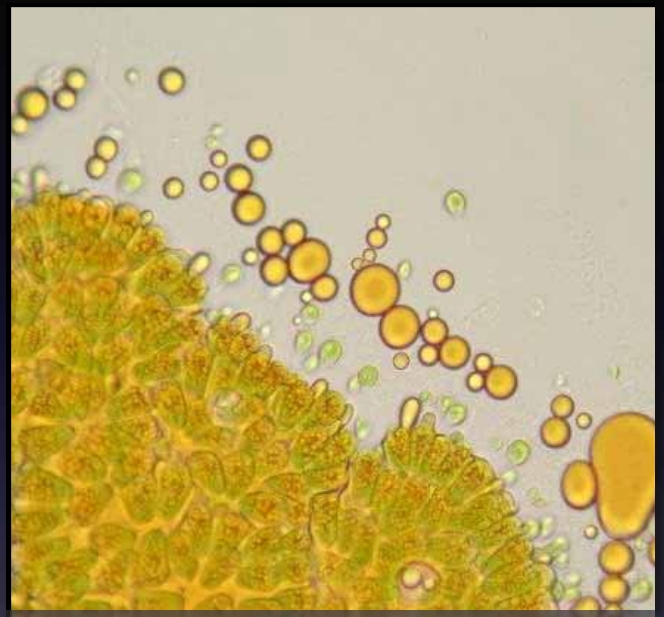
Algae redux the US saga



John Sheehan

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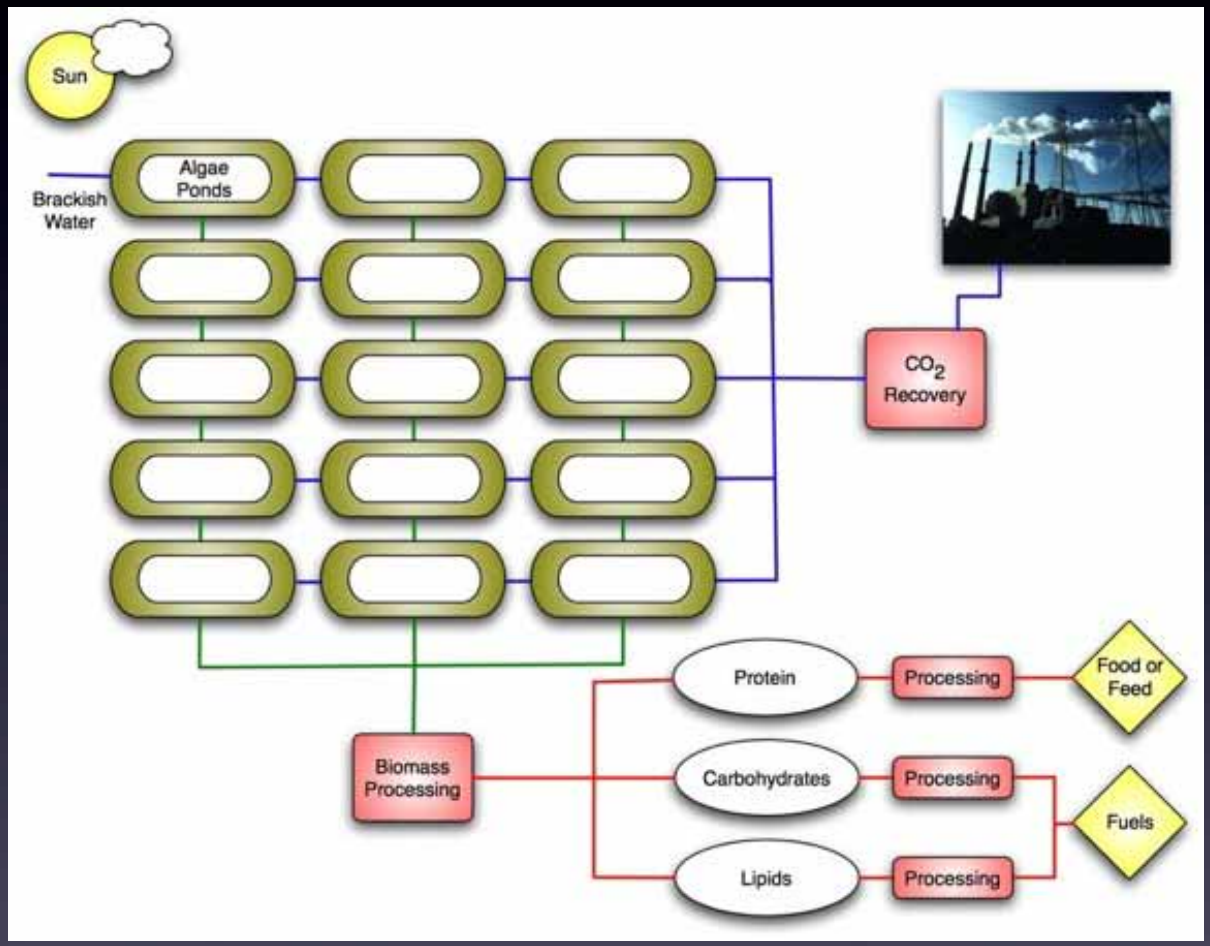
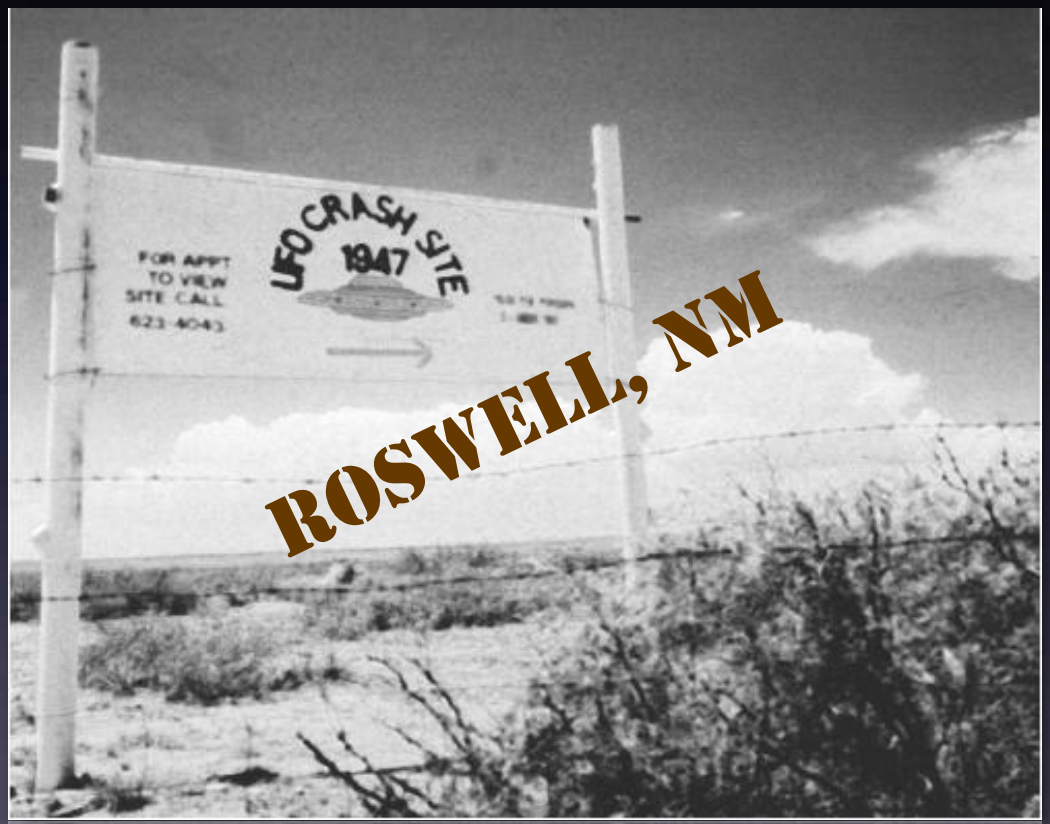
A little history



