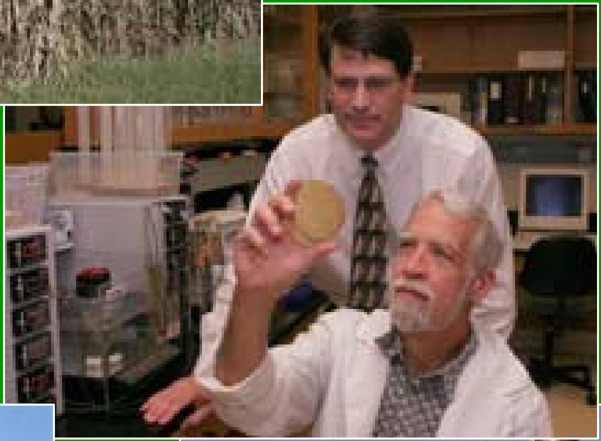
Fueling Florida's Future with Ethanol from Biomass

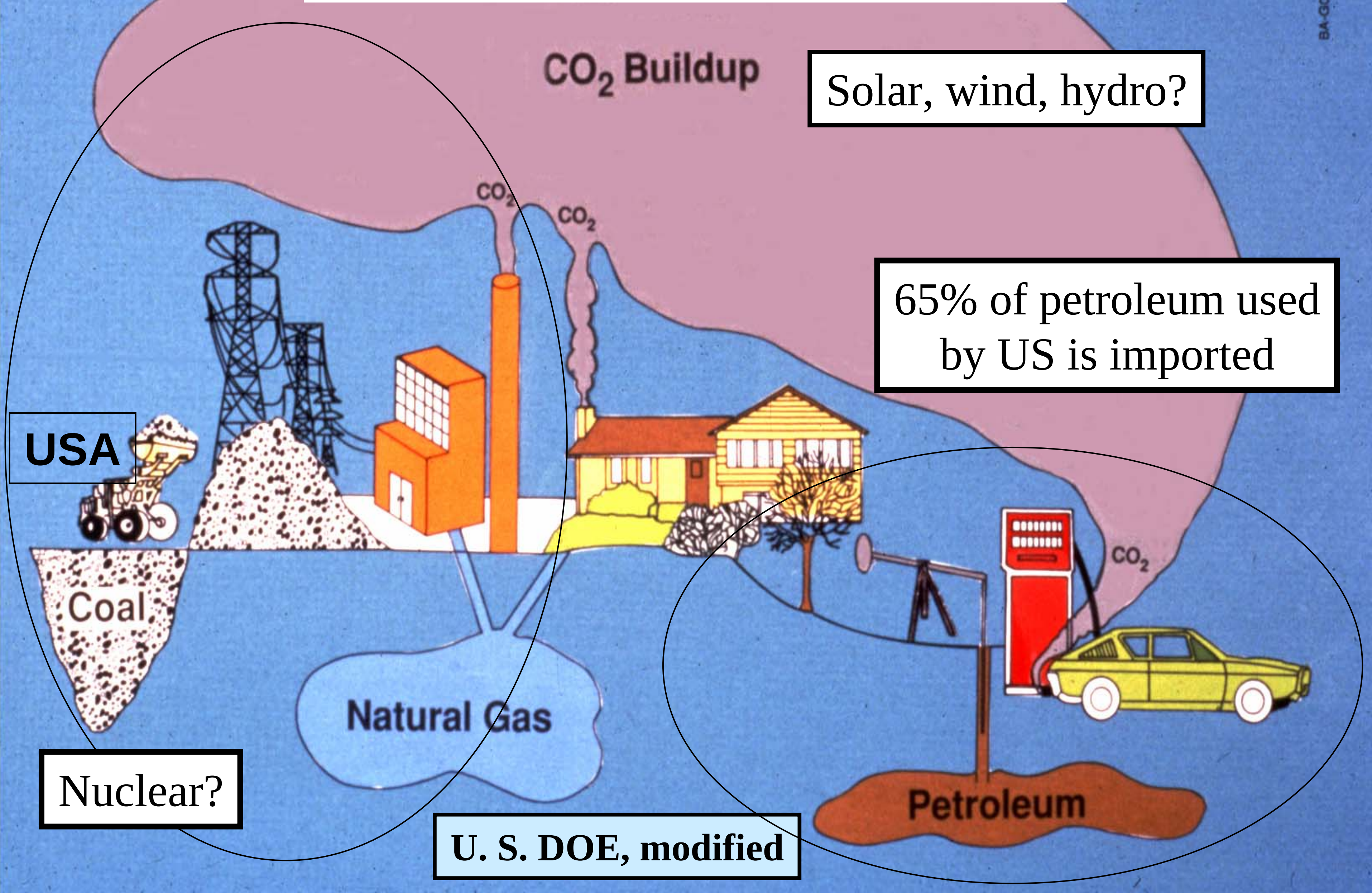


March 7, 2006

UNIVERSITY OF FLORIDA
IFAS

A rather dim future?



Biofuel Alternative to Fossil Fuel

Biopower (Most of US power from coal)

- Grid-connected capacity
  - 9700 MW direct combustion
  - 400 MW co-firing
- Biopower electricity prices generally range from 8-12¢/kWh

US needs 160 billion gal/yr of automotive fuel

Biofuels (Most of US fuel is from petroleum)

- Biodiesel – 15 million gallons (2002)
- Corn ethanol
  - 81 commercial plants
  - 3.4 billion gallons (2004)
  - ~$1.50/gal
- Cellulosic ethanol*
  - $2.50/gal includes cost of biomass
  - **Less than $1.50 / gal with zero cost feedstock**
  - **less than $1.00 / gal for negative cost feedstock (materials with a disposal costs)**

Rated at 21 MW and providing the San Francisco Bay Area with baseload capacity, the Tracy Biomass Plant uses wood residues discarded from agricultural and industrial operations.

Larger plant in South Florida – 74 MW (Okeelanta, Florida)

