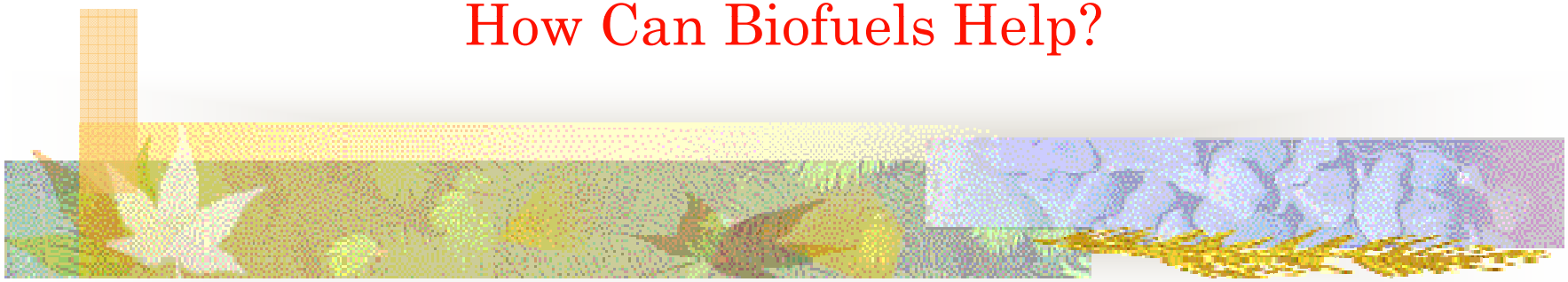
Global Warming

How Can Biofuels Help?



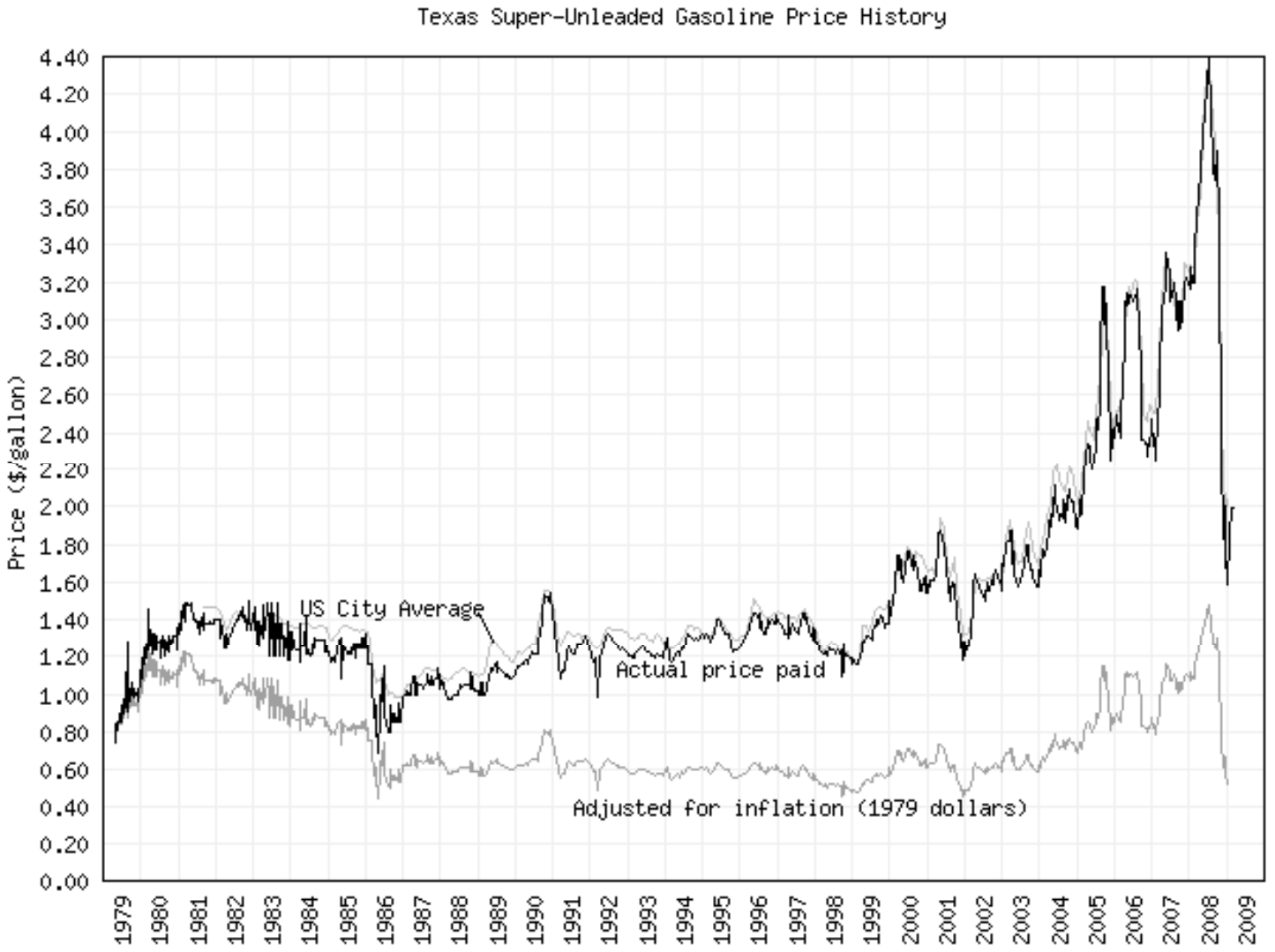
Clint Williford

Department of Chemical Engineering

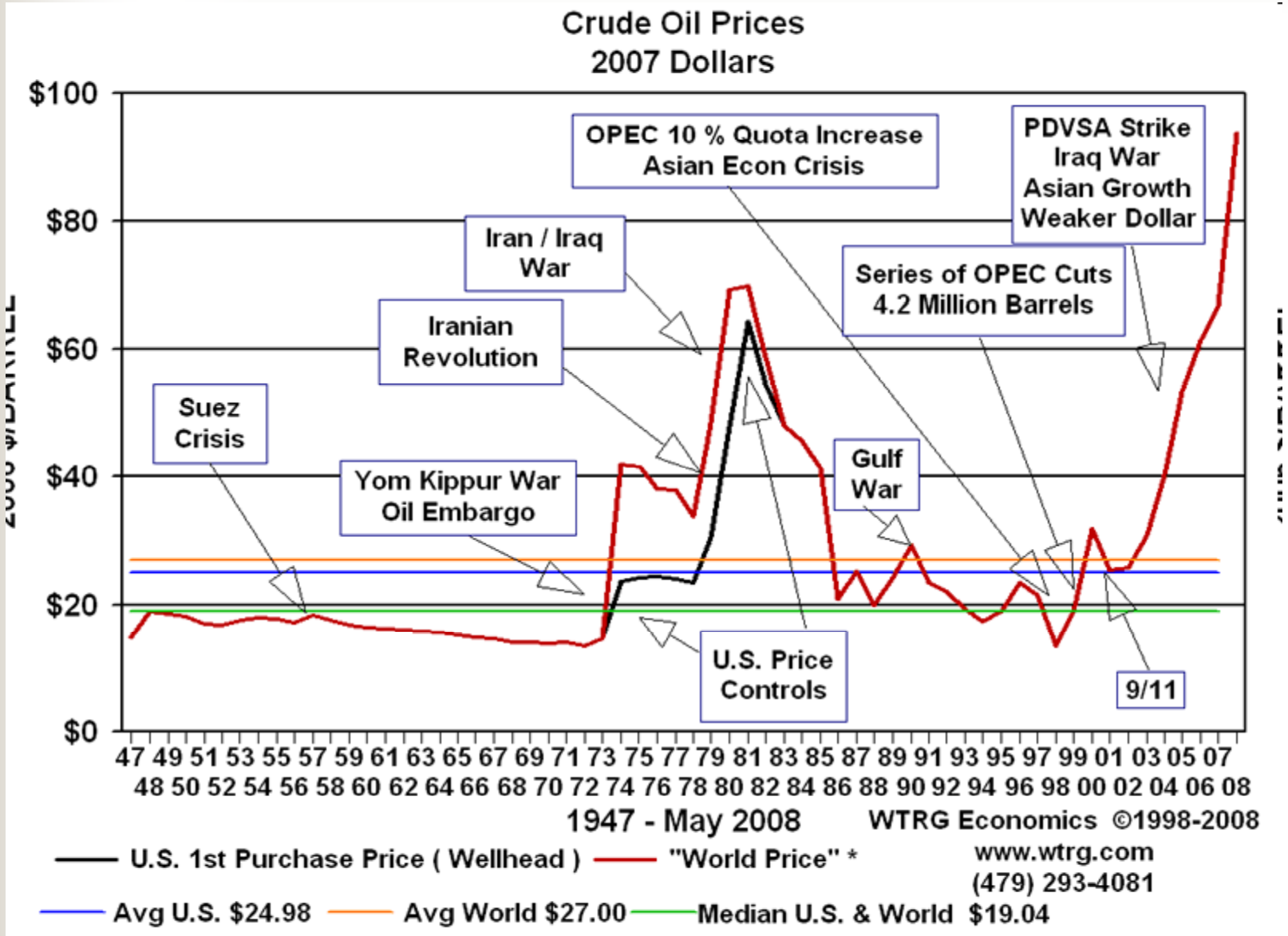
Introduction

- Greenhouse emissions
- Reducing growth of GHG emissions
- Biofuels
  - Why and why now?
  - What they are?
  - How they are made?
  - Potential for energy & GHG reduction
  - Issues