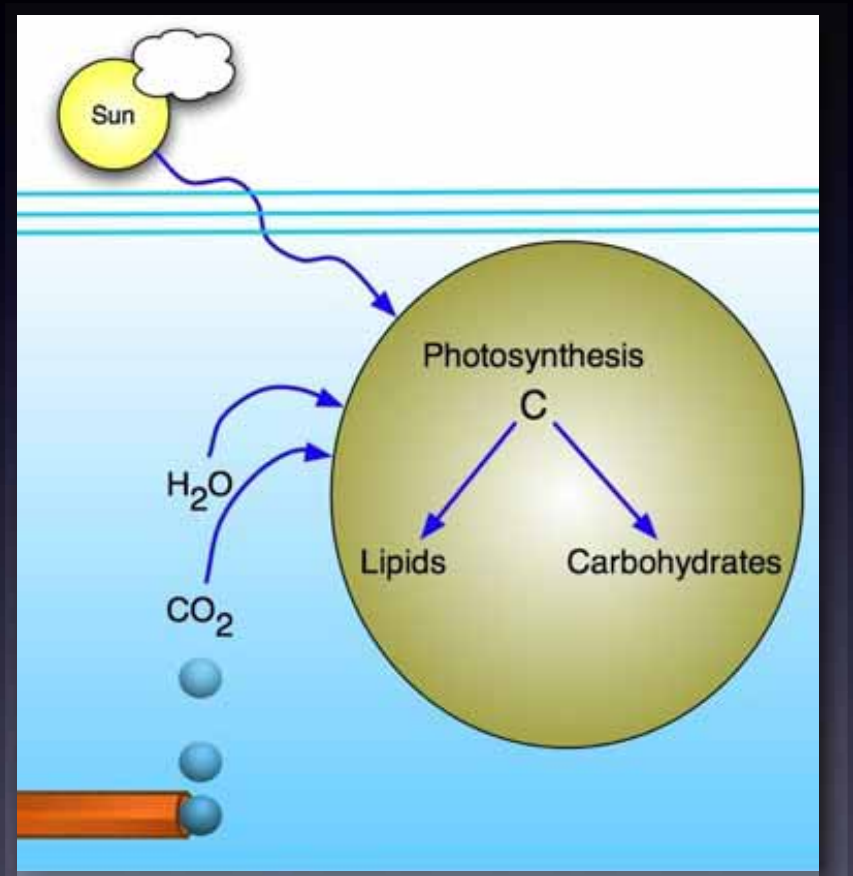
DOE/NREL Aquatic Species Program
20+ years of R&D

A little history



0.1 hectare ponds
90% CO_2 capture
10 g/ m^2 per day
Alleged 50 g/ m^2 per day
& up to 50% oil content

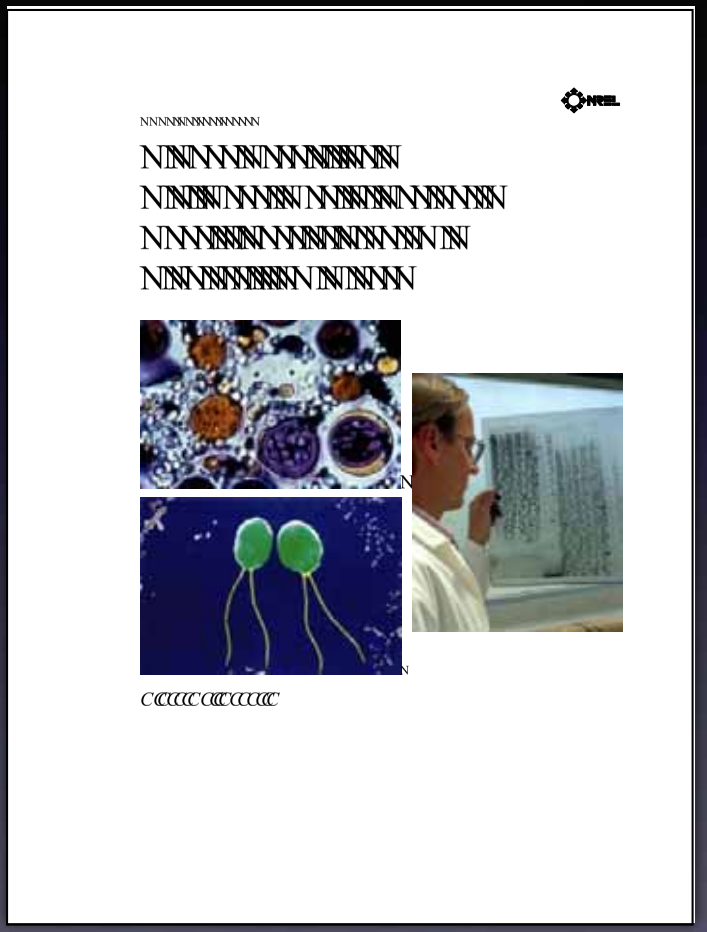
A little history



First genetic transformation of an algae with potential for biodiesel production in 1994

“The end of an era”

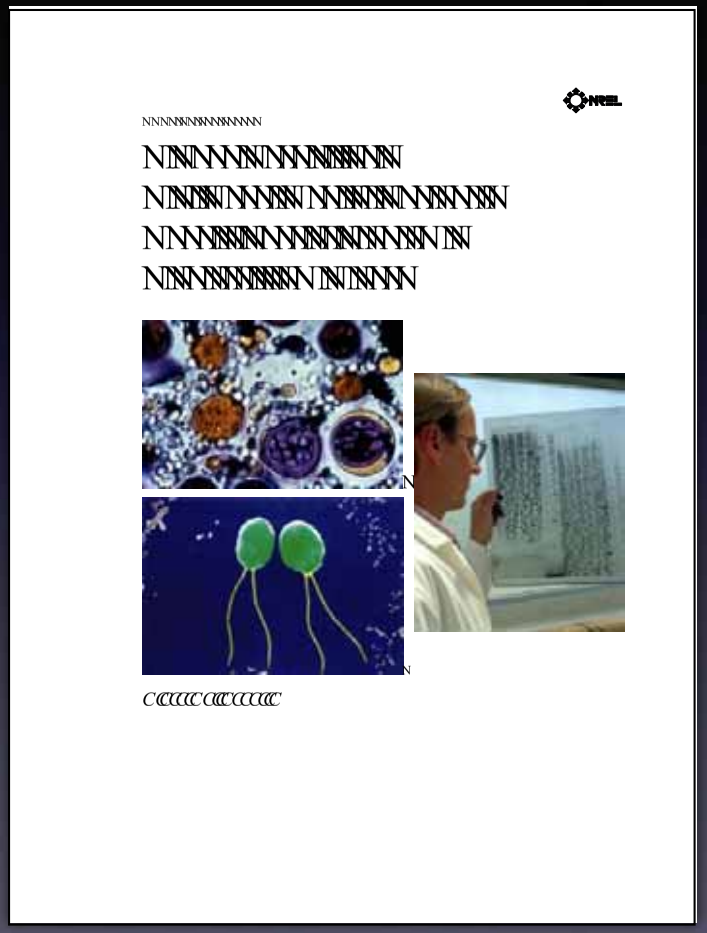
- Program ended in 1996
- Clinton-era zeal for budget cuts
- Low oil prices
- Focus on “immediate” results
- Ethanol–centric biofuels program ($0.60 per gallon ethanol by 2000!)



“Born again”

4 years ago, my phone at NREL began ringing off the hook with inquiries from investors.

Our close-out report on algae is now the #1 download on NREL’s website.