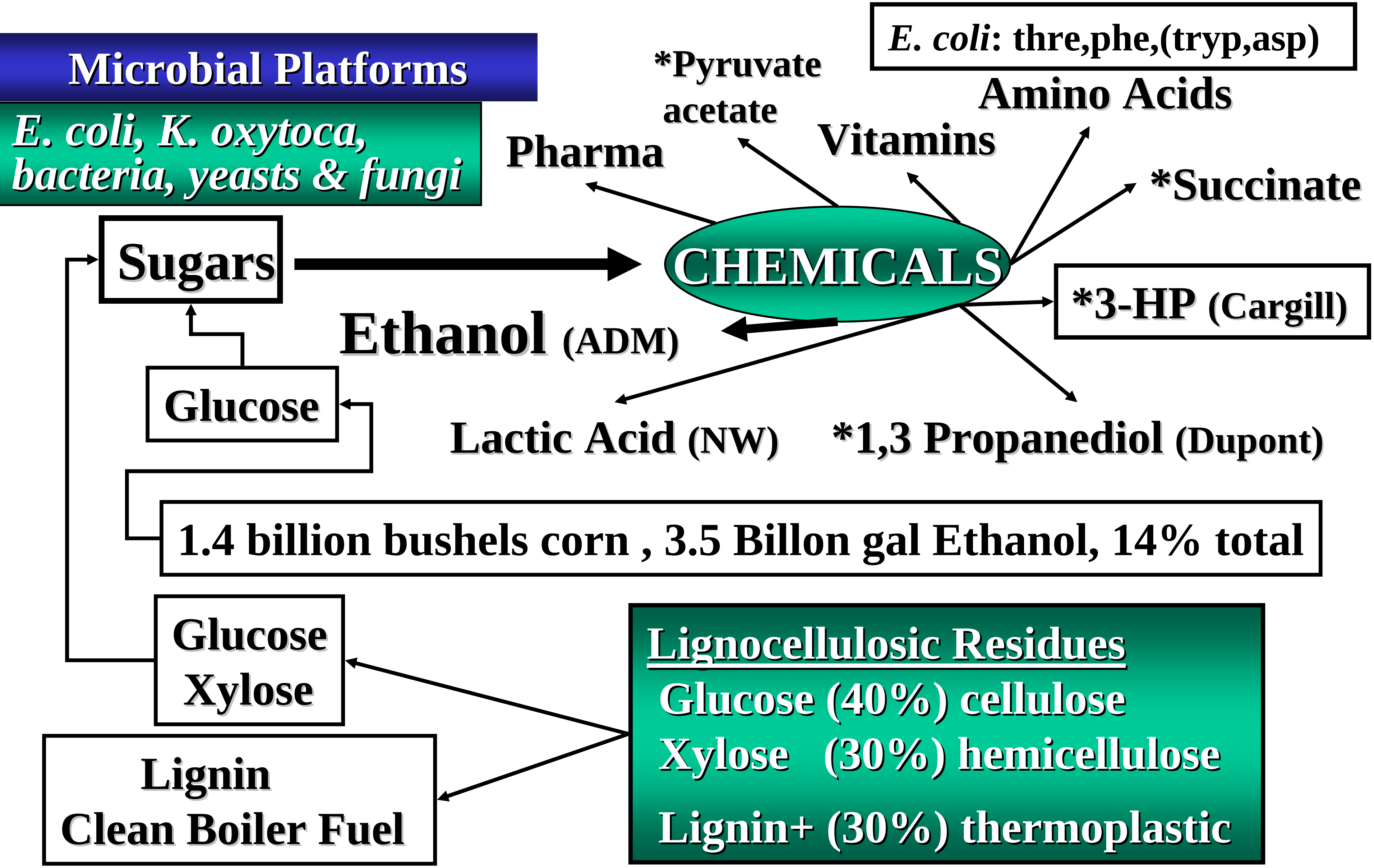
Modified from DOE, Dec. 2005

DOE, 2005

BioDiesel (B20)
85% Ethanol Gasoline
10% Ethanol Gasoline

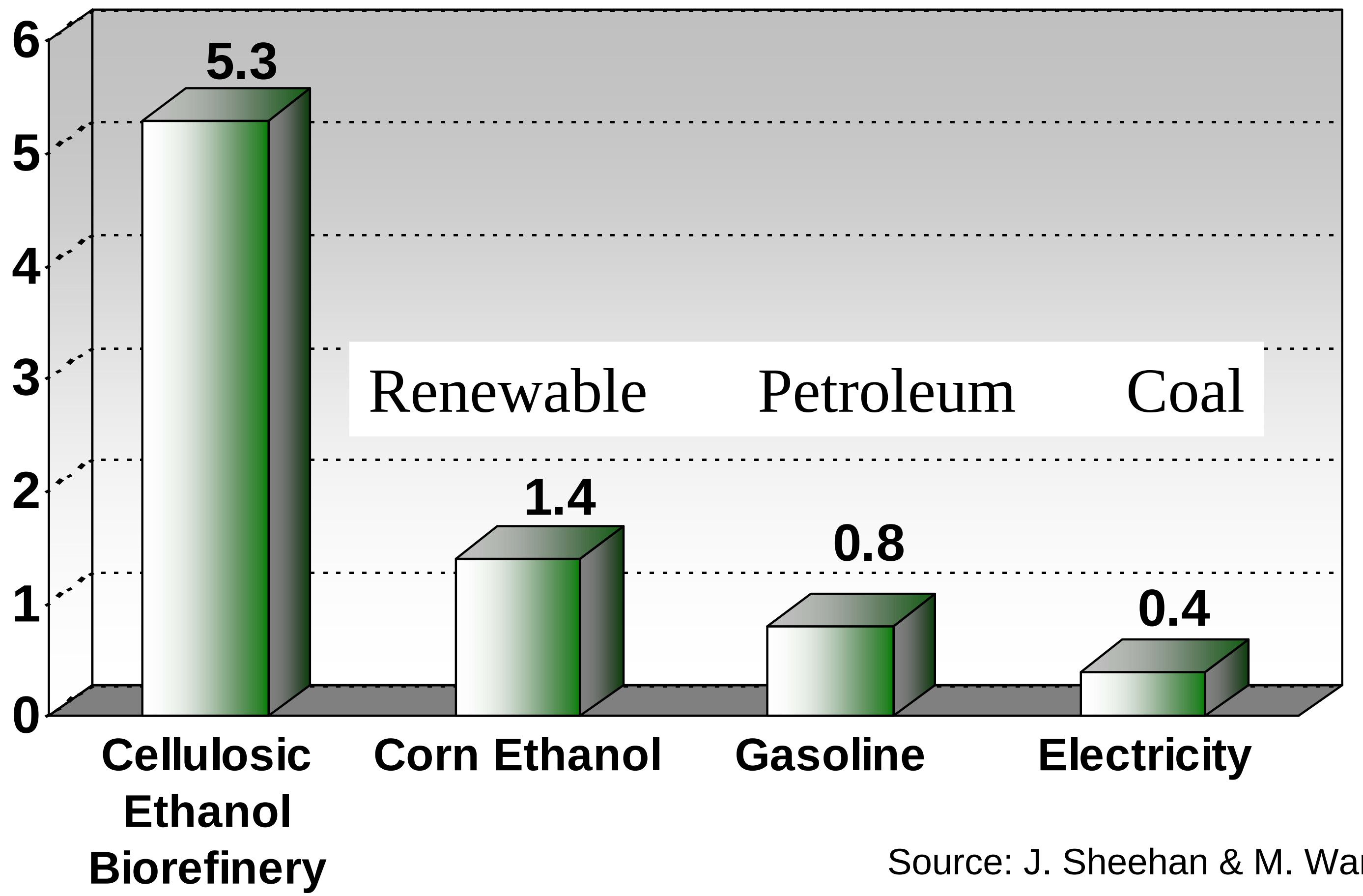
Brazil currently burns E85 in many vehicles. There are no technology barriers to expanding the level of ethanol in automotive fuel.

Renewable Feedstocks > Renewable Chemicals



Fossil Energy Replacement Ratio

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



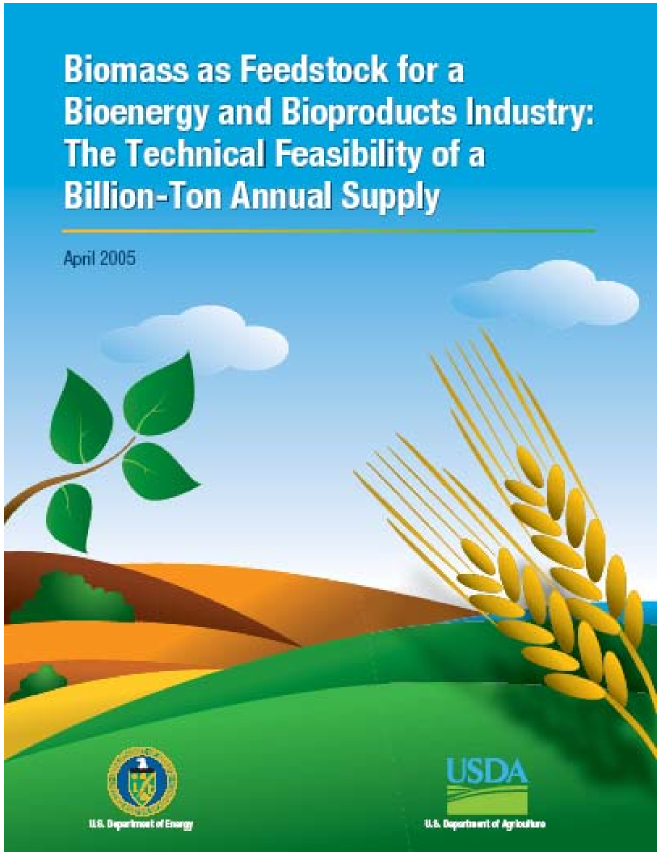
Source: J. Sheehan & M. Wang (2003)

US Department of Energy
Office of Energy Efficiency
and Renewable Energy 2005

Biomass Resource Base

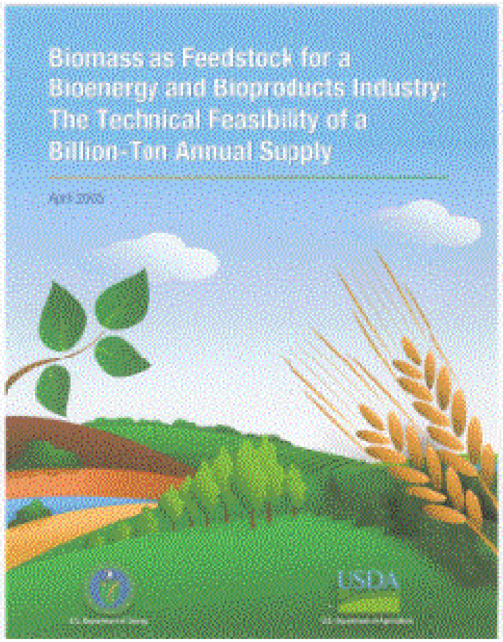
- **Land resources of the U.S. can sustainably supply more than 1.3 billion dry tons annually and still continue to meet food, feed, and export demands**
- **Realizing this potential will require R&D, policy change, stakeholder involvement**
- **Required changes are not unreasonable given current trends**
- **Should be sufficient to replace 30% of current US petroleum requirements**
- **Increased car mileage!**
- **Wise energy use, Conservation!**

