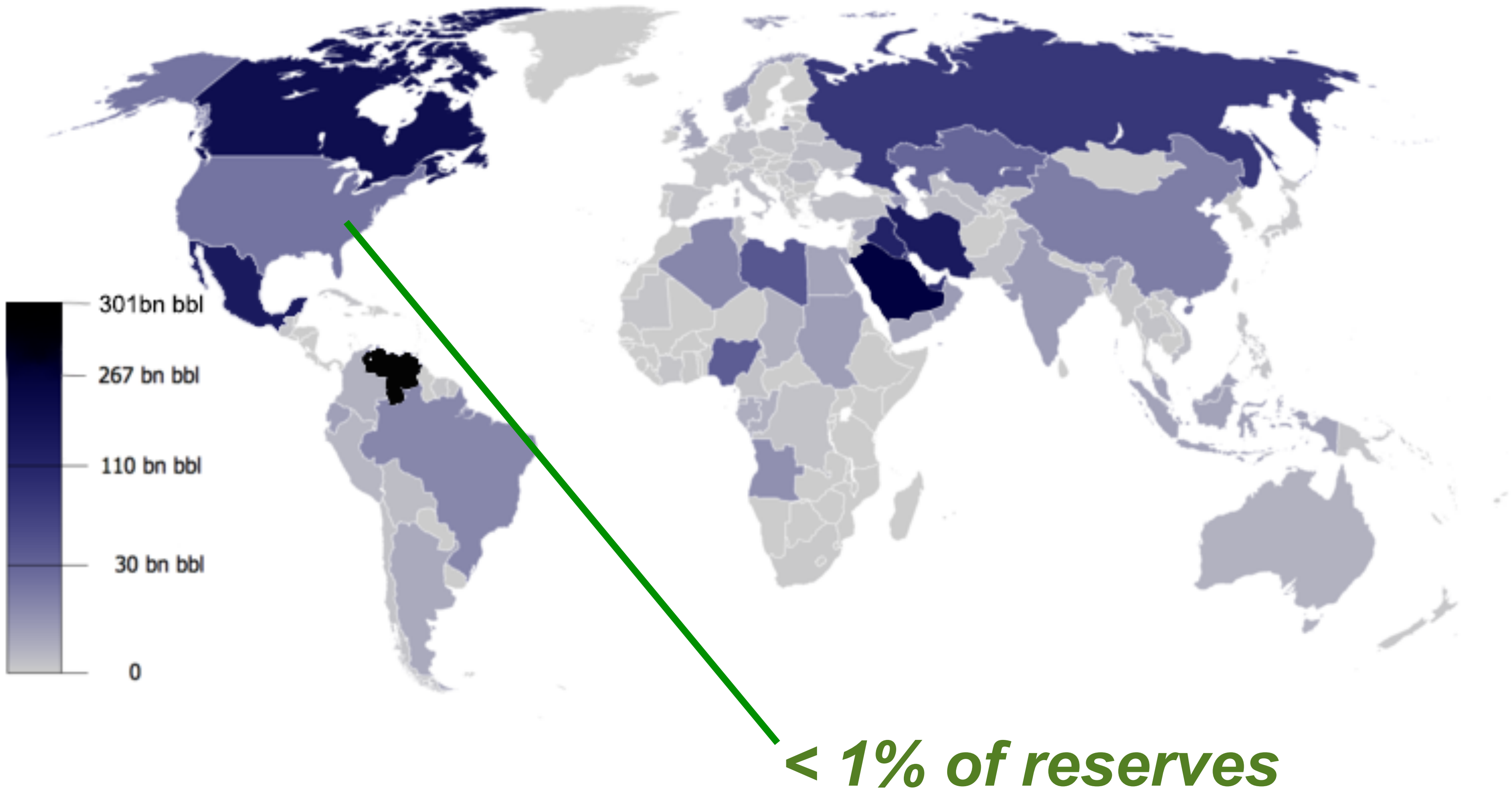
http://www.oilspillsolutions.org/oil.htm

