

Let's Talk Biofuels

Doug Elgin

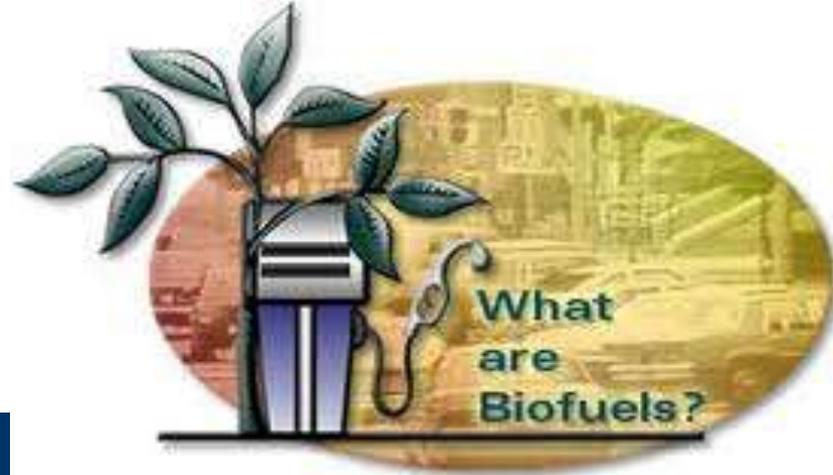
Alabama Solar Association





Alabama Solar Association

- We are a volunteer organization
- We promote all things solar, energy conservation, and living green
- We sponsor speaking and demonstration events for the public
- We'd love to have you join us, dues are minimal (\$20/yr regular, \$15/yr student/senior - \$5 off at ASA events)
- Barring that, give us your e-mail address and we will keep in touch
- Visit us at **www.AL-Solar.org**



- Biofuels are fuels manufactured from plant and animal life or organic waste
- Biofuels may be bioethanol (converted sugars and starches), biodiesel (converted oils or fats) or other
- Energy is obtained from recent carbon fixation
- Biofuels are a renewable resource
- Biofuels are made from biomass conversion by thermal, chemical, or biochemical means
- Solid biofuels include wood, sawdust and even dried manure

Why Is ASA Talking About Biofuels?

- Alabama Solar Association is interested in biofuels because we promote the use of the sun and the sun provides the energy that is converted to biofuels
- Biofuels can reduce the green house gases released which should help the environment
- Biofuels show promise to ultimately cost less than fossil fuels

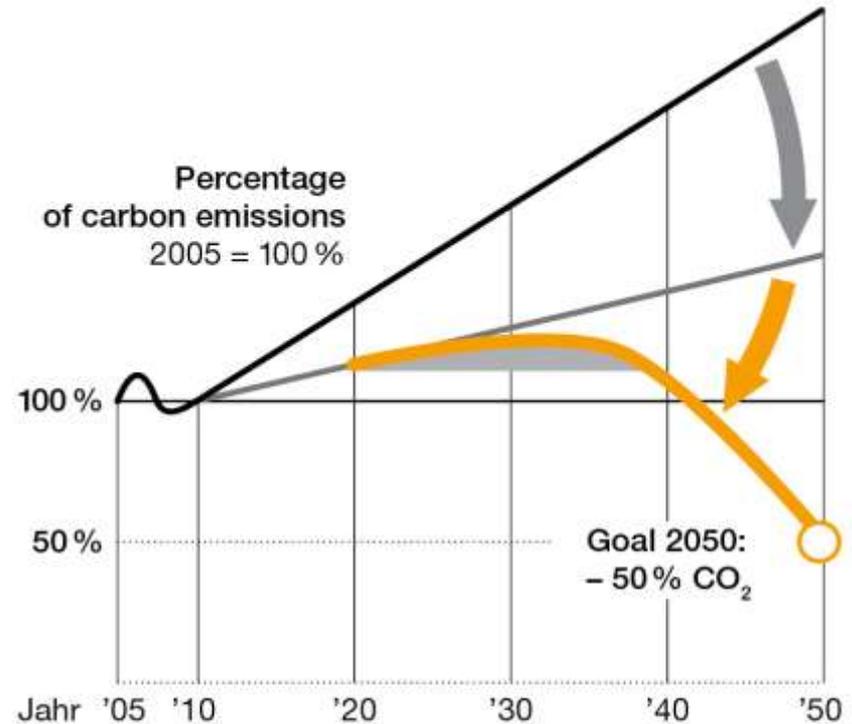
Some Definitions

- Biomass – plant matter for energy use
- Cellulosic – pertaining to the complex carbohydrate that is the main constituent in the cell walls of most plants
- Lignin – a complex polymer of aromatic alcohols – mostly derived from wood
- Pyrolysis – a thermochemical decomposition of organic material at high temperatures in the absence of oxygen
- Transesterification – An organic chemistry reaction to convert oils and fats to biodiesel (polymers to monomers)

Biofuels Can Reduce GHGs

- As we shall see later, current approaches aren't very helpful

Biofuels are of major importance



- CO₂ reduction through **use of biofuels** and additional technological innovations
- CO₂ reduction through investments in low-carbon technology, operational measures, improved infrastructure
- Economic measures to be able to grow carbon neutral from 2020 onward
- No measures (Forecast)