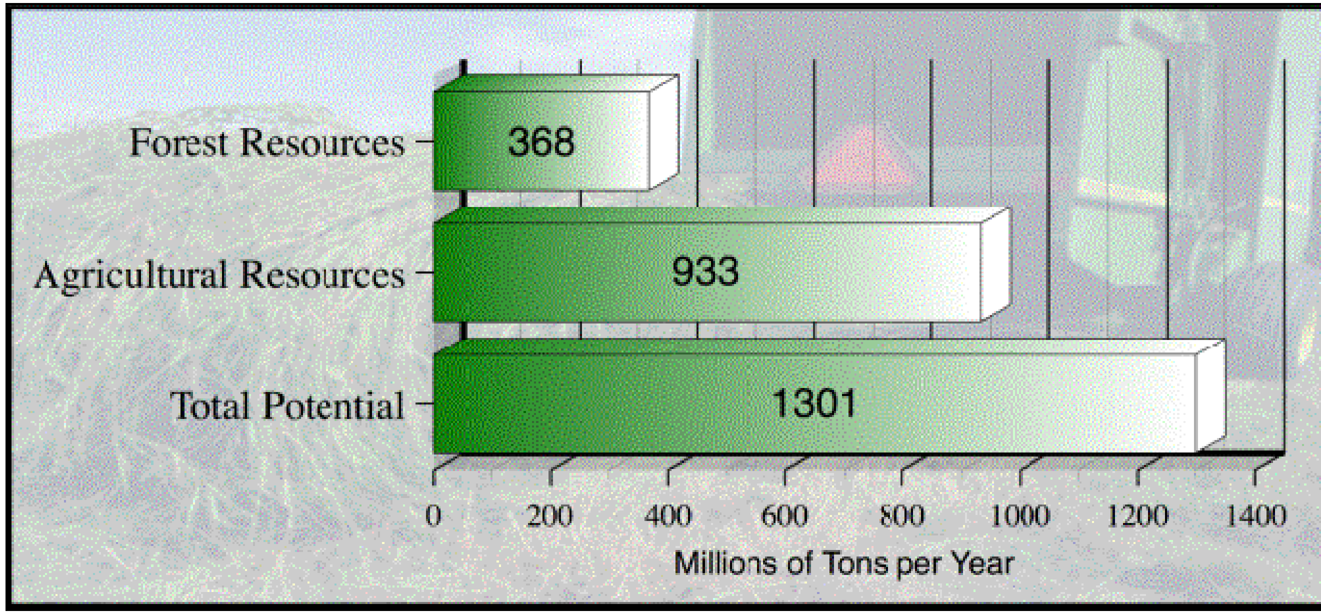
USDA/DOE Billion Ton Vision Paper



25% by 2025; 30% by 2030 programs

Biomass Availability and Type



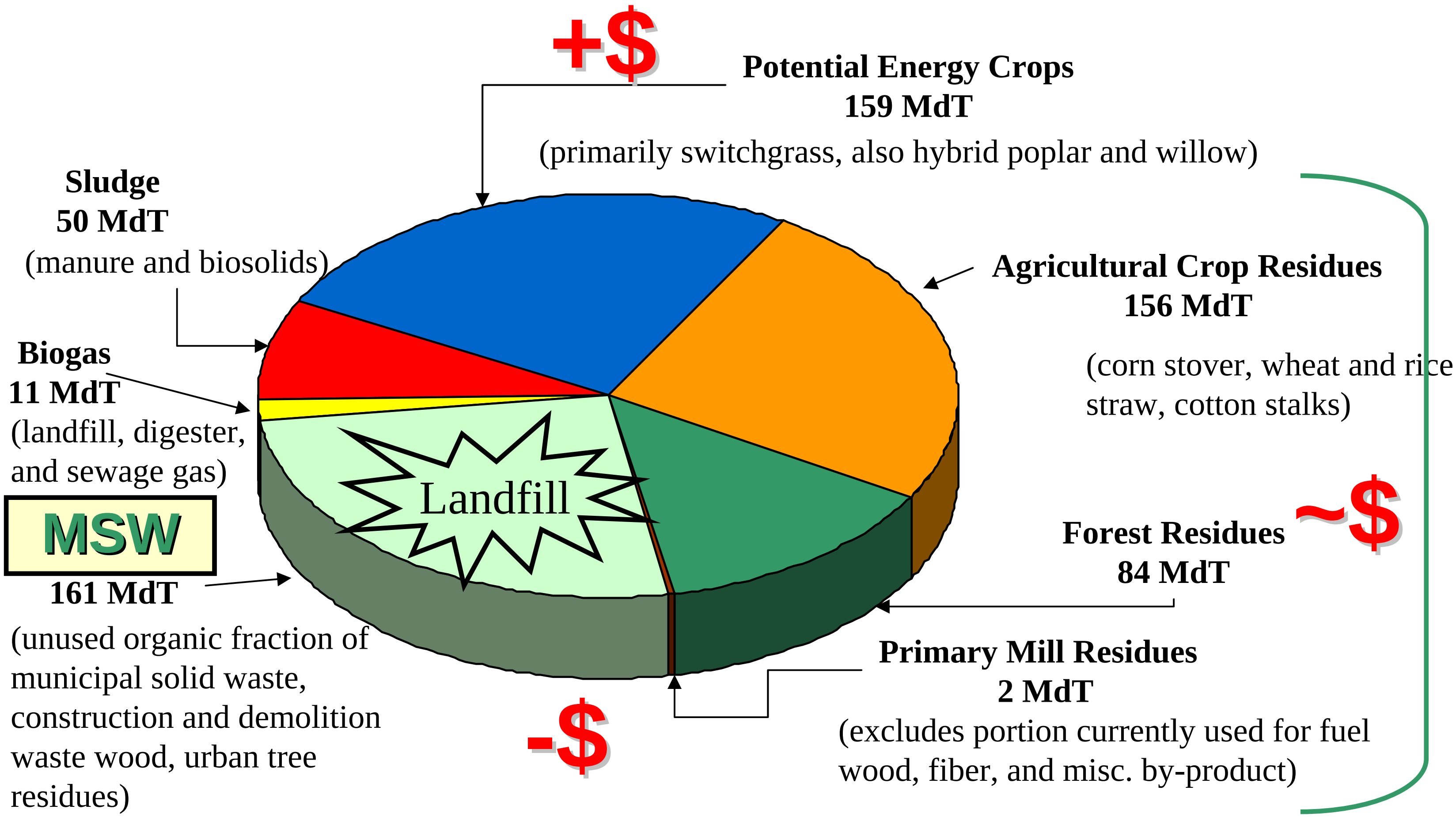


- "Billion Ton" study indicates that an annual biomass supply is potentially available to displace 30%+ of current U.S. petroleum consumption by 2030 using a variety of biomass types:
  - Agricultural lands
    - Corn stover, wheat straw, soybean residue, manure, switchgrass, poplar/willow energy crops, etc.
  - Forest lands
    - Forest thinnings, fuelwoods, logging residues, wood processing and paper mill residues, urban wood wastes, etc.

Also MSW Green Waste in Florida

Modified from US DOE, 2005

U.S. Feedstocks Available by Biomass Type



2 X in 2005 report

Mdt = million dry tons

Source: DOE, Biobased Products and Bioenergy Roadmap, 2001

US Department of Energy
Office of Energy Efficiency
and Renewable Energy 2005

New Domestic Bio-Industry

Biomass Feedstock

– Trees
– Grasses
– Agricultural Crops
– Agricultural Residues
– Forest Residues
– Animal Wastes
– Municipal Solid Waste

Conversion Processes

- Enzymatic Fermentation
- Gas/liquid Fermentation
- Acid Hydrolysis/Fermentation
- Gasification
- Pyrolysis
- Combustion
- Co-firing

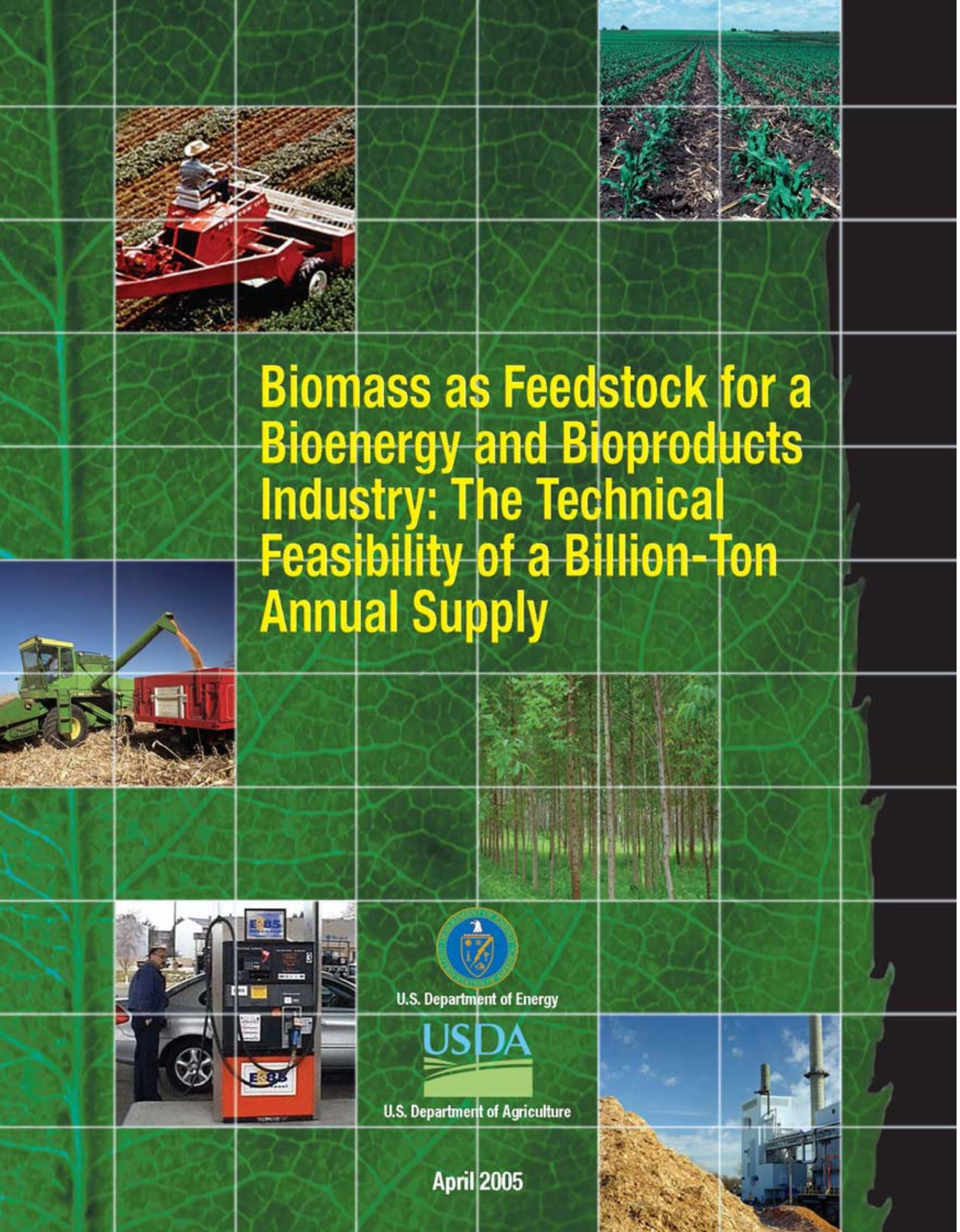
PRODUCTS

Fuels:
– Ethanol
– Renewable Diesel
– Renewable Gasoline
– Hydrogen

Power:
– Electricity
– Heat (co-generation)

Chemicals
– Plastics
– Solvents
– Chemical Intermediates
– Phenolics
– Adhesives
– Furfural
– Fatty acids
– Acetic Acid
– Carbon black
– Paints
– Dyes, Pigments, and Ink
– Detergents
– Etc.

Food, Feed, Fuel and Fiber



1.3 Billion dry tons/year

70% Carbohydrate, 20% Lignin

From the Carbohydrate

1.0 Billion tons of chemicals
or
130 Billion gal of fuel ethanol
or
Some Combination

(Need 160 Billion gal/yr)

Lignin and residues burned for power

Florida ---

- Depends almost exclusively on other states and nations for supplies of oil and gasoline, producing less than one percent of the nation's crude oil annually.

- Consumes 8.6 billion gallons of gasoline per year and consumption is growing by 300 million gallons per year.

  (***twice total corn ethanol***)

Florida Dept. of Agriculture, 2006

Opportunities for Renewable Energy in Florida

Florida is Number 1 in something other than athletics.

FL leads the country in tons plant biomass produced per yr. (but not corn)

Florida has the resources to lead the country in

- **Renewable fuel ethanol – automotive (& chemicals)**
- **Combustion/co-firing/gasification – power**
- **Anaerobic digester/ biogas -- on-site power and vehicles**
- **Development of energy crops for the future**

Positive economic impacts for Florida

Producing Automotive Fuel in Florida

1

Established, conventional technology with yeasts

Sugar cane, syrup - Brazil
Corn (local and shipped into Florida)- US
Citrus molasses, Cane molasses
Waste sugar (soft drinks, candy, etc.)

2

Alternative crops – sweet sorgham for ethanol,
Increasing cane, increasing corn?
Oil crops for biodiesel? -- soybeans, other?

3

Inedible biomass -- Lignocellulose to ethanol

Florida's Inedible Biomass Feedstocks

Municipal waste, green waste – disposal cost

Bagasse and cane waste – gathered, low value

Citrus pulp – fuel ethanol (animal feed)

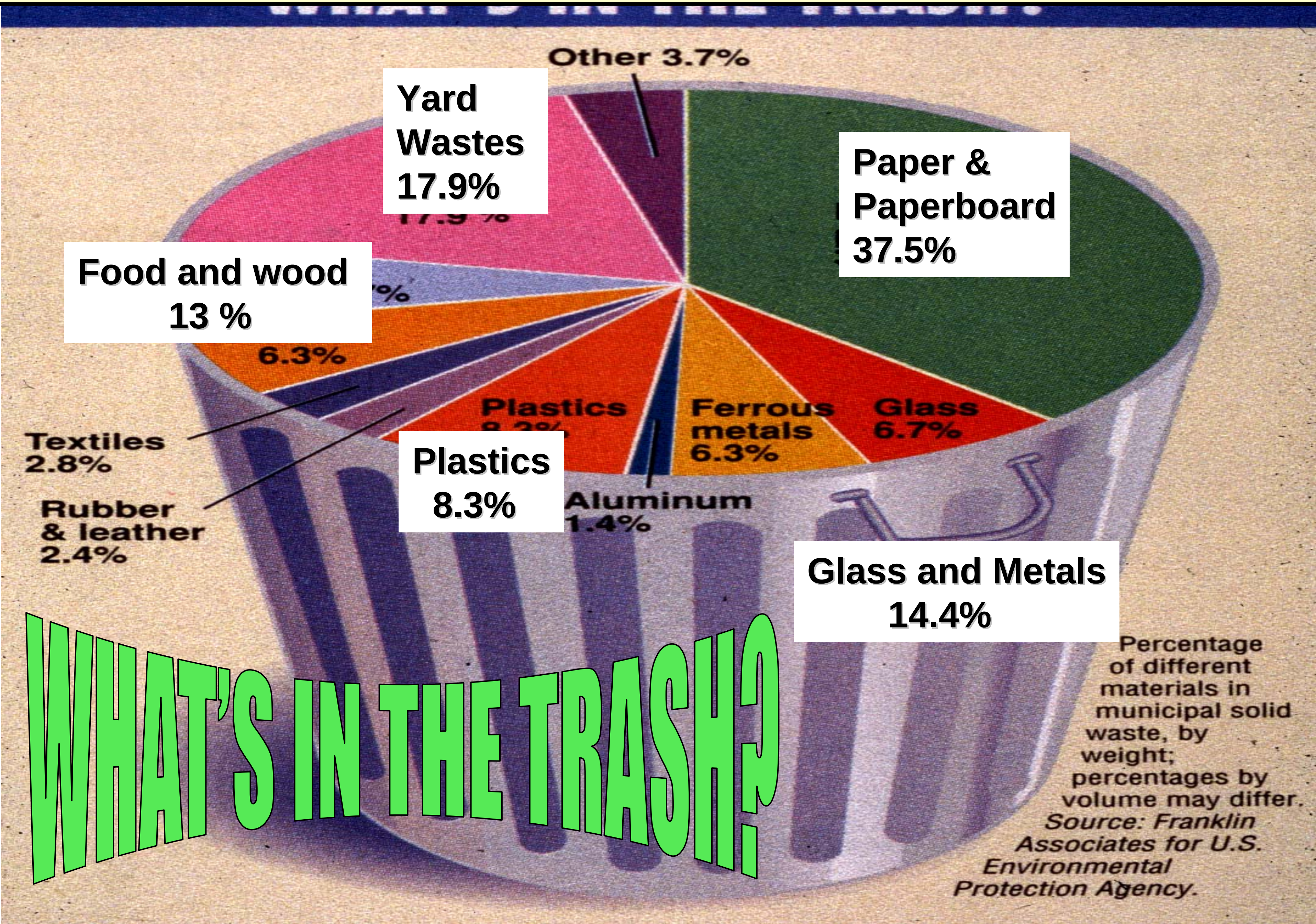
Forest & timber residues – disposal cost