Petroleum dominates transportation fuels



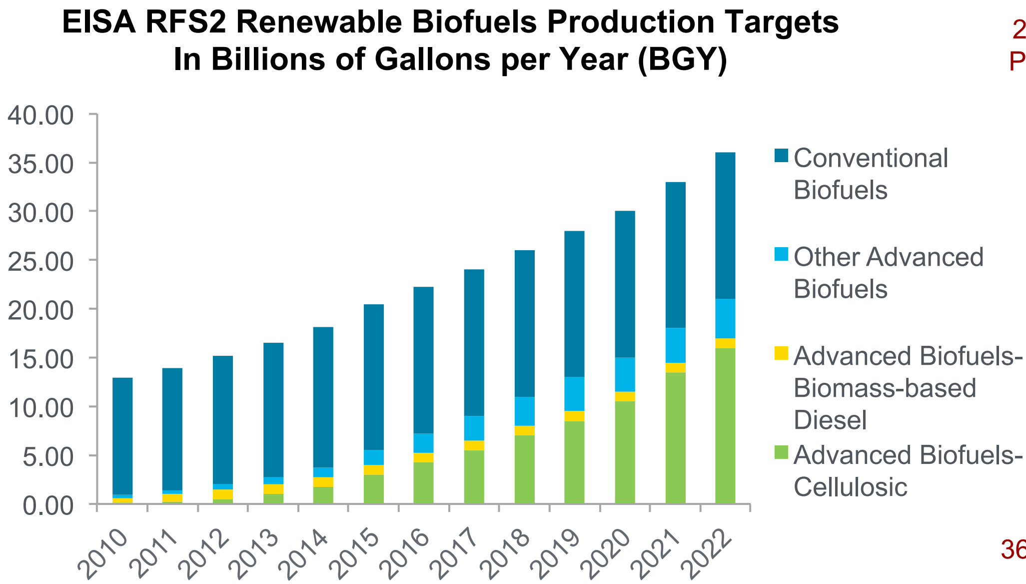
Source: Alternatives to Traditional Transportation Fuels, 2007, Release Date: April 2009
Statistics: Estimated Consumption of Vehicle Fuels in the United States, by Fuel Type

Most petroleum reserves are outside of the United States



Source: OPEC (2013)

U.S. produced 14.6B gallons per year of biofuels in 2013



2022 RFS Production Targets

15 BGY

4 BGY

1 BGY

16 BGY

36 BGY Total

Categories for Algae Biofuels Contribution

POET Ethanol Plant in South Dakota

- *13.3B gallons of ethanol mostly from corn*
- *1.3B gallons of biodiesel mostly from soybean oil*
- *Limited growth potential*

Cellulosic biofuels are potential next step with estimated 85B gal/year

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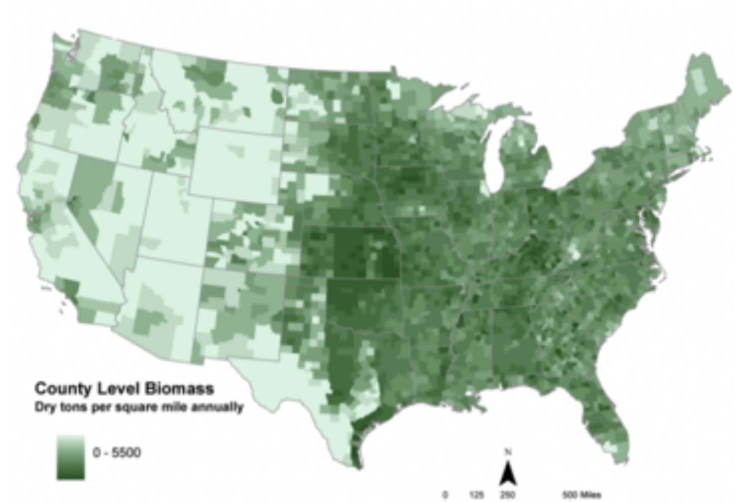
- *2011 billion-ton study by the DOE*
- *Great promise*
- *Progress is measured*



DuPont Plant in Iowa

Turning biomass into drop-in fuels at Joint BioEnergy Institute (JBEI)

Unified Research & Operations

- $250M, 10-year DOE Office of Science
- Highly focused research agenda
- Single operation and facility