Introduction



Introduction



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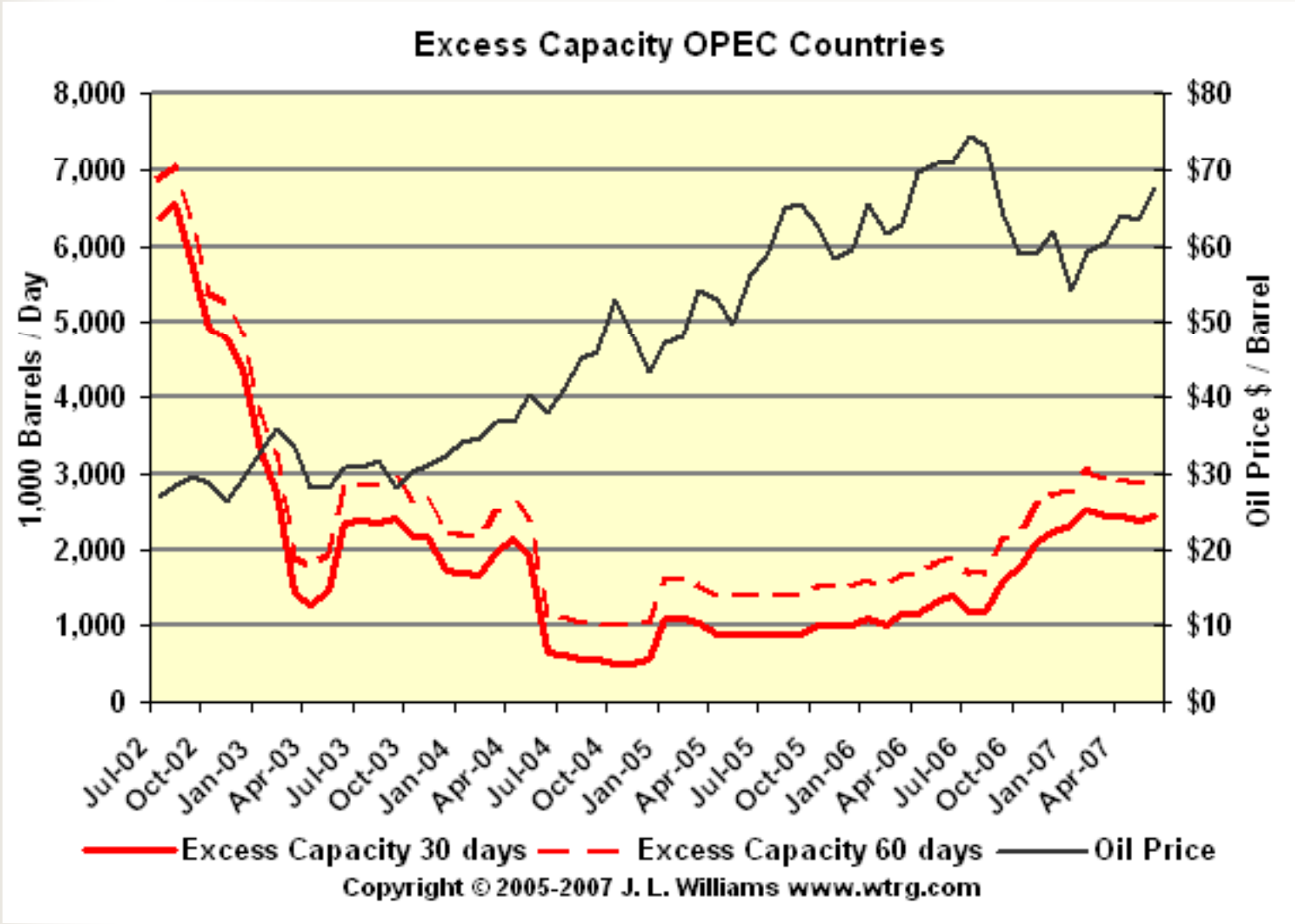

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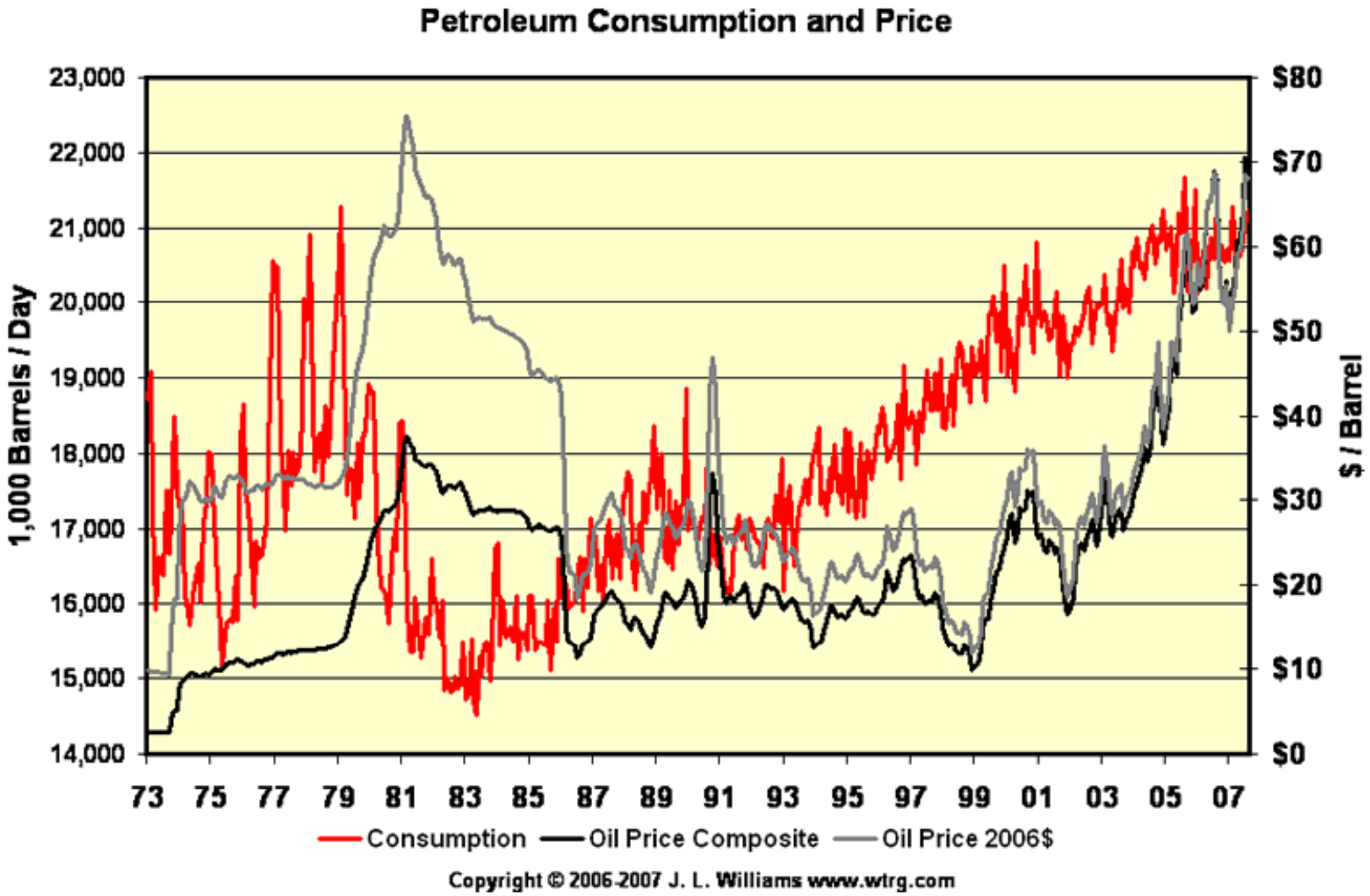
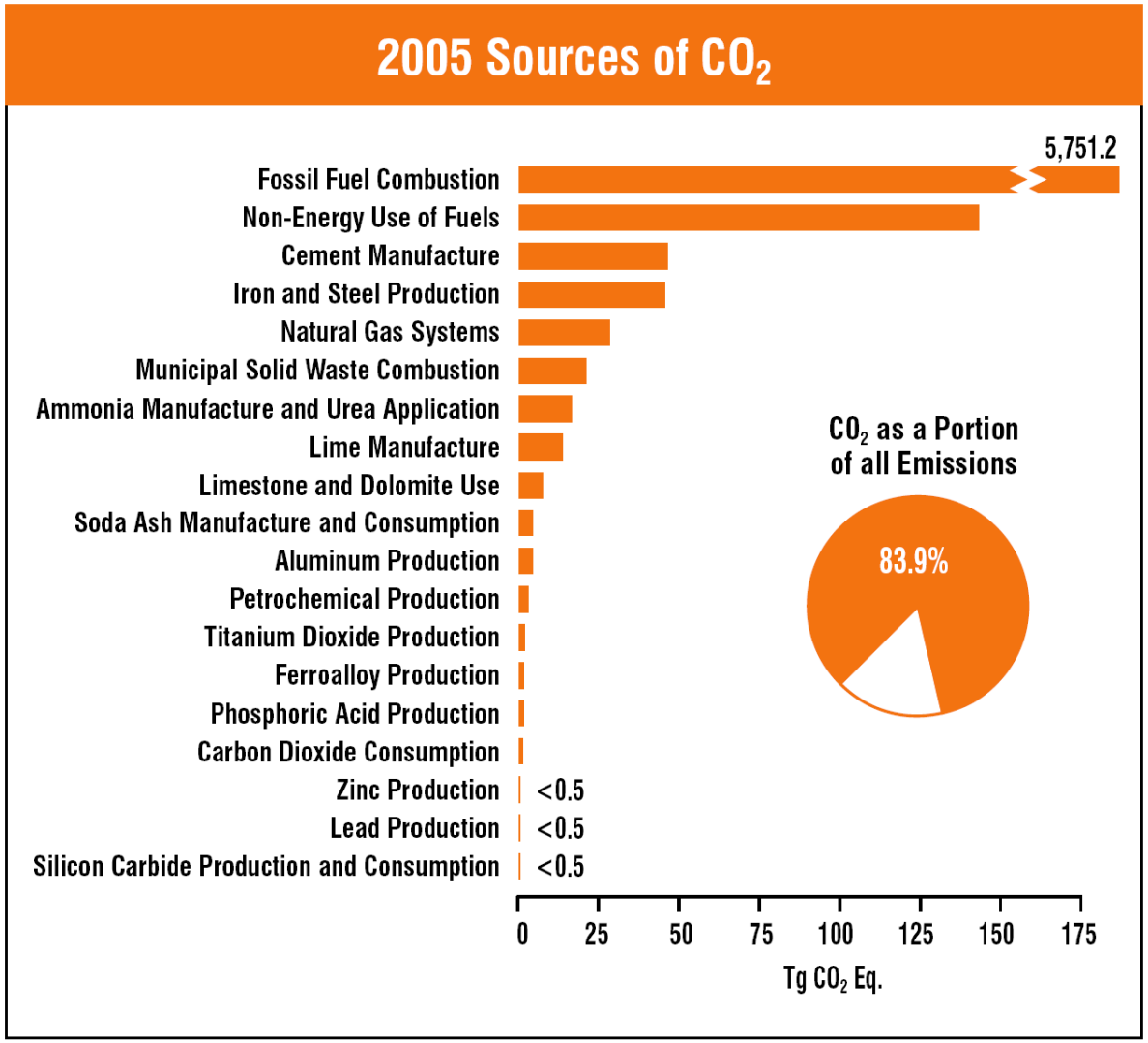