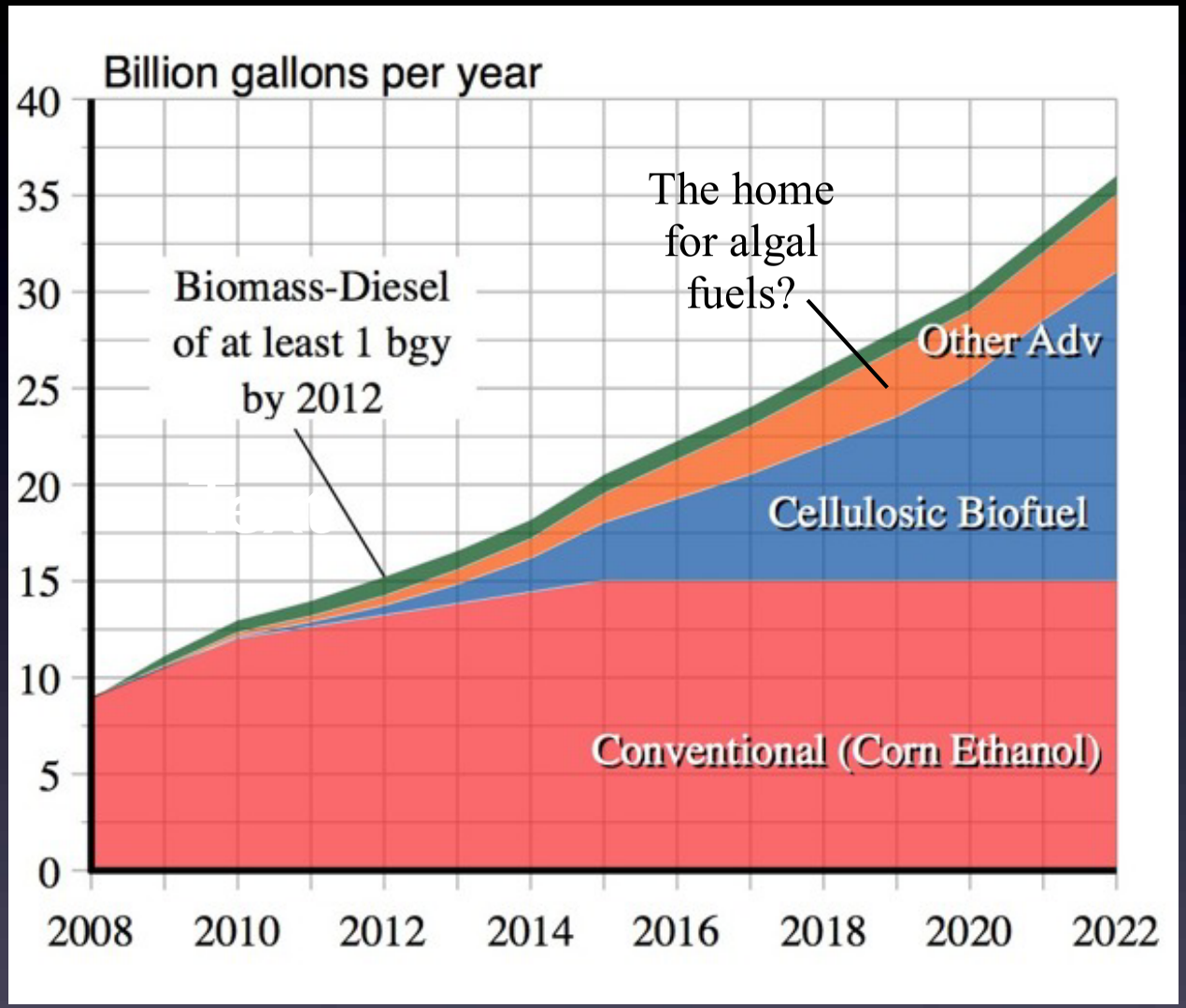


I accepted an offer from one of those calls to work for LiveFuels in 2007

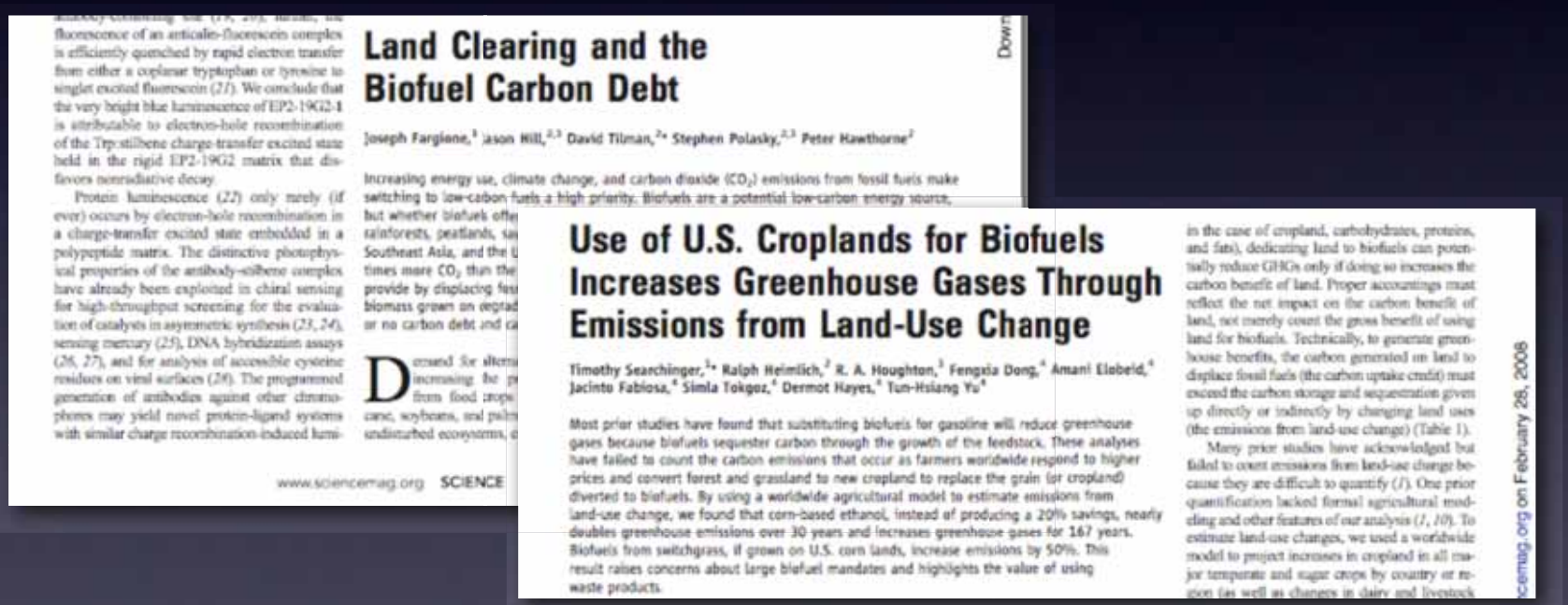
Clever, but now abandoned approach—combined fish and algae ecosystem

Energy Security and Independence Act of 2007

"RFS2"



The great land debate of 2008



Land Clearing and the Biofuel Carbon Debt

Joseph Fargione,[1] Jason Hill,[2,3] David Tilman,[2]* Stephen Polasky,[2,3] Peter Hawthorne[2]

Increasing energy use, climate change, and carbon dioxide (CO_2) emissions from fossil fuels make switching to low-carbon fuels a high priority. Biofuels are a potential low-carbon energy source,

fluorescence of an articaïn-fluorescein complex is efficiently quenched by rapid electron transfer from either a coplanar tryptophan or tyrosine to singlet excited fluorescein (*21*). We conclude that the very bright blue luminescence of EP2-19G2-I is attributable to electron-hole recombination of the Trp:stilbene charge-transfer excited state held in the rigid EP2-19G2 matrix that disfavors nonradiative decay.

Protein luminescence (*22*) only rarely (if ever) occurs by electron-hole recombination in a charge-transfer excited state embedded in a polypeptide matrix. The distinctive photophysical properties of the antibody-stilbene complex have already been exploited in chiral sensing for high-throughput screening for the evaluation of catalysts in asymmetric synthesis (*23*, *24*), sensing mercury (*25*), DNA hybridization assays (*26*, *27*), and for analysis of accessible cysteine residues on viral surfaces (*28*). The programmed generation of antibodies against other chromophores may yield novel protein-ligand systems with similar charge recombination-induced lumi-

Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land-Use Change

Timothy Searchinger,[1]* Ralph Heimlich,[2] R. A. Houghton,[3] Fengxia Dong,[4] Amani Elobeid,[4] Jacinto Fabiosa,[4] Simla Tokgoz,[4] Dermot Hayes,[4] Tun-Hsiang Yu[4]

Most prior studies have found that substituting biofuels for gasoline will reduce greenhouse gases because biofuels sequester carbon through the growth of the feedstock. These analyses have failed to count the carbon emissions that occur as farmers worldwide respond to higher prices and convert forest and grassland to new cropland to replace the grain (or cropland) diverted to biofuels. By using a worldwide agricultural model to estimate emissions from land-use change, we found that corn-based ethanol, instead of producing a 20% savings, nearly doubles greenhouse emissions over 30 years and increases greenhouse gases for 167 years. Biofuels from switchgrass, if grown on U.S. corn lands, increase emissions by 50%. This result raises concerns about large biofuel mandates and highlights the value of using waste products.

in the case of cropland, carbohydrates, proteins, and fats), dedicating land to biofuels can potentially reduce GHGs only if doing so increases the carbon benefit of land. Proper accountings must reflect the net impact on the carbon benefit of land, not merely count the gross benefit of using land for biofuels. Technically, to generate greenhouse benefits, the carbon generated on land to displace fossil fuels (the carbon uptake credit) must exceed the carbon storage and sequestration given up directly or indirectly by changing land uses (the emissions from land-use change) (Table 1).