Invasive plants – disposal cost

Animal waste -- disposal cost

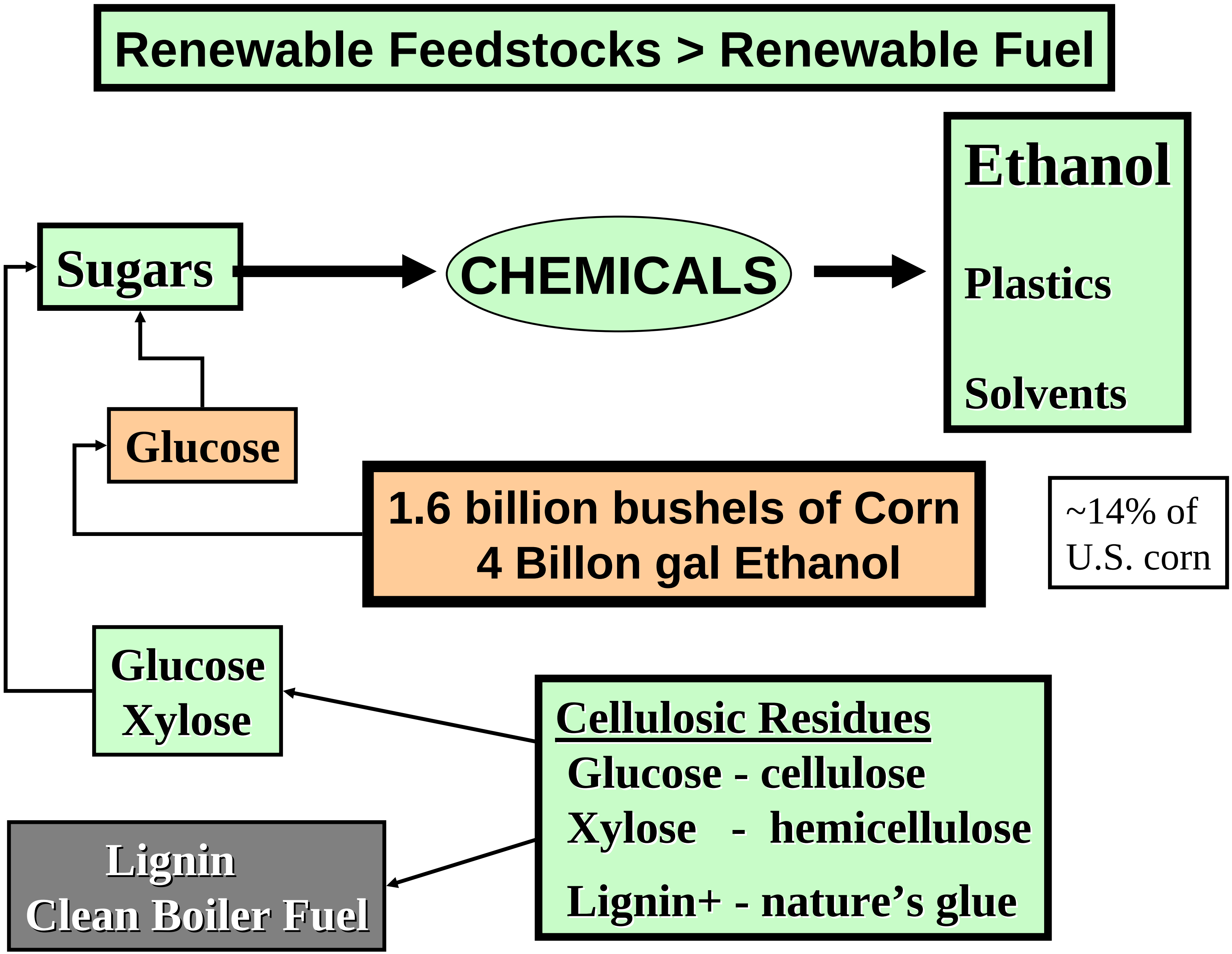
Agricultural residues – collection costs

> 70% LIGNOCELLULOSE

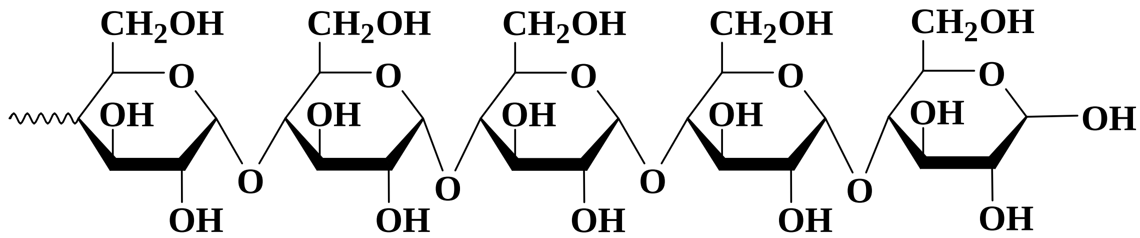


Cane Bagasse – Biomass Residues

(“Brown Gold” of the future) South of Lake Okeechobee, Florida

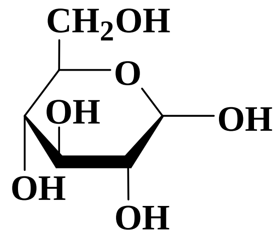

Renewable Feedstocks > Renewable Fuel
Sugars
CHEMICALS
Ethanol
Plastics
Solvents
Glucose
1.6 billion bushels of Corn
4 Billon gal Ethanol
~14% of
U.S. corn
Glucose
Xylose
Cellulosic Residues
Glucose - cellulose
Xylose - hemicellulose
Lignin+ - nature’s glue
Lignin
Clean Boiler Fuel

The main feedstock in the US today

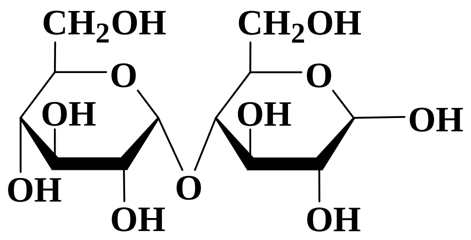


starch

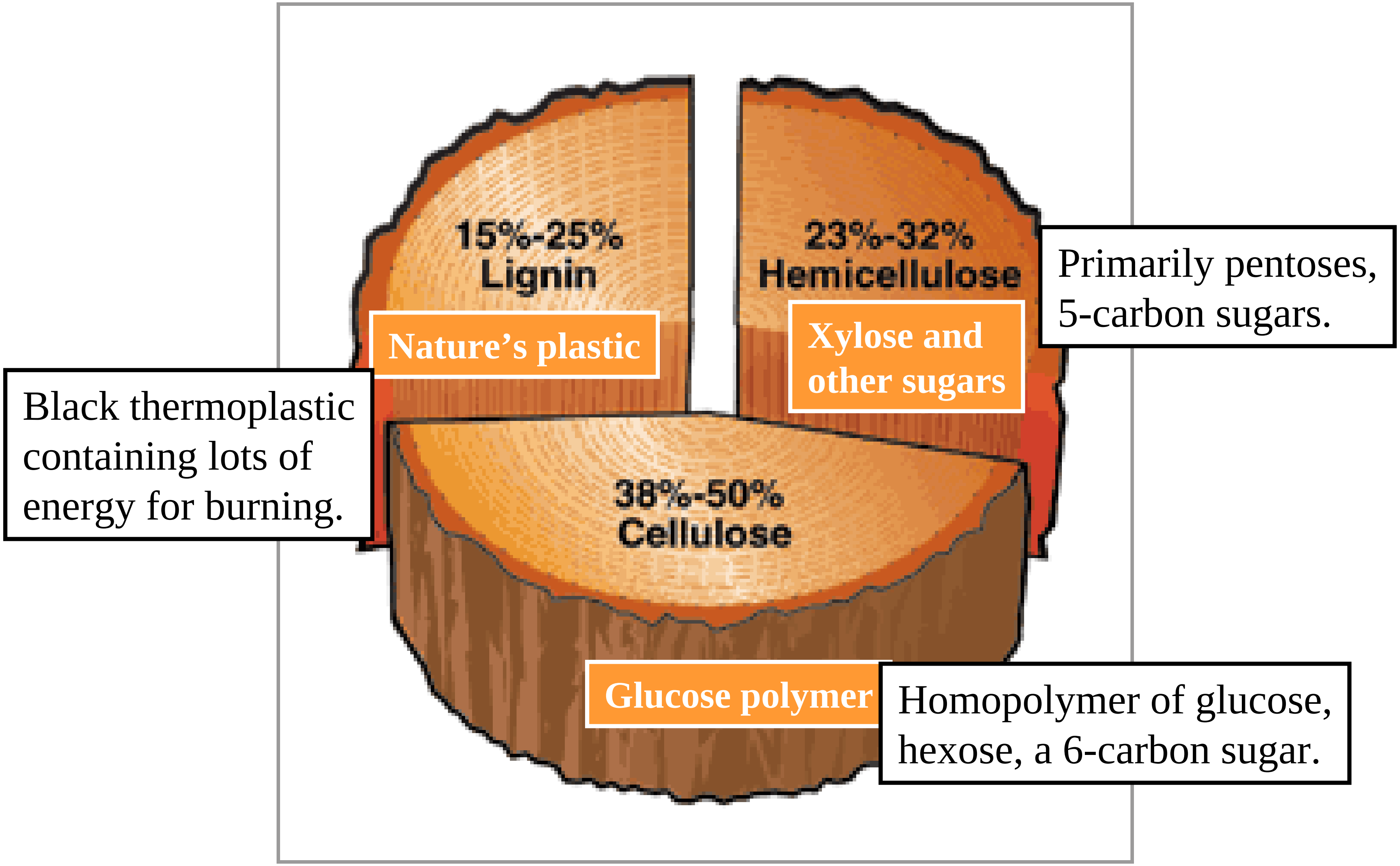
enzymes



D-glucose (dextrose)
(6-carbon sugar)

