US Energy Consumption by Source

BIOMASS 2.9%

renewable

Heating, electricity, transportation

HYDROPOWER 2.7%

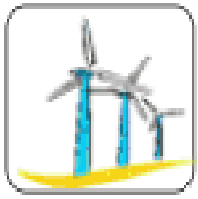
renewable

Electricity

GEOTHERMAL 0.3%

renewable

Heating, electricity



WIND 0.1%

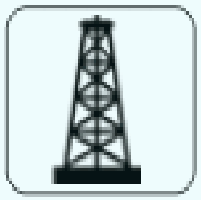
renewable

Electricity

SOLAR & OTHER 0.1%

renewable

Light, heating, electricity



PETROLEUM 38.1%

nonrenewable

Transportation, manufacturing

NATURAL GAS 22.9%

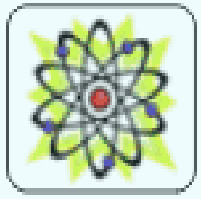
nonrenewable

Heating, manufacturing, electricity

COAL 23.2%

nonrenewable

Electricity, **manufacturing**



URANIUM 8.1%

nonrenewable

Electricity

PROPANE 1.7%

nonrenewable

Manufacturing, heating

Source: DOE, Energy Information Administration

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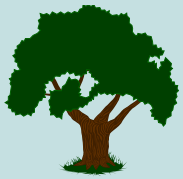
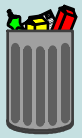
Typical Biomass Composition

Softwoods



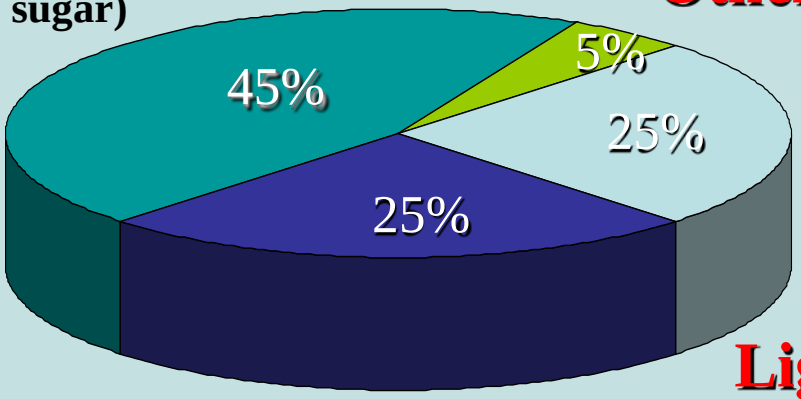
Hardwoods

Crop residues



MSW

Cellulose
(Chains of glucose sugar)



Lignin
(Young clean coal)

Hemicellulose
(Chains of xylose and arabinose in hardwoods; mannose and xylose in softwoods)

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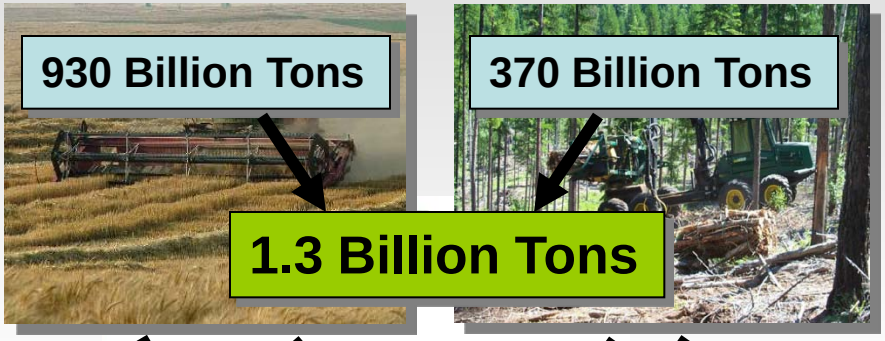
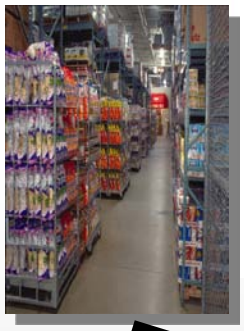
Biomass Flows



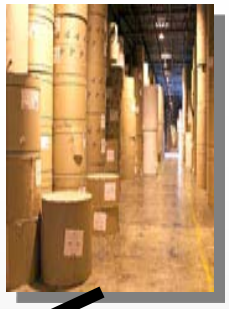
Energy crops, residual straw, grass, bio-gax

Wood, chips, pellets



Biogas from sewage Treatment, solid bio-fuels

Landfill and sewage gas Treatment gas



Sawdust, chips, pellets

1 Billion Tons To Displace 30% of Petroleum

http://feedstockreview.ornl.gov/pdf/billion_ton_vision.pdf

Direct biomass for energy

Indirect biomass for energy

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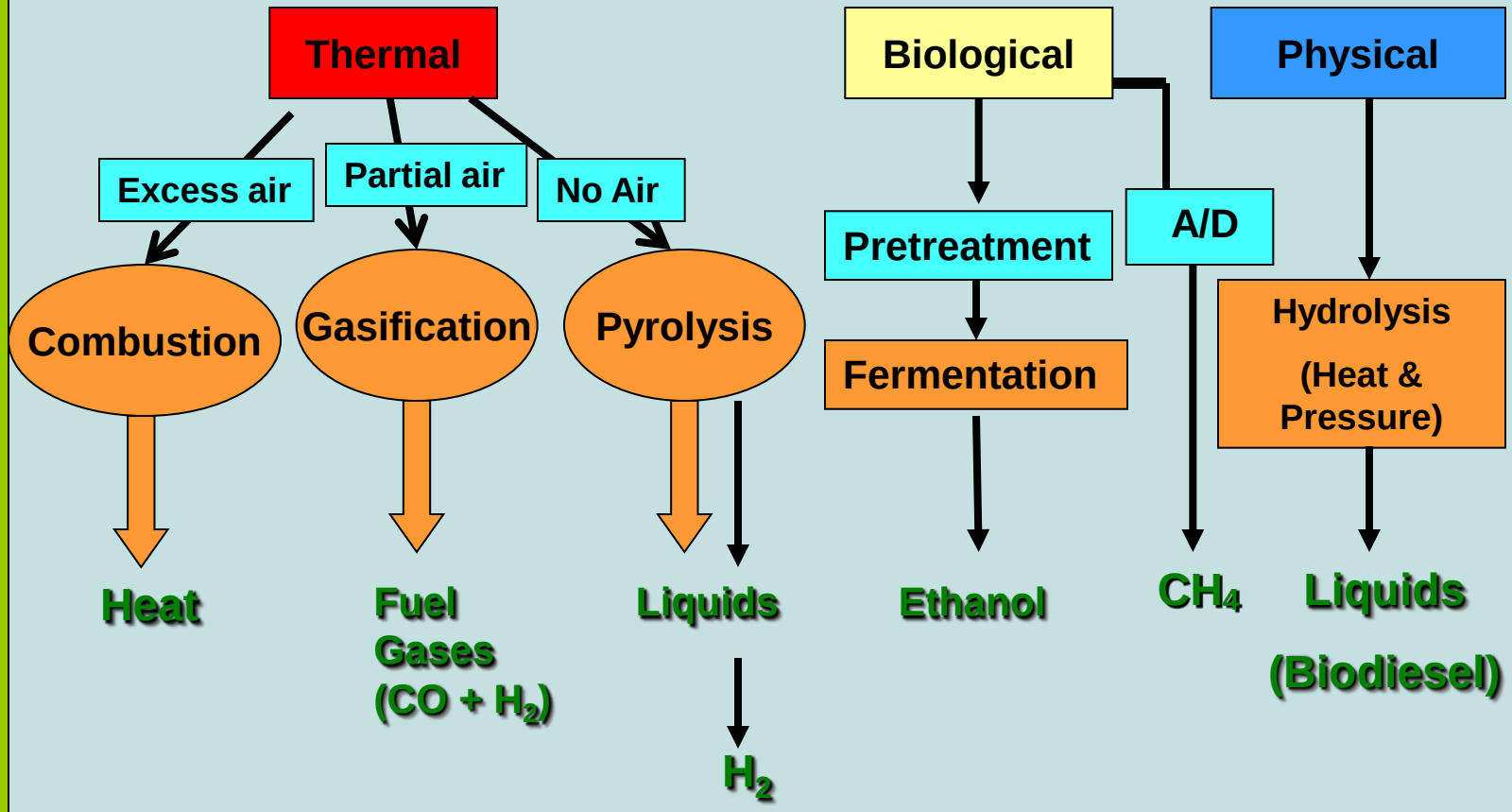
Biomass Conversion Pathways