Many prior studies have acknowledged but failed to count emissions from land-use change because they are difficult to quantify (*1*). One prior quantification lacked formal agricultural modeling and other features of our analysis (*1*, *10*). To estimate land-use changes, we used a worldwide model to project increases in cropland in all major temporate and sugar crops by country or region (as well as changes in dairy and livestock

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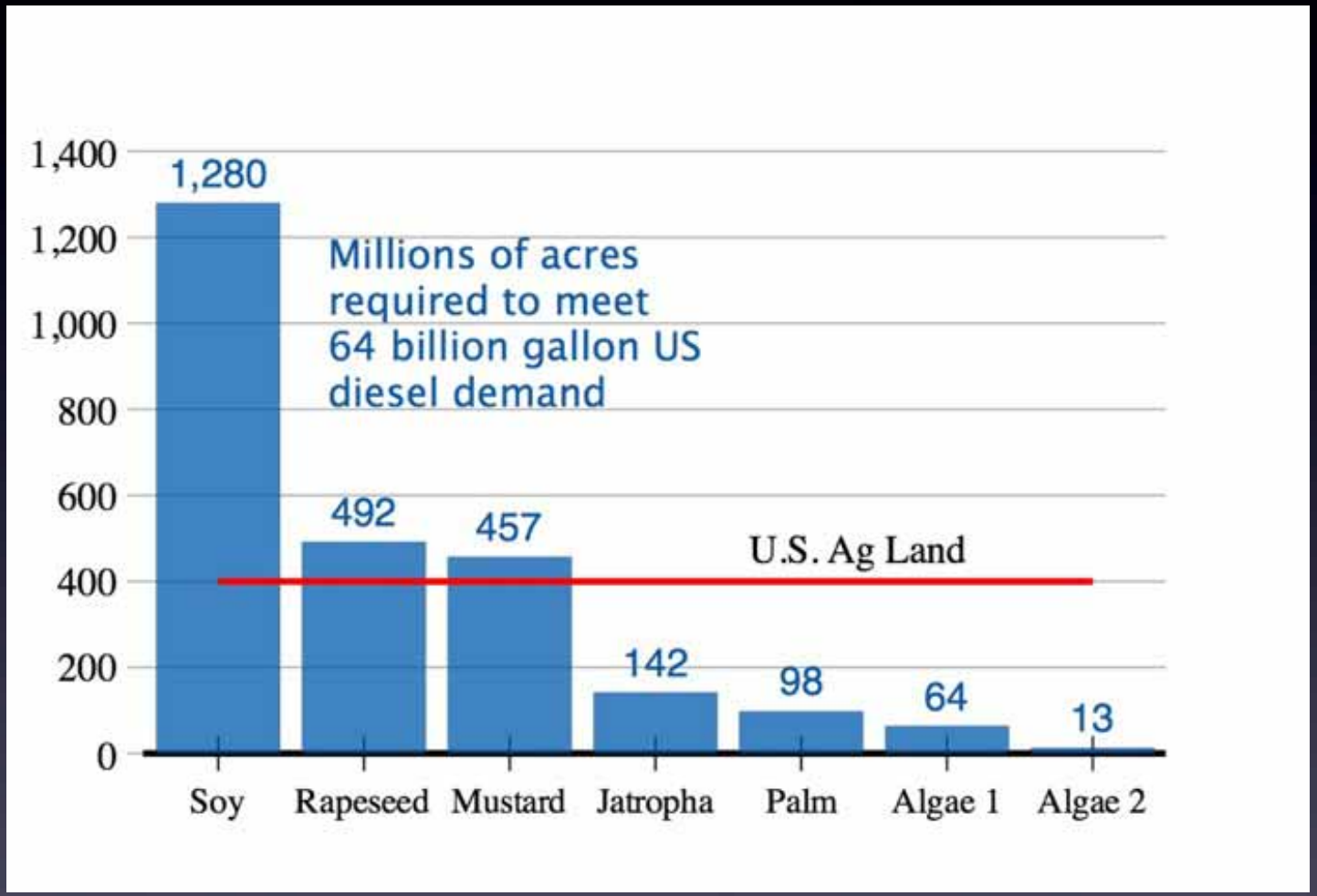
Game changer?



Prospecting for gold

More than 150 companies worldwide investing in algae. But how many are for real?

The era of "too big to fail"

American Recovery and Renewal Act of 2009

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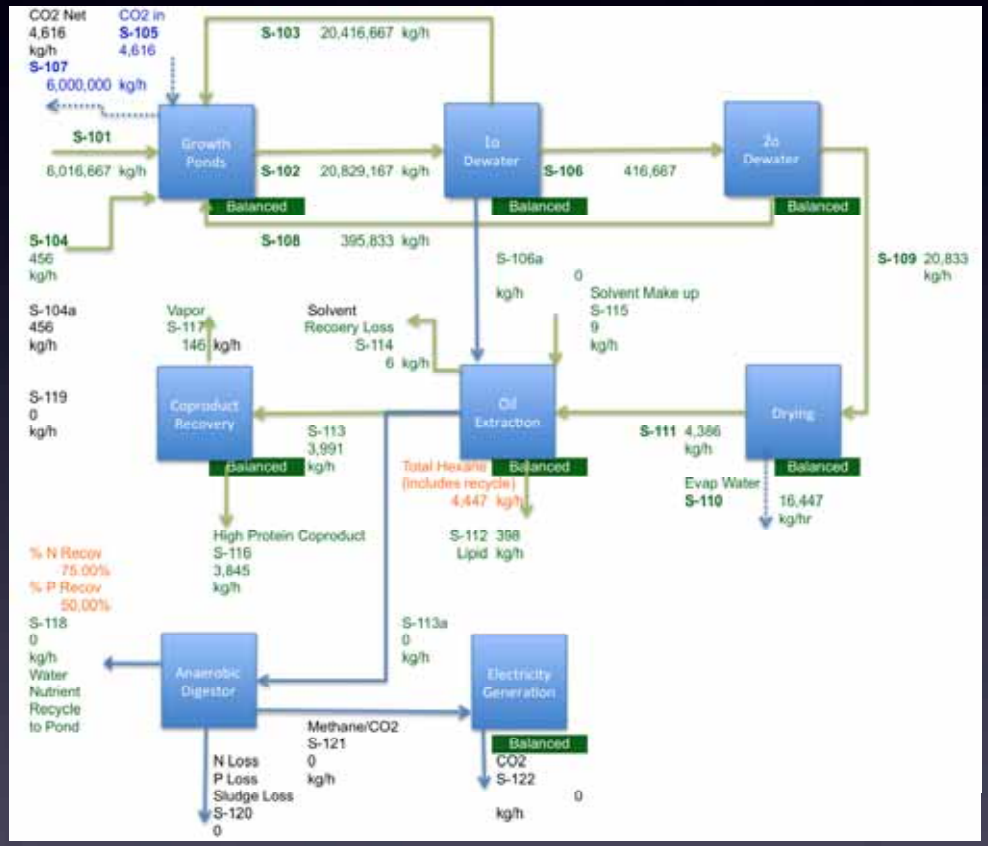
May 5, 2009 USDOE announcement of $800 million in recovery funds for new biofuel research activities