Greenhouse Emissions



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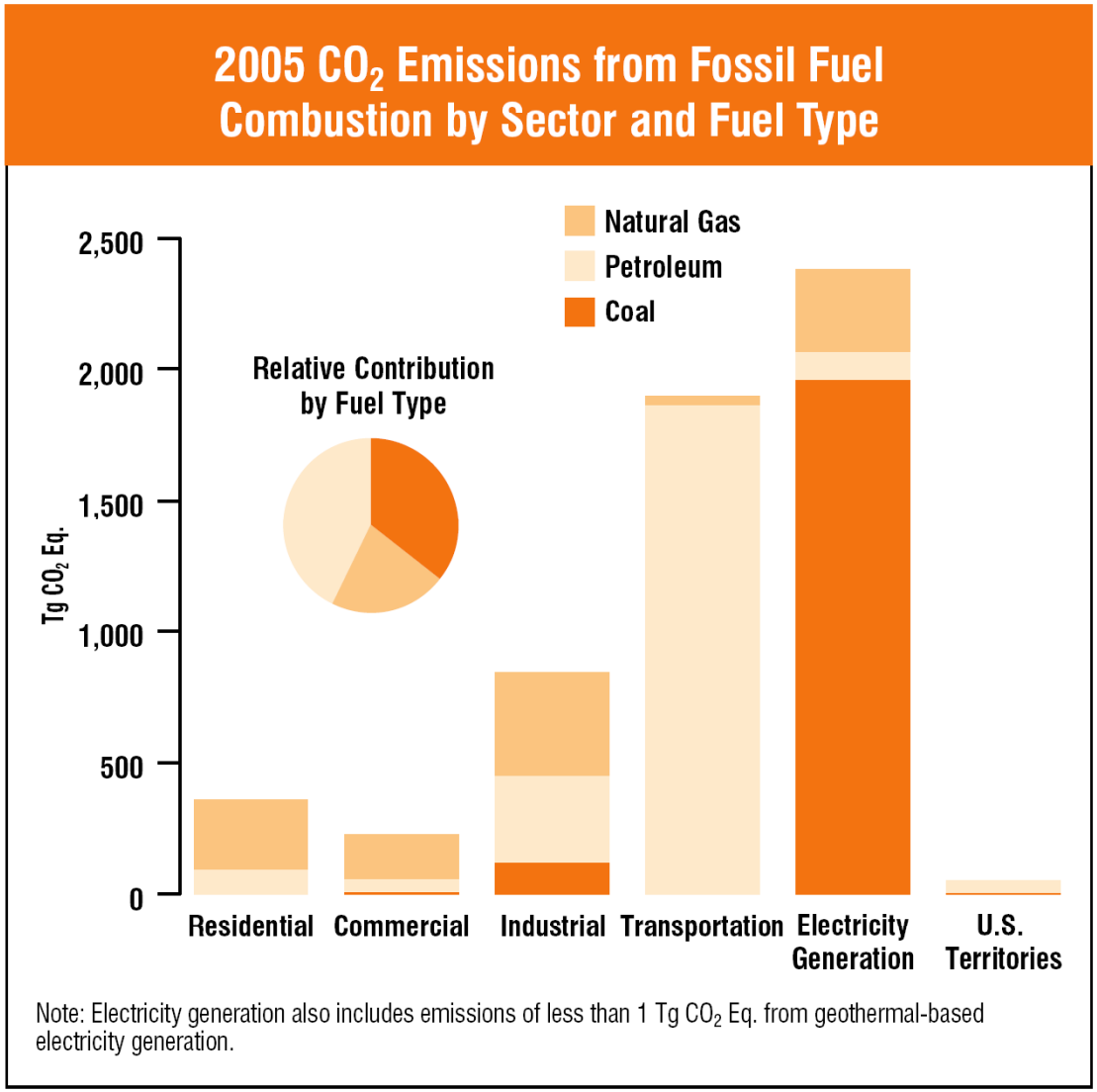
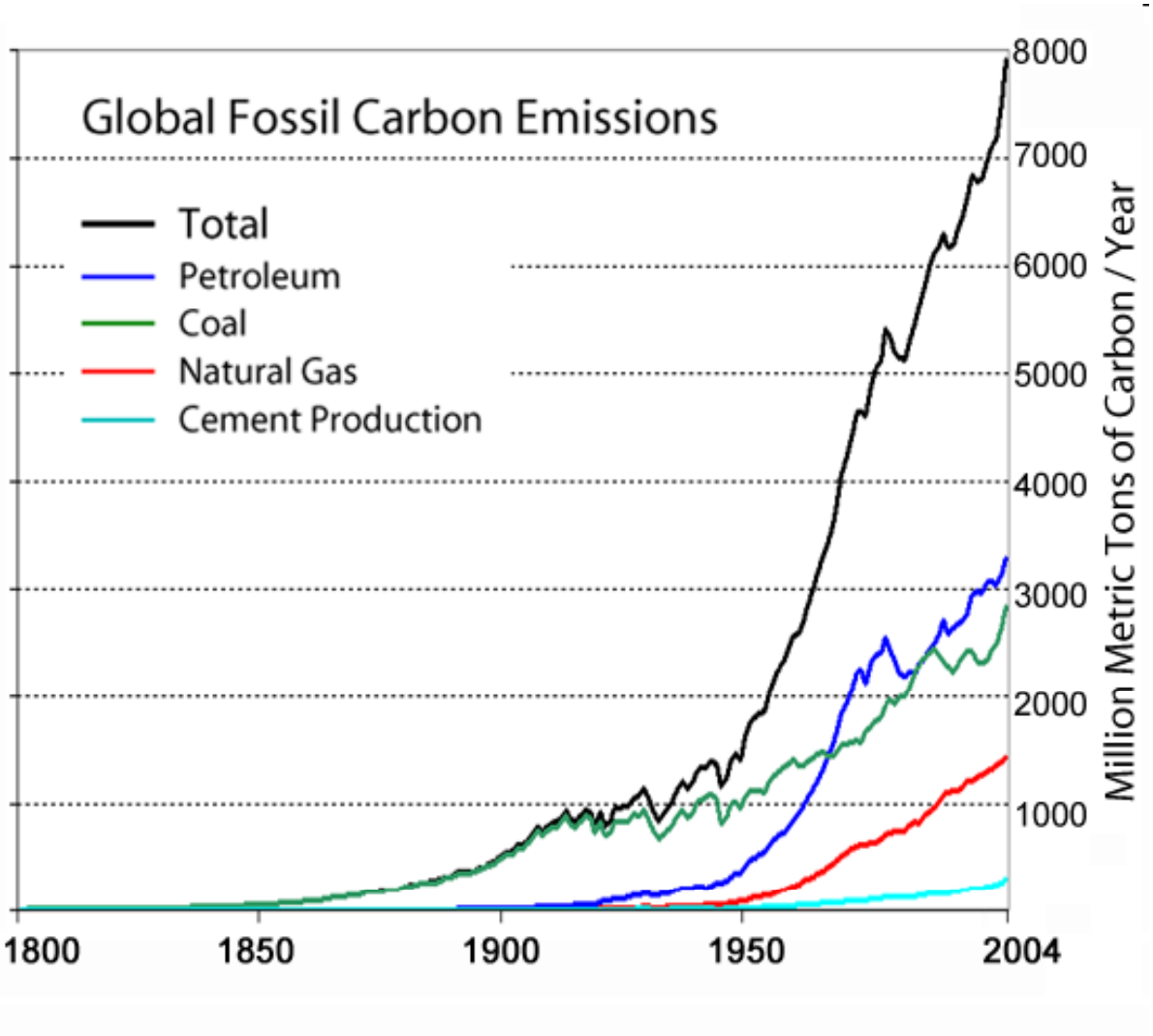


Greenhouse Emissions



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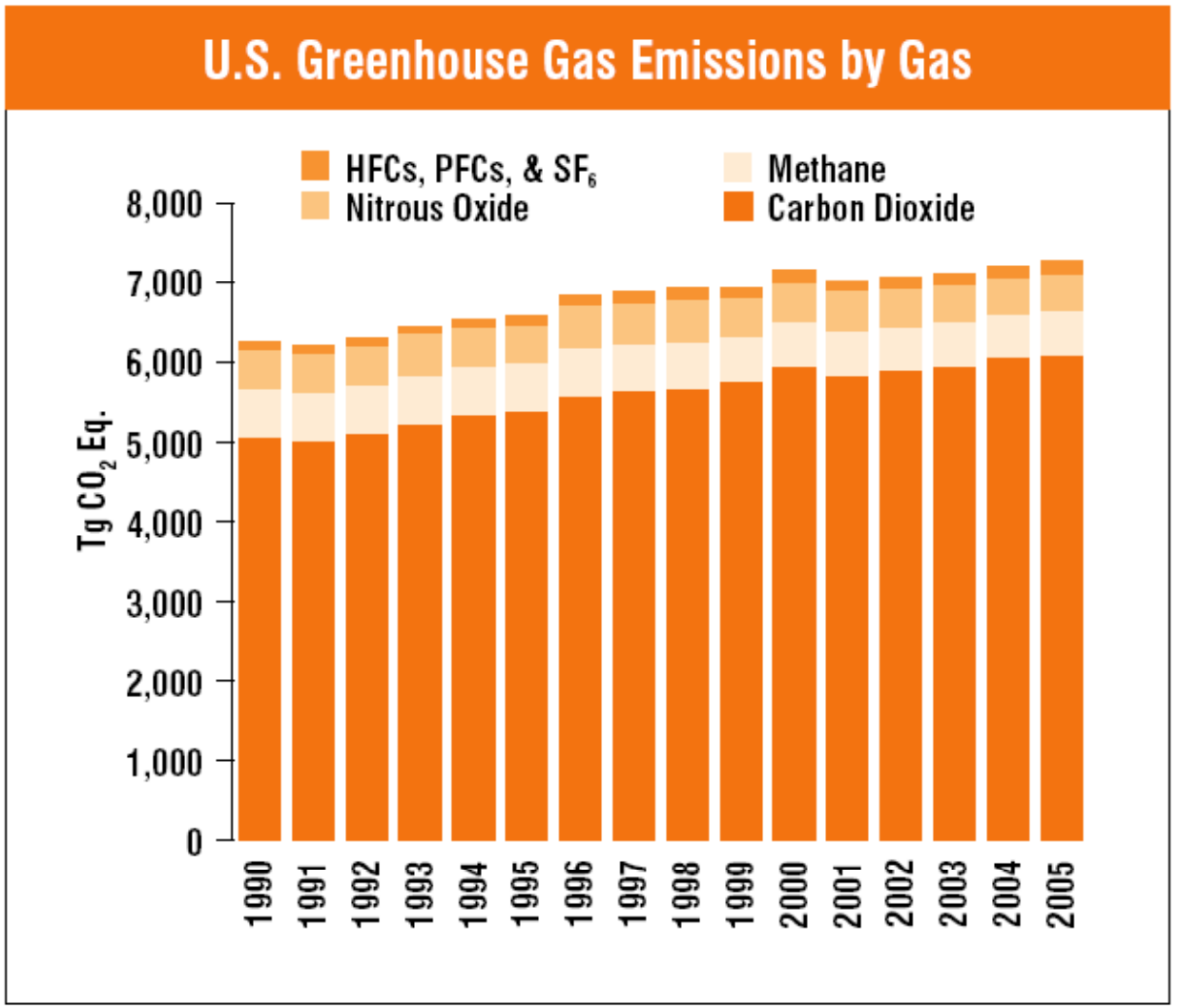
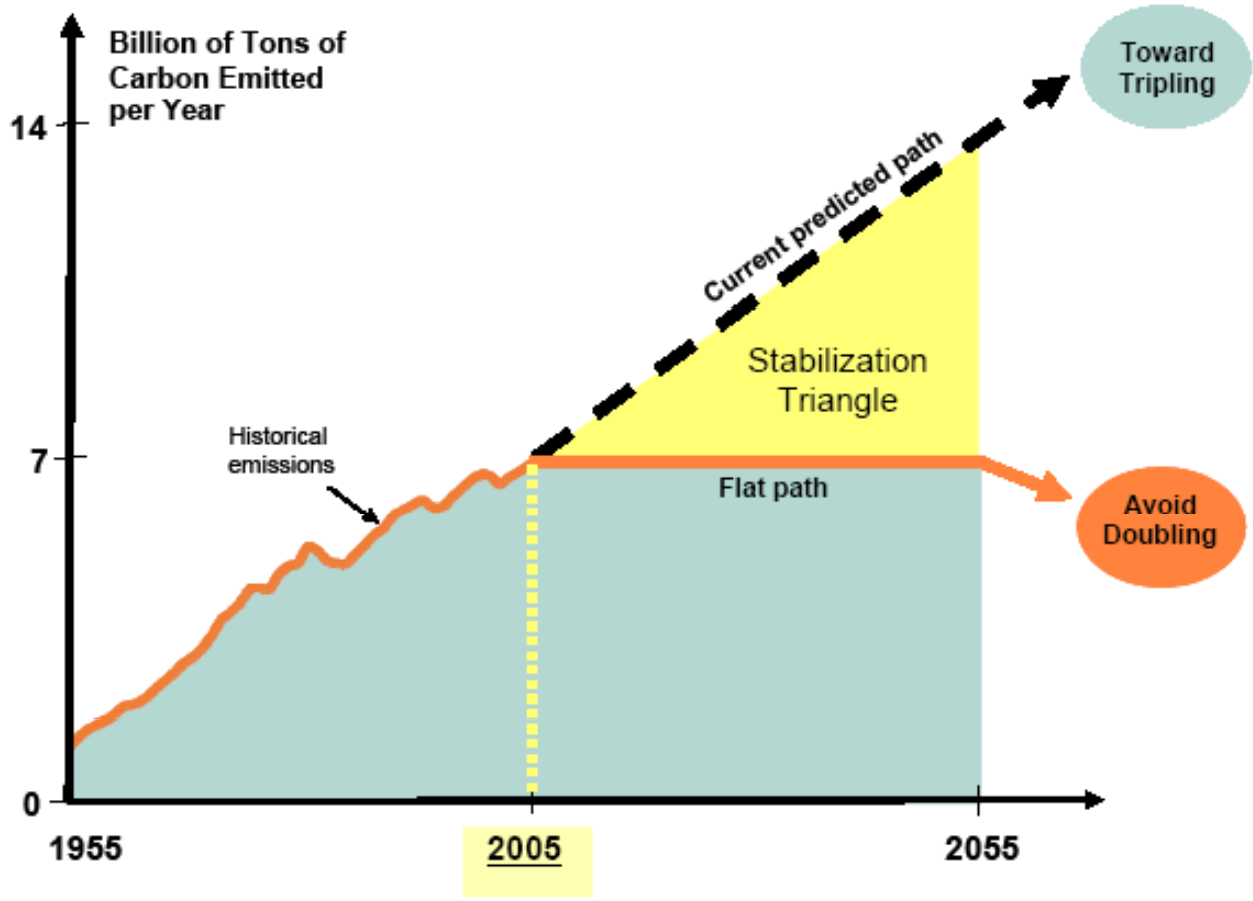