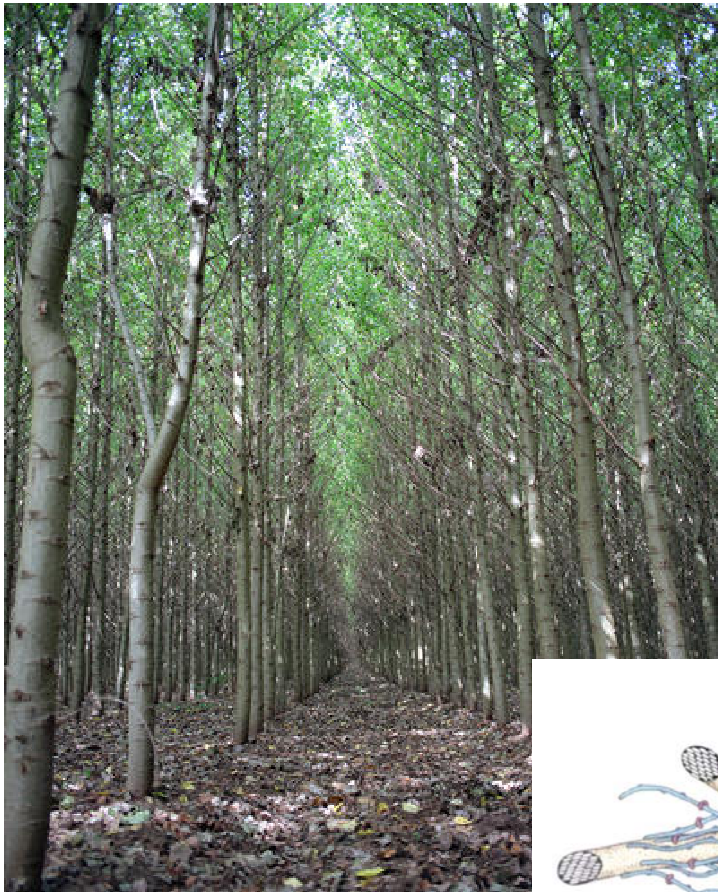


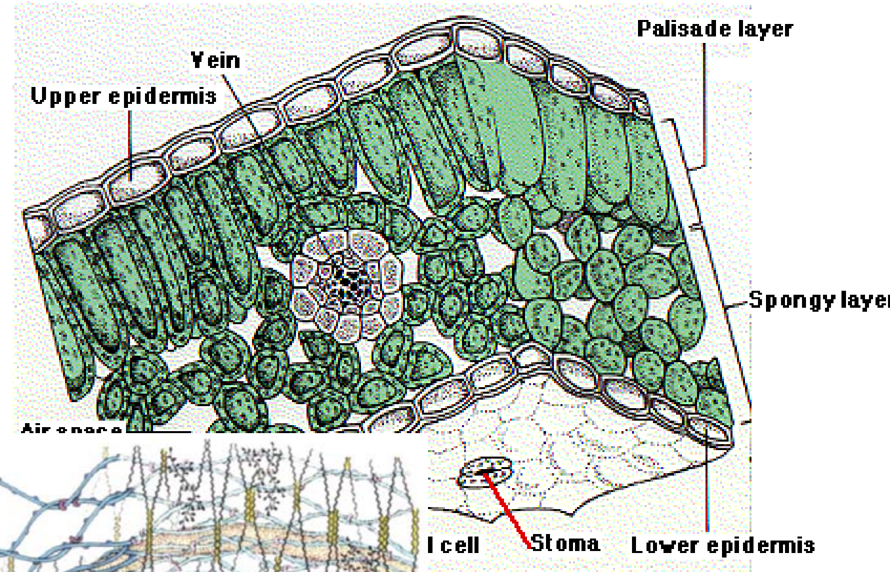
maltose and other
longer chains

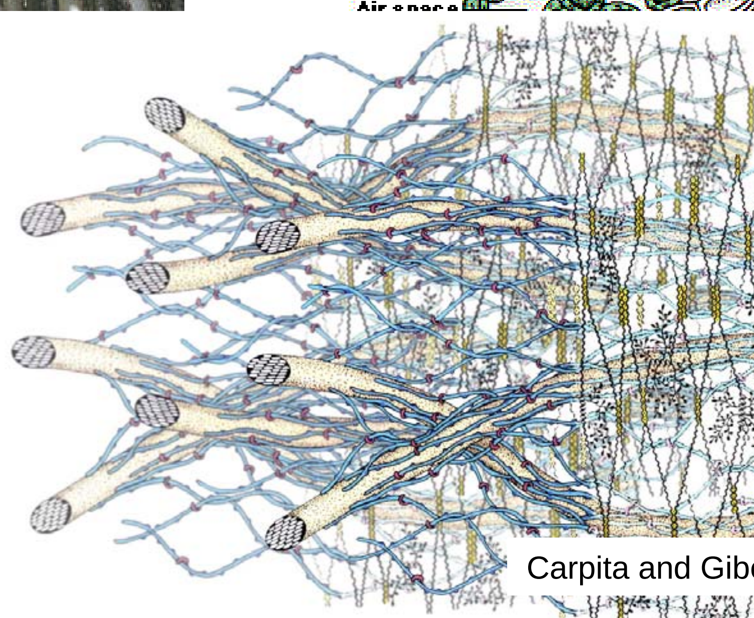


Composition of Lignocellulosic Biomass

Plant Cell Wall Synthesis and Biorefining





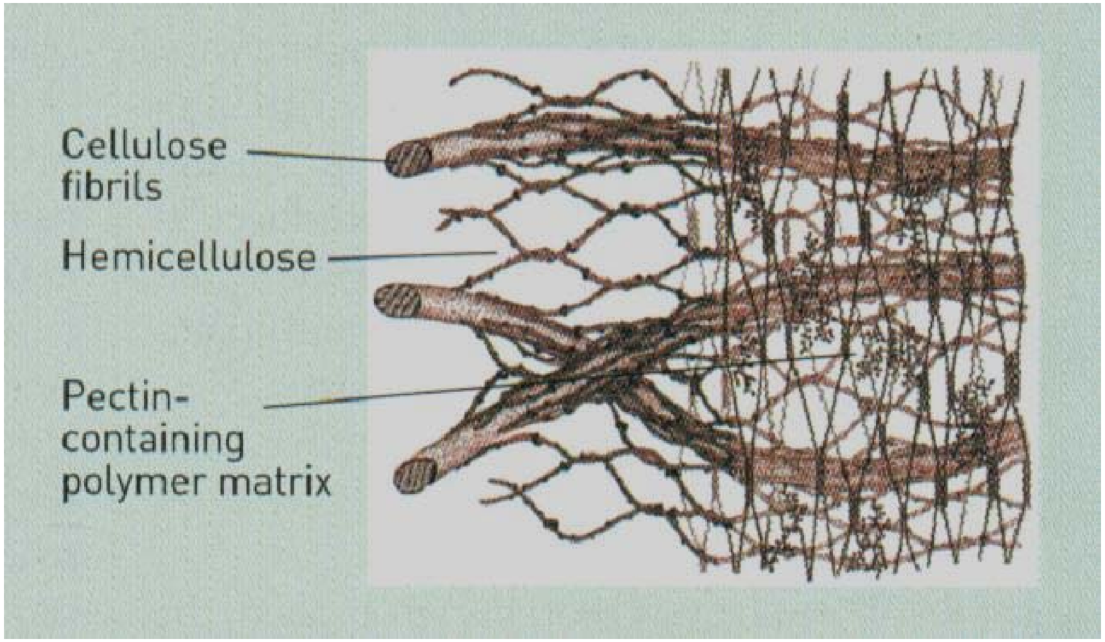


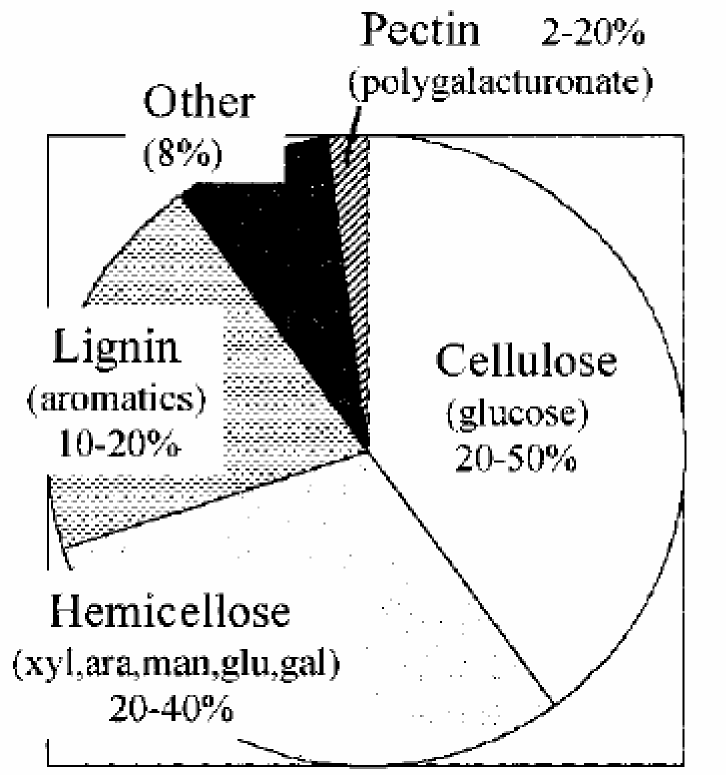
Carpita and Gibeaut, 1993

Composition of Biomass

Monomeric sugars released from hemicellulose by cooking with dilute mineral acids or adding enzymes.

Cellulose – Strong acid treatment or cellulolytic enzymes



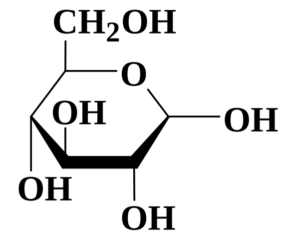


Future feedstock: Cellulosic biomass

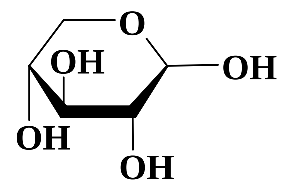
Biocatalyst??