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Benefits of Using Biomass Over Fossil Fuels

- **Economic advantages**
  - Can be cheaper than fossil fuels
  - Stimulates rural economies
  - Encourages local energy production & consumption
- **Energy advantages**
  - Reduces reliance on fossil fuels & oil prices (OPEC)
  - Enhances national & economic security
  - Highly efficient heating combustion methods
- **Environmental advantages**
  - Reduces greenhouse gases-carbon dioxide
  - Reduces amounts of landfill (waste wood is biomass fuel)

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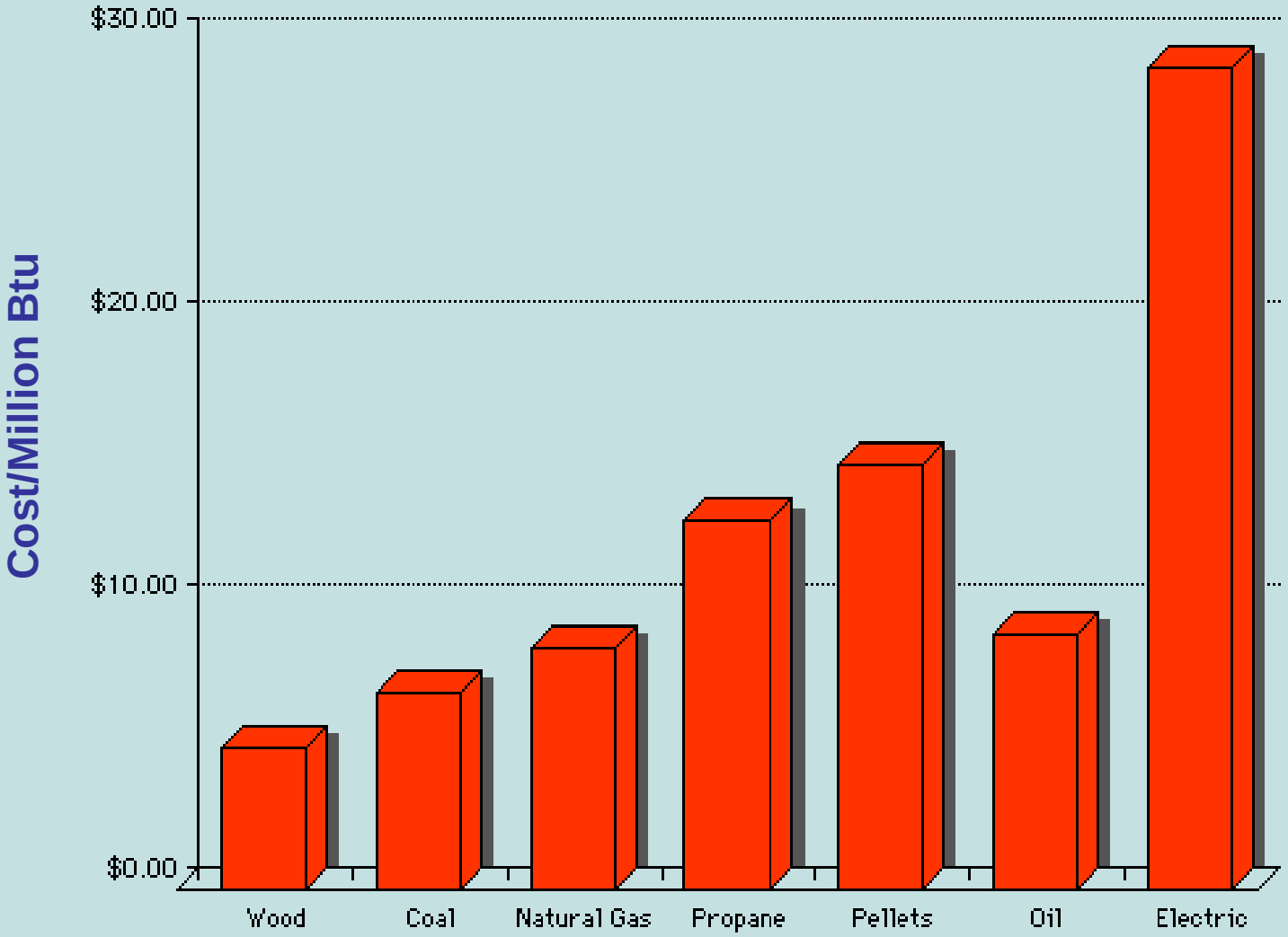
Price Comparisons of Popular Home Heating Options



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Electricity Estimated Wholesale Costs for Various Fuel Sources

Resource	Cost (cents per kilowatt-hour)
Hydroelectric	1.1 to 7.0
Chemical recovery boilers	2.6
Natural gas	2.7
Industrial cogeneration (natural gas)	2.7 to 6.4
Landfill gas	3.1
Wood residue	4.3 to 5.4
Geothermal	5.2 to 6.5
Wind	5.3 to 8.1
Forest biomass	5.5 to 6.6
Solar thermal	8.6
Solar photovoltaic (large-scale)	19.4
Solar photovoltaic (small-scale)	21.5 to 23.6

http://www.oregon.gov/ENERGY/RENEW/costs.shtml#Levelized%20life-cycle%20cost

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Some Challenges to Biomass Use

- Low cost of fossil based energy
- Financial barriers
- Technology issues
- Feedstock availability and cost
- Interest typically focused on a single product (energy) from a single feedstock
- Lack of a level-playing field (compared to petroleum and coal-electricity)

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Other Challenges to Biomass Use

- Access to energy markets
- Incentives for biobased energy are limited, too specific, not uniformly available
- Lack of qualified workforce

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Biofuels

- Liquid Biofuels
  - Ethanol
    - Sugar
    - Corn
    - Cellulosic
- Biodiesel
- Biogas