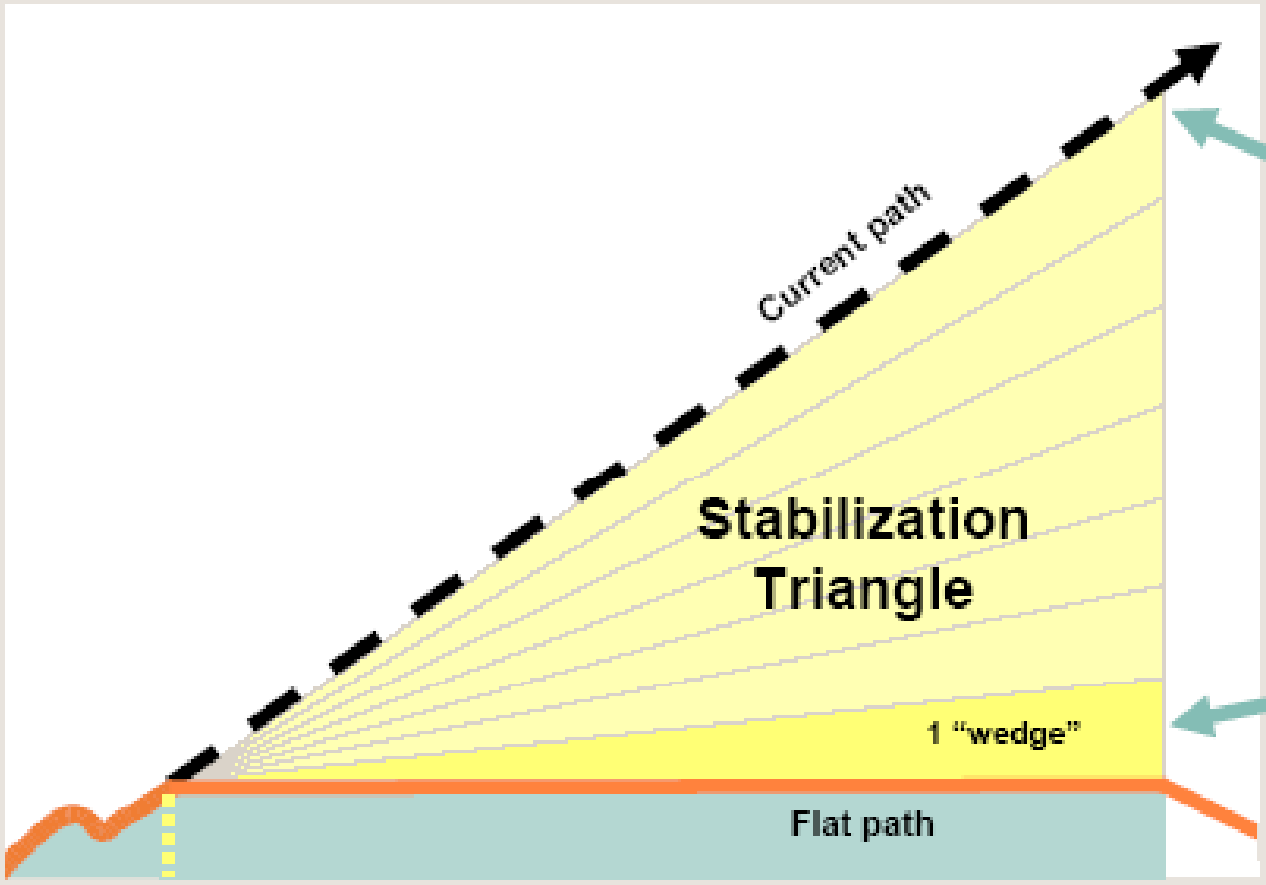
Greenhouse Emissions

Gas	Preindustrial Level	Current Level	Increase since 1750	Radiative Forcing(W/m^2)
Carbon Dioxide	280 ppm	387ppm	104 ppm	1.46
Methane	700 ppb	1,745 ppb	1,045 ppb	0.48
Nitrous Oxide	270 ppb	314 ppb	44 ppb	0.15
CFC-12	0	533 ppt	533 ppt	0.17

Reducing Growth of GHG Emissions



Reducing Growth of GHG Emissions



7 wedges

are needed to build the stabilization triangle

1 wedge

avoids 1 billion tons of carbon emissions per year by 2054

- **1 Wedge – Increase Bio EtOH X 50**

Biofuels- Why &Why Now?

- 2006 – Tipping Point for industrial biotech & cell EtOH
  - Higher energy prices
  - Concern for energy security
  - Global warming – a mainstream issue
  - Technological advance - enzymatic hydrolysis
  - Political support – farmers, environmentalists, security interests, business leaders, politicians
  - Grain corn ethanol building an industry and a market

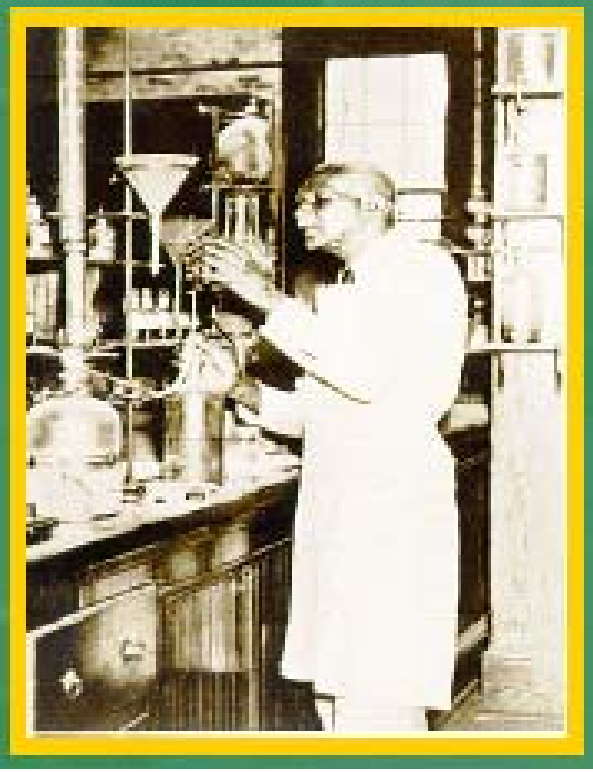
George Washington Carver

(1864-1943)

Had a dream to develop an economy based on ag crops as feedstocks

Carver's pioneering work resulted in the creation of:

- 325 products from peanuts
- More than 100 products from sweet potatoes
- And hundreds more from a dozen other plants
- Industrial biotech is helping his dream come true.