<u>Approximate composition</u>

Cellulose, 45%

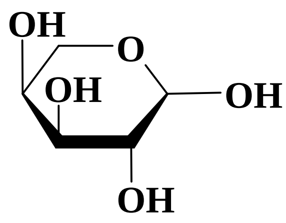


D-glucose



D-xylose
(5-carbon sugar)

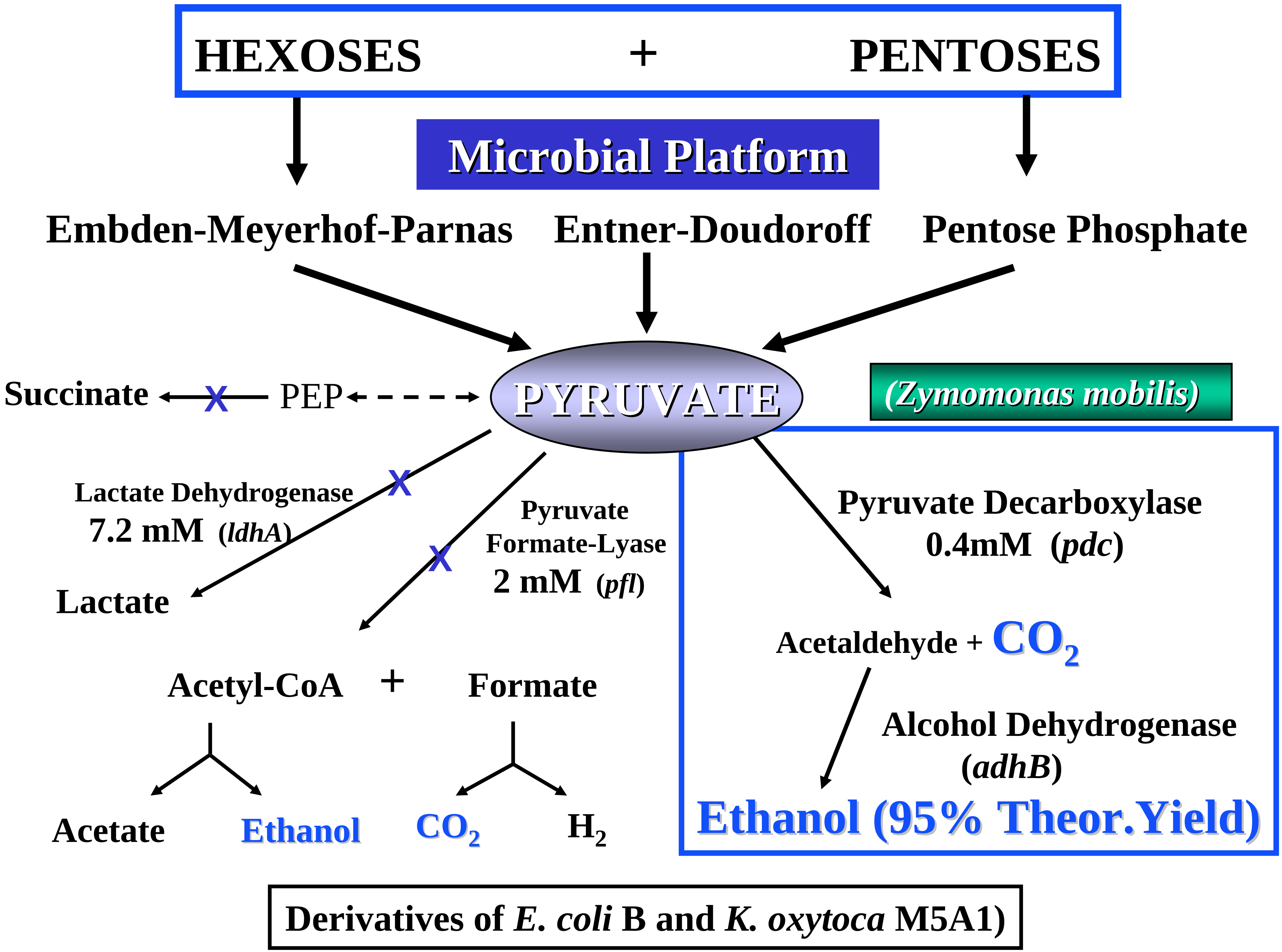
Hemicellulose, 25%



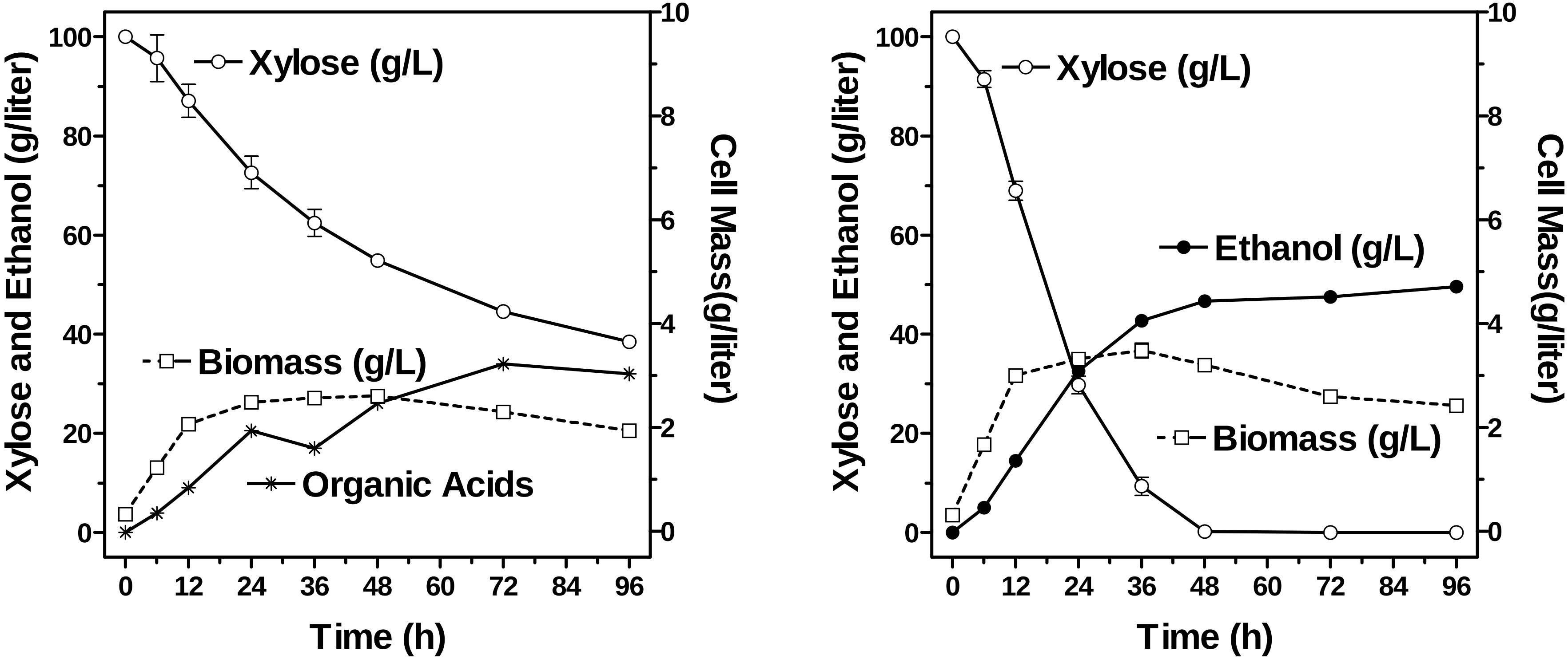
L-arabinose
(5-carbon sugar)

Lignin, 25%

Other, 5%

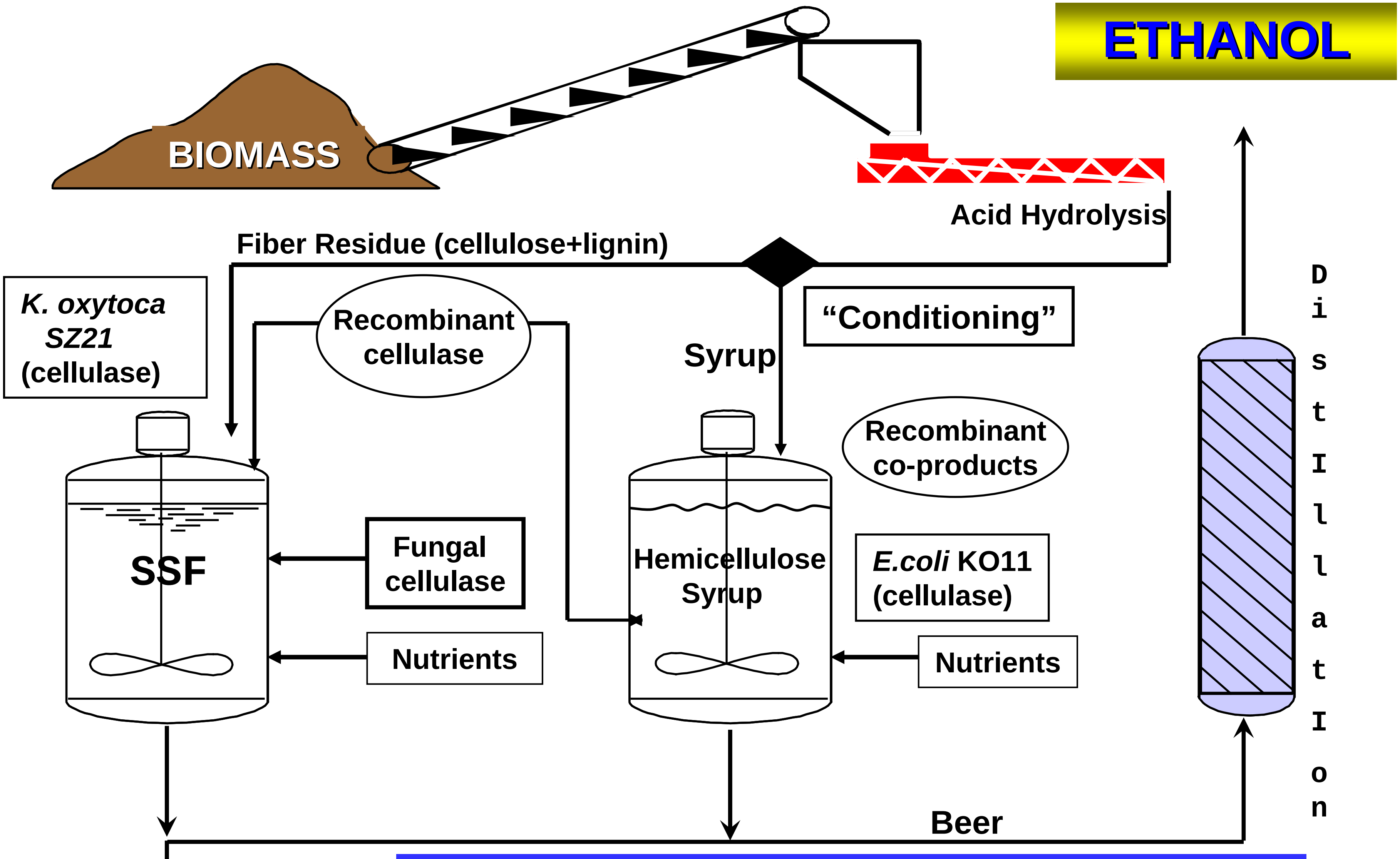

HEXOSES + PENTOSES
Microbial Platform
Embden-Meyerhof-Parnas
Entner-Doudoroff
Pentose Phosphate
Succinate
PEP
PYRUVATE
(Zymomonas mobilis)
Lactate Dehydrogenase
7.2 mM (ldhA)
Pyruvate
Formate-Lyase
2 mM (pfl)
Pyruvate Decarboxylase
0.4mM (pdc)
Lactate
Acetaldehyde + CO2
Acetyl-CoA + Formate
Alcohol Dehydrogenase
(adhB)
Acetate
Ethanol
CO2
H2
Ethanol (95% Theor.Yield)
Derivatives of E. coli B and K. oxytoca M5A1)