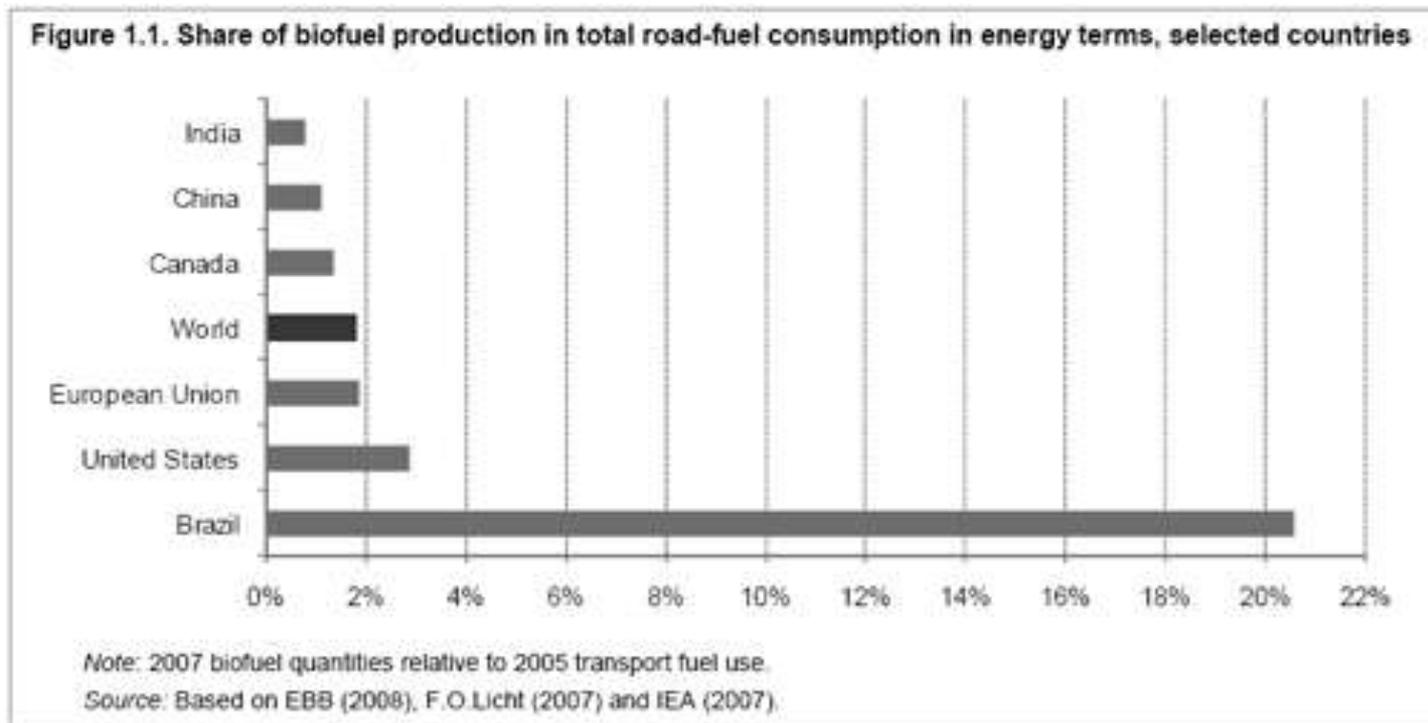
Source: IATA

The Global Landscape

- Biofuels help reduce consumption of fossil fuels, but usually compete for arable land against crops for food
- 2010 worldwide production of biofuels was 28 billion gallons (up 17% from 2009)
- The US and Brazil are the top producers of bioethanol
- The European Union is the top producer of biodiesel
- As of 2011, 31 countries have set goals for blending biofuels.
- The International Energy Agency wants biofuels to meet 25% of the world demand by 2050

Who Is Producing Biofuels?

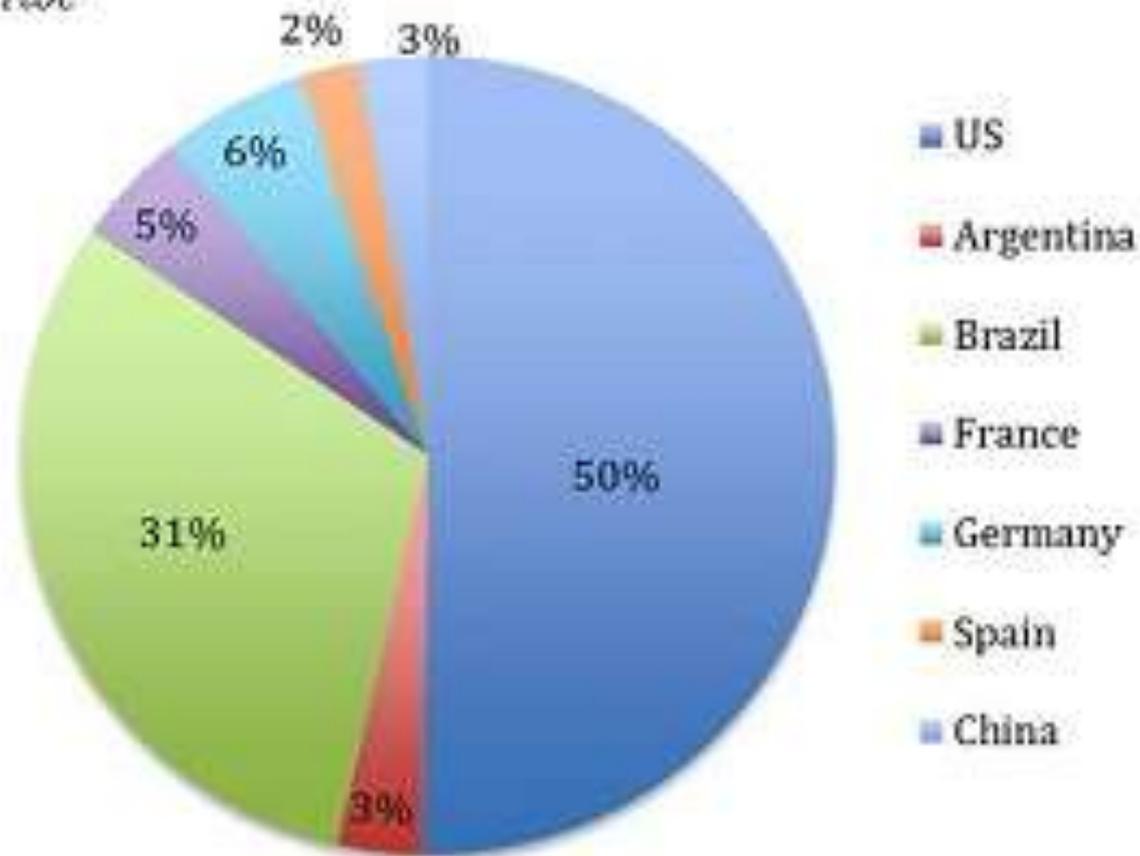
- This shows the percentage of transportation energy that comes from biofuels



Global Biofuel Production - 2010

(top 7 producing countries)

Total:
50.4 million toe



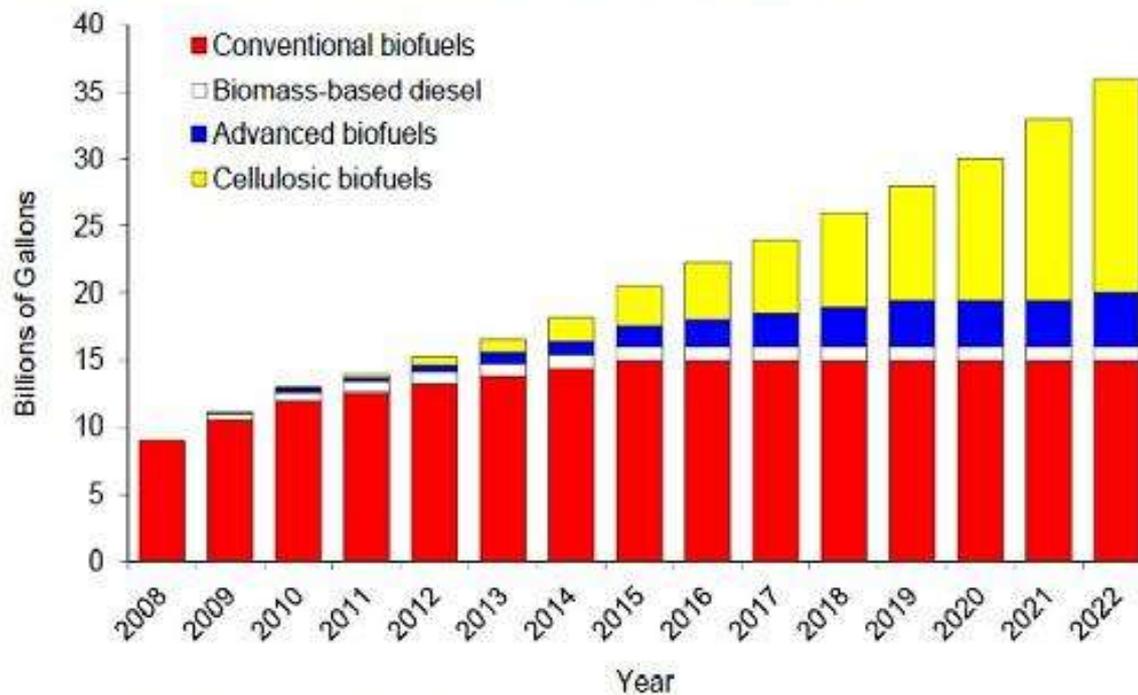
Source: BP Statistical Review of World Energy 2011

Government Involvement

- Department of Energy (DOE)
 - Office of Energy Efficiency and Renewable Energy (EERE)
 - National Renewable Energy Laboratory (NREL) - the principle laboratory
 - Conducting a large number of projects to increase productivity and reduce GHGs
- Renewable Fuel Standard – sets goals for use of biofuels
- Tax Incentives
 - Ethanol fuels production
 - Cellulosic biofuel production
 - Alternate fuel infrastructure tax credit

Biofuel Utilization Mandates

The Renewable Fuel Standard Consumption Mandate



Source: National Academy of Sciences

- Goals set in U.S. for use of biofuels
- Conventional biofuels are mainly from corn

What Are Biofuels Made From?