Six Partners

- Four DOE National Laboratories
- Two Universities
- One Foundation

Four Science Divisions

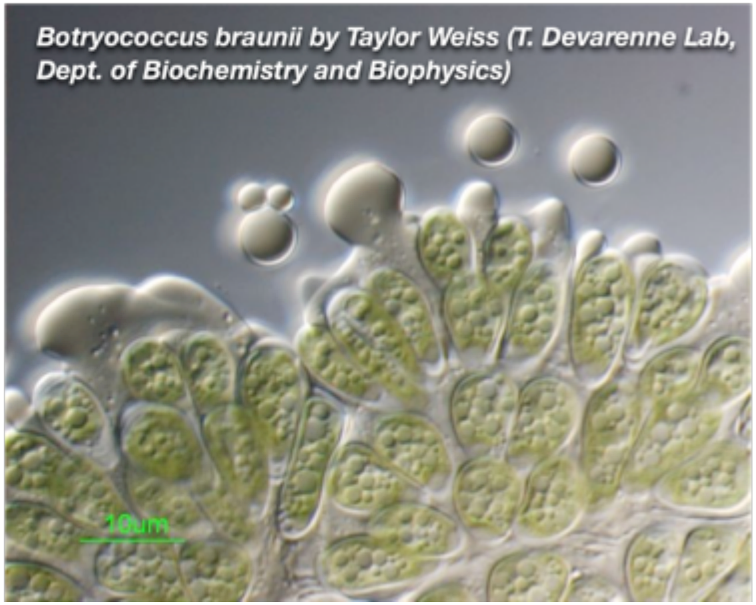
- Feedstocks
- Deconstruction
- Fuels Synthesis
- Cross-cutting Technologies

Industry Partnership Program

- Underpin growth of biofuels industry
- Ensure technology transfer to the developing biofuels industry

Algae: Next generation of biomass

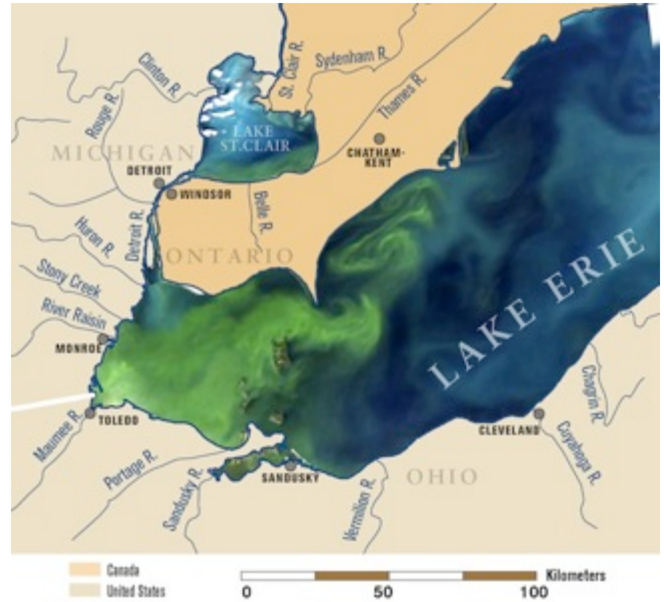
- *Doubles every day*
- *Produces lipids (aka – vegetable oil)*
- *No need to arable land or fresh water*