E. coli B (organic acids) and KO11 (ethanol)



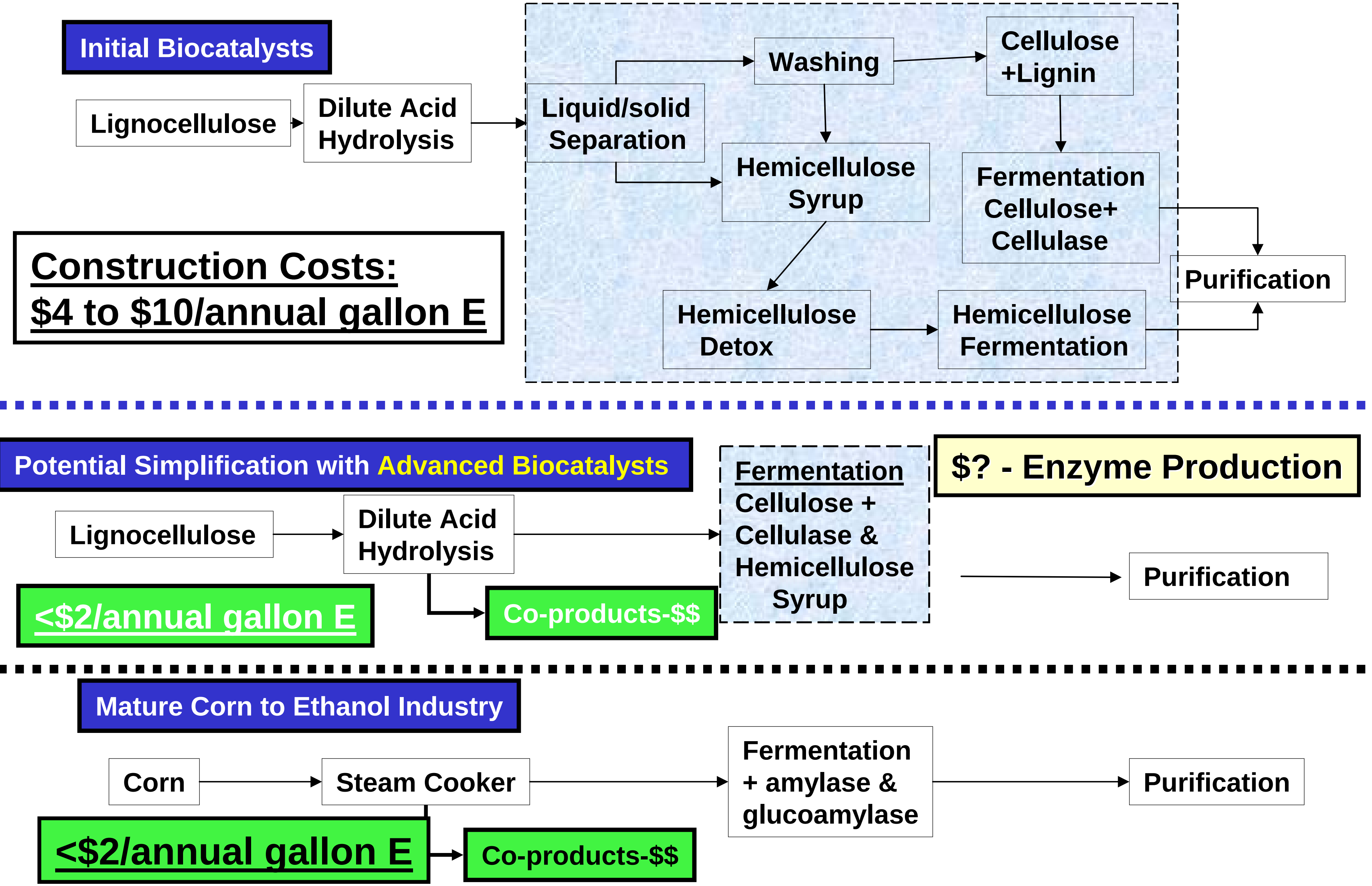
Yield – 0.50 g ethanol and 0.49 g CO_2 per g xylose

(10% Xylose, pH 6.5, 35C)

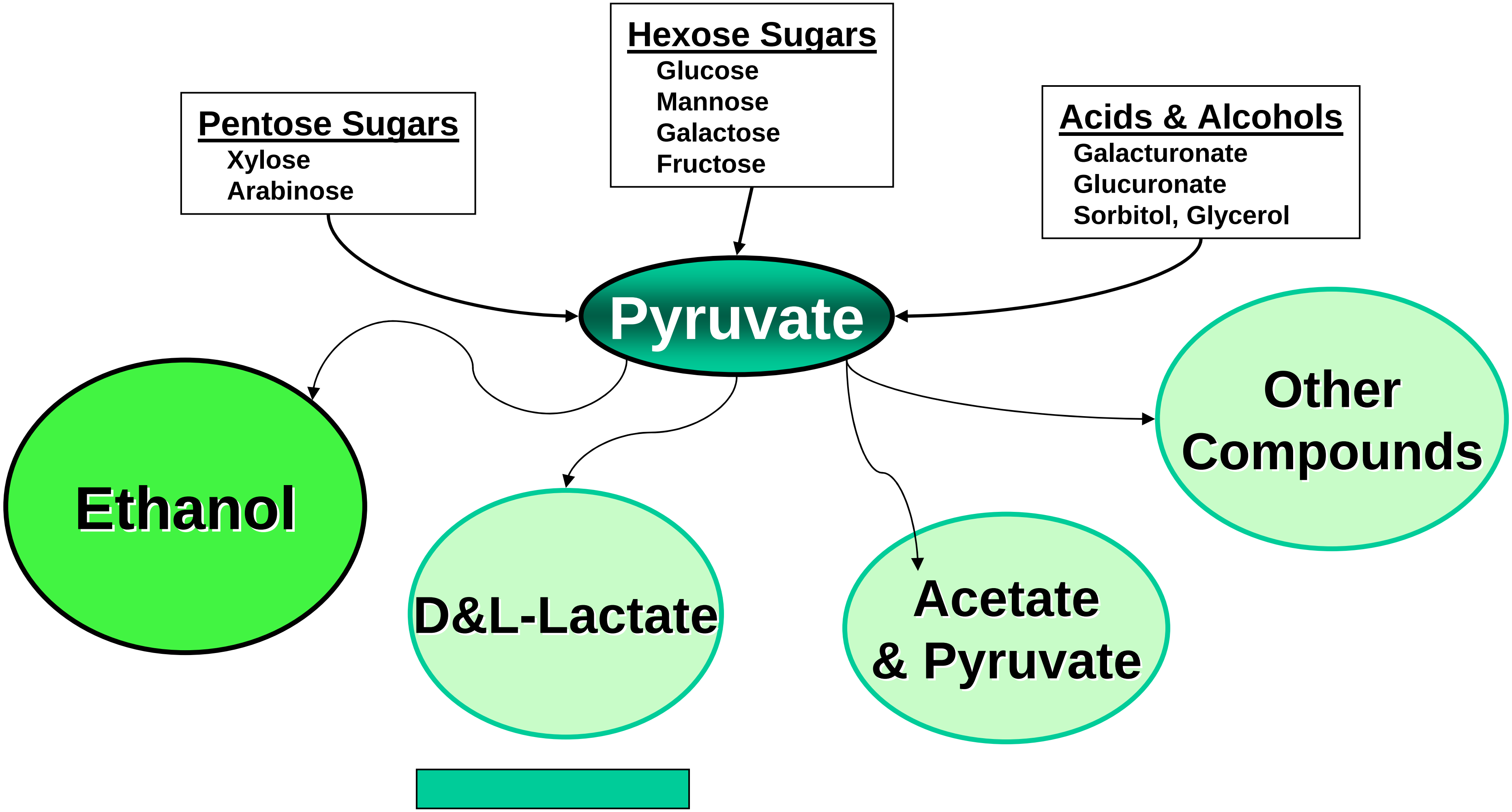


Lignocellulose to Ethanol

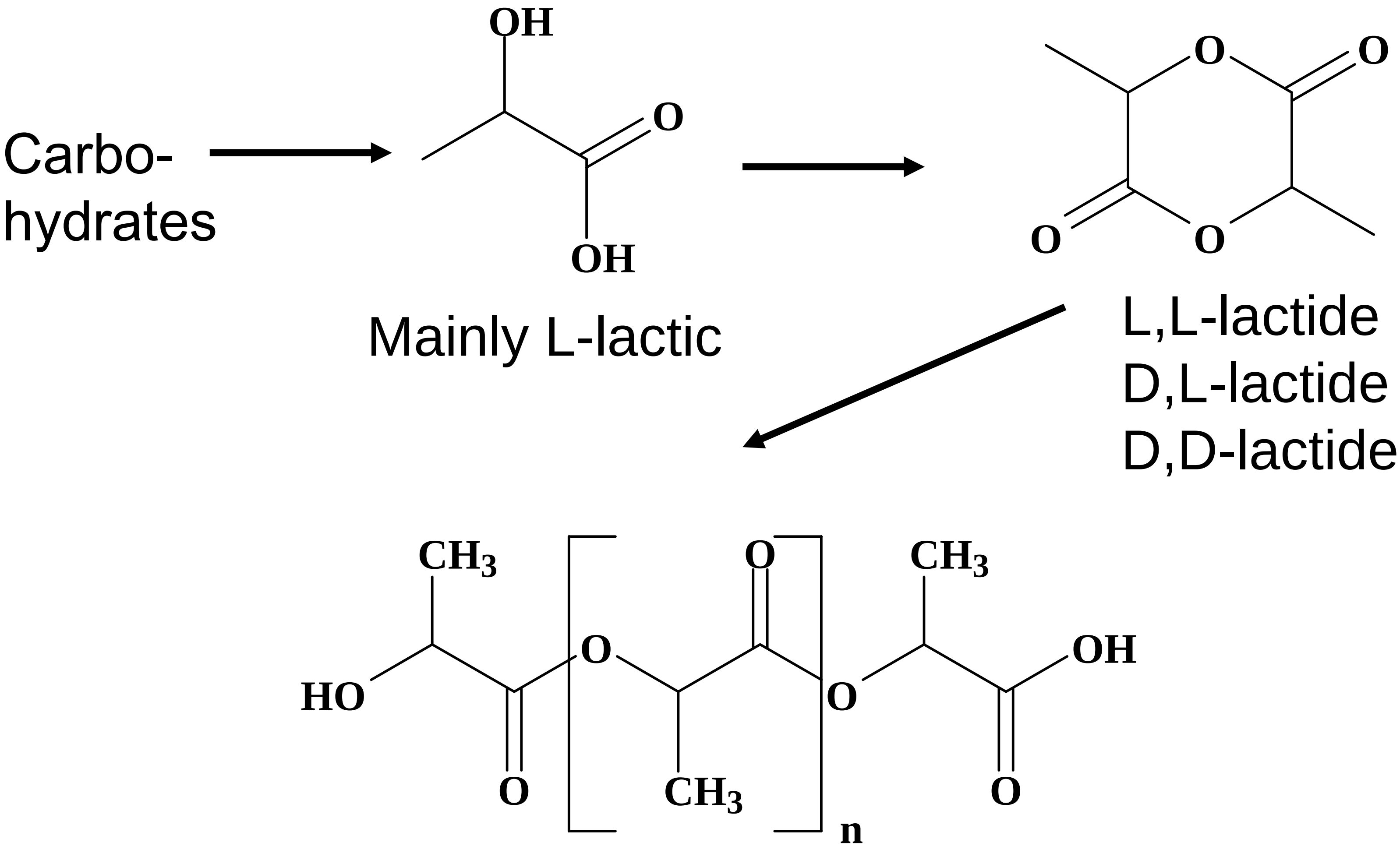
Conversion of Biomass to Fuel Ethanol & Chemicals