Camelina plantation



Straw plantation



Short rotation coppice willow harvesting



Algae

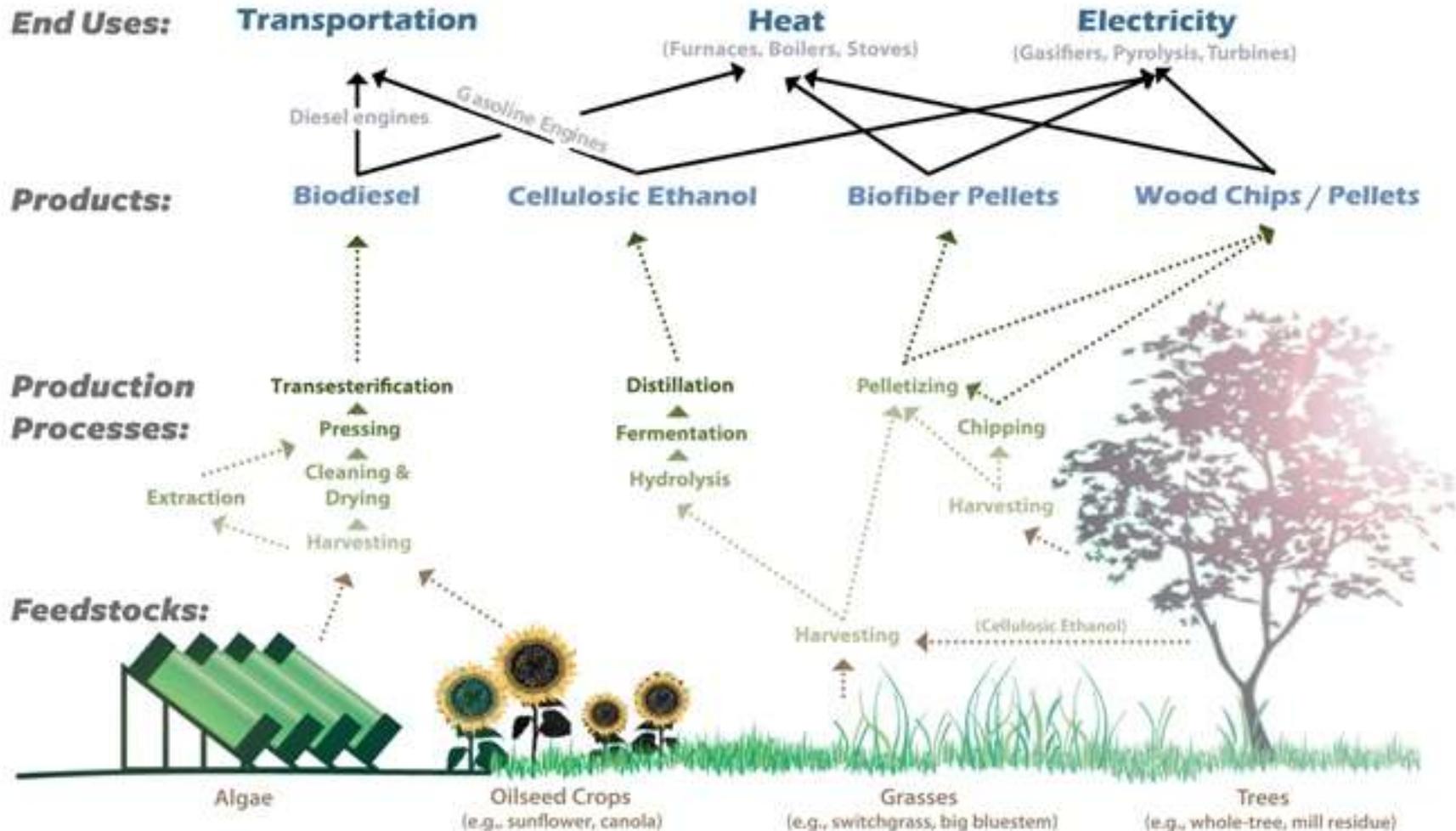


Jatropha



Food and kitchen waste

Biomass to Biofuels





Gasoline

Bad

A non-renewable fossil fuel produced by refining crude oil; emits large quantities of CO₂ upon combustion.



Biodiesel

Good

A renewable alternative to petroleum diesel produced from animal fat or vegetable oil.



Corn-derived Ethanol

Transitional

The main source of ethanol in the U.S. But growing corn is energy-intensive and requires large amounts of fertilizer made with fossil fuel.



Cellulosic Ethanol

Potentially Great

Production results in the same ethanol that corn produces, but the feedstocks, especially switchgrass, are inexpensive and easy to grow and the process of refining them is environmentally friendly.

Net Energy Balance *

N/A

3.20

1.34

2.62

Reduction in Greenhouse Gas Emissions

None
(1 gallon produces 19 lbs of CO₂)

67.7%

21.8%

91%

Cost (per gallon)

\$3.10

\$2.90 average

\$2.55 (E85)

\$2.55 (E85)

Gallons/Acre

n/a

Varies by feedstock
Rapeseed: 127

328

Varies by feedstock
Switchgrass: 1000

Current U.S. Production (gallons/year)

79 billion

75 million

4.9 billion

(no current production at commercial scale)