Steven Chu, Secretary of Energy with President Obama

Includes $50-75 million for an algae R&D consortium to be awarded in Jan ’10

US Congress earmarked $35 million in funds as part of DOE's FY 2010 biomass program

Reality check
Process model



Full material and energy balances

Capital and operating costs

Reality check
Water

View from the entrance of the Biolight/Carbon Capture Facility (former Nutralite Beta Carotene operation) in Calipatria, CA

Evaporative water loss equivalent to 1,600 kg per kg of algal oil produced in the Imperial Valley

Reality check
Water

1950s

Today

Reality check
Cost

Algal oils are a tough sale for dedicated algae to biofuels facilities

Problem for all biofuels

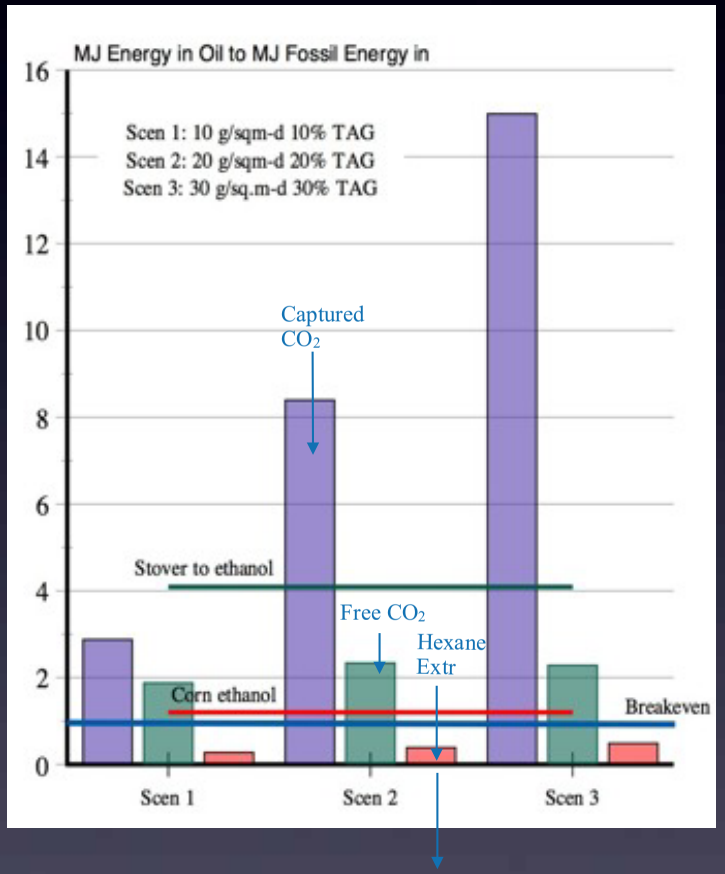
Universally high capital costs

Reality check
Life cycle energy

Algae drying and hexane are energy losers

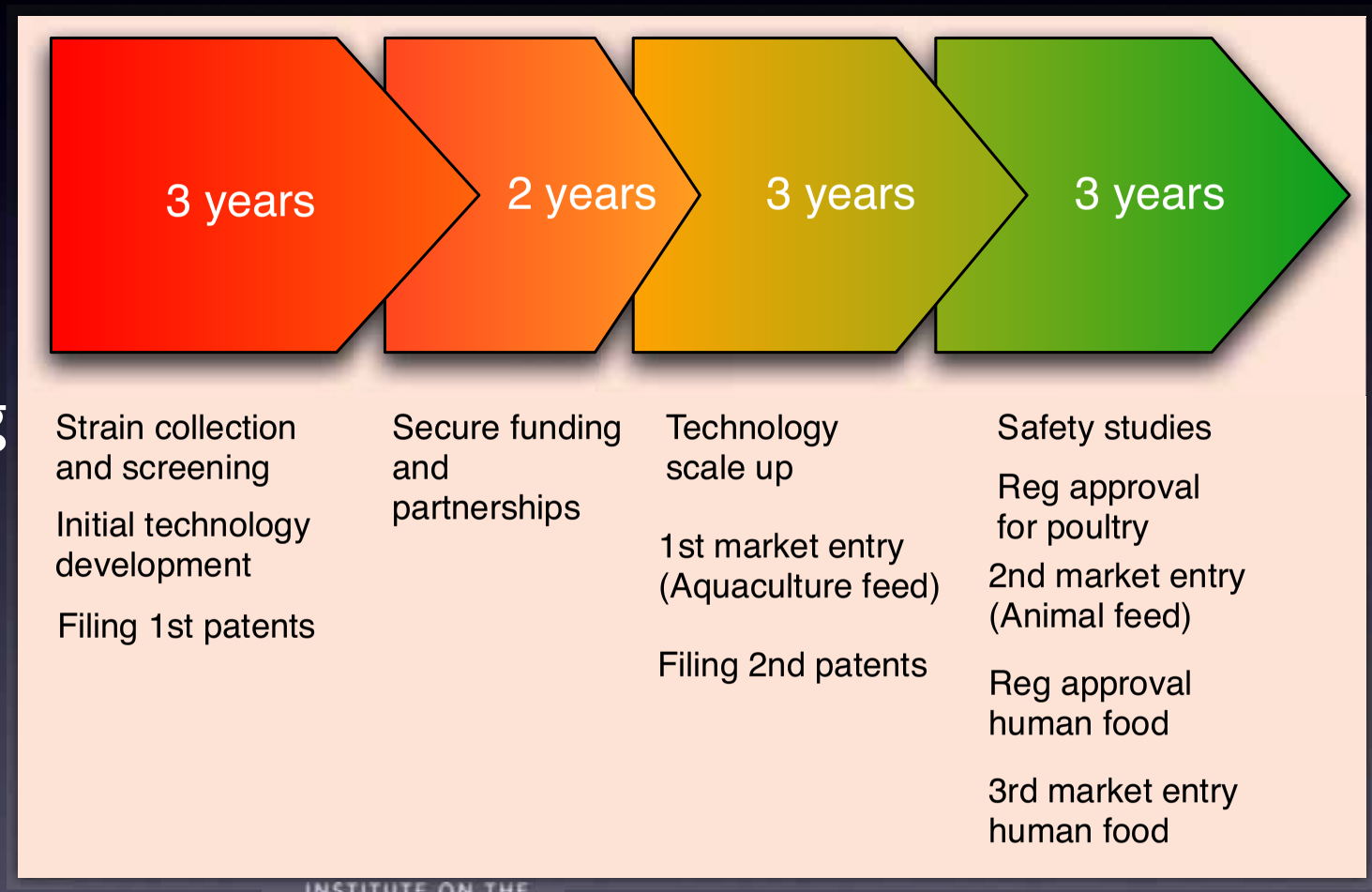
CO_2 recovery consumes a huge amount of savings

