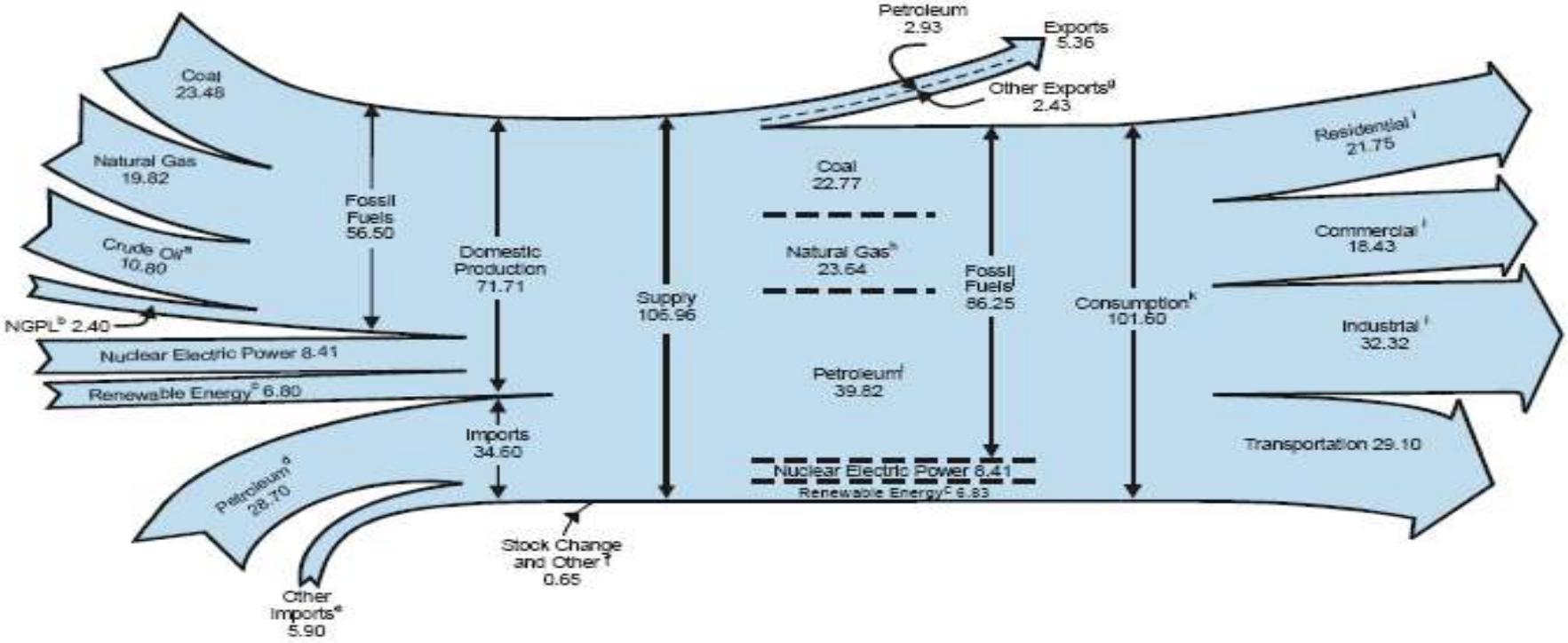
Biorenewable Resources

Objectives

- Versatility of biorenewable processes
- Variety of products
- Environmental/economic tradeoffs