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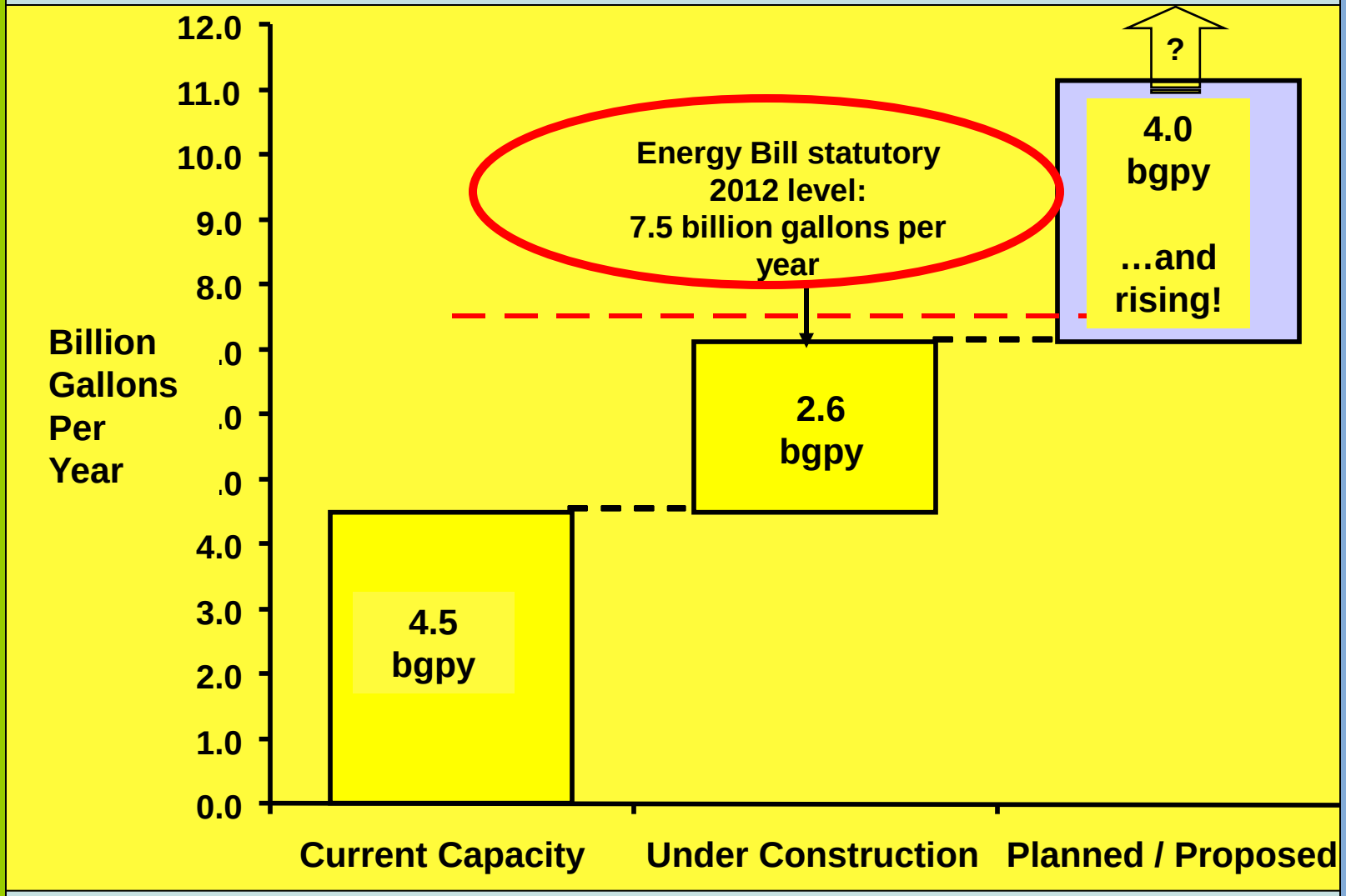
US Ethanol Capacity Build-up



Source: Cambridge Energy Research Associates, Renewable Fuels Association

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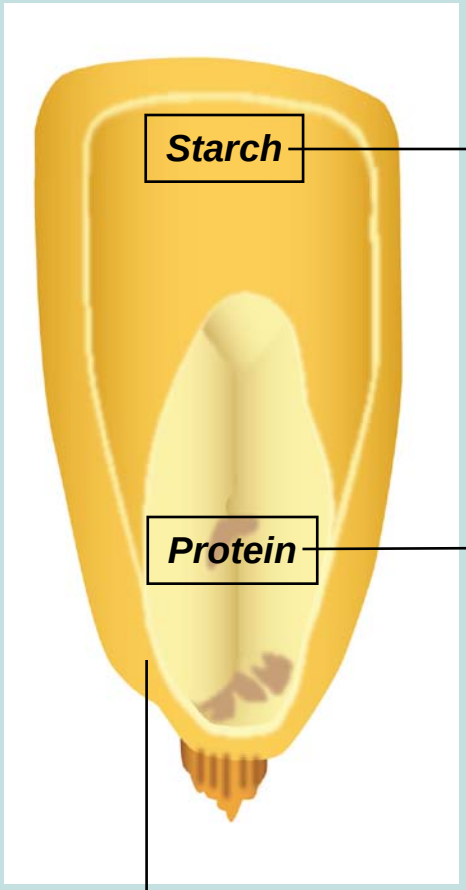
One-Third of Corn Kernel Mass Ends as Animal Feed (a Co-Product) in Ethanol Plants



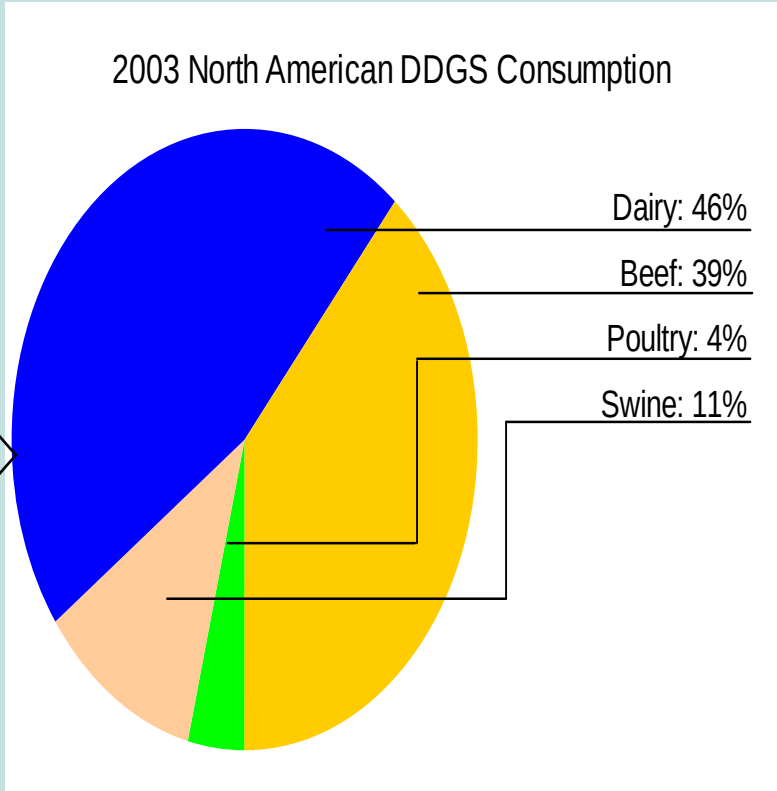
Starch

Protein

Ethanol

Distillers Dry Grains and Solubles (DDGS)

Carbon Dioxide



Source: RFA - Renewable Fuels Association

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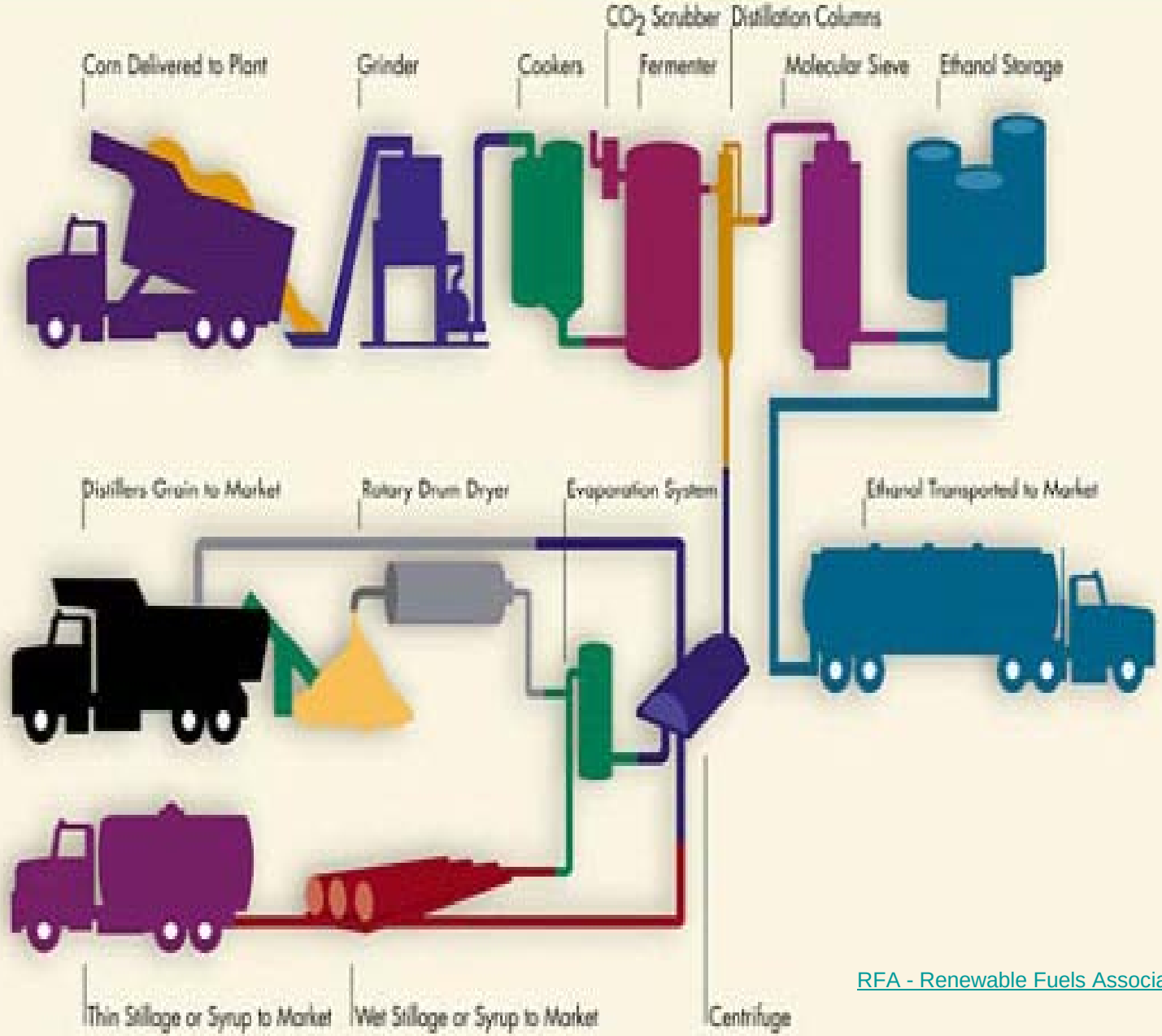
The Ethanol Production Process (Dry Mill)