Free CO_2 and water friendly extraction a must

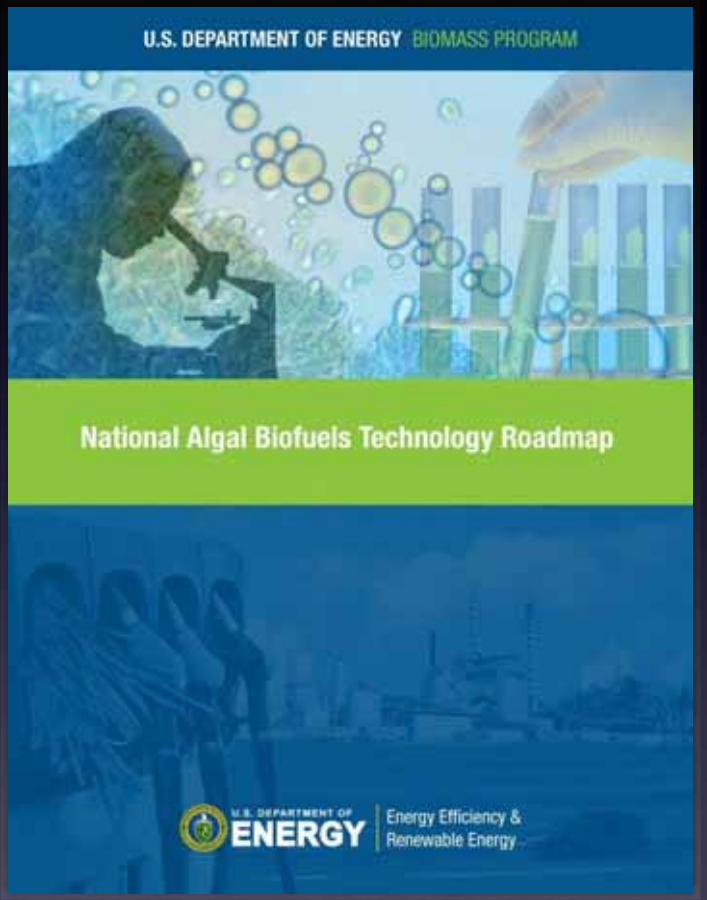


Reality check Time

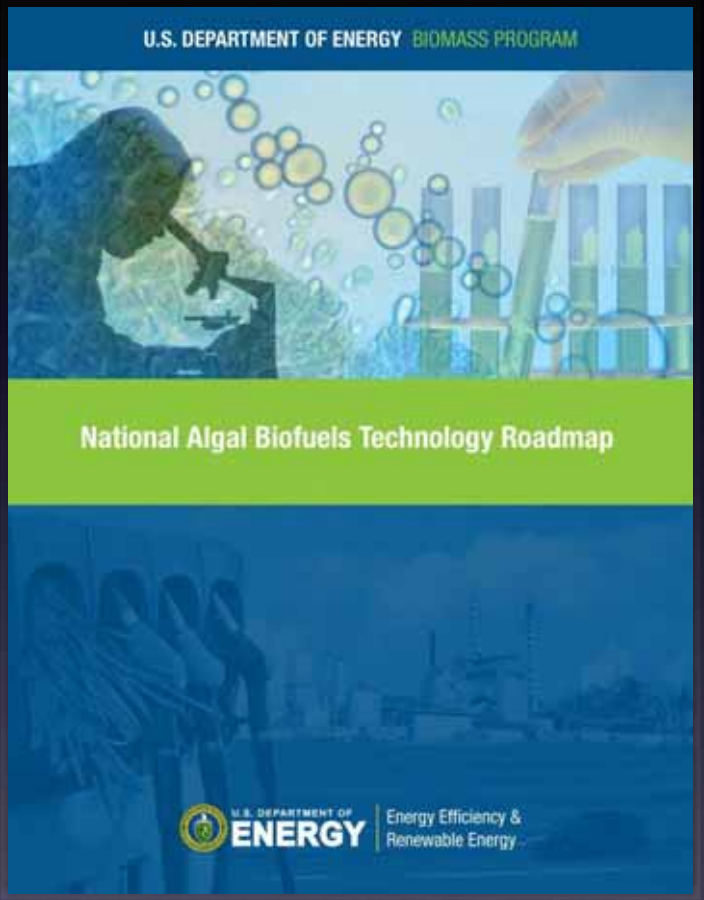
Bill Barclay (Martek) on commercializing algae

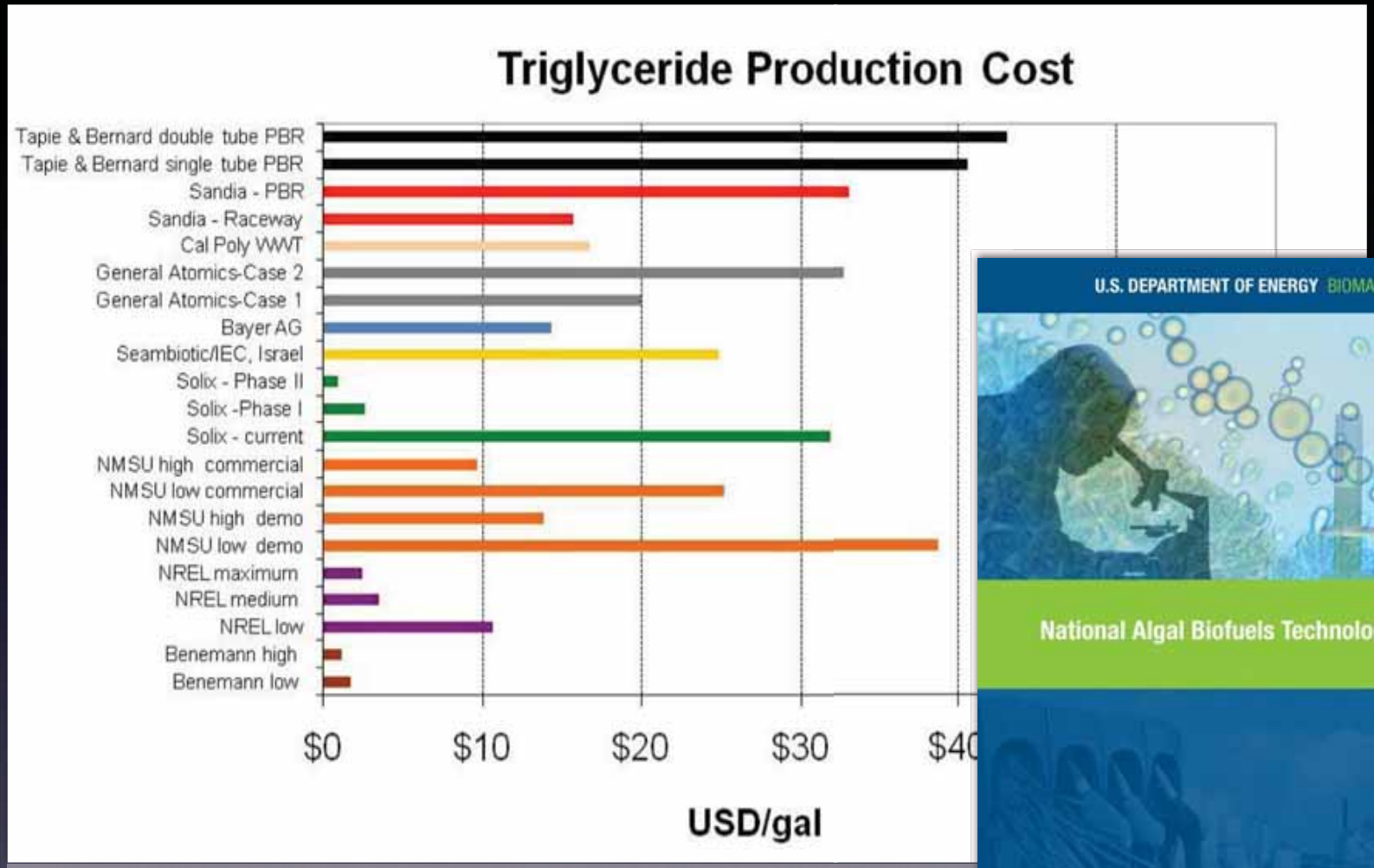


DOE's draft roadmap



"...many years of both basic and applied R&D will likely be needed to overcome the current technical barriers"