National Geographic Photograph from Qingdao, China

U.S. already produces lots of algae

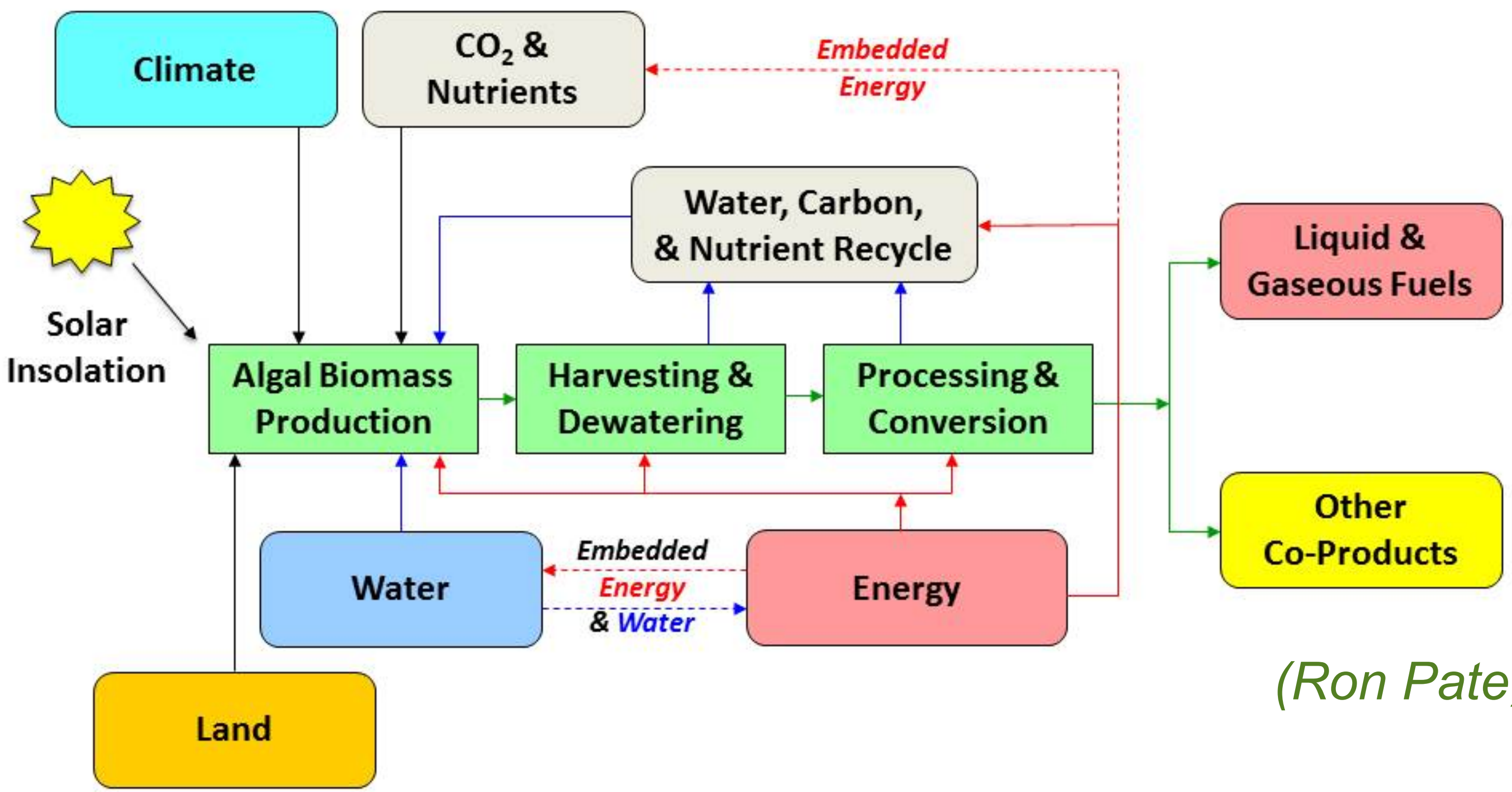
Gulf of Mexico



Lake Erie

Salton Sea

Algae biofuels production process

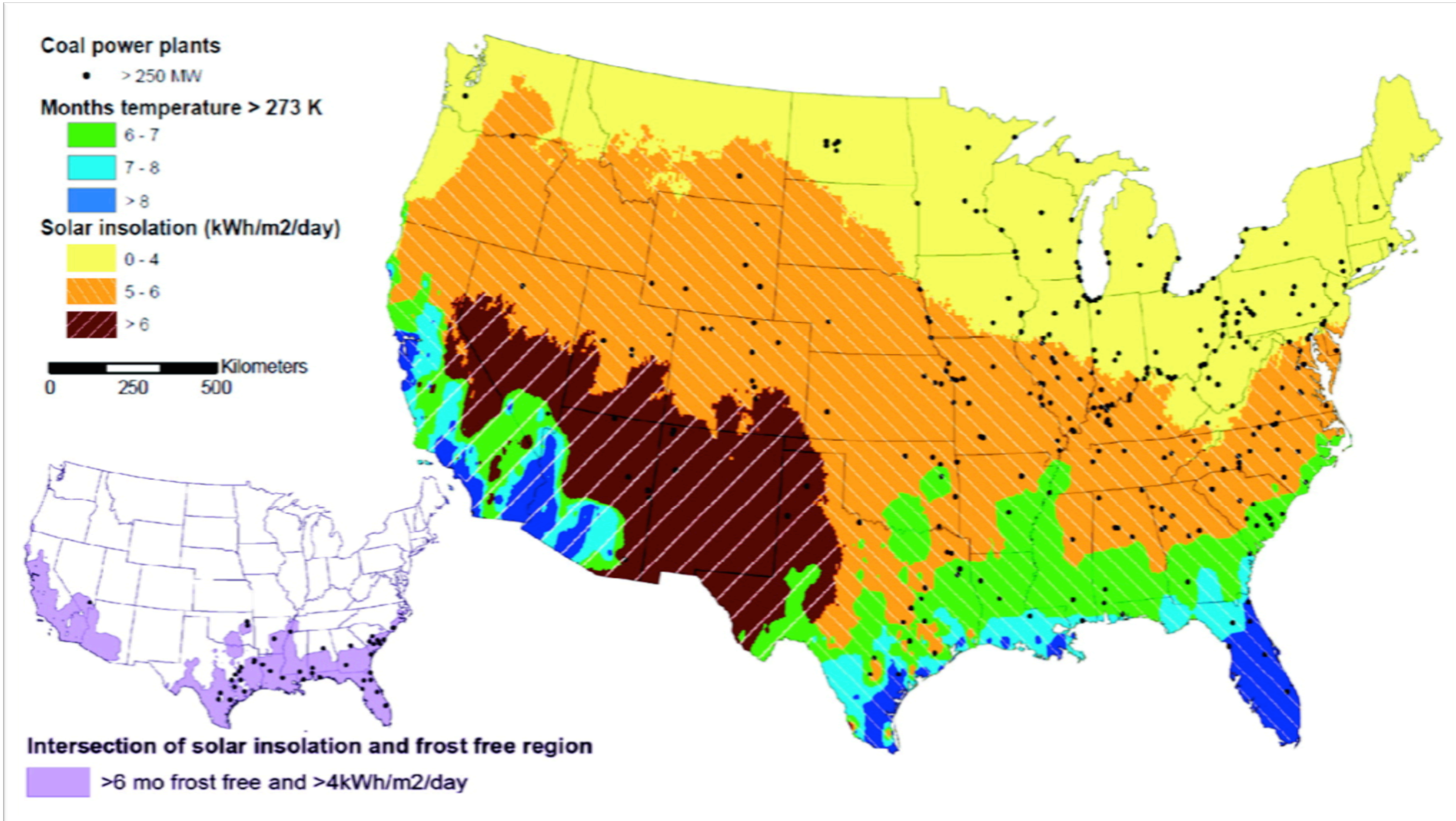


(Ron Pate, 2014)

Resources and Environmental Factors and Parameters

Climate	Water	Nutrients	Land	Energy
Solar Insolation	Surface/Ground	CO_2, Organic Carbon*	Location/Use Category	Electric Power
Temperature	Location/Access	N, P, Other	Topography	Process Heat
Evaporation	Supply/Allocation	Sources/Supplies	Soil type/Ground Cover	Fuel Resource Use
Precipitation	Salinity/Chemistry	Cost & Availability	Geology/Hydrology	Life Cycle Emissions
Weather Events	Sustainability	Sustainability	Ownership/Access	Cost & Availability
		* for heterotrophic & mixotrophic growth	Structures & Facilities	Other: e.g., hydrogen & catalysts for fuel upgrading