RFA - Renewable Fuels Association

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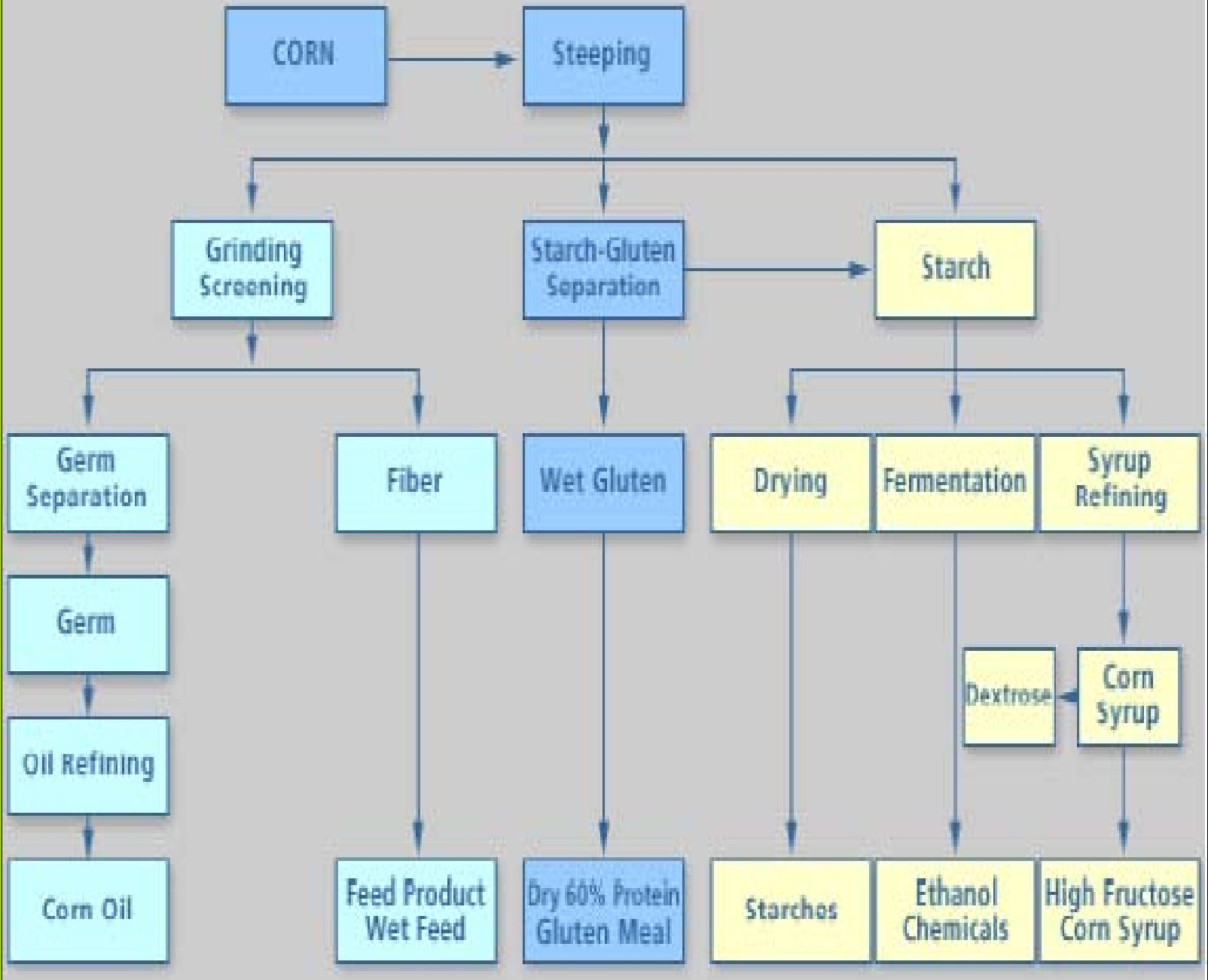
The Ethanol Production Process (Wet Mill)



RFA - Renewable Fuels Association

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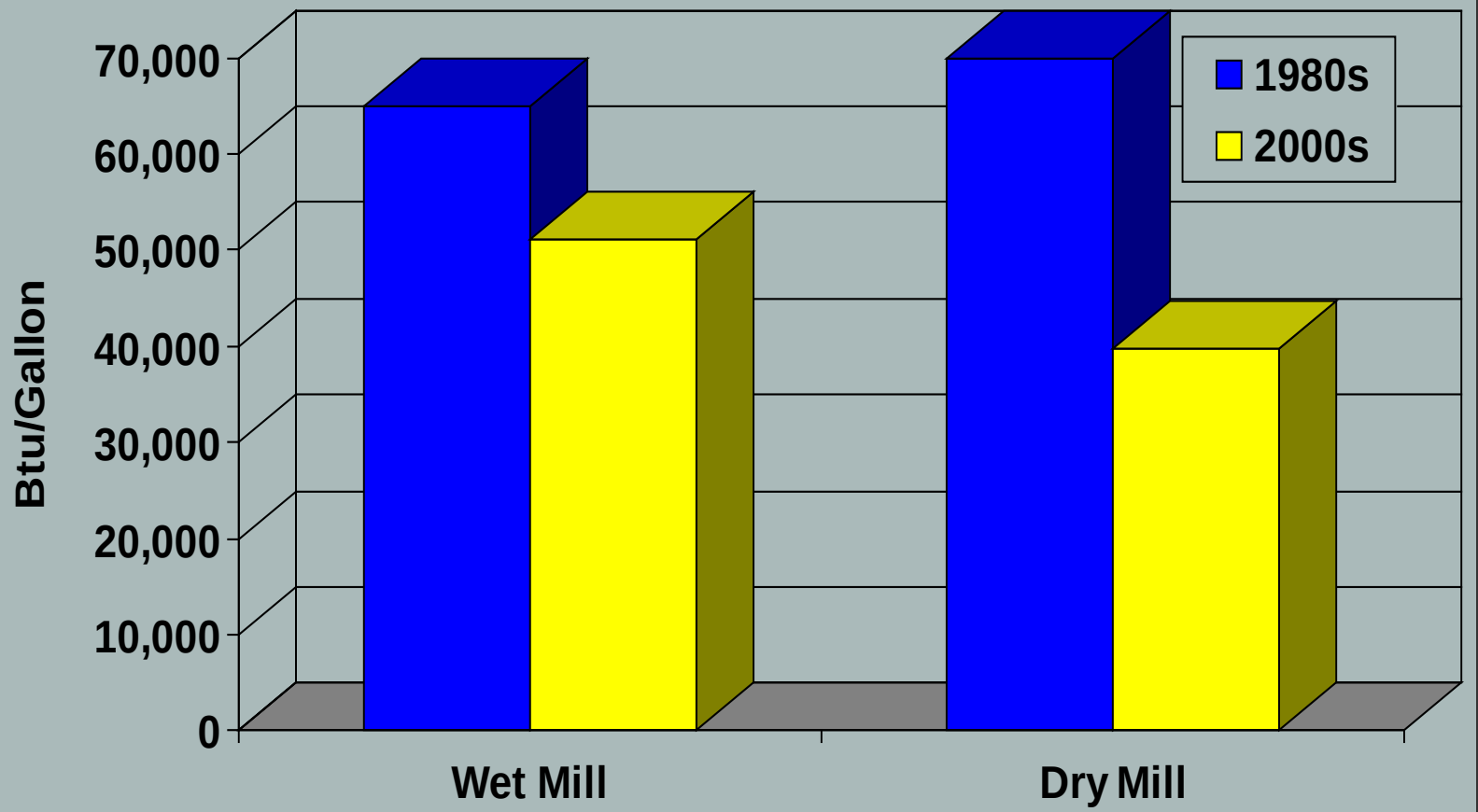
Improved Technology Has Reduced Energy Use and Operating Costs in Corn Ethanol Plants