Availability

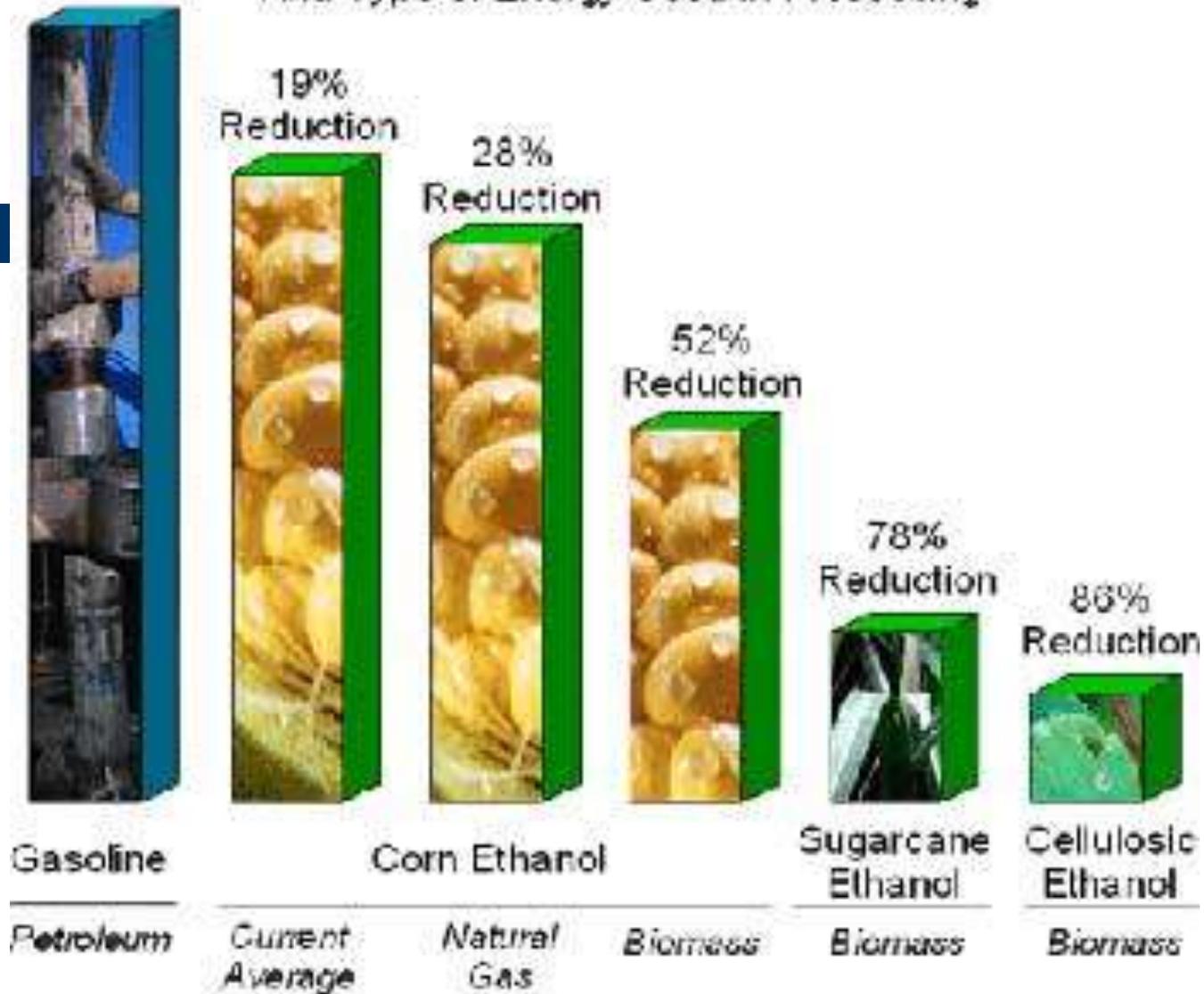
114,974 stations

1,485 Stations

1,133 E-85

1,133 (E85)

Greenhouse Gas Emissions by Transportation Fuel And Type of Energy Used in Processing



Fuel	Source	Benefits	Maturity
Grain/Sugar Ethanol	Corn, sorghum, and sugarcane	<ul style="list-style-type: none"> • Produces a high-octane fuel for gasoline blends • Made from a widely available renewable resource 	Commercially proven fuel technology
Biodiesel	Vegetable oils, fats, and greases	<ul style="list-style-type: none"> • Reduces emissions • Increases diesel fuel lubricity 	Commercially proven fuel technology
Green Diesel and Gasoline	Oils and fats, blended with crude oil	<ul style="list-style-type: none"> • Offer a superior feedstock for refineries • Are low-sulfur fuels 	Commercial trials under way in Europe and Brazil for fuel
Cellulosic Ethanol	Grasses, wood chips, and agricultural residues	<ul style="list-style-type: none"> • Produces a high-octane fuel for gasoline blends • Is the only viable scenario to replace 30% of U.S. petroleum use 	DOE program is focused on commercial demonstration by 2012
Butanol	Corn, sorghum, wheat, and sugarcane	<ul style="list-style-type: none"> • Offers a low-volatility, high energy-density, water-tolerant alternate fuel 	BP and DuPont plan to introduce butanol fuel in 2007



Most Mature

Pyrolysis Liquids	Any lignocellulosic biomass	<ul style="list-style-type: none"> • Offer refinery feedstocks, fuel oils, and a future source of aromatics or phenols 	Several commercial facilities produce energy and chemicals
Syngas Liquids	Various biomass as well as fossil fuel sources	<ul style="list-style-type: none"> • Can integrate biomass sources with fossil fuel sources • Produce high-quality diesel or gasoline 	Demonstrated on a large scale with fossil feedstocks, commercial biomass projects under consideration
Diesel/Jet Fuel From Algae	Microalgae grown in aquaculture systems	<ul style="list-style-type: none"> • Offer a high yield per acre and an aquaculture source of biofuels • Could be employed for CO₂ capture and reuse 	Demonstrated at pilot scale in 1990s
Hydrocarbons From Biomass	Biomass carbohydrates	<ul style="list-style-type: none"> • Could generate synthetic gasoline, diesel fuel, and other petroleum products 	Laboratory-scale research in academic laboratories

Least Mature

Bioethanol

- Made mostly by fermentation of sugars and starches in corn, sugarcane, sugarbeets, and sweet sorghum
- Cellulosic biomass (from non-food sources like trees and grasses) is being developed as feedstock for bioethanol
- Has lower energy density than gasoline by about 1/3 (lower mpg), but higher octane rating allowing higher compression ratios

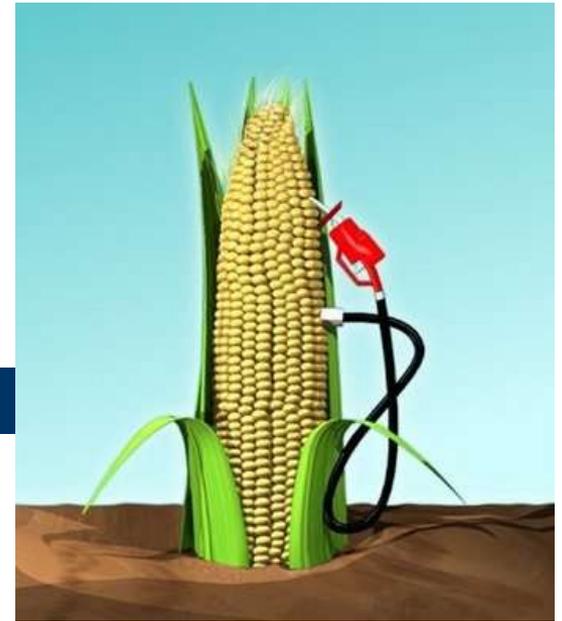
Biofuels Save On CO₂

- The key idea is to reduce fossil fuel use
- Fossil fuels release CO₂ that has been stored for millions of years
- Biofuels reuse the CO₂ to create the biomass and release oxygen