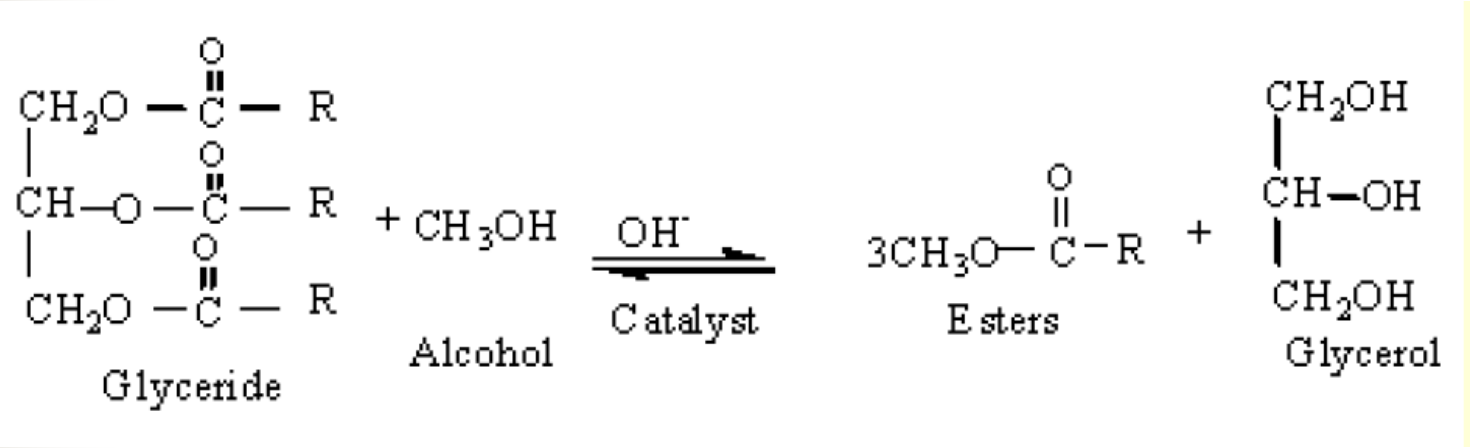


Types of Biofuels

- Biodiesel
- Grain corn ethanol
- Cellulosic ethanol (Cell EtOH)
- Others – Butanol, Renewable biodiesel

Biodiesel

- Biodiesel is known chemically as a 'fatty acid methyl ester'
- "Transesterification"



- Vege oil or fat reacted with an alcohol using a catalyst, usually a base (OH^-)
- Settling and washing steps
- Glycerol is main byproduct

http://www.utahbiodieselsupply.com/biodieselbasics.php

Biodiesel

http://pathtofreedom.com/pathproject/offthegrid/biodiesel.shtml

Types of Biofuels

http://pathtofreedom.com/pathproject/offthegrid/biodiesel.shtml

Biodiesel

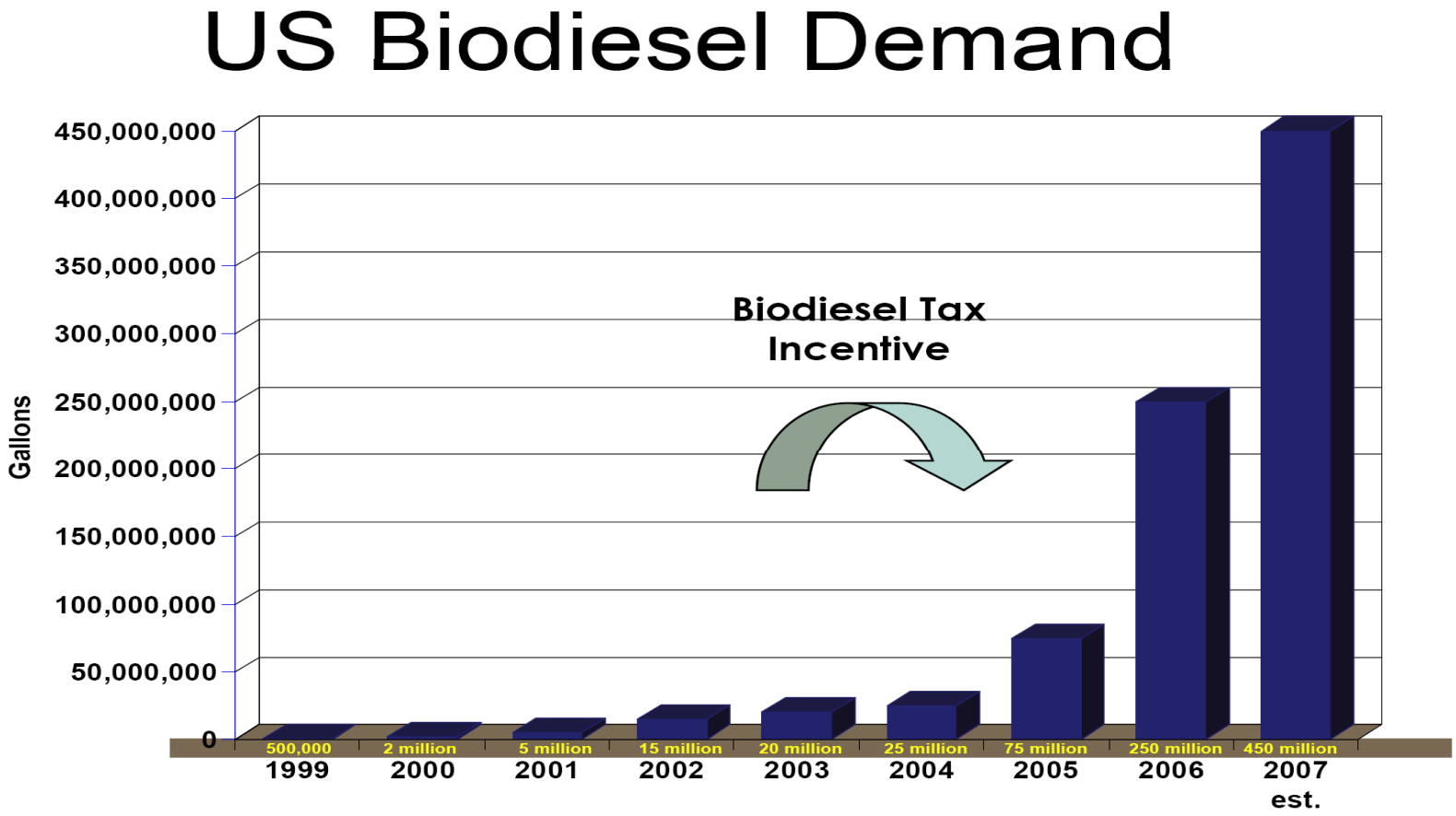
AVERAGE BIODIESEL EMISSIONS COMPARED TO CONVENTIONAL DIESEL, ACCORDING TO EPA

Emission Type	B100	B20
Regulated		
Total Unburned Hydrocarbons	-67%	-20%
Carbon Monoxide	-48%	-12%
Particulate Matter	-47%	-12%
Nox	+10%	+2% to -2%

Average Density and Heating Value of Biodiesel and Diesel Fuel

Fuel	Density, g/cm3	Net Heating Value Avg., Btu/gal.	% Difference vs. No. 2 Diesel Avg.
No. 2 Diesel	0.850	129,500	
Biodiesel (B100)	0.880	118,296	8.65 %
B20 Blend (B20)	0.856*	127,259*	1.73 %*
B2 Blend (B2)	0.851*	129,276*	0.17 %*

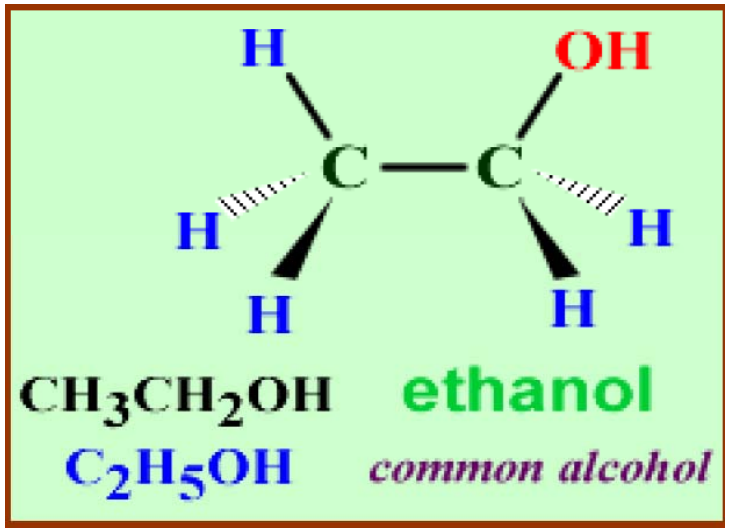
Biodiesel



Production and demand surging;$1/gal blending incentive

Grain Corn Bioethanol

- Ethanol (CH3CH2OH; also known as ethyl alcohol, grain alcohol, and EtOH) is a clear, colorless liquid.



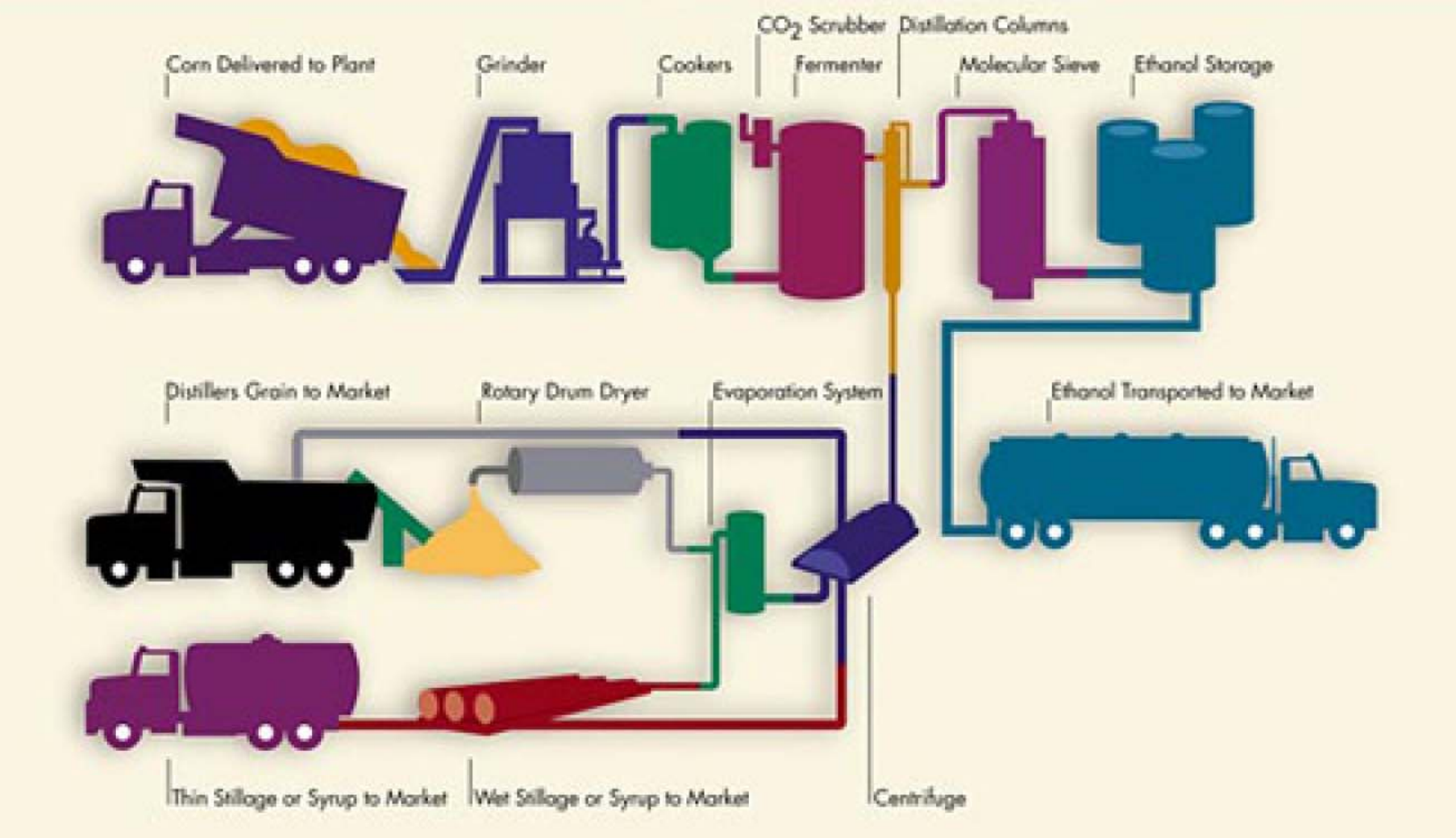
http://www.eere.energy.gov/afdc/fuels/ethanol_what_is.html