US Energy Flow in Quads

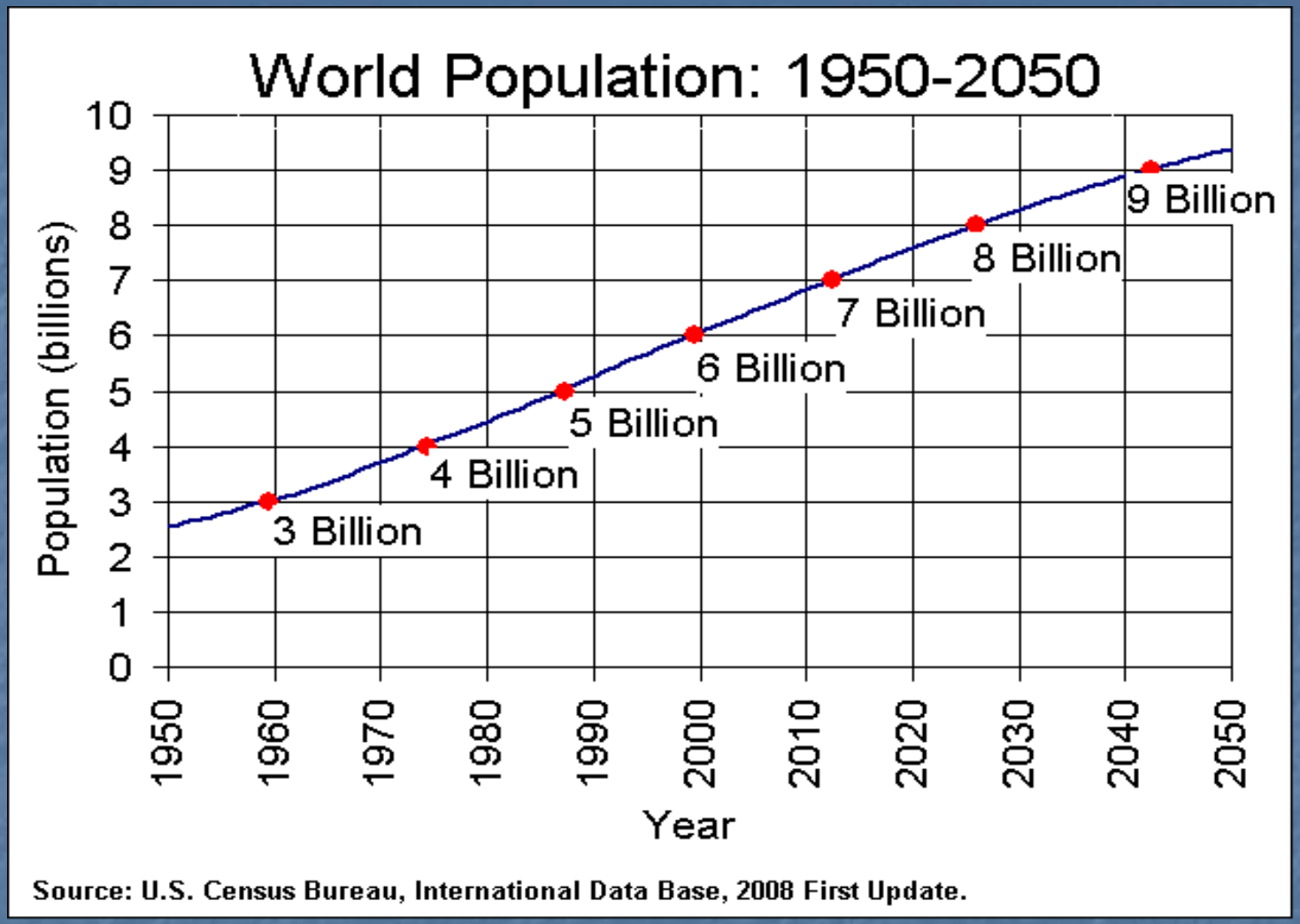



03/31/2009 C=49.66 +4.90 O=42.35 H=54.34 L=40.15 Mov Avg 3 lines
130.00
110.00
90.00
70.00
50.00
30.00
Volume 9104395.00 Open Interest 920185.00
1100000
6000000
2001
2002
2003
2004
2005
2006
2007
2008
Created with SuperCharts by Omega Research © 1997

Terminology

- Renewable
- Sustainable
- Green
- Alternative
- Clean Tech

Renewable = Sustainable?


World Population: 1950-2050
Population (billions)
0
1
2
3
4
5
6
7
8
9
10
1950
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
Year
3 Billion
4 Billion
5 Billion
6 Billion
7 Billion
8 Billion
9 Billion
Source: U.S. Census Bureau, International Data Base, 2008 First Update.

Biomass Definition

- Any renewable organic matter such as agricultural crops, crop-waste residues, wood, animal and municipal wastes, aquatic plants and fungal growth used for the production of energy.

The Promise of Biomass

- Renewable
- Abundant
- Carbon Neutral
- Diffuse
- Global
- Helps Agriculture, Forest
- Multiuse
  - Food
  - Shelter
  - Energy
  - Materials

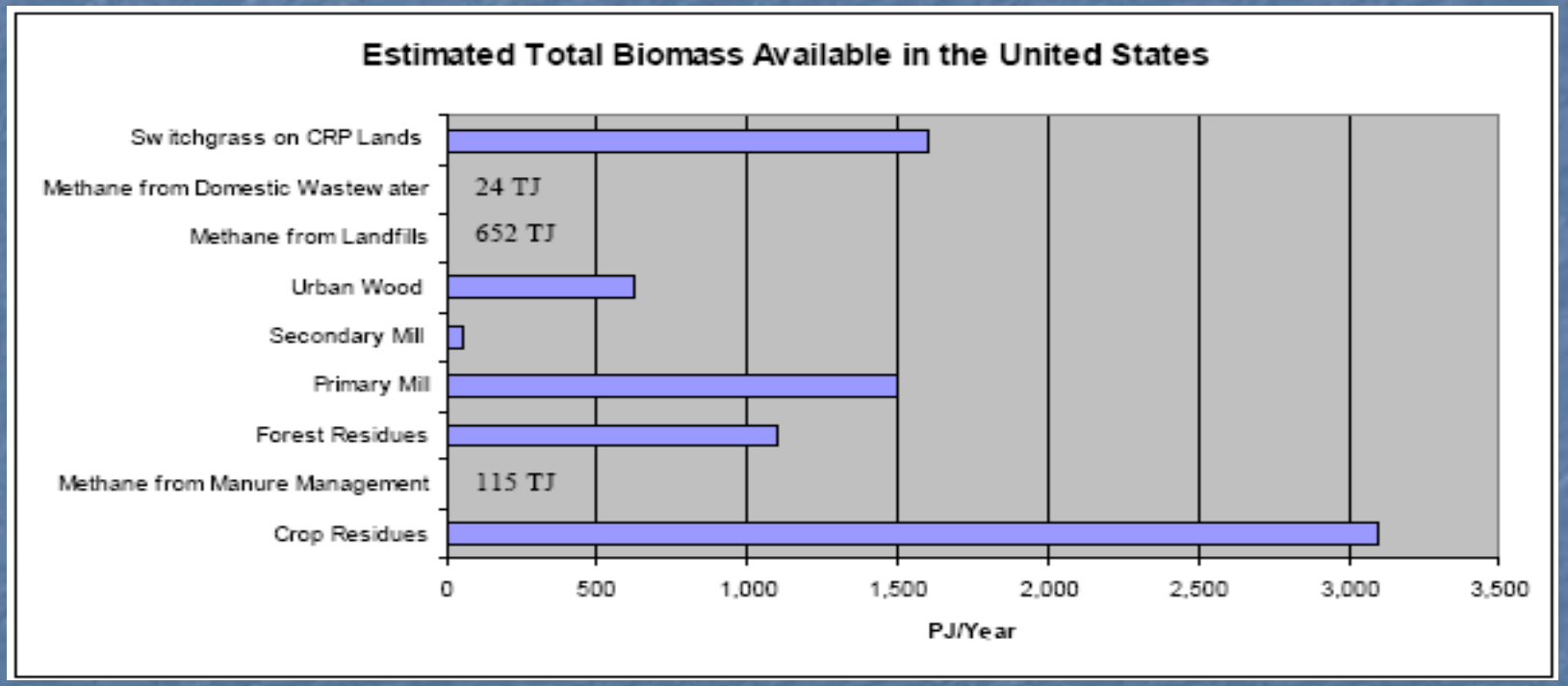
The Problem with Biomass

- Costly to gather
- Low energy content
- Low physical density
- Moisture content
- Costly to transport
- Additional processing
- Arable land competition
- Water resources
- Fuel vs. feed
- Deforestation