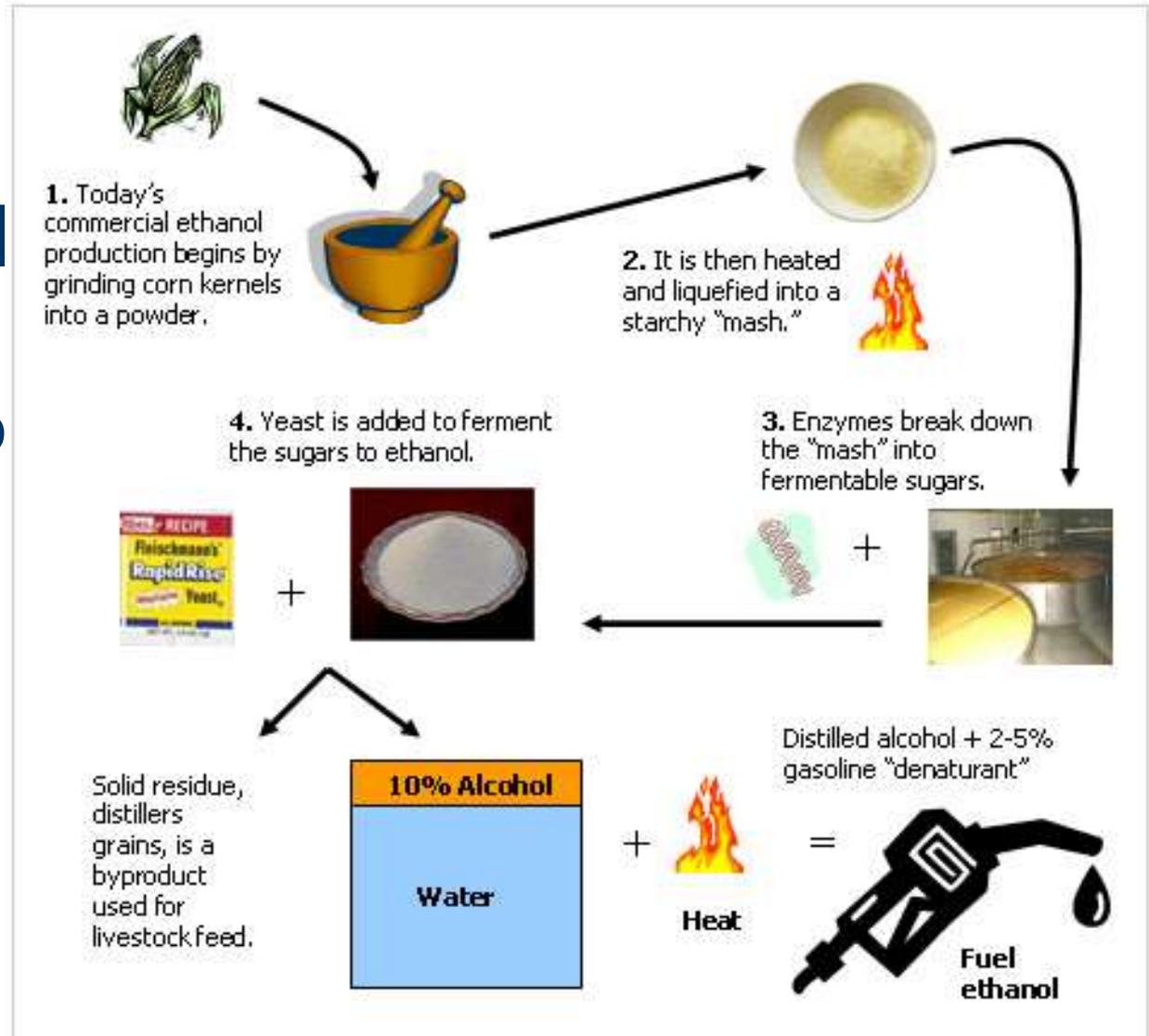
Corn-To-Ethanol Model

- Considering all energy consumed to make bioethanol, the net energy content value added is very small
- Without subsidies bioethanol fuel costs more per distance traveled than current gasoline prices



Corn To Ethanol

- Much GHG is created to process the ethanol



United States Ethanol Biorefineries



Date Source: Renewable Fuels Association and Ethanol Producer Magazine, October 2007



But Here Is A Problem



Alternative Sources Look Like Better Choices

Corn
300 bu/acre

900 gal (300 bu @ 3 gal/bu)
400 gal (4 tons stover* @ 100 gal/ton)



1300 gal

Biomass Crop
20 ton/acre

2000 gal (20 tons @ 100 gal/ton)



2000 gal

* Assumes a total of 8 tons with 50% removal

Chopping Sugarcane

- Sugarcane works well as a source in Brazil



CELLULOSIC ETHANOL IS COMING

LARGE SCALE PRODUCTION PLANTS UNDER CONSTRUCTION (CAPACITY IN MILLION US GALLONS PER YEAR)



AND WE ARE JUST GETTING STARTED

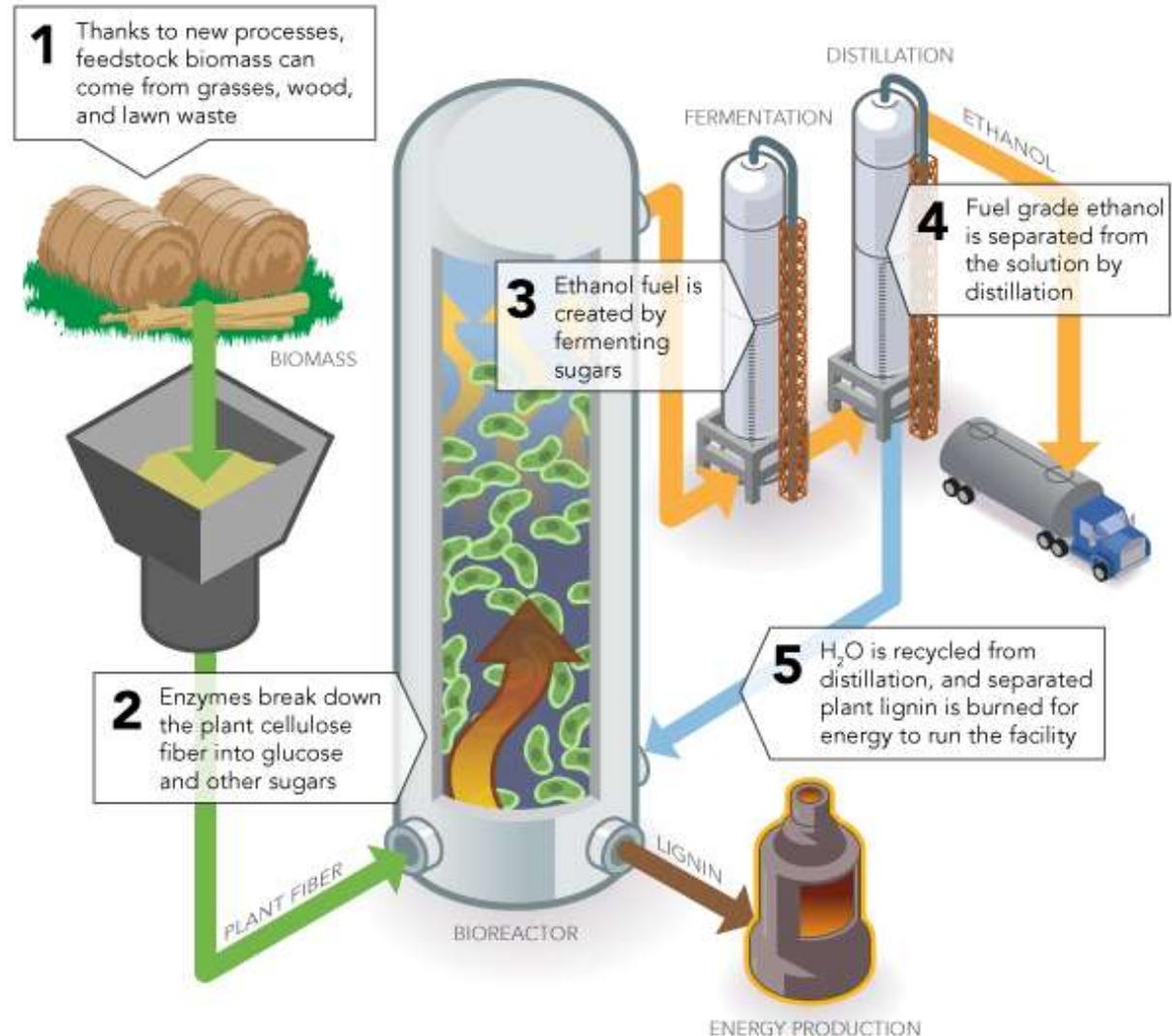
In 2014 the estimated production capacity of cellulosic ethanol is about 250 million US gallons. According to Bloomberg New Energy Finance there is enough biomass available to produce 93 billion US gallons of cellulosic ethanol in 2030.