And http://arreffett.iweb.bsu.edu/ethanol.htm

Grain Corn Bioethanol

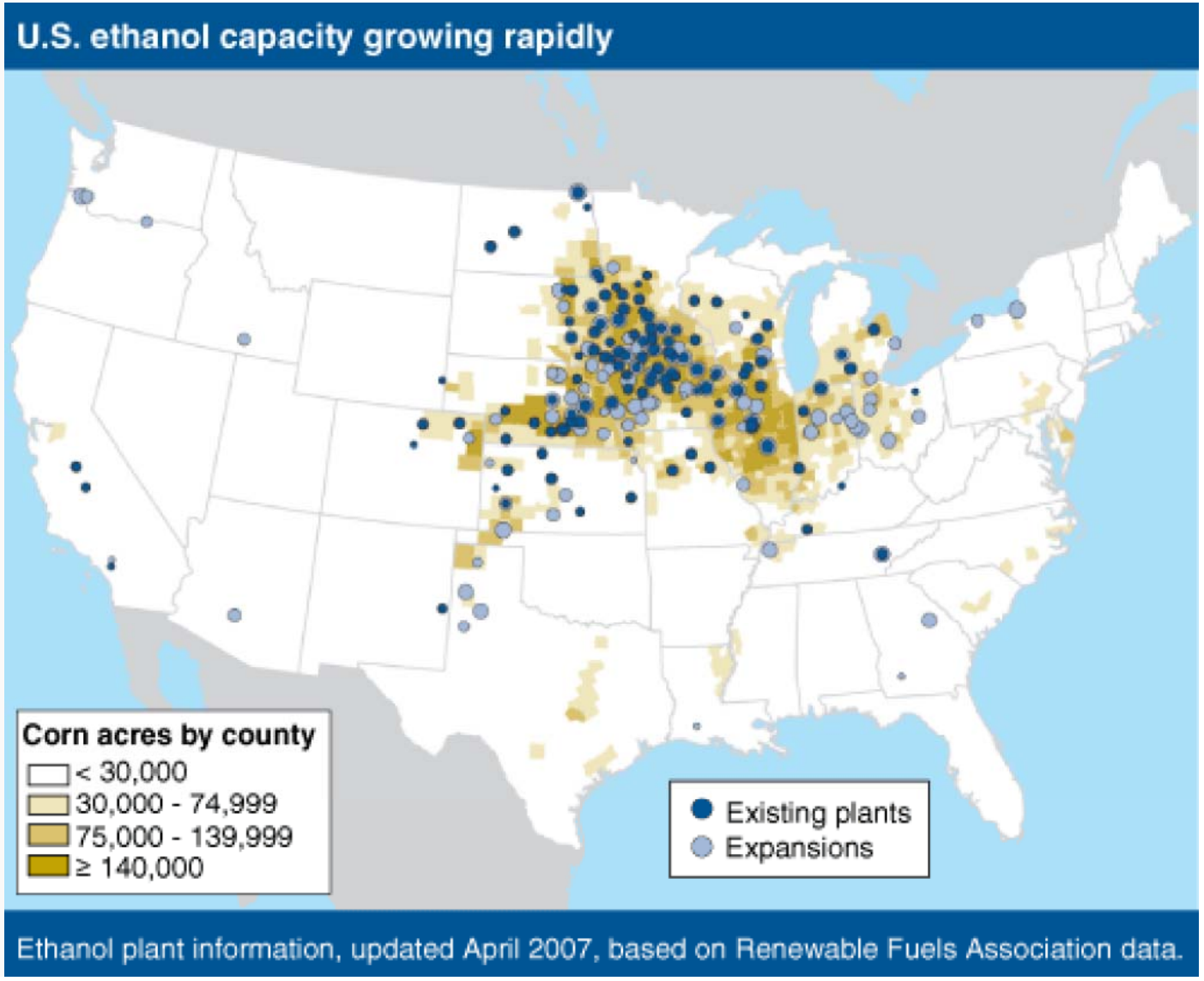
- Ethanol produced from corn and sugar crops by dry milling
- Main products: EtOH,CO_2, high protein animal feed wet distillers grains with solubles or WDGS
- Corn is ground into coarse flour
- Water and enzymes are added and the mixture "cooked“
- Yeast is added, and the mixture fermented.
- The “mash” is distilled to recover the EtOH

Grain Corn Bioethanol



http://www.ethanolrfa.org/objects/documents/337/mgpcd3-1.wmv

Grain Corn Bioethanol



Cellulosic Ethanol

Status of the Technology: Biomass Conversion – the need to pretreat

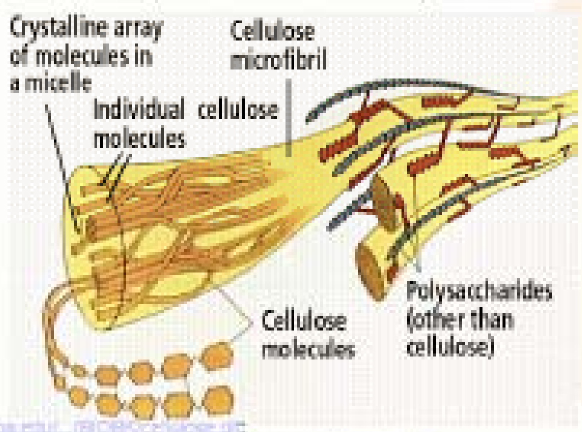
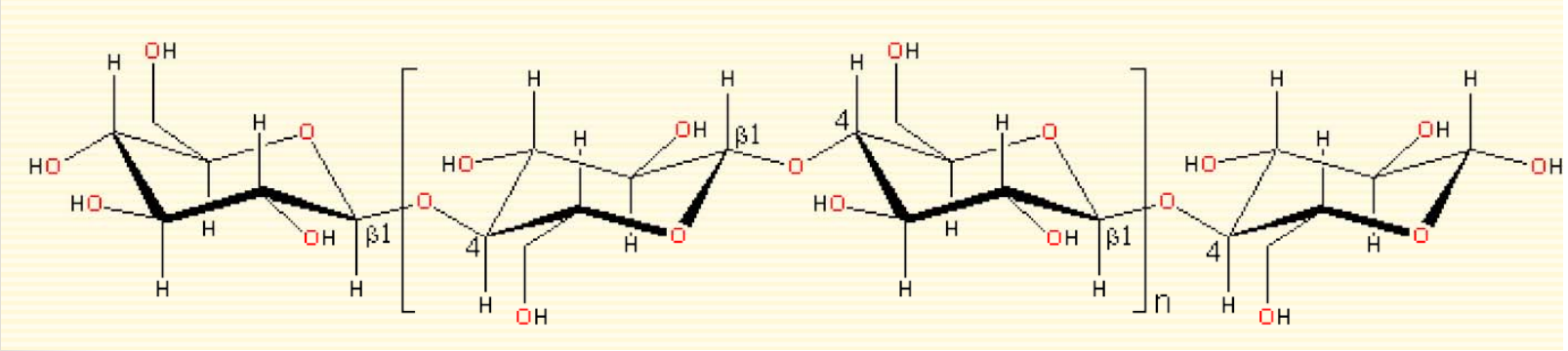


Image Credits: www.emc.maricopa.edu/.../BIOBK/cellulose.gif; www.gillandrobinson.co.uk/.../Lavian%20Logs.jpg; en.wikipedia.org/.../March-2006

