Bioenergy, Agriculture and the Chemical Industry

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Bioenergy and Agriculture

Bioenergy

Energy derived from renewable resources in the form of transportation fuels, electrical energy, heat and power. Broadly defined, bioenergy would includes solar, photovoltaic, wind energy, and biomass, including energy crops. Agriculture provides biomass.

Agriculture

"the science, art, and business of cultivating the soil, producing crops, and raising livestock; farming."

The American Heritage Dictionary, 1982

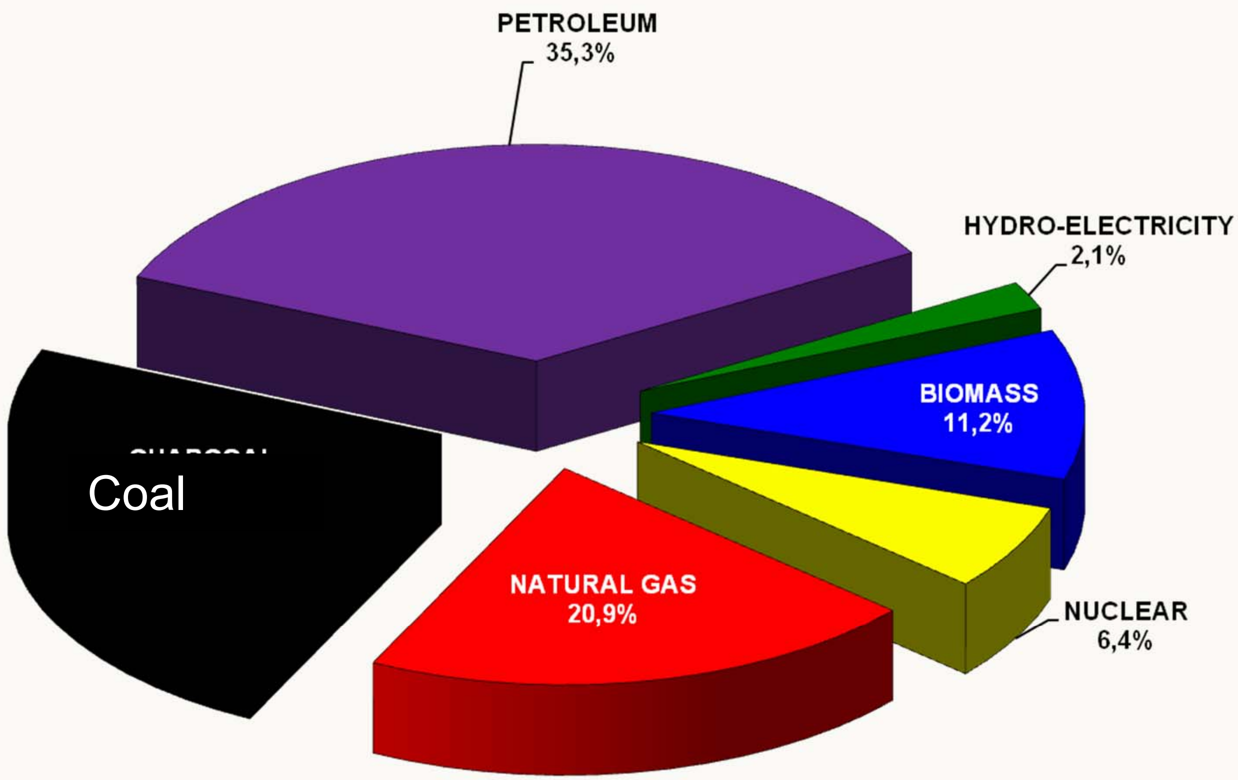
Snapshot: Agriculture in Mexico and US

Mexico:	27.3	million hectares total
	7.7	million corn
	67	kg fertilizer / hectare
US:	179	million hectares
	28.7	million in corn
	103	kg fertilizer / hectare

Mexico’s population about 40% of that of US.

2.47 acres = 1 hectare

World Energy Use: *13% is Renewable*



International Energy Agency (IEA) **2008**.

Embrapa

Ministério da Agricultura, Pecuária e Abastecimento

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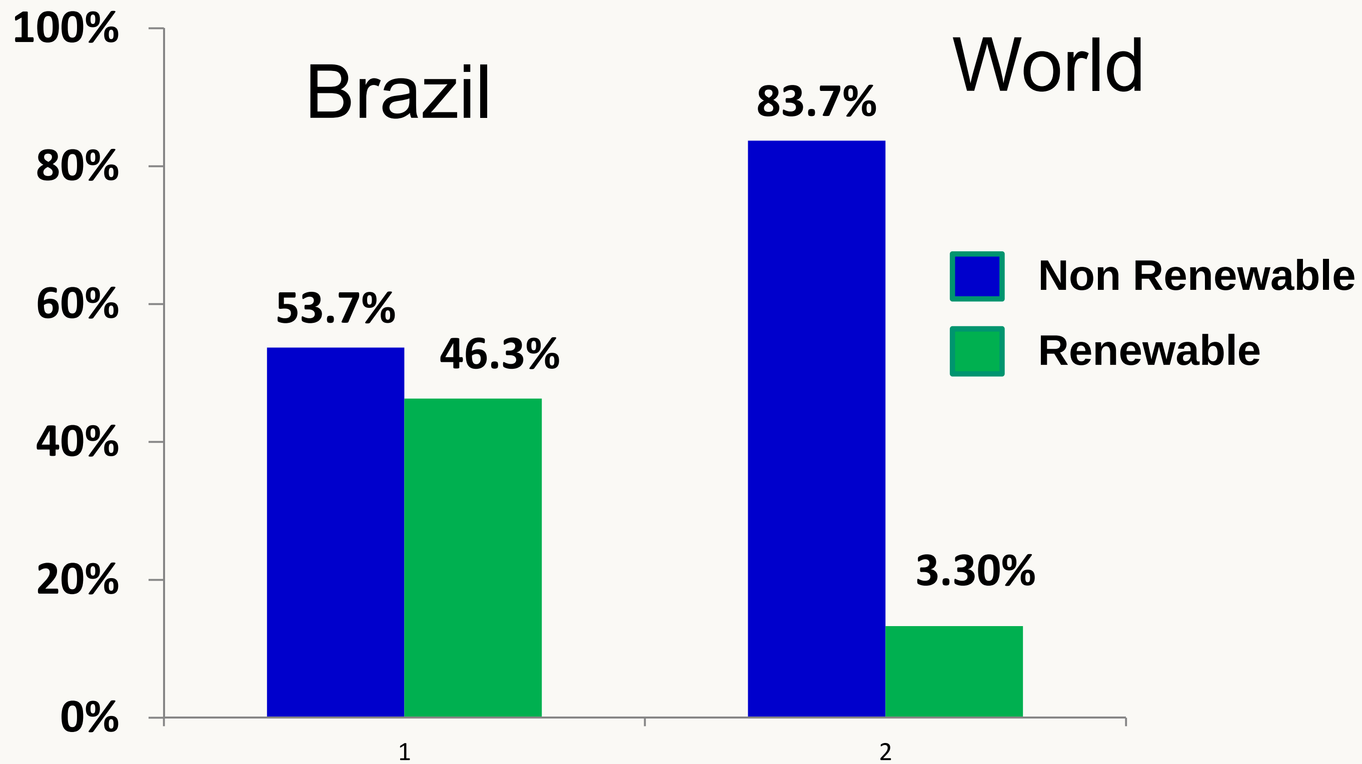
46 % Renewable Energy Use in Brazil



Source: MINISTÉRIO DE MINAS E ENERGIA - Brasil**, 2008**

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