Biomass Utilization

- Bioenergy
  - heat & power
- Transportation Fuels
- Chemicals
- Fibers

US Annual Biomass Resource



Montana Biomass Resource

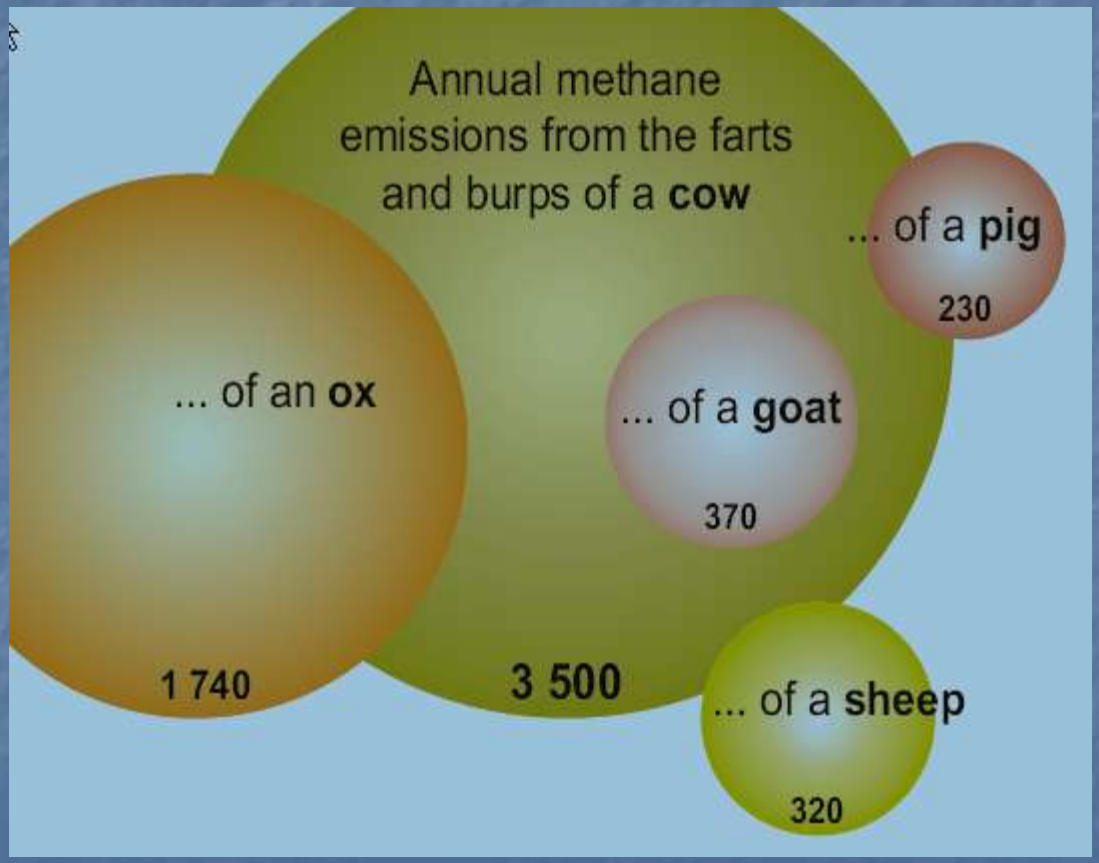
Criteria for Biomass Development

- Residues/wastes utilized
- Does not compete with food/feed
- Energy crops on unused or marginal lands
- Minimizes or eliminates cultivation inputs
  - Irrigation, tilling, pesticides, herbicides
- Regionally produced and consumed

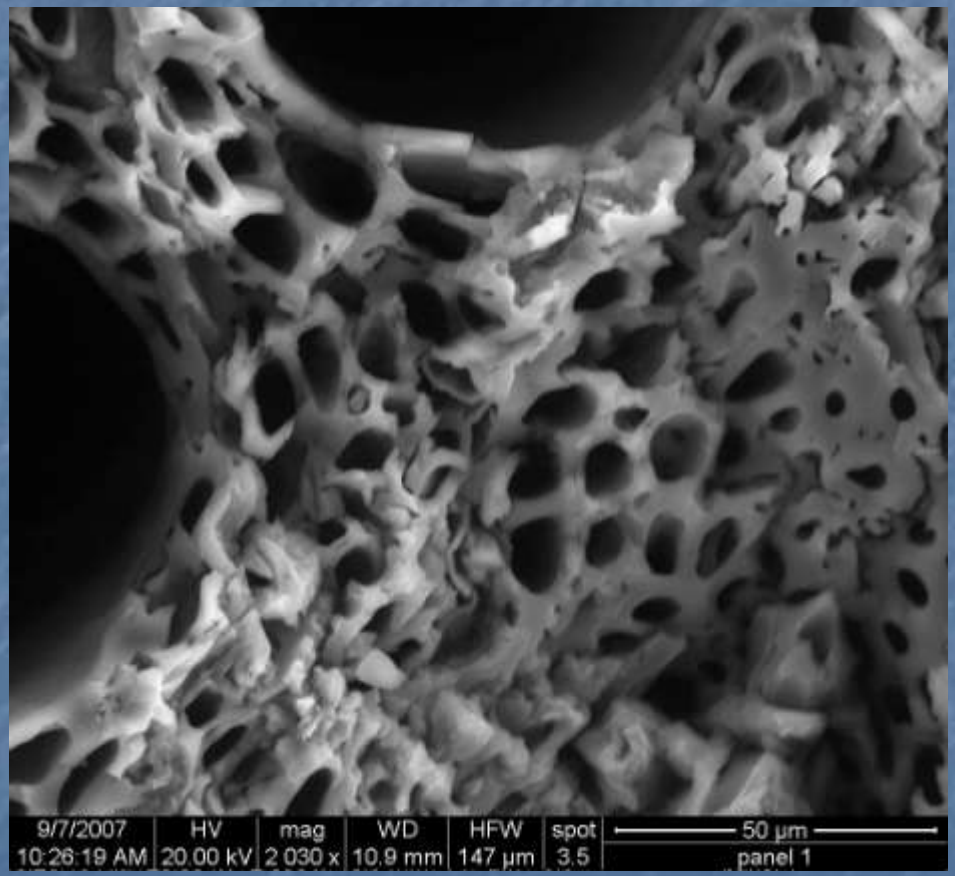
Bioenergy

- Combustion – CO2 Group
- Gasification
- Pyrolysis - biochar
- Anaerobic digestion