Source: from Argonne's discussions with ethanol plant designers, recent USDA data, and other reported data.

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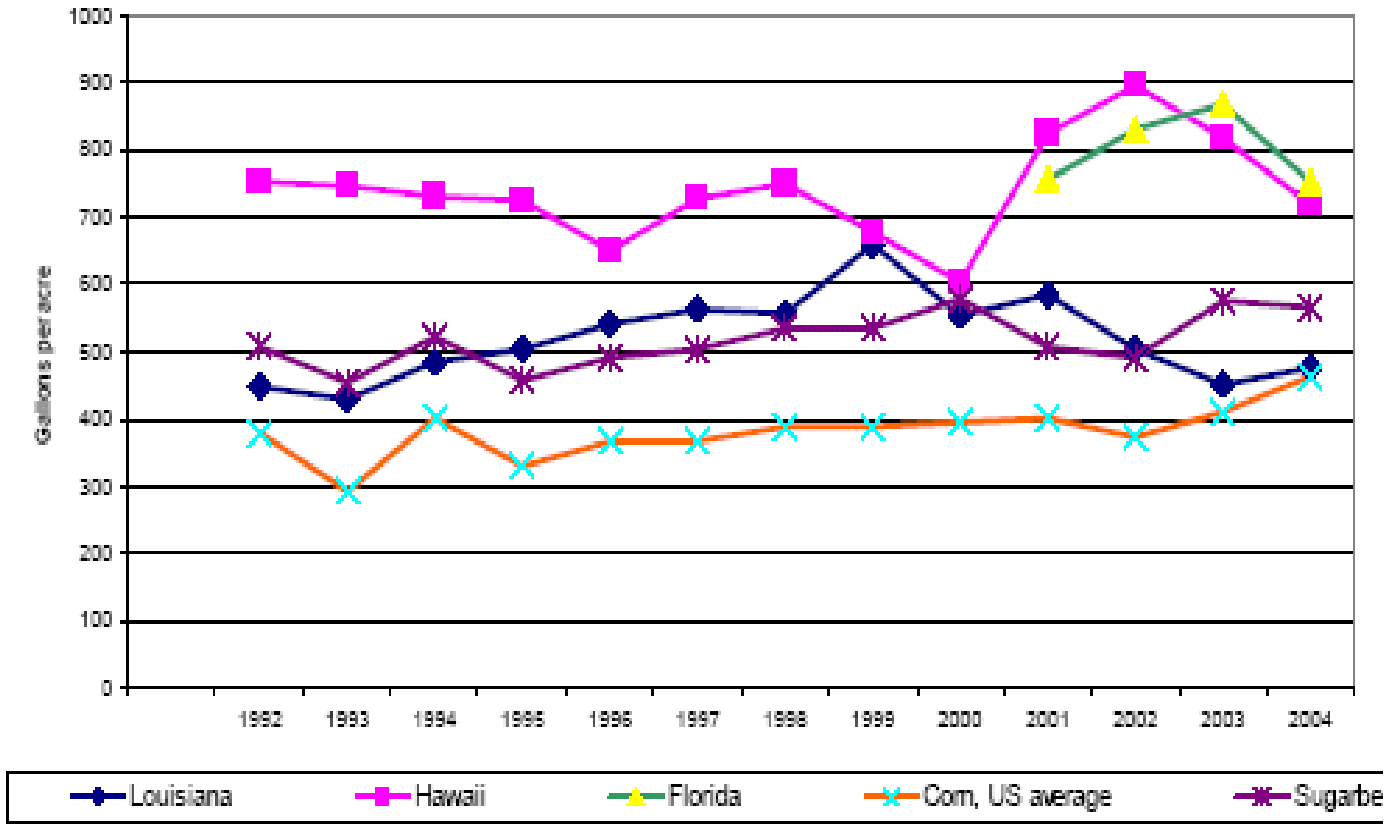
Ethanol yield per acre per year, sugar crops and corn



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Cellulosic Ethanol

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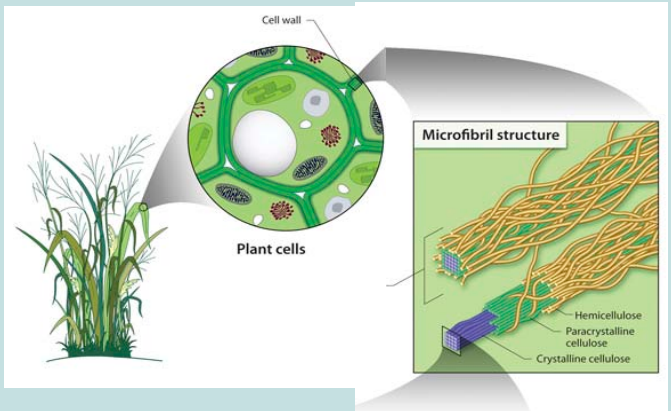
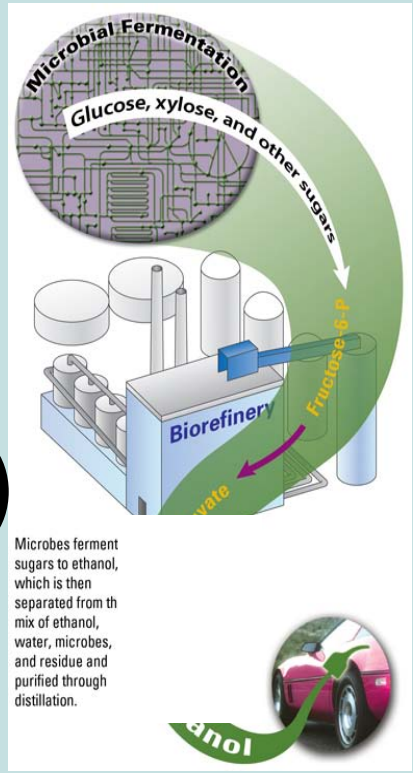
BASIC TRANSFORMATION:

CELLULOSE → SUGARS → ETHANOL





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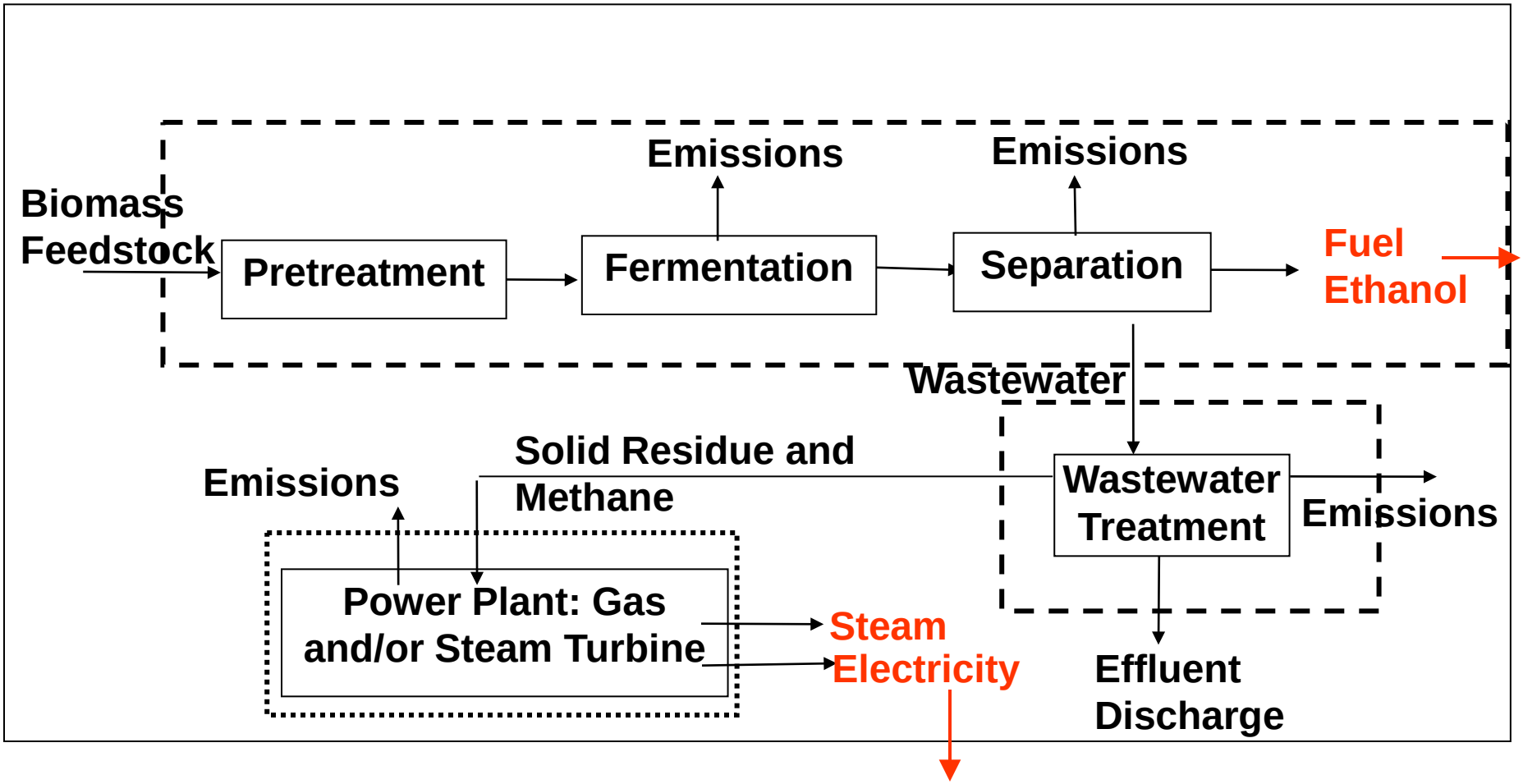
Cellulosic Ethanol Plants Will Be Significantly More Efficient than Corn Ethanol Plants



Plants under intensive R&D efforts are designed to use the unfermentable portion of biomass to generate steam and electricity.

Oilseed Biodiesel Production

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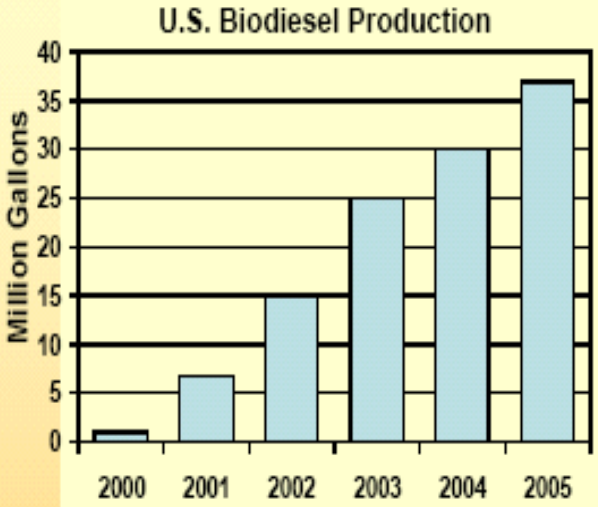
- The majority of bio-diesel produced uses waste grease and soybean oil



Soybean

Safflower

Mustard

Other oilseed crops such as mustard, rapeseed, safflower, sunflower and canola produce 1.2 – 2.5 times more oil/acre than soybeans. The result will be lower feedstock costs thru improved production efficiencies.

Rapeseed/canola

Sunflowers

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BioDiesel Production

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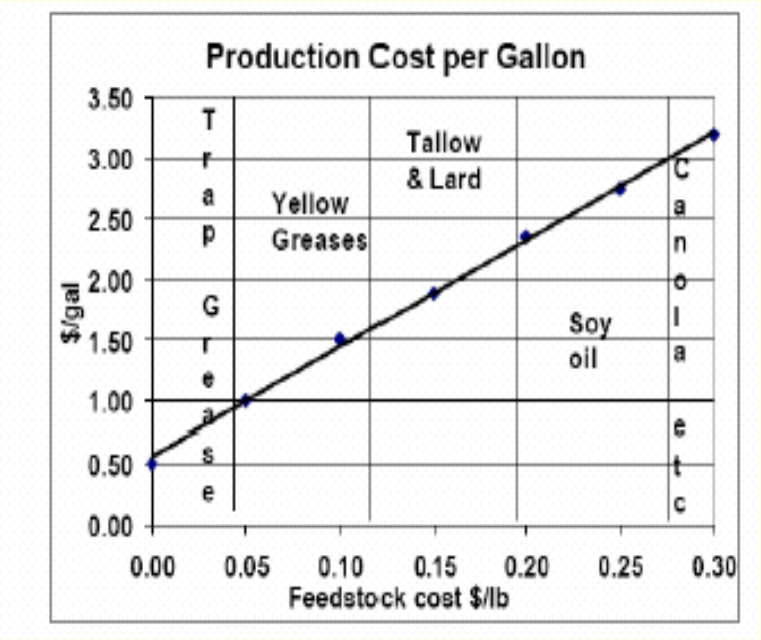
- The major economic factor to consider for input costs of bio-diesel production is the feedstock, which is about 80% of the total operating cost.



Source: National Renewable Energy Laboratory

To bring down costs value added products are needed:

- animal feed
- glycerin
- biofumigants
- other

- It takes around 7.5 pounds of fat or oil to produce a gallon of bio-diesel.