Broin companies

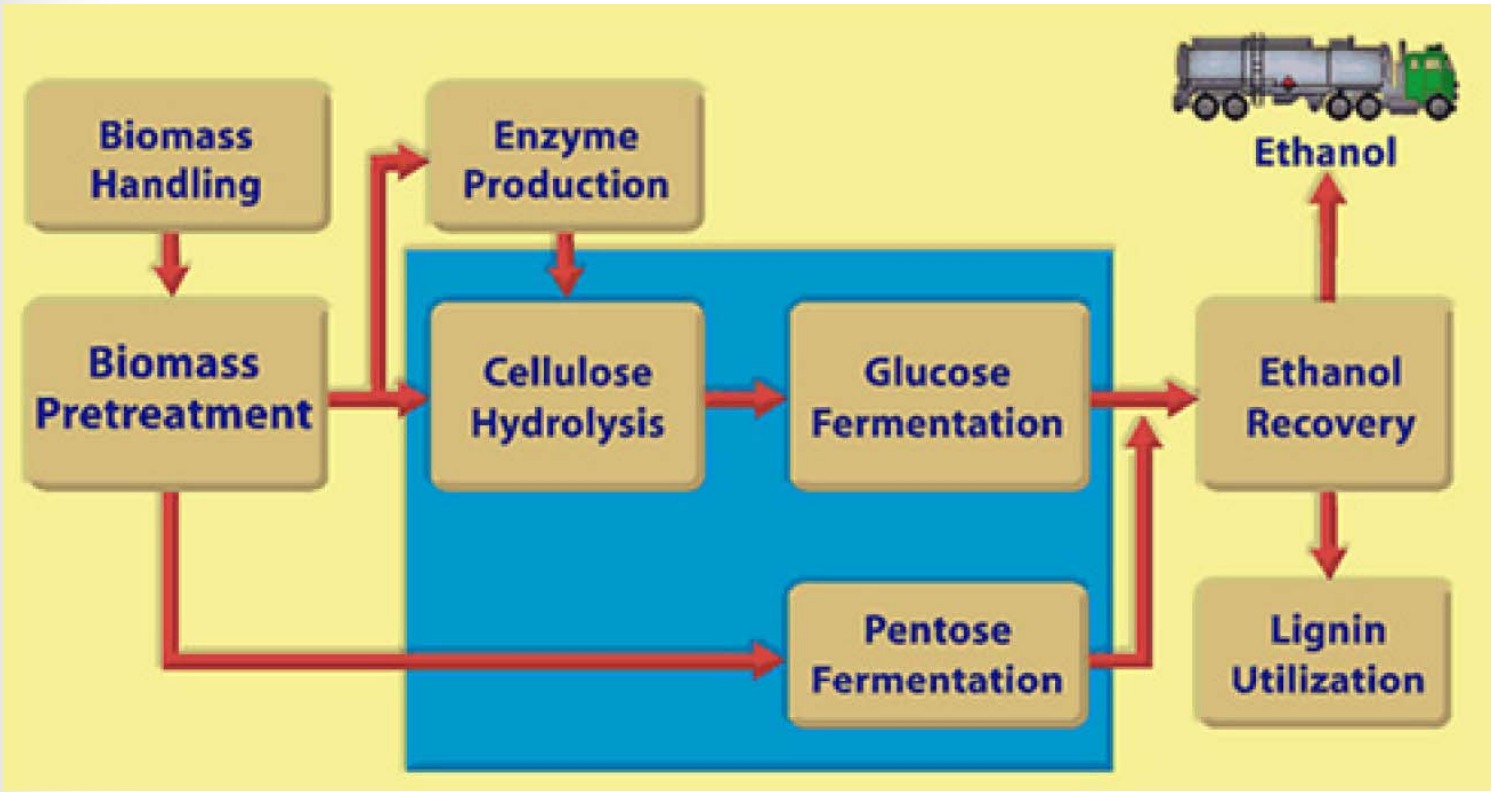
Cellulosic Ethanol

- Cellulose - main component in plant cell walls
- Most common organic compound on earth
- A polymer of glucose
- Enzymes convert to glucose
- Yeats ferment to EtOH
- But, resists conversion
- Requires pretreatment- acids, high Temp & Pres



http://www.lsbu.ac.uk/water/hycel.html

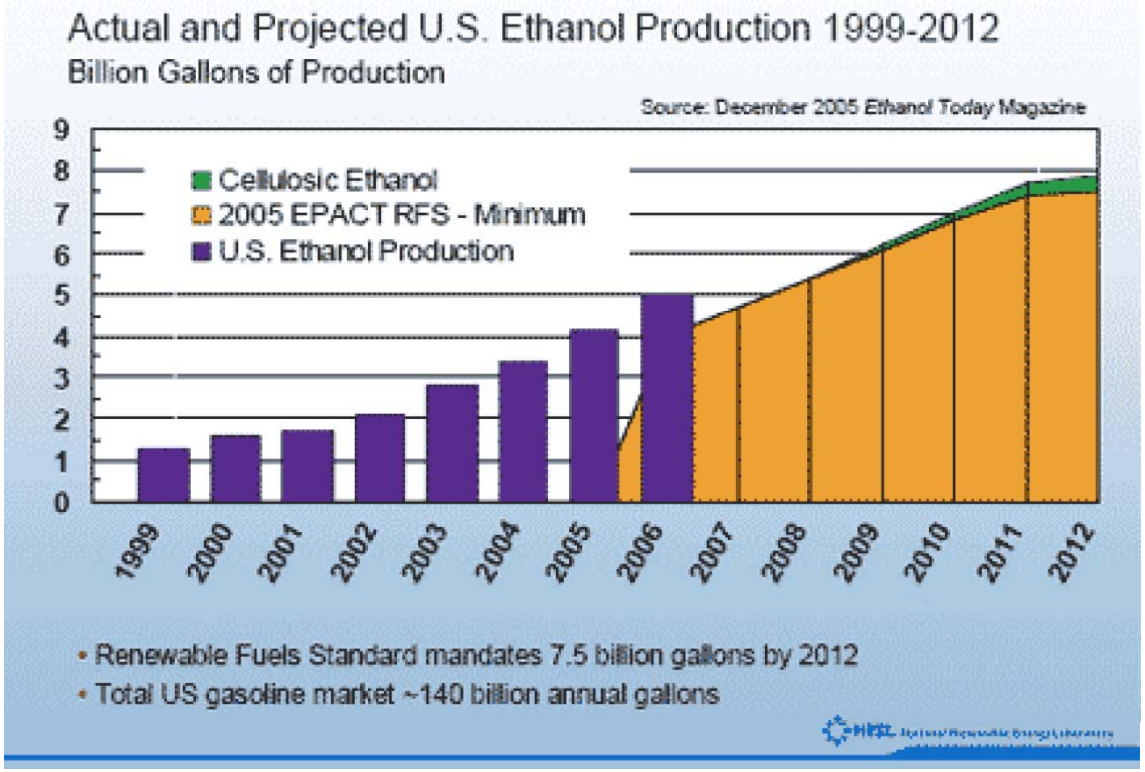
Cellulosic Ethanol



- Potential to convert 1 billion tons biomass per year to replace 30% of U.S. petroleum use

Cellulosic Ethanol

- Iogen making CellEtOH in Canada
- Other R& D & demo plants in works
- Needs for better enzymes, pretreatment, plant yields, etc.