Another GHG Source



Char Surface Pores

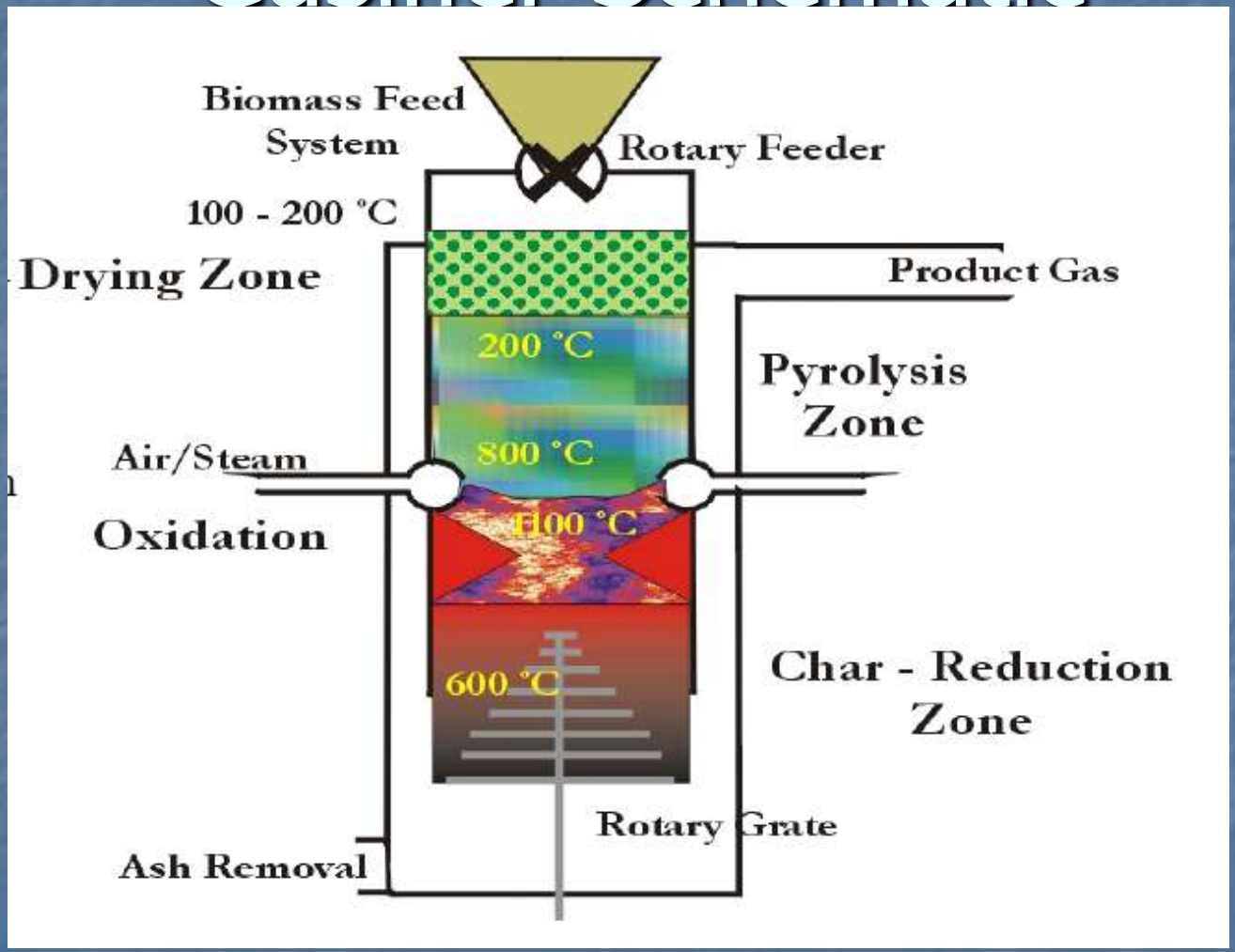


Downdraft Gasification

- 1st explored in late 1600's
- Used in WWII by Swedes & Germans
- Updated technology
  - Computerized
  - Advanced process control
- Combined heat & power
- Modular & portable

Bus, Germany

Gasifier Schematic



Gainesville, Florida, 1981. The tiny generator that powers this wood-burning motorcycle was constructed at the University of Florida out of a fire-extinguisher casing. The vehicle gets 70 km per kg of wood (20 miles per lb). (*Sun* Photo by Barbara Hansen)

Germany, about 1943. Mass production of gas producer vehicles, Imbert factory, where some 500,000 gas producers were manufactured during World War II. (E. E. Donath)