Source: "Moving towards a next generation ethanol economy" Bloomberg New Energy Finance, 2012 and public information on large scale production plants (biochemical conversion only) under planned construction

Cellulosic Bioethanol

- Most cellulosic sources do not compete with food crops
- Switchgrass, miscanthus, wood, lawn waste, corn stalks, wheat straw are all good sources

Ethanol from Biomass



Cost Of Biofuels

- These numbers are at cost, not price
- More development is required to get competitive

Relative costs of biofuels from various feedstocks
Estimated cost per barrel of fuel



Let's talk about



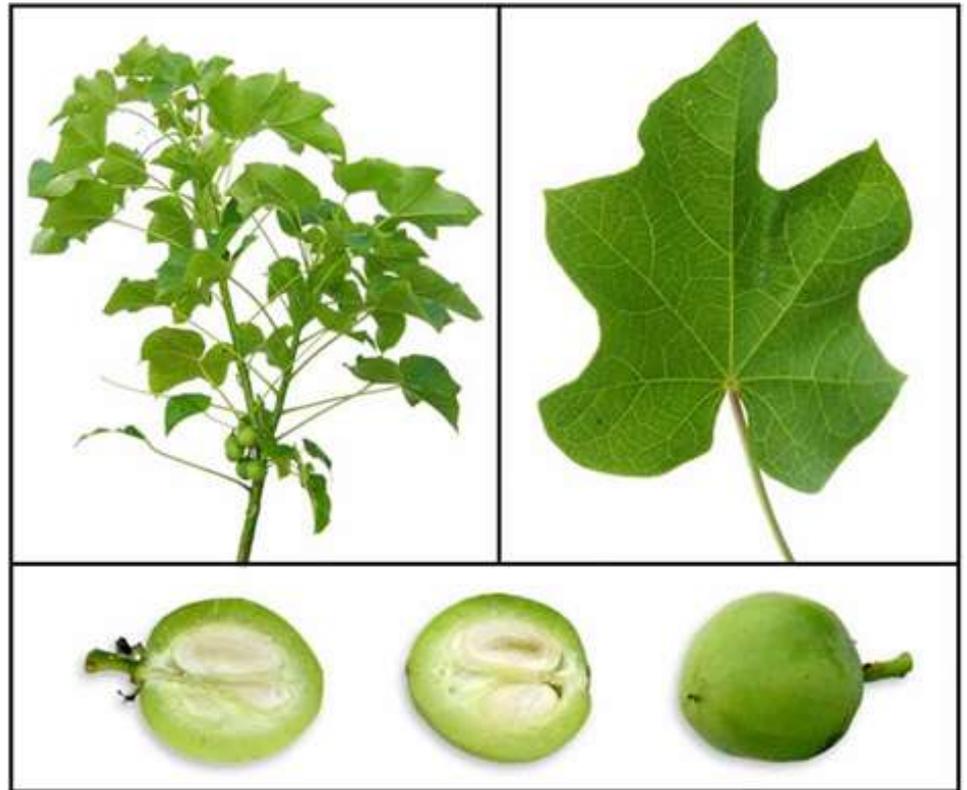
- Biodiesel is processed from palm oil, soy, rapeseed, jatropha, sunflower, animal fats, other vegetable oils, recycled cooking grease, and (some day) oil-rich algae
- Biodiesel is the most common biofuel in Europe
- Pure biodiesel is labeled B100
- Thicker than diesel at lower temperatures
- 5% biodiesel is common in Europe
- It's a good solvent and helps clean the engine
- In the US, more than 80% of commercial trucks and city buses run on diesel
- Better lubricating properties than diesel fuels
- 9% lower energy density than diesel

Oil Palm

- Oil palm is used extensively in Europe to make biodiesel
- Oil palm is now the number one fruit crop, surpassing the banana
- Grown mainly in Malaysia, Indonesia and Thailand
- The most productive oil seed. 2.5 acres of oil palm produces 2,000 gallons of crude oil
- A lot of natural acreage is being cleared to make way for oil palm

Jatropha

- Used to make biodiesel
- High oil content
- Grows on land unsuitable for food crops
- SB Biofuels has developed a high-producing hybrid

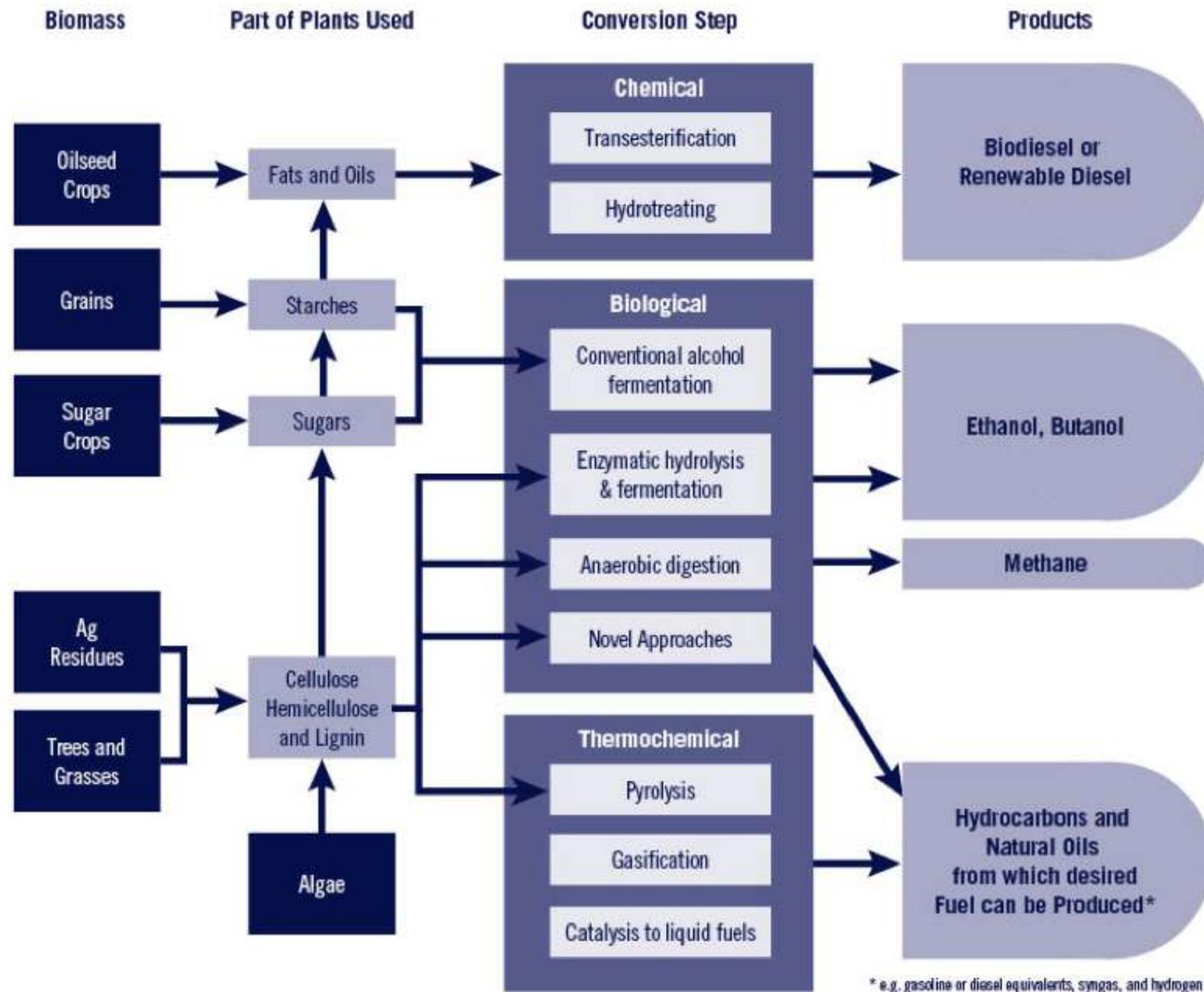


You Can Make Your Own Biodiesel

- Get Waste Vegetable Oil from restaurant (now selling for about \$0.30 per gallon)
- Filter out trash and deacidify
- Mix in lye and methanol
- Separate out the biodiesel
- Put it in your diesel engine tank