Fuels and Chemicals from Biomass



Polylactic acid (NatureWorks, LLC)

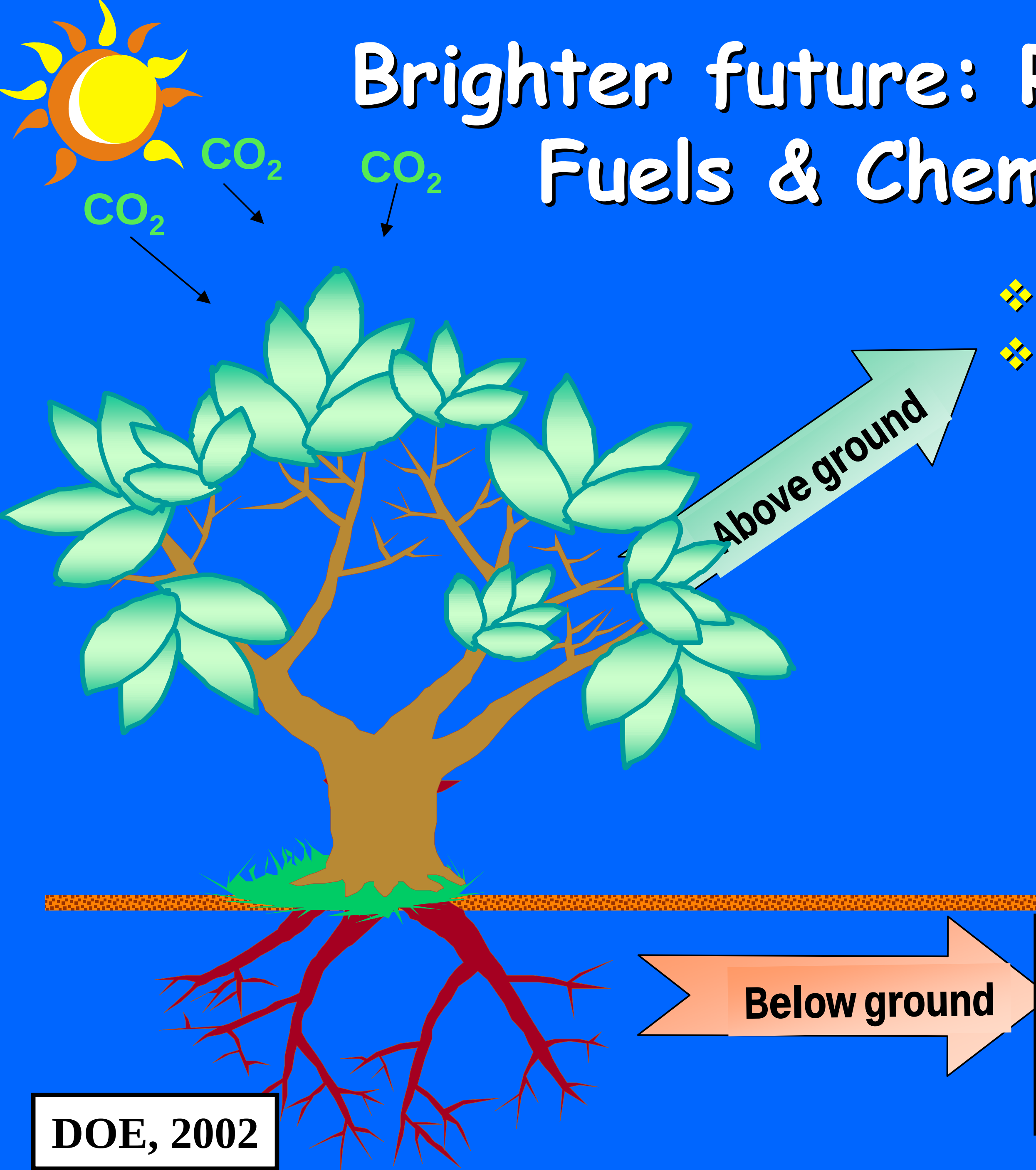


NatureWorks™

Cargill Dow Polymers LLC


INTERNA
TIONAL
TALENT
SUPPO
RT
DIESEL
FOR SUCCESSFUL LIVING
ingeo

Brighter future: Renewable Fuels & Chemicals



DOE, 2002

- **Displacement of oil**
- **Recycling waste**
  - Commodity chemicals
    - polylactic acid
    - 3-HP, 1-3 PD
    - Solvents, acids
  - Fuels
    - ethanol
    - biodiesel
    - power
  - Rural Employment

- **Carbon sequestration (short term)..**

UF Commercial Development

- Ethanol Technology – BC International LLC

  90/10 Hybrid Plant planned in US

  (Corn to ethanol + lignocellulose to ethanol)

  100% lignocellulose to ethanol in Japan

Two-ton per day pilot plants in Louisianna and Tokyo

- Organic Acid Technology – BioEnergy Inter., LLC

  (in large scale trials with multi-national company)

- Federal, State and Industry Sponsored Research

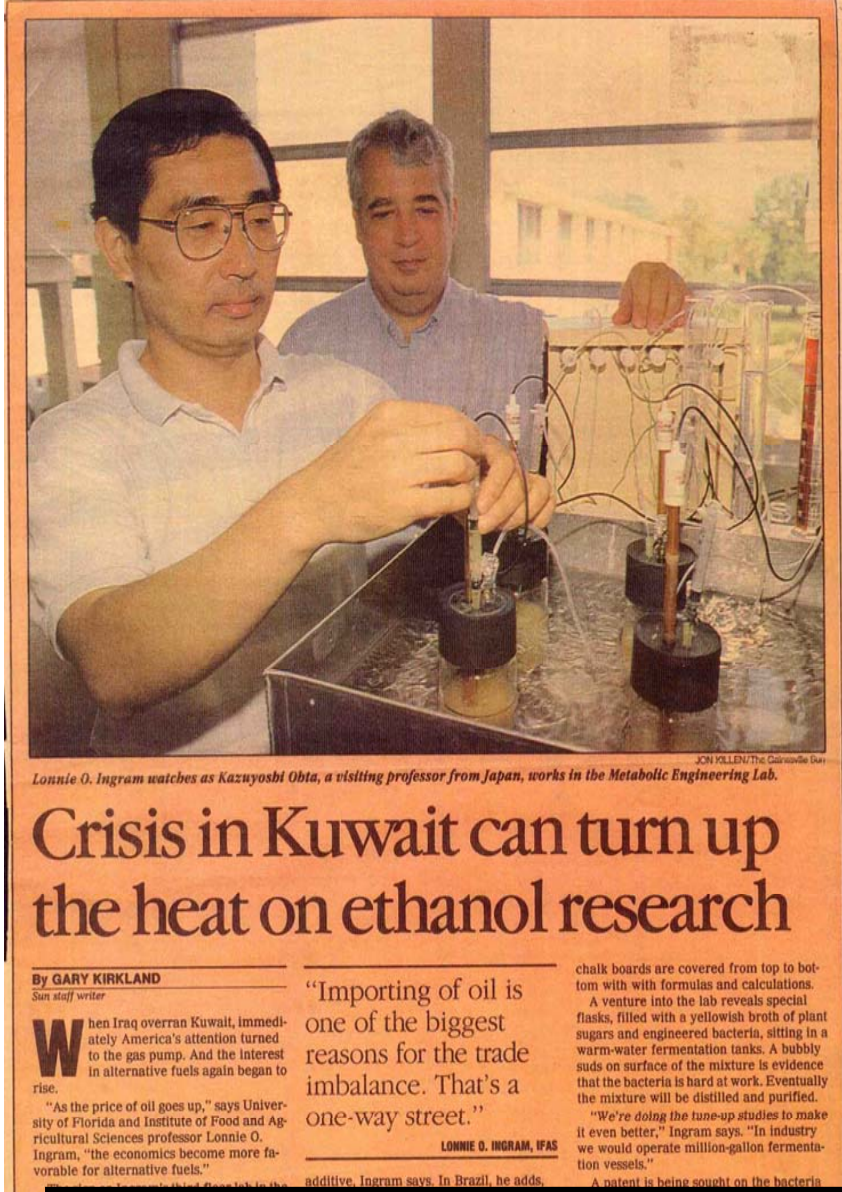
- Over 20 patents issued and pending; all licensed.

A short movie

- In Japanese, no subtitles
- Ethanol Pilot operation -- Wood waste
- Approximately 2 tons wood/day

Dependence on petroleum remains as the single most important factor affecting the world distribution of wealth, global conflict, human health, and environmental quality.

Reversing this dependence would increase employment, preserve our environment, and facilitate investments that improve the health and living conditions for all.



JON KILLEN/The Gainesville Sun

Lonnie O. Ingram watches as Kazuyoshi Ohta, a visiting professor from Japan, works in the Metabolic Engineering Lab.

Crisis in Kuwait can turn up the heat on ethanol research

By GARY KIRKLAND
Sun staff writer

When Iraq overran Kuwait, immediately America's attention turned to the gas pump. And the interest in alternative fuels again began to rise.

"As the price of oil goes up," says University of Florida and Institute of Food and Agricultural Sciences professor Lonnie O. Ingram, "the economics become more favorable for alternative fuels."

"Importing of oil is one of the biggest reasons for the trade imbalance. That's a one-way street."
LONNIE O. INGRAM, IFAS

chalk boards are covered from top to bottom with with formulas and calculations.

A venture into the lab reveals special flasks, filled with a yellowish broth of plant sugars and engineered bacteria, sitting in a warm-water fermentation tanks. A bubbly suds on surface of the mixture is evidence that the bacteria is hard at work. Eventually the mixture will be distilled and purified.

"*We're doing the tune-up studies to make* it even better," Ingram says. "In industry we would operate million-gallon fermentation vessels."

1989 - Professor Ohta conducting fermentation studies at Univ. Fla.