UM Mobile Gasifier

Helena Demo for Jag

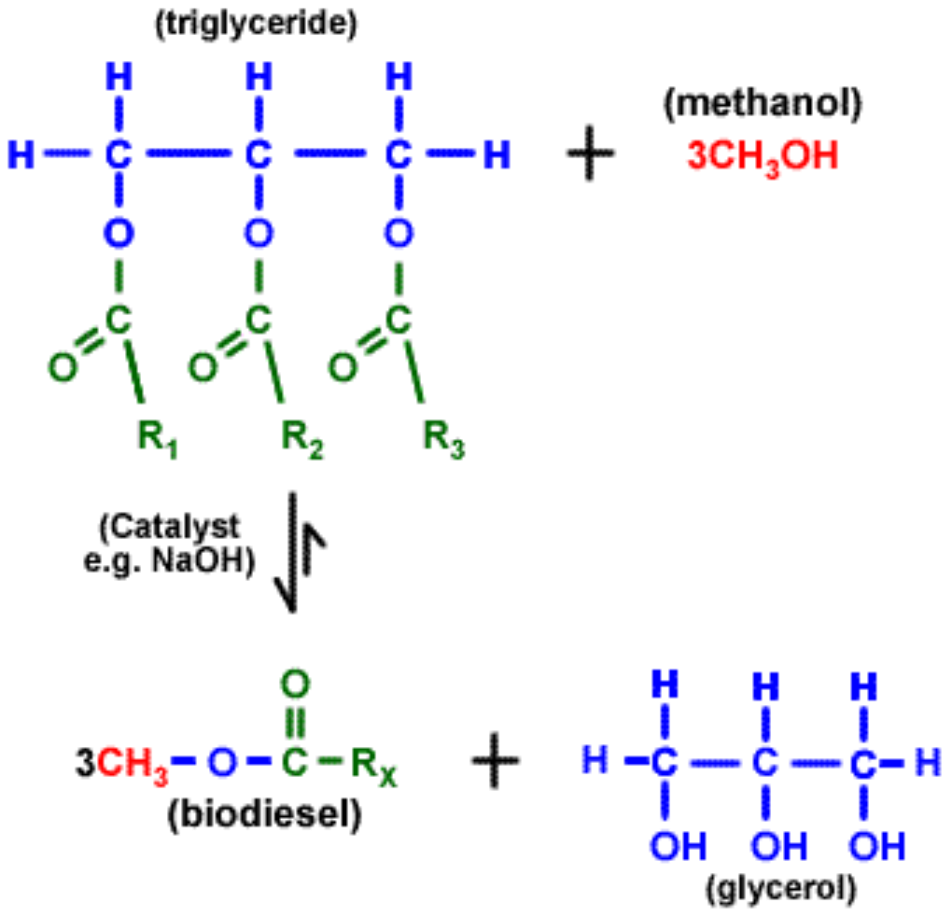
Transportation Fuels

- Biodiesel
- Ethanol
- Methanol
- Methane
- Hydrogen
- Producer gas

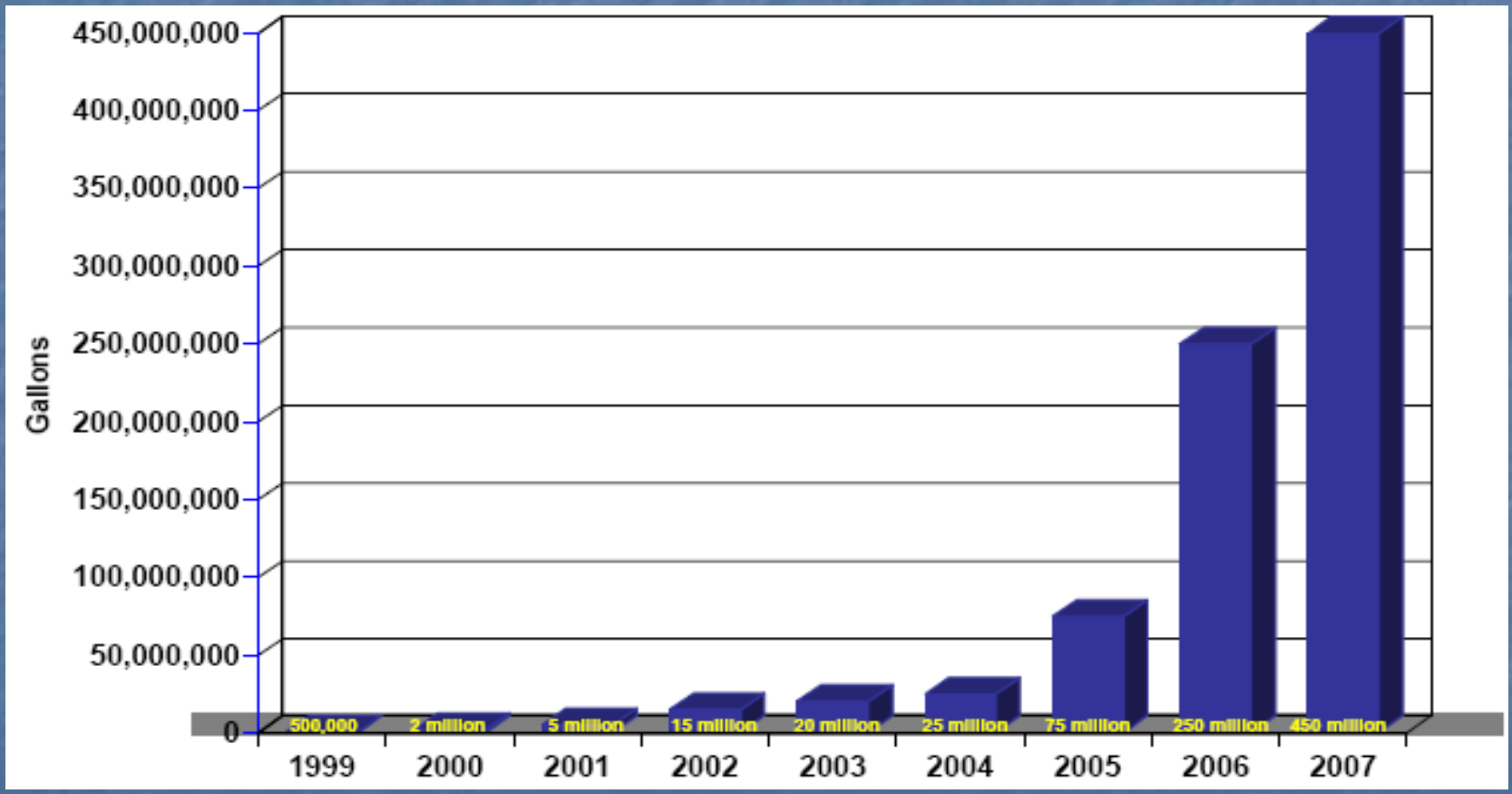
Biodiesel Facts

- Lower energy content than Diesel
  - Biodiesel: 118,296 BTUs per gallon
  - No. 2 Diesel: 129,500 BTUs per gallon
    - Source National Biodiesel Board
- Energy Lifecycle
  - 3.2 units of energy are produced for each energy unit used
    - Source NREL

The Chemistry



US Bio Diesel Production



The Algae Option

Algae Yields

Table 1
Comparison of some sources of biodiesel

Crop	Oil yield (L/ha)	Land area needed (M ha)[a]	Percent of existing US cropping area[a]
Corn	172	1540	846
Soybean	446	594	326
Canola	1190	223	122
Jatropha	1892	140	77
Coconut	2689	99	54
Oil palm	5950	45	24
Microalgae[b]	136,900	2	1.1
Microalgae[c]	58,700	4.5	2.5

[a] For meeting 50% of all transport fuel needs of the United States.
[b] 70% oil (by wt) in biomass.
[c] 30% oil (by wt) in biomass.