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Biodiesel Production Cost

	Unit Cost	$/gal
Oil (soy)	$0.27/lb	$2.03
Methanol	$1.35/gal	$0.17
Catalyst (25% $aOCH_3$)	$0.55/lb	$0.08
Neutralizer (HCl)	$0.08/lb	$0.01
Nat. gas/electricity	$9/mmbtu, $0.05/kwh	$0.02
Labor	1 shift, 2.5 people	$0.05
Depreciation	10 yr	$0.09
Maintenance	3.8% plant	$0.03
Admin + overhead		$0.02
	Total:	$2.50

From: Jon Van Gerpen, BAE, University of Idaho

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Biodiesel Retail Cost

Producer

Production Cost	**$2.50/gal**
Producer profit	**$0.30**
Small Producer Tax credit	**-$0.10**
CCC credit	**0**
Transportation	**$0.08**
Distributor purchase price	**$2.78**

Distributor/Blendor

Purchase Price	**$2.78/gal**
Excise Tax Credit	**-$1.00**
Freight	**$0.08**
Blendor profit	**$0.05**
Retail Purchase Price	**$1.91**

Retailer

Purchase Price	**$1.91/gal**
Retailer mark up	**$0.12**
WA + Federal Tax	**$0.524**
Retail Price (B100)	**$2.55**

- Assumes CCC program expires in 2006.
- Assumes no glycerin credit

With current incentives, biodiesel should be competitive with diesel fuel when retail prices are above $2.55/gal

Current price: $2.57/ gal

From: Jon Van Gerpen, BAE, University of Idaho

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Agricultural Derived Biogas for Energy Production

- Generally not that economically feasible unless:
  - Very large operation
  - Significant amount of incentives
    - Grants
    - Low interest loans
    - Tax credits
    - Carbon credits
  - Other revenue generating opportunities

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The Benefits of Using Biofuels Over Fossil Fuels

- Energy security
- Climate change mitigation
- Lower emissions of harmful pollutants
- Positive net energy balance

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Life-cycle Carbon Dioxide Emissions for Various Transportation Fuels

FUEL	CO2 EMISSIONS (LBS./ GALLON)
Biodiesel	5.84
Ethanol	14.60
Gasoline	24.30
Petrodiesel	26.55

DOE - Fossil Energy: DOE's Carbon Sequestration Research Program

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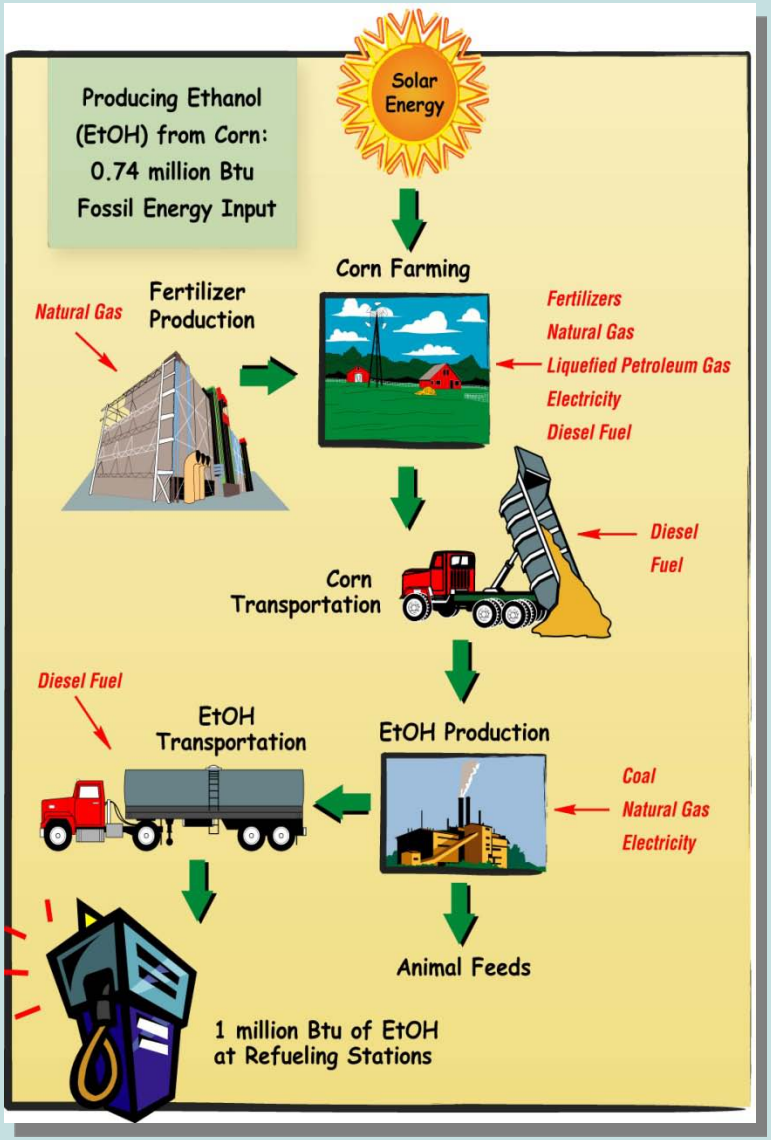
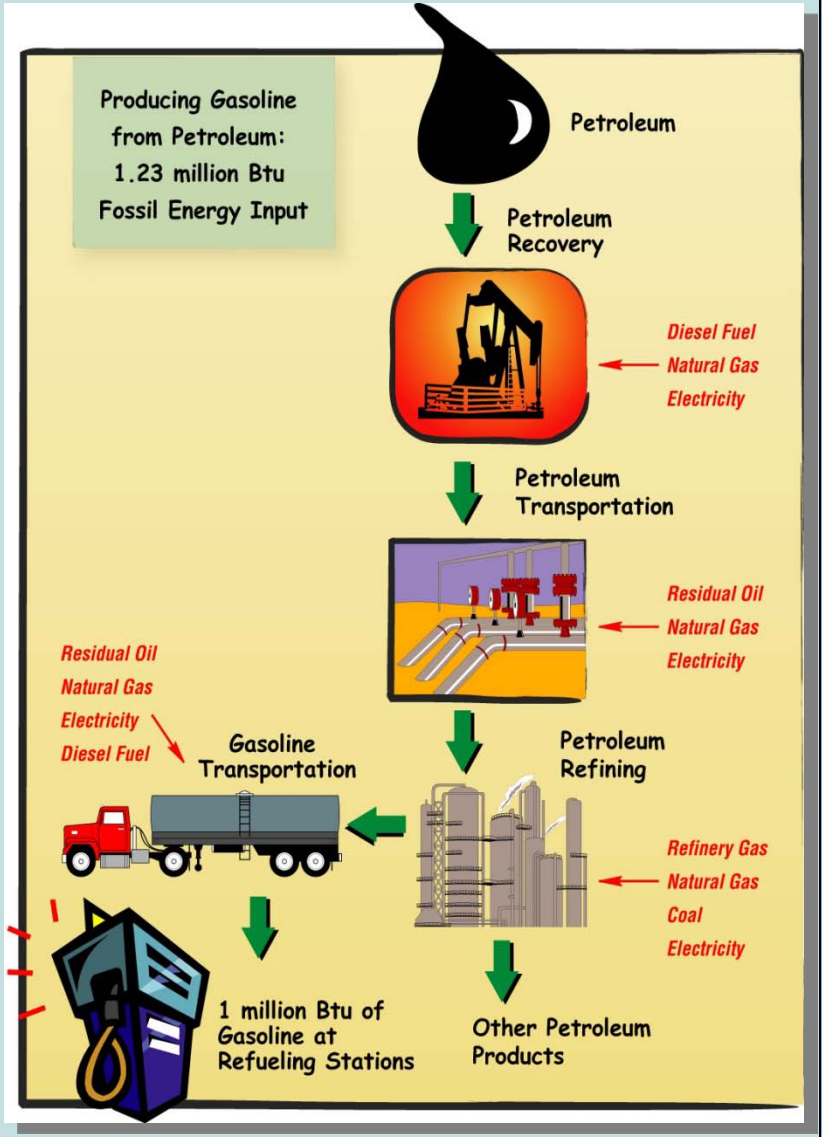
Comparative Results Between Ethanol and Gasoline