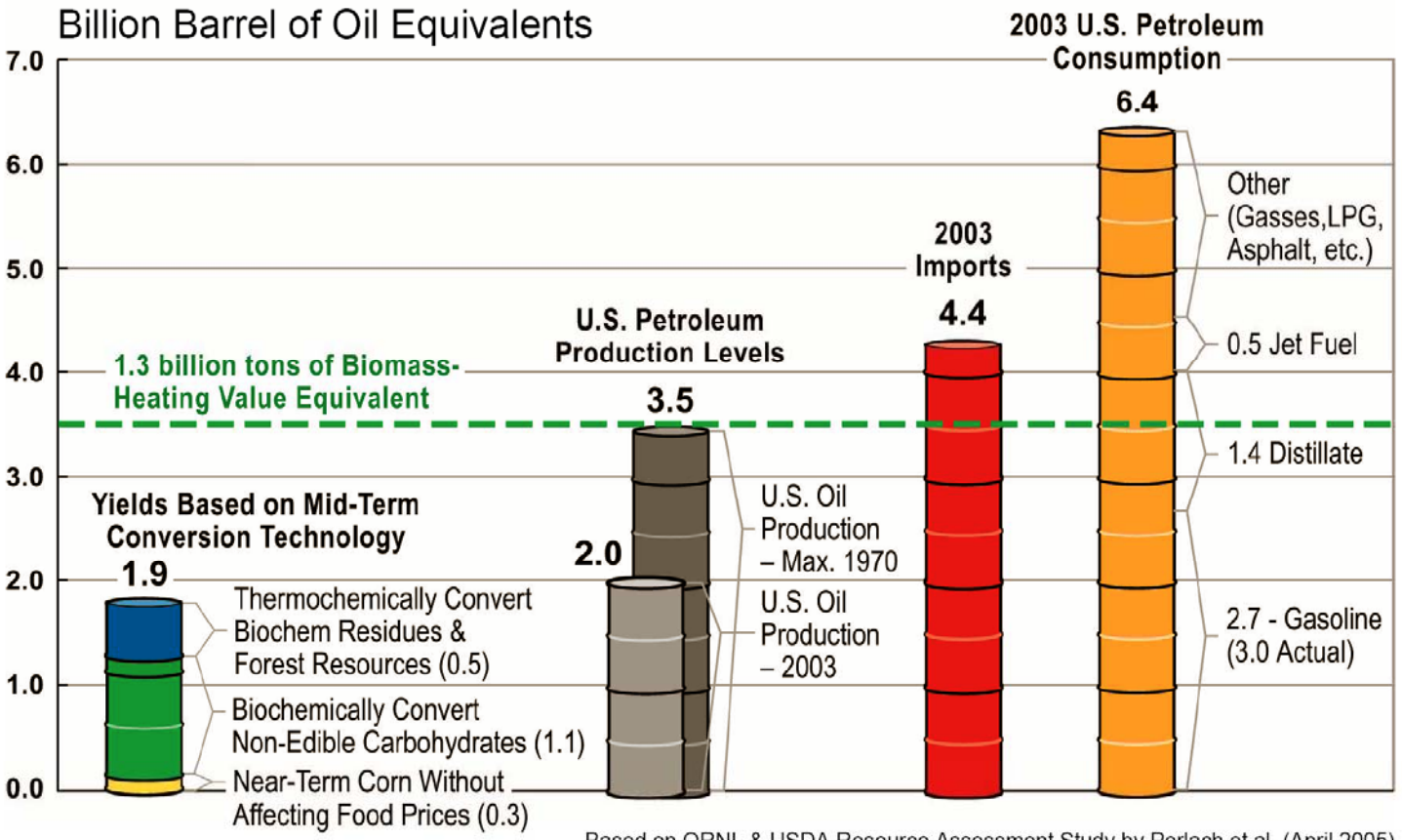


http://www.ethanolrfa.org/resource/cellulosic/

http://www.seco.cpa.state.tx.us/re_ethanol.htm

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

The 1.3 Billion Ton Biomass Scenario

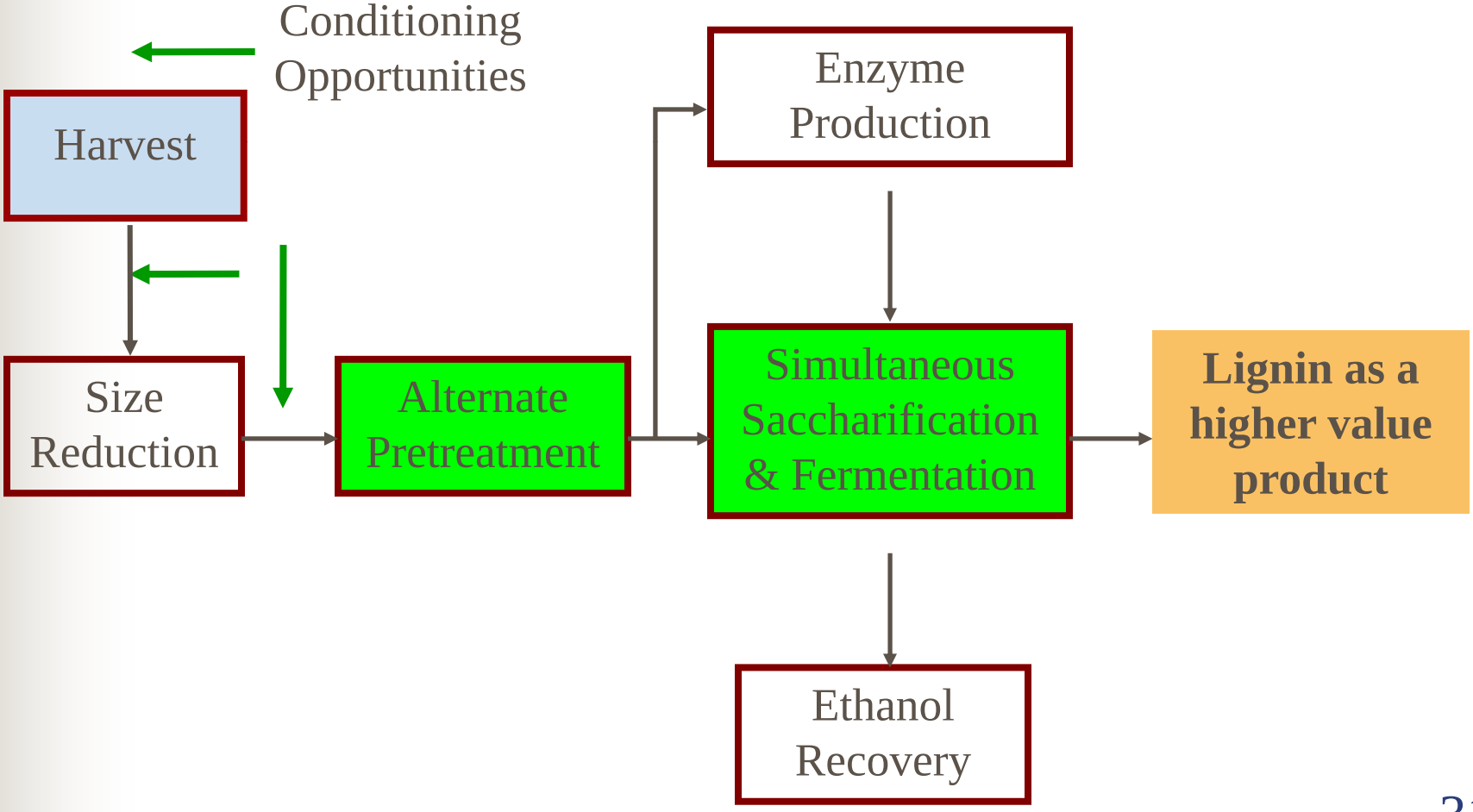


Based on ORNL & USDA Resource Assessment Study by Perlach et.al. (April 2005)
http://www.eere.energy.gov/biomass/pdfs/final_billionton_vision_report2.pdf

U of M Project

Microbial conditioning with alternate pretreatment –

improved ethanol yield, economics, and useable lignin adhesives

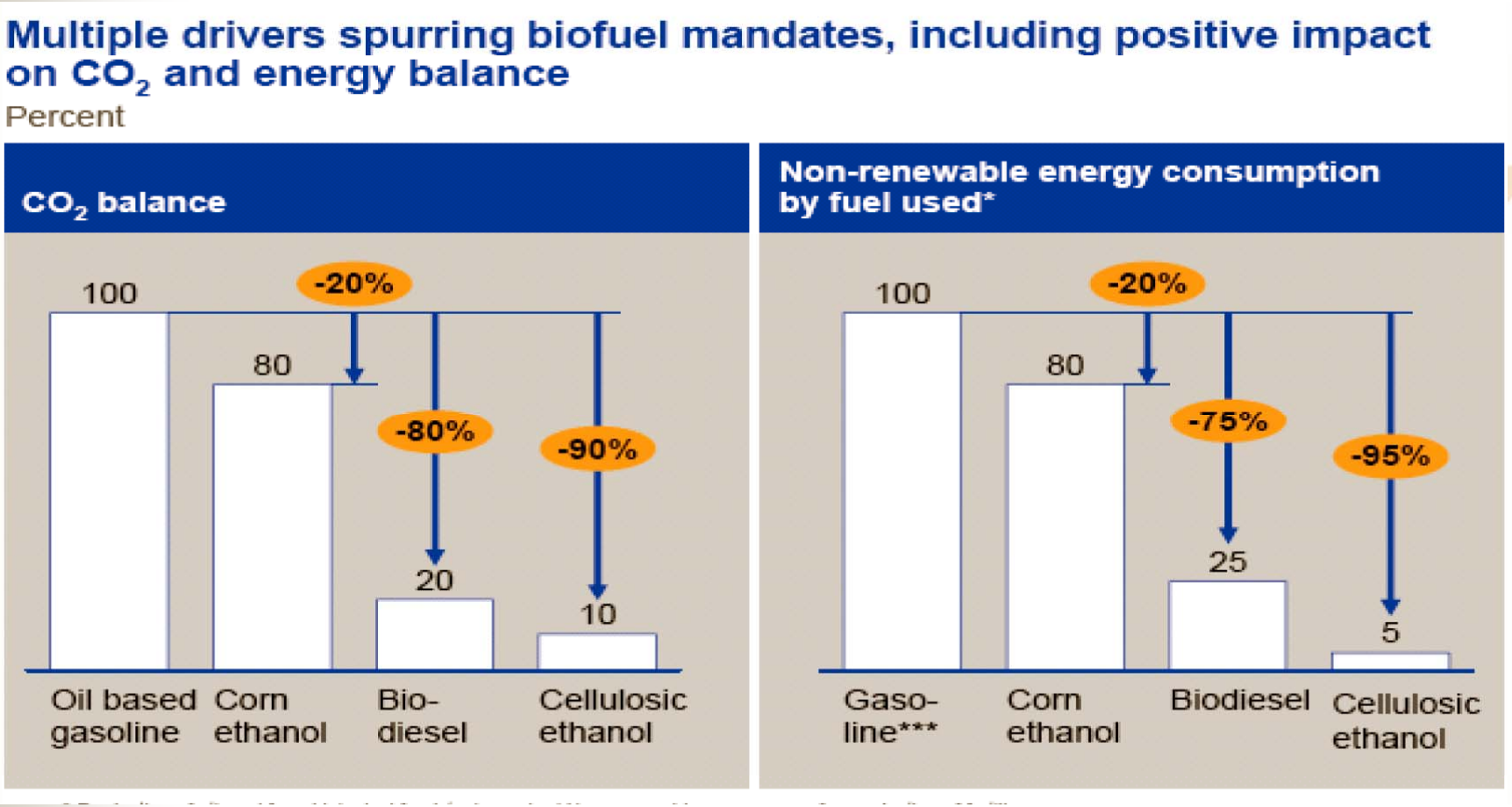


Switch Grass

Sorghum Sudan Grass

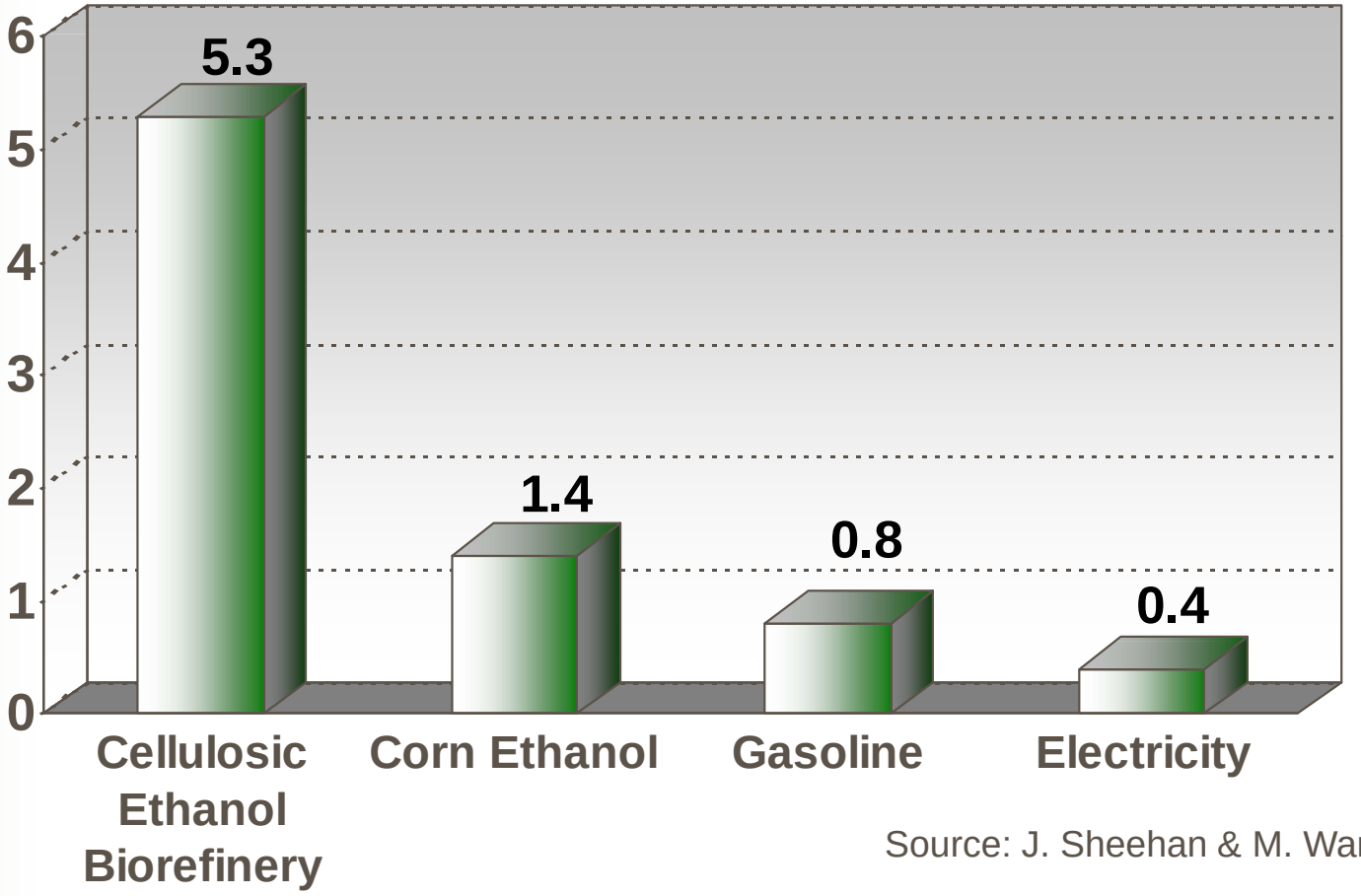
Medicinal Plant Garden, University of Mississippi

Introduction



Fossil Energy Replacement Ratio

$$\text{Fossil Energy Ratio (FER)} = \frac{\text{Energy Delivered to Customer}}{\text{Fossil Energy Used}}$$



Source: J. Sheehan & M. Wang (2003)

Fossil Energy Replacement Ratio

- **http://www.rangefuels.com/interactive-map.html**

Others

Emerging Fuels

Biobutanol
Biogas
Biomass to Liquids
Coal to Liquids
Fischer-Tropsch Diesel
Gas to Liquids
Hydrogenation-Derived Renewable Diesel
P-Series

http://www.eere.energy.gov/afdc/fuels/emerging.html

Issues and Implications- How Green are Biofuels?

- Net energy & fossil fuel use
- Net GHG emissions reduction
- Deforestation for palm oil plantations
- Nitrous oxide emissions from fertilizer
- Food prices
- Food and grain exports
- U.S. and world food prices (especially developing)
- Opportunity Costs – Iowa study – grain EtOH 18 B gal; Cell EtOH 4.5 B gal (w/$1.55 incentive)