Y. Chisti, Biotech Adv 2007

Bio-Ethanol Debate

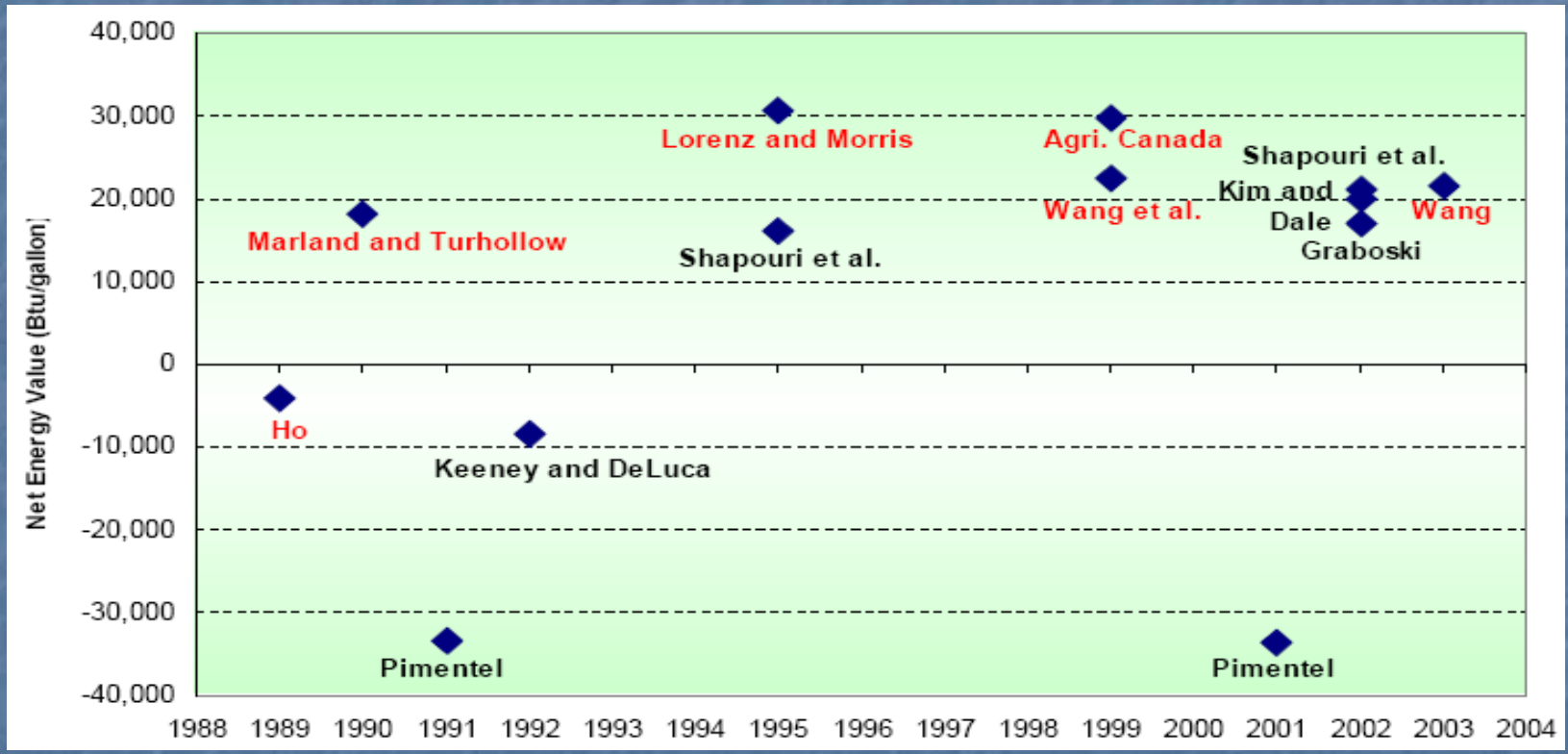
"Ethanol fuel from corn faulted as 'unsustainable subsidized food burning' in analysis by Cornell scientist"

Cornell News Headline, 8/16/2001

- Author: David Pimentel

- Current studies estimate 25% to 35% more energy derived than invested.

Ethanol Energy Balance



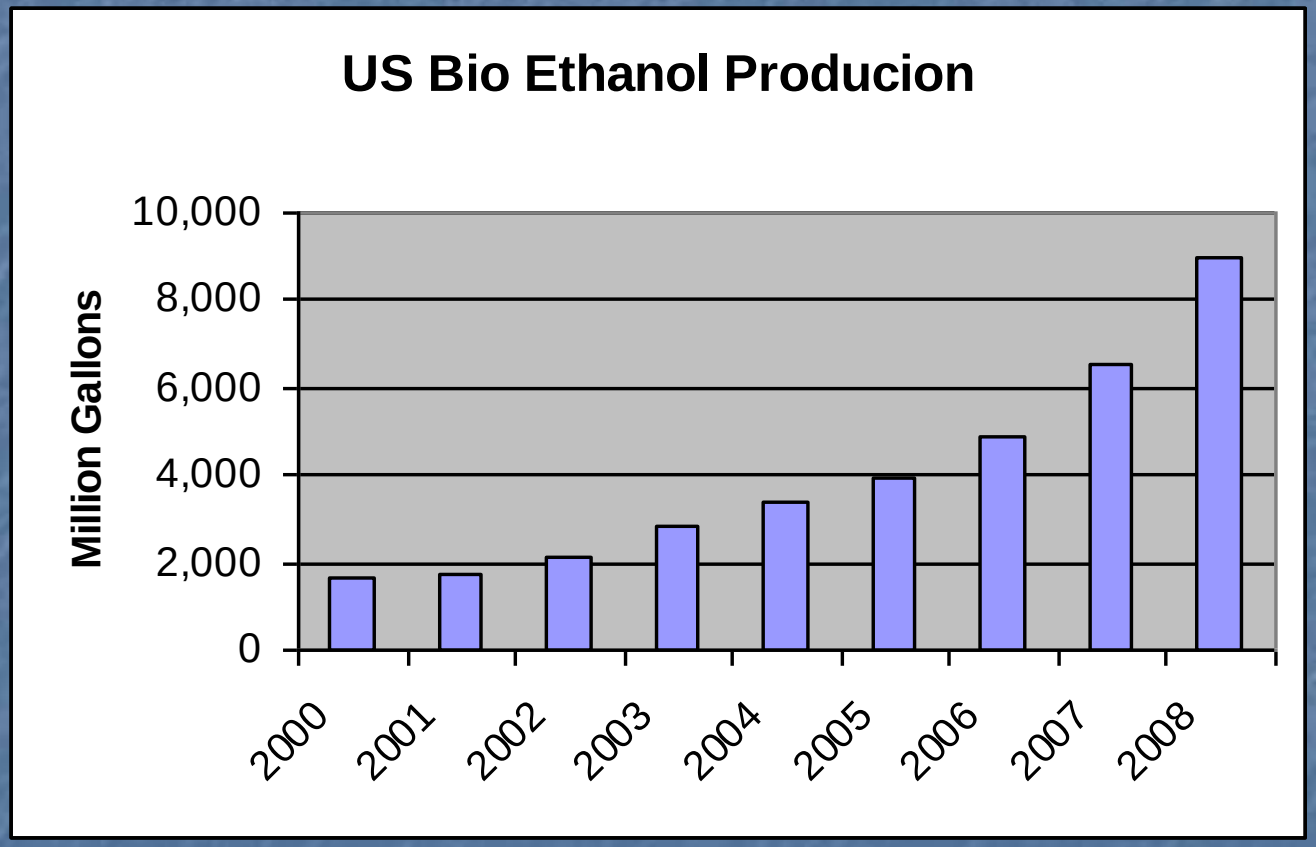
Ethanol Summary

Authors and Date	NEV [Btu]
Pimentel (1991)	-33,517
Pimentel (2001)	-33,562
Keeney and DeLuca (1992)	-8,438
Marland and Turhollow (1990)	18,154
Lorenz and Morris (1995)	30,589
Ho (1989)	-4,000
Agri.and Agri-Food, CAN (1999)	29,826
Wang et al. (1999)	22,500
Shapouri et al. (1995)	20,436
Kim and Dale (2002)	23,886 – 35,463

Pimentel Critique

- His corn yields date from pre-1992
- His value for energy required to produce ethanol and the ethanol yield date from pre-1980
- His figures for energy to produce fertilizer are 1990 world-wide values, not recent U.S. values
- He assumes all corn is irrigated (only 16% is)
  - virtually no irrigated corn is converted to ethanol
- He does not properly assign an energy credit for the high protein DDGS co-product