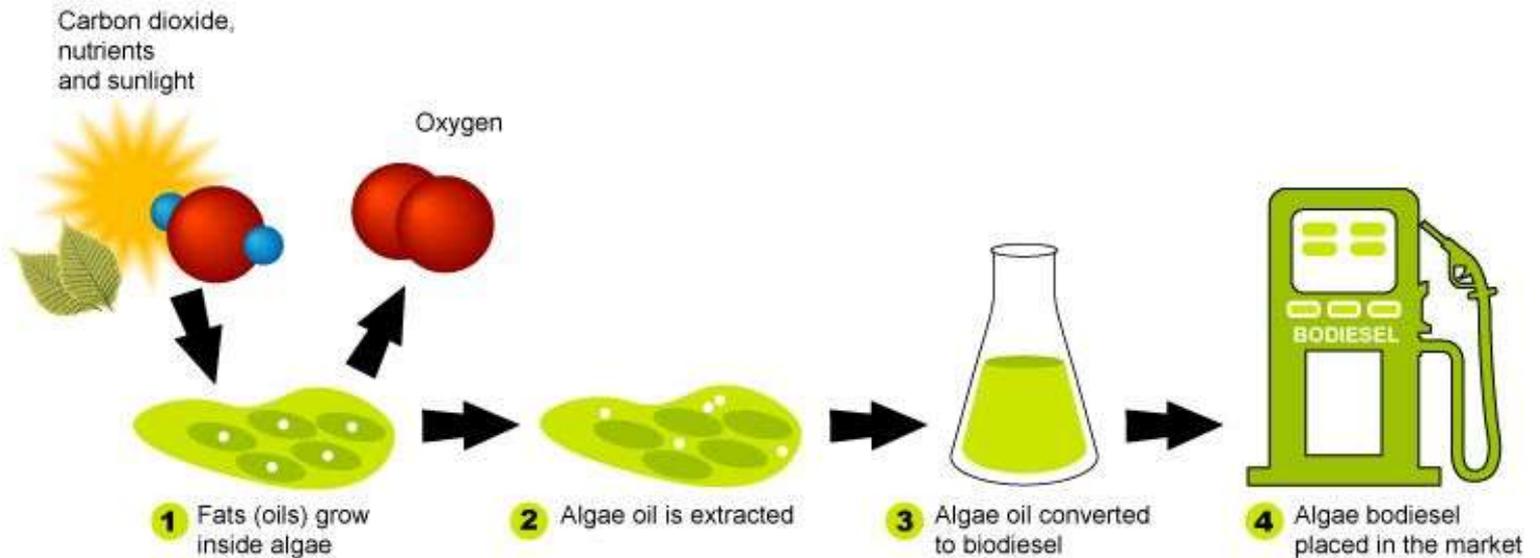
- Much cleaner than fossil diesel
- Can cost as little as about \$1/gallon (excluding cost of equipment and your time)
- Should register with government

Figure 2: Current and Emerging Biofuel Pathways



Algae Has Great Promise

- Does not use farmland or fresh water
- High yield

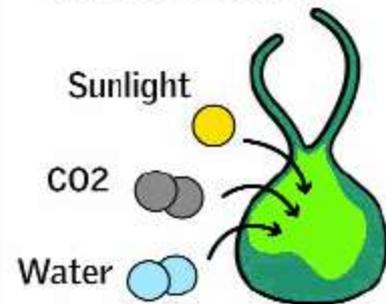


Biodiesel from algae

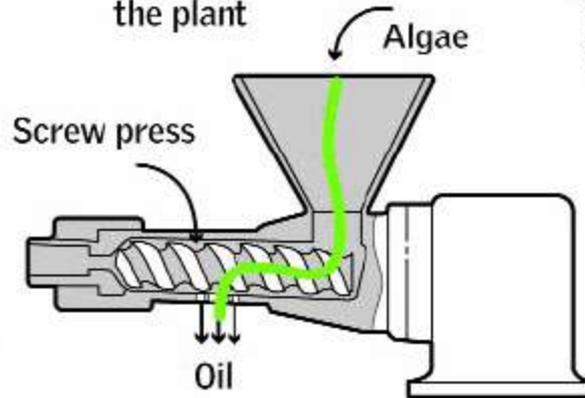
High oil prices and advances in biotech over the past decade have refueled the algae biofuel race.

The process

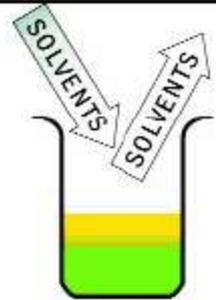
1 After initial growth, algae is deprived of nutrients to produce a greater oil yield



2 Extraction of oil
A press produces 70-75% of the oils from the plant



3 Solvents used to separate sugar from oil; solvents then evaporate



4 Oil is ready
Can be used as oil directly in diesel engines or refined further into fuel



Yield of various plant oils

(Gallons per hectare)

Soy	118
Safflower	206
Sunflower	251
Castor	373
Coconut	605
Palm	1,572
Algae	26,417