Best regions for algae production



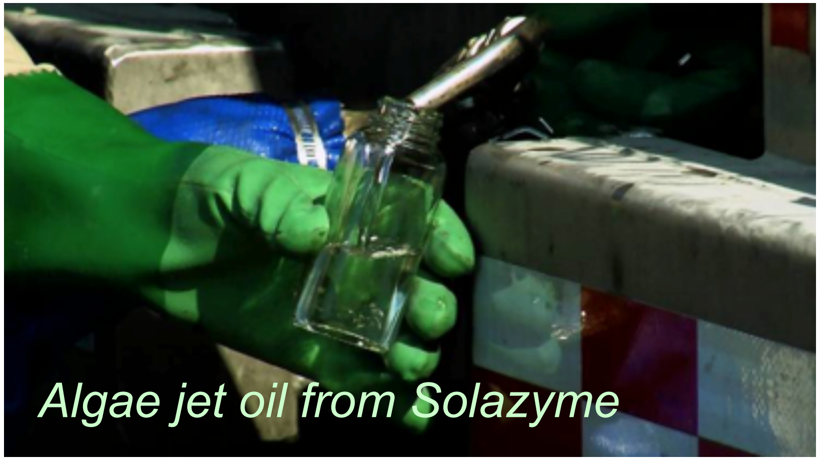
Source: Vasudevan, et al. (2012). "Environmental Performance of Algal Biofuel Technology Options", Environmental Science & Technology, v.46, pp. 2451-2459. Used with permission.

Algae oil converted directly to jet fuel and diesel

- *700,000 gallons of green jet fuel produced*
- *Solazyme delivered 20,000 gallons of algae* marine diesel and jet fuel to the Navy*
- *Dept of Navy soliciting 37.5M gal of drop-in diesel and jet fuel (July 9, 2014)*

** grown on sugar*

Honeywell (UOP) green diesel process makes drop-in jet fuel and diesel



Algae jet oil from Solazyme

Great Green Fleet demonstration in 2012

- *450,000 gallons of renewable diesel* used for surface ships and aircraft*
- *Demonstration part of 2012 Rim of the Pacific Exercise (RIMPAC)*
- *Navy plans on sailing Great Green Fleet again in 2016*

** only part of this was algae oil*

Algae produced commercially for decades

- *10,000 tons/year*
- *$10,000/ton production cost*
- *Need millions of tons at $1,000/ton*

Parry Nutraceuticals, India

NBT, Israel

Earthrise, California

Chlorella, Japan

Key technical challenges for algae

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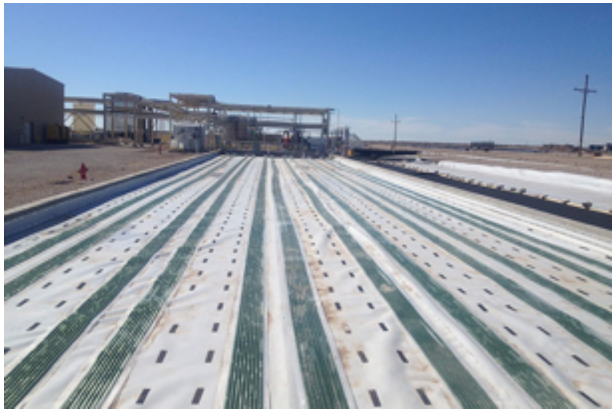
- *Disease and predation – bottom of food chain*
- *How to harvest?*
- *How to get high oil production?*
- *Where to get carbon dioxide?*
- *Where to get cheap fertilizer?*

Algae start-ups tackling key challenges

- *Reactor designs*
- *Innovations in biology, engineering, and operations*
- *High valued co-products*
- *Genetic engineering*

Sapphire, NM



Joule, NM

Algenol, Florida

Hydrothermal liquefaction innovation for producing crude oil from algae

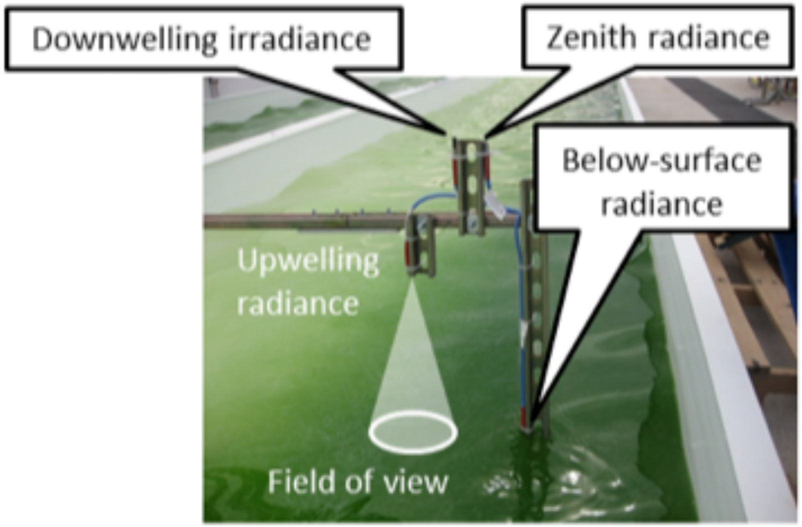
- *Mimic geologic forces with high temperature and pressures*
- *Being commercialized by Sapphire and Algenol.*
- *DOE development at PNNL as part of NAABB*
- *Product needs to be sent to refinery to upgrading to product.*