US Ethanol Capacity



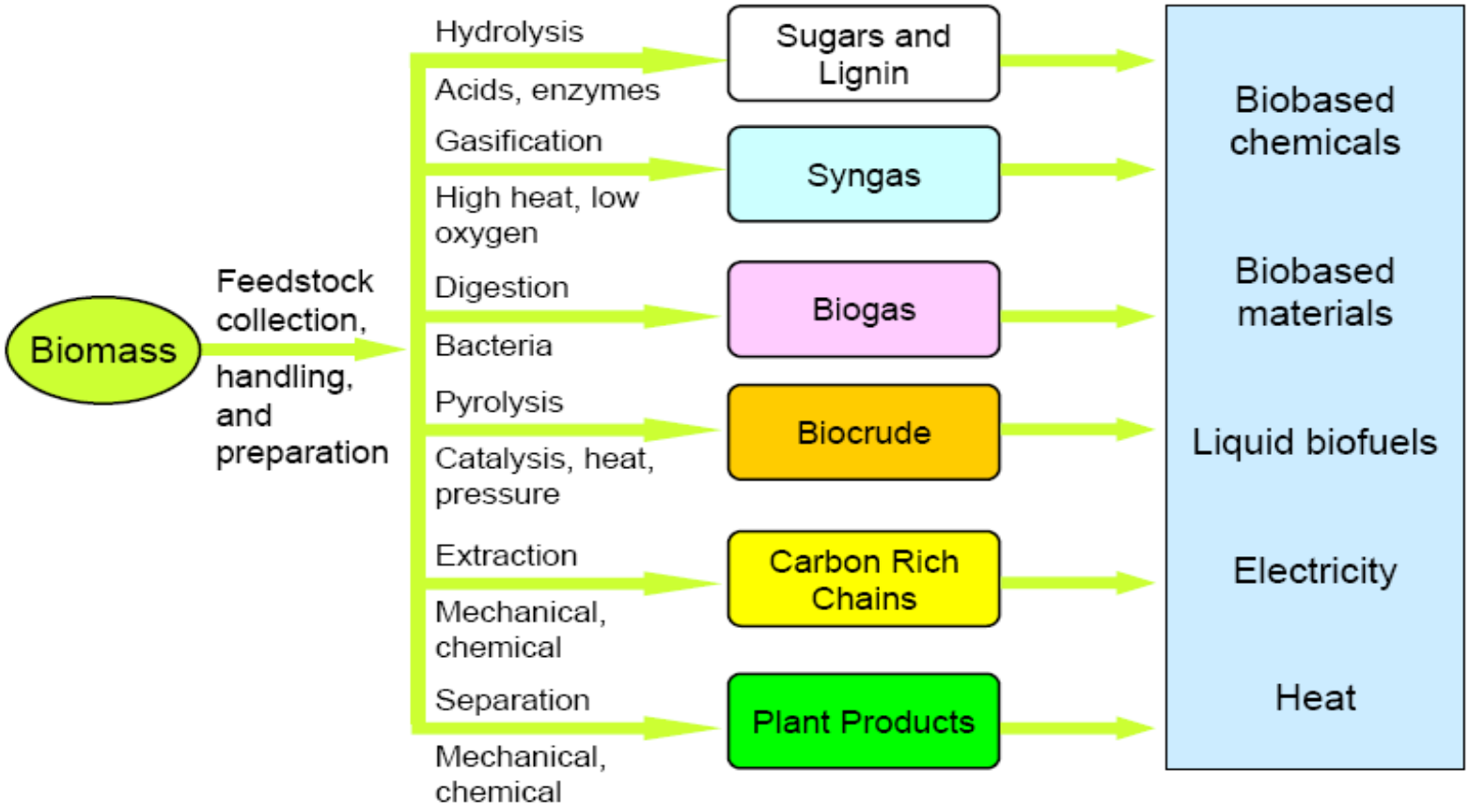
Biochemicals

- Commodity chemicals
  - Ethylene, benzene, lactic acid, sorbitol
- Specialty chemicals
  - Pharmaceuticals