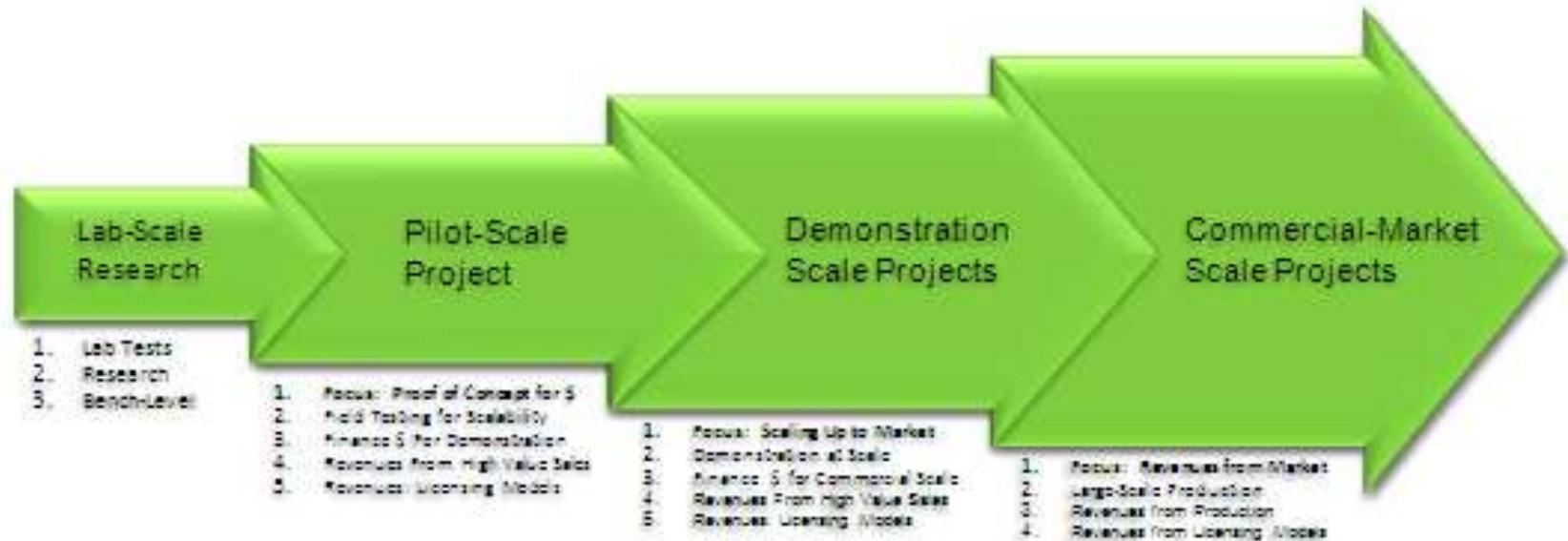


About algae

- Among the fastest growing plants; about 50% of their weight is oil
- Contains no sulfur; non toxic; highly biodegradable
- Algae fuel is also known as algal fuel or oilgae

26,417

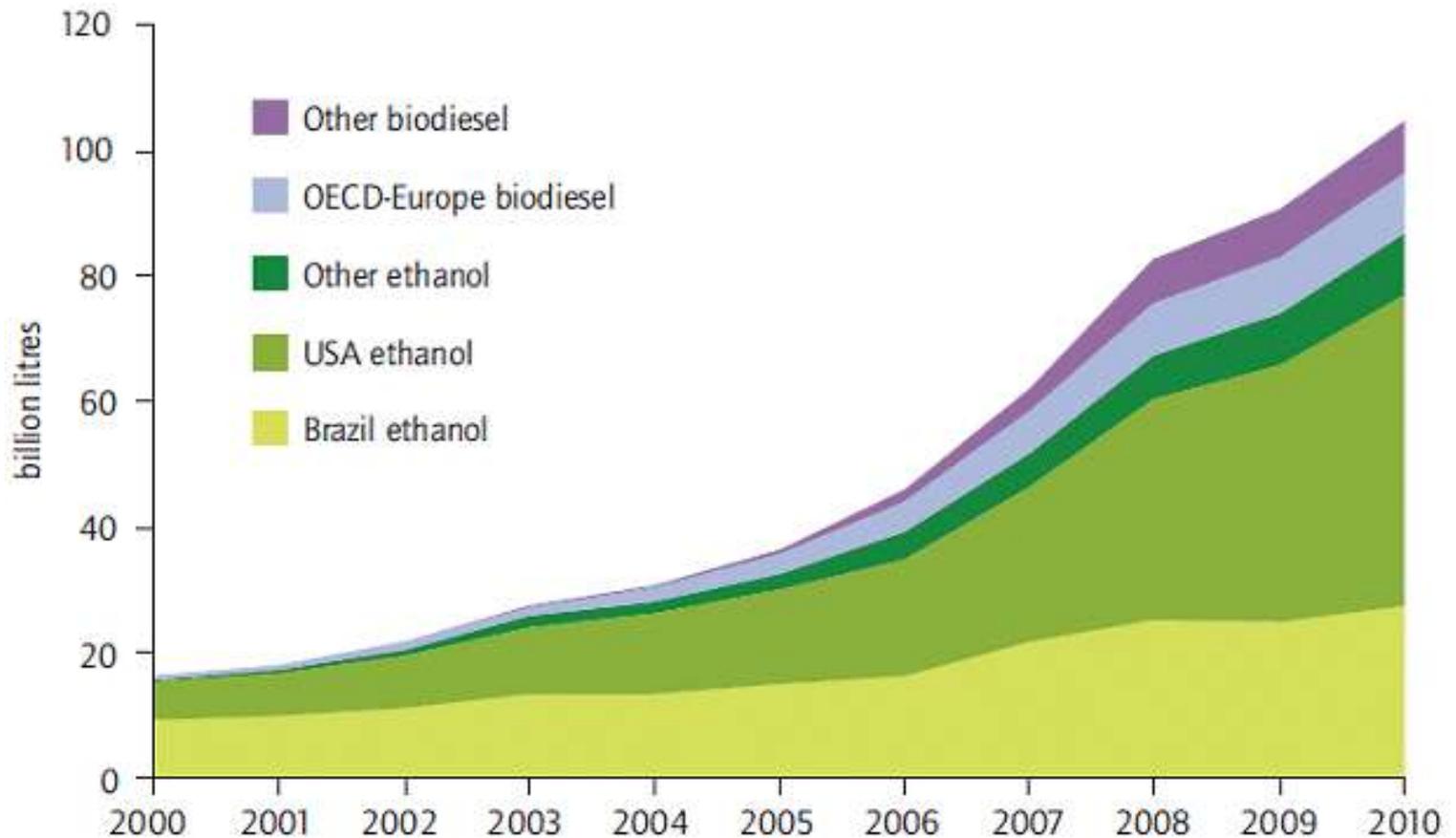
Evolution of Algal Biomass Producers and Projects



Timeline Evolution and Maturation of Algae Producers and Projects From Concept to Commercial Market Scale

Sources: Algae 2020 study, Emerging Markets Online Consulting Services

Global Biofuel Trends



Source: IEA, 2010

HOW GREEN ARE BIOFUELS?

Biofuels are getting a bad rap as stories of rising food prices and shortages fill the news. But the environmental, energy and land use impacts of the crops used to make the fuels vary dramatically. Current fuel sources – corn, soybeans and canola – are more harmful than alternatives that are under development.

CROP	USED TO PRODUCE	GREENHOUSE GAS EMISSIONS* Kilograms of carbon dioxide created per mega joule of energy produced	USE OF RESOURCES DURING GROWING, HARVESTING AND REFINING OF FUEL				PERCENT OF EXISTING U.S. CROP LAND NEEDED TO PRODUCE ENOUGH FUEL TO MEET HALF OF U.S. DEMAND	PROS AND CONS
			WATER	FERTILIZER	PESTICIDE	ENERGY		
Corn	Ethanol	81-85	high	high	high	high	157%-262%	Technology ready and relatively cheap, reduces food supply
Sugar cane	Ethanol	4-12	high	high	med	med	46-57	Technology ready, limited as to where will grow
Switch grass	Ethanol	-24	med-low	low	low	low	60-108	Won't compete with food crops, technology not ready
Wood residue	Ethanol, biodiesel	N/A	med	low	low	low	150-250	Uses timber waste and other debris, technology not fully ready
Soybeans	Biodiesel	49	high	low-med	med	med-low	180-240	Technology ready, reduces food supply
Rapeseed, canola	Biodiesel	37	high	med	med	med-low	30	Technology ready, reduces food supply
Algae	Biodiesel	-183	med	low	low	high	1-2	Potential for huge production levels, technology not ready

* Emissions produced during the growing, harvesting, refining and burning of fuel. Gasoline is 94, diesel is 83.

Source: Martha Groom, University of Washington; Elizabeth Gray, The Nature Conservancy; Patricia Townsend, University of Washington; as published in Conservation Biology

Summary

- Biofuels have great potential to reduce dependence on fossil fuels and reduce generation of green house gases
- But we aren't there yet