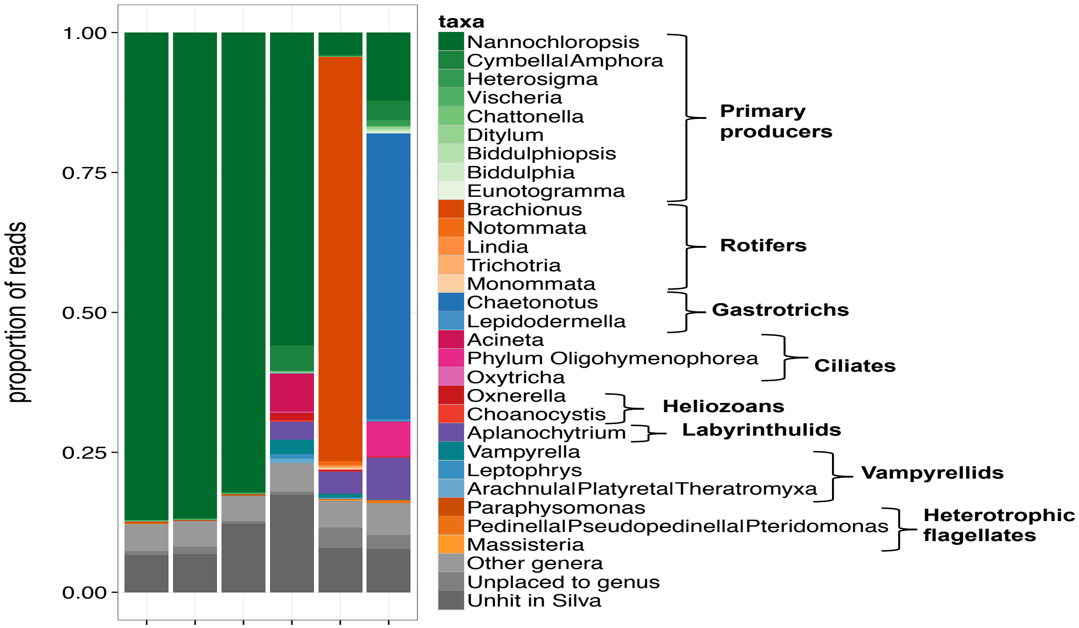
Controlled algae bloom systems

- *Algae Turf*
  - *Hydromentia*
- *Fast and natural*
- *No fertilizer or carbon dioxide costs*
- *Easy harvesting*
- *Economics?*

Fast response is key to control disease and predation

- *Critical real-time monitoring for early detection*
- *Forensic tool*
- *Mitigation strategies*
  - *Pesticides*
  - *Anti-bacterial*
  - *Isolation*





National resource implications from large-scale algae biofuel production

Sandia National Laboratories

- ***Land*** *… probably manageable for high scale-up*
- ***Water*** *… significant challenge if limited freshwater*
  - *Need marine and other non-fresh waters*
  - *Closed systems?*
- ***Nutrients (N & P)*** *… significant challenge*
  - *Could compete with agriculture and other commercial fertilizer uses*
  - *Need cost-effective nutrient recycling*
- ***CO_2 Sourcing*** *… significant challenge*
  - *Liquid CO_2 is too expensive*
  - *How much from stationary emitters can be affordably tapped and utilized?*
- ***In short, resource constraints likely to emerge at 5-15B gallons/year***

(Ron Pate, 2014)

Summary

- *Algae represent an enormous potential for the production of a renewable and domestic feedstock for US transportation fuels*
- *Technical innovations are needed to reduce economic costs to be competitive with petroleum*
- *Continued and increased support is needed to maintain momentum*

Thank you

Questions?