http://www.usda.gov/oce/reports/energy/aer-814.pdf

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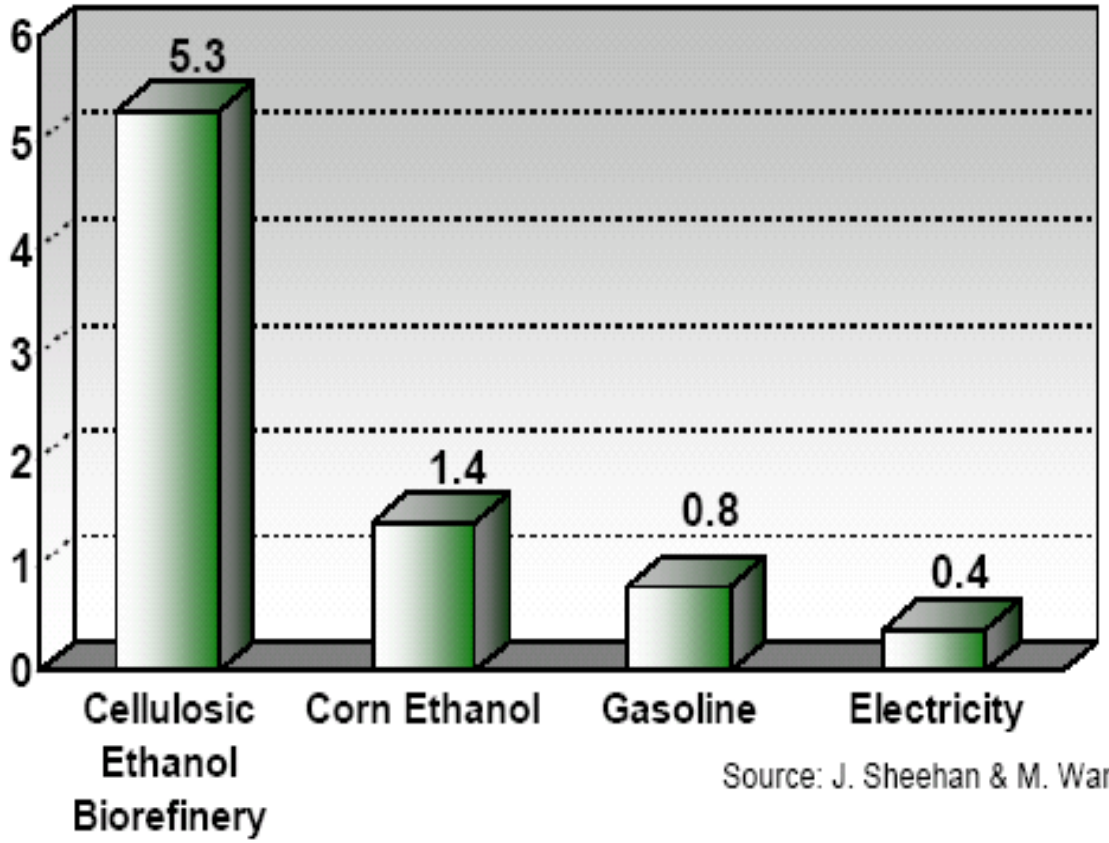
MICHIGAN STATE UNIVERSITY

Fossil Energy Replacement Ratio:
the Primary Climate Security Driver

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



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

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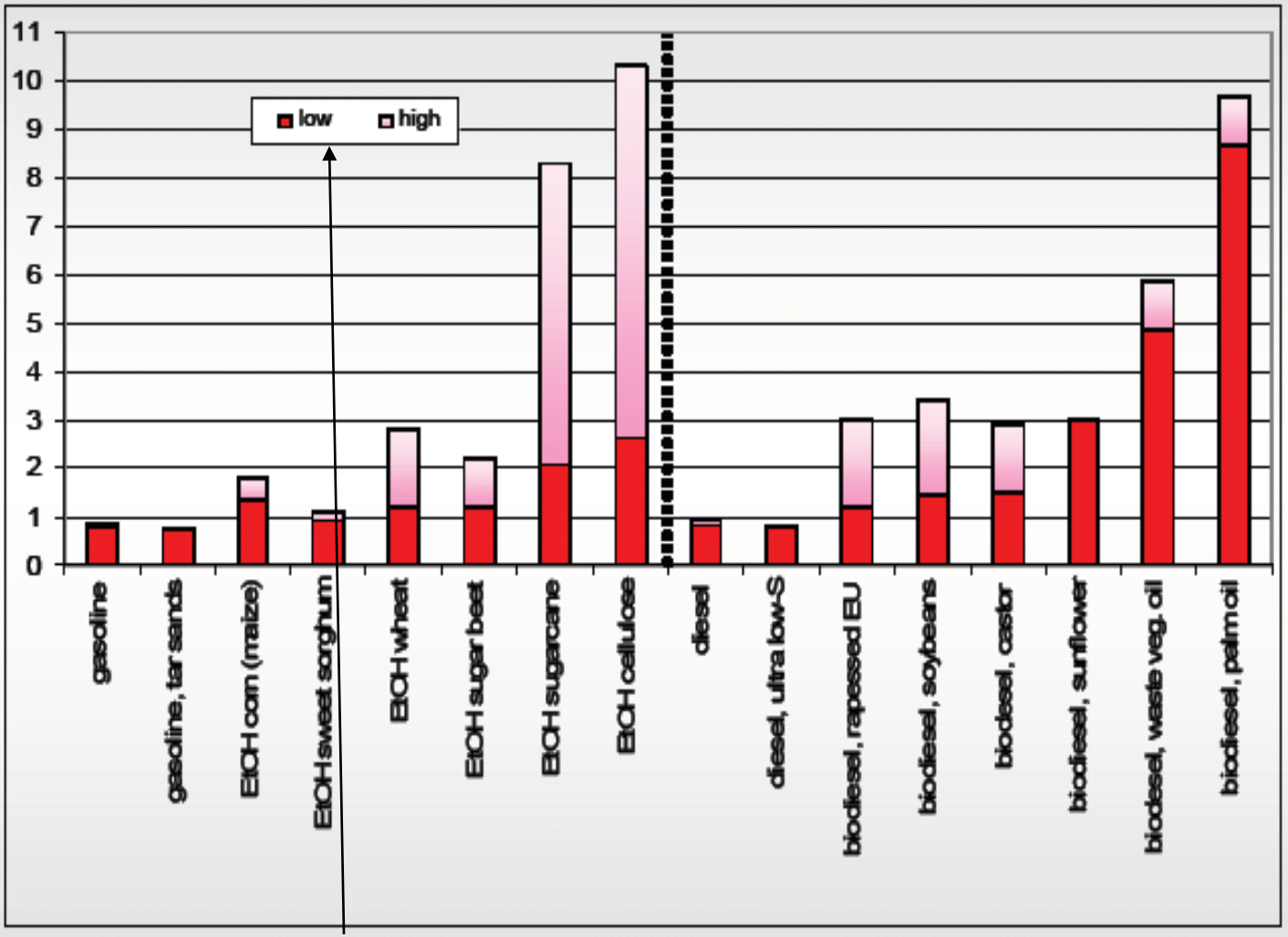
Öko-Institut e.V.
Institut für angewandte Ökologie
Institute for Applied Ecology

Energy Balance

Sustainable Biomass



Fossil Energy Balance of Transport Fuels, data from WWI/gtz (2006)

http://www.oeko.de/aktuelles/dok/544.php

*Data given as ratio of energy output per **fossil** energy input*

www.oeko.de

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Fuel Type	Unit	Btu
Coal (Anthracite)	Pound	12,500
#2 fuel oil	Gallon	139,000
Diesel	Gallon	138,694
Electricity	Kwh	3,413
Ethanol	Gallon	84,400
Gasohol (10% ethanol)	Gallon	120,900
Gasoline	Gallon	125,000
Kerosene	Gallon	135,000
Methanol	Gallon	62,800
Natural Gas	Cubic Foot	1,014
Propane LPG	Gallon	95,475
Residual fuel oil	Gallon	149,690
Wood (average)	Standard cord	21,000,000
Corn grain	Bushel	392,000

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Some Challenges to Biofuel Use

- Less Btu per volume in relation to respective fossil fuel
- Very dependant on price of fossil fuels
- Food vs. fuel
- Potential impacts on soil and water conservation

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Assumptions in 2005 Biomass Study

- All manure in excess of that which can be applied on-farm for soil improvement under anticipated EPA restrictions; and all other residues and wastes are utilized
- Soybeans have an increased residue to grain ratio of 2:1
- Harvest technology is capable of taking 75% of annual crop residues
- All cropland is managed with no-till methods;
- 55 million acres of cropland, idle cropland, and cropland pasture are dedicated to the production of perennial bio-energy crops

http://feedstockreview.ornl.gov/pdf/billion_ton_vision.pdf

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