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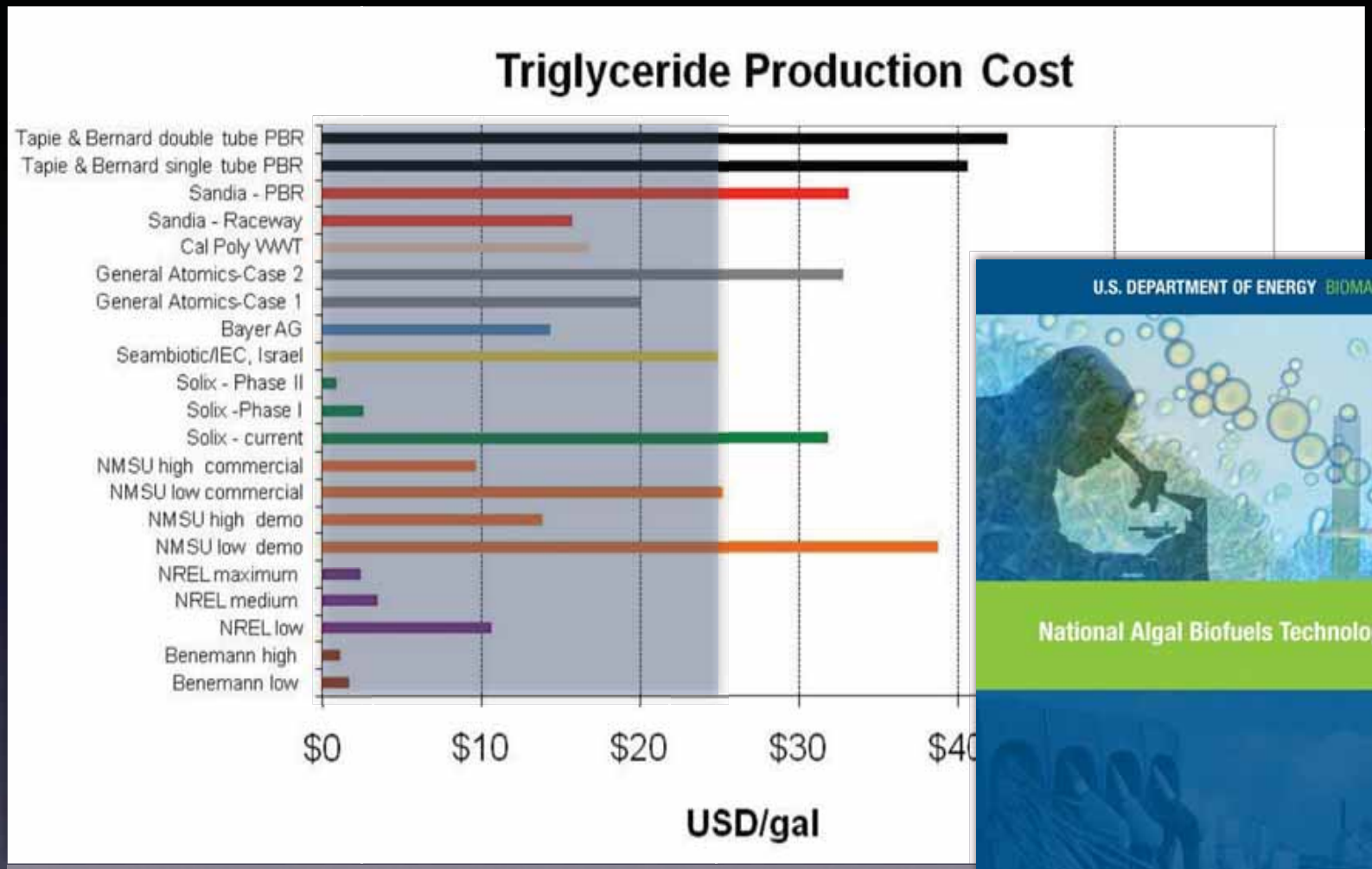
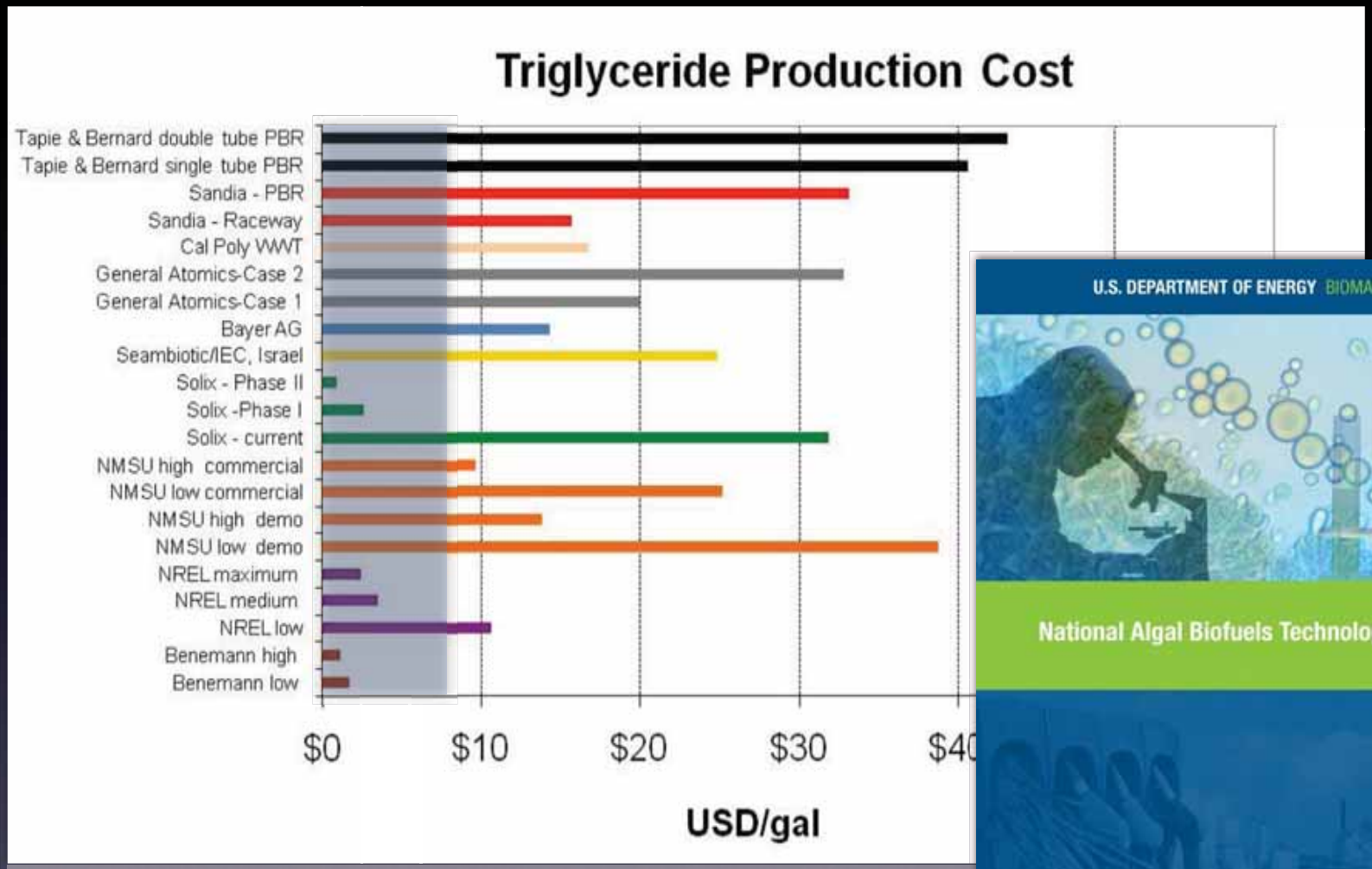
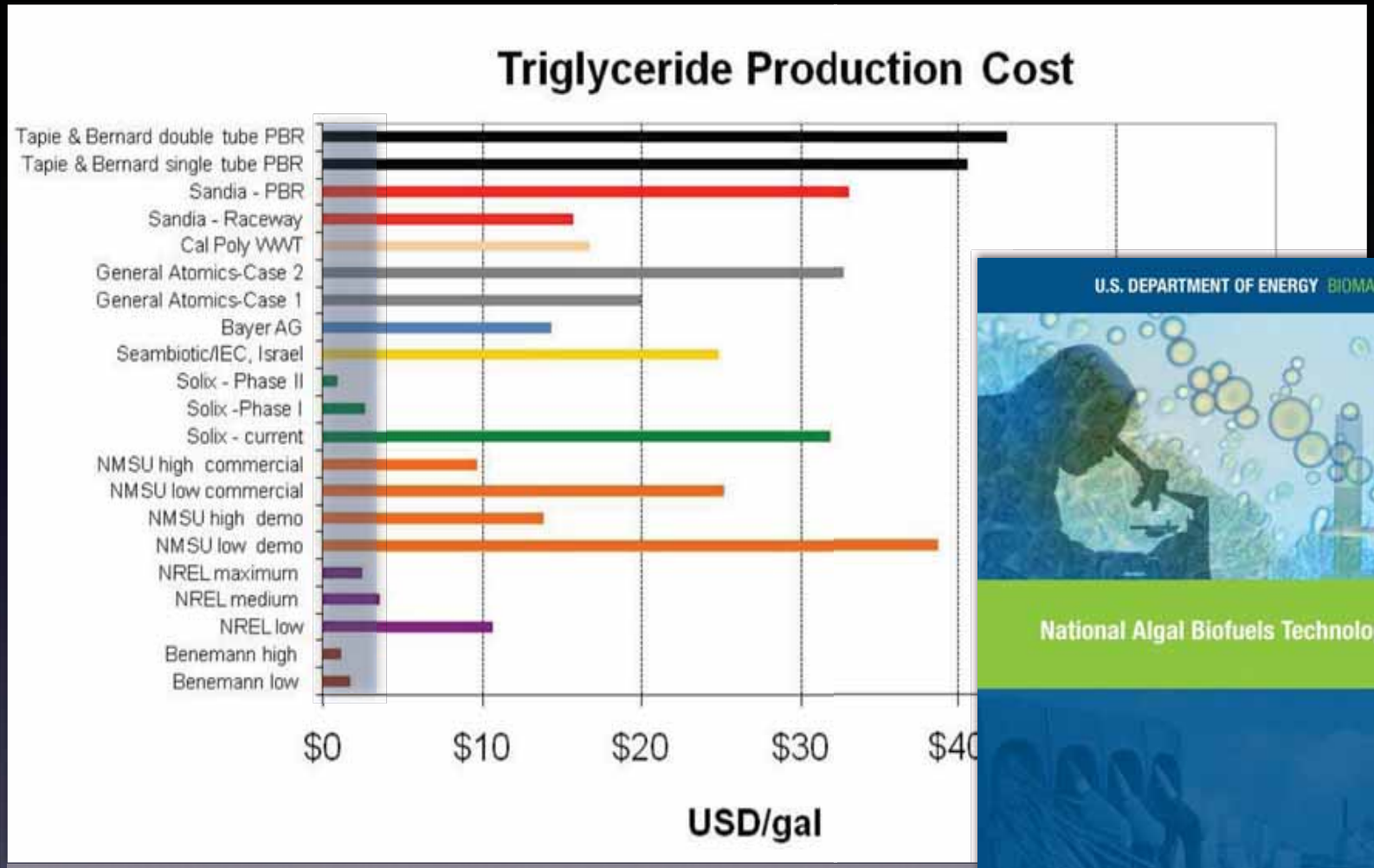