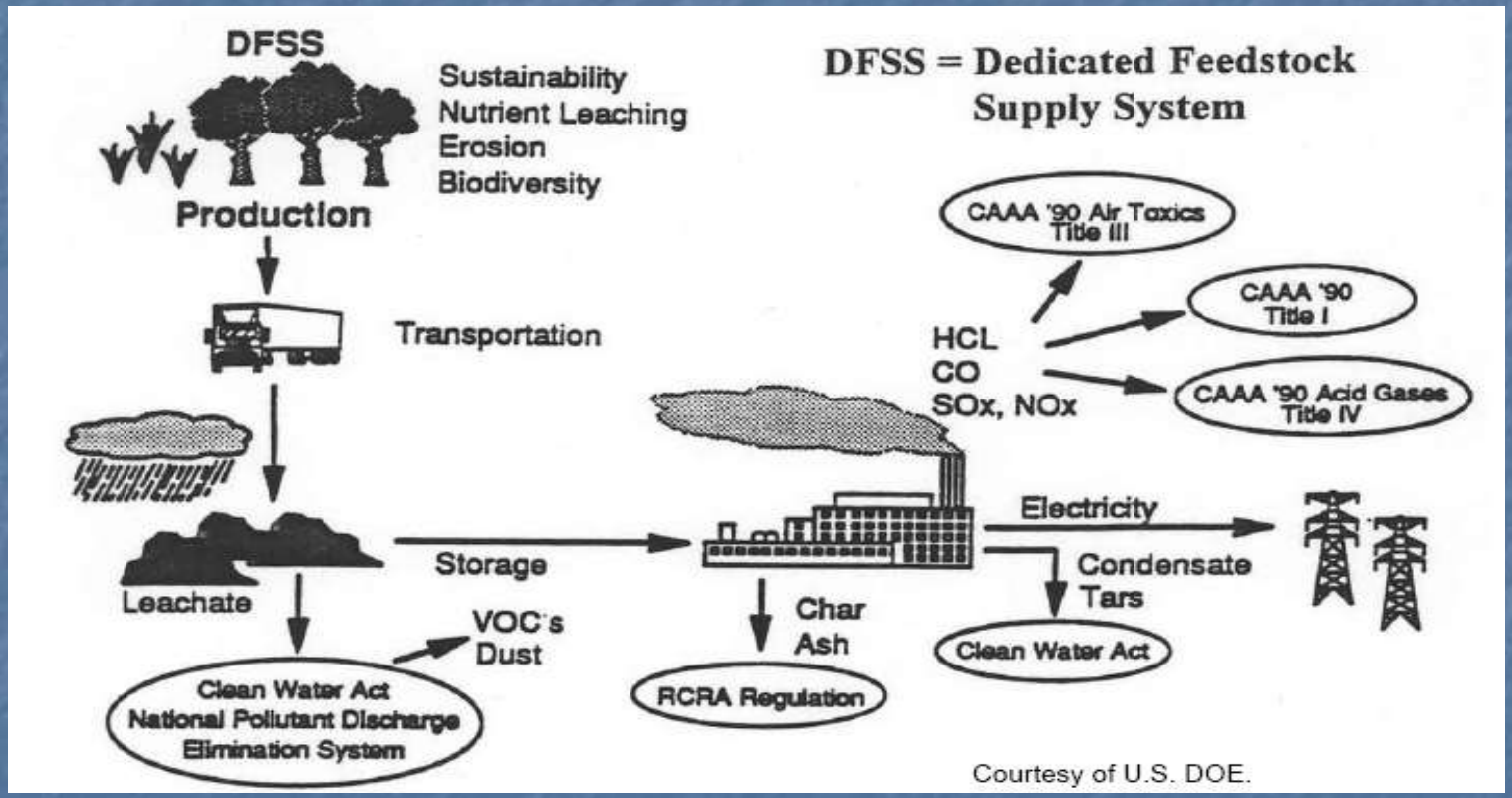
Fibers

- Textiles
  - sisal, flax, hemp, ramie
- Paper products
- Composite materials
  - Trex

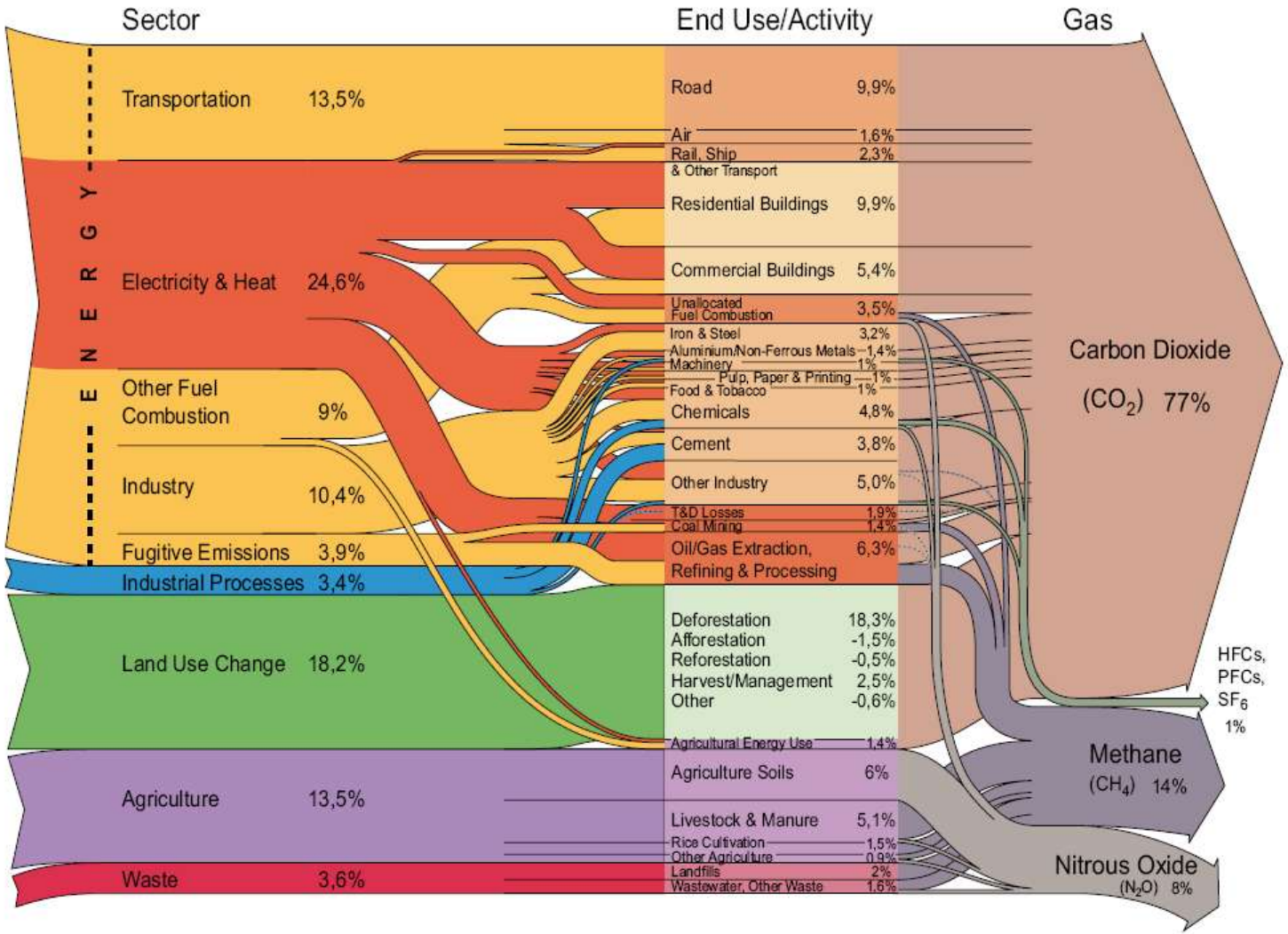
Biorefinery "Platforms"



Biomass & the Environment



World Greenhouse gas emissions by sector



Carbon Footprint

- Carbon neutral
- Carbon sequestering
- Carbon negative

Other Alternative Fuels

- Natural gas
- Propane, lpg
- Reformulated gasoline
- Hybrid
- Hydrogen
- Electric
- Compressed air

Hydrogen

- Hydrogen safety
- ICE vs Fuel Cell
- Storage
- Water is exhaust

Electric

- Speed, range, charging
- Batteries

Compressed Air

- 68 mph
- 125 mile range
- 5 minute refill
- On-board compressor
- 5000 psi
- $13,000
- India 2009

Conventional Mass Transit

- Massive Costs
  - 10 to 100's million $
- Limited coverage
- Schedule
- Frequent stops
- Often crowded
- Inconvenient
- High maintenance & operating costs

Personal Rapid Transport

Summary

- Biomass has vast potential
- Focus on utilizing residues and marginal lands
- Bio ethanol has a positive energy balance
- Biorenewable resources improve environment, economy, and security