My "current case" estimate

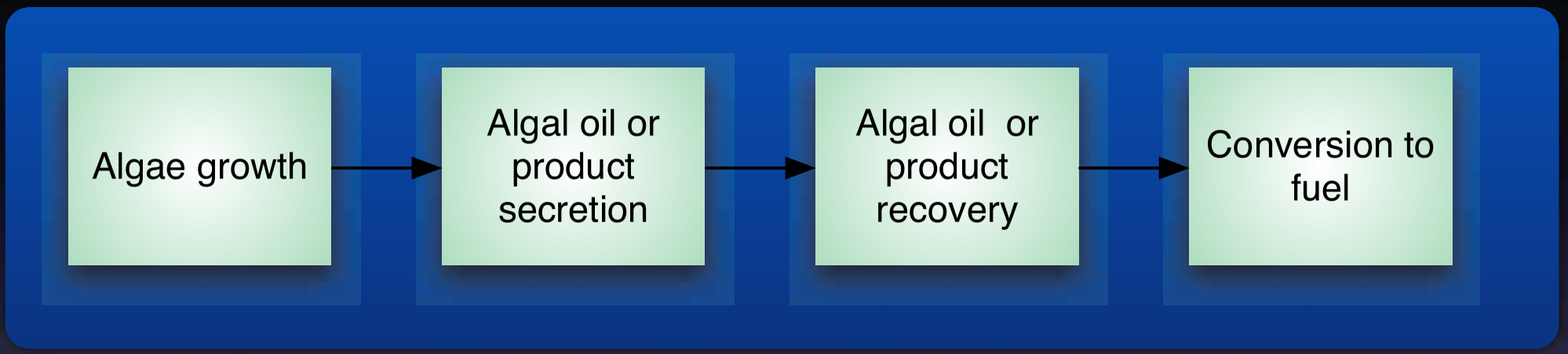


My "current case" estimate (Probable future outcome)

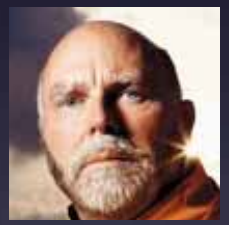


My "current case" estimate (High risk future outcome)

ExxonMobil







Synthetic Genomics

Use the magic of synthetic genomics to cure the yield, productivity and recovery problem

Solix

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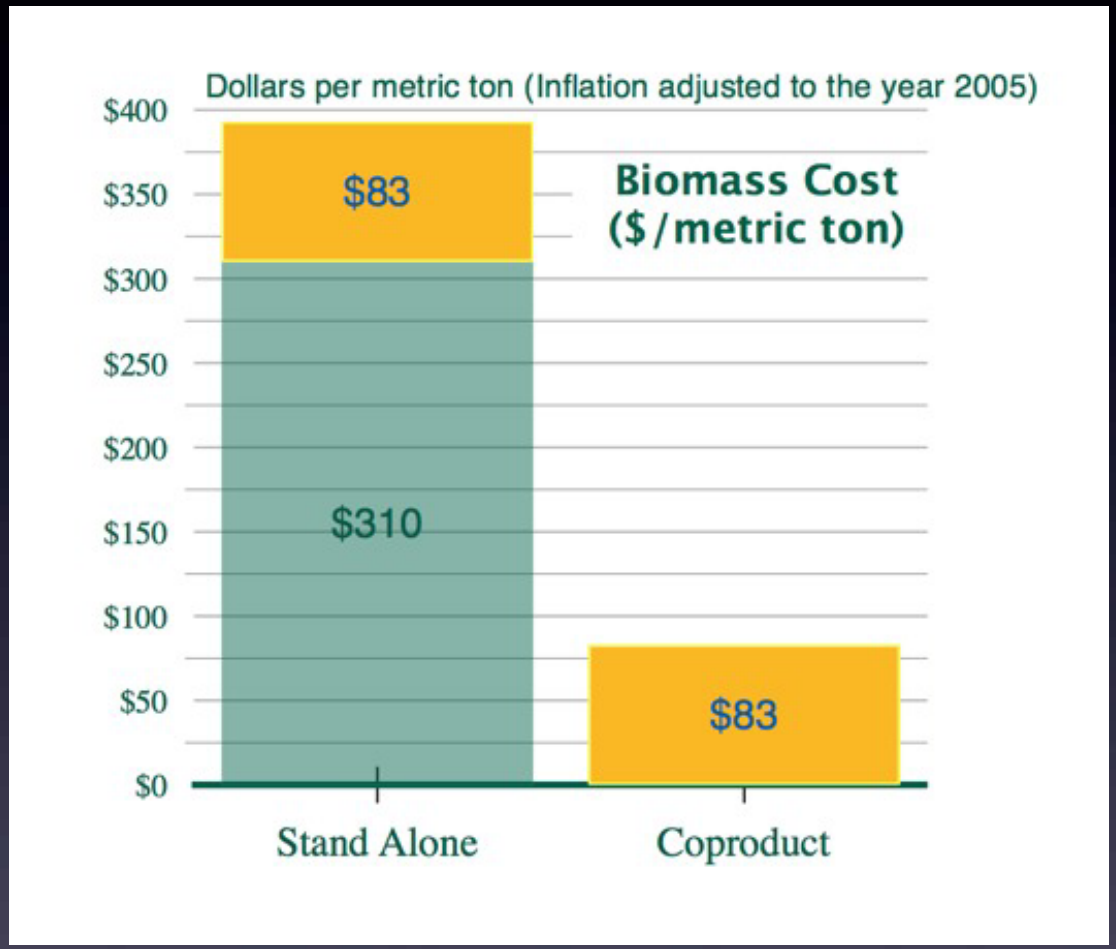
Dual purpose

Dual purpose of cleaning up nitrogen and phosphate pollution while making fuel

Dual purpose

The original LiveFuels approach
Algae and aquaculture

Shared capital



Dual purpose of cleaning up nitrogen and phosphate pollution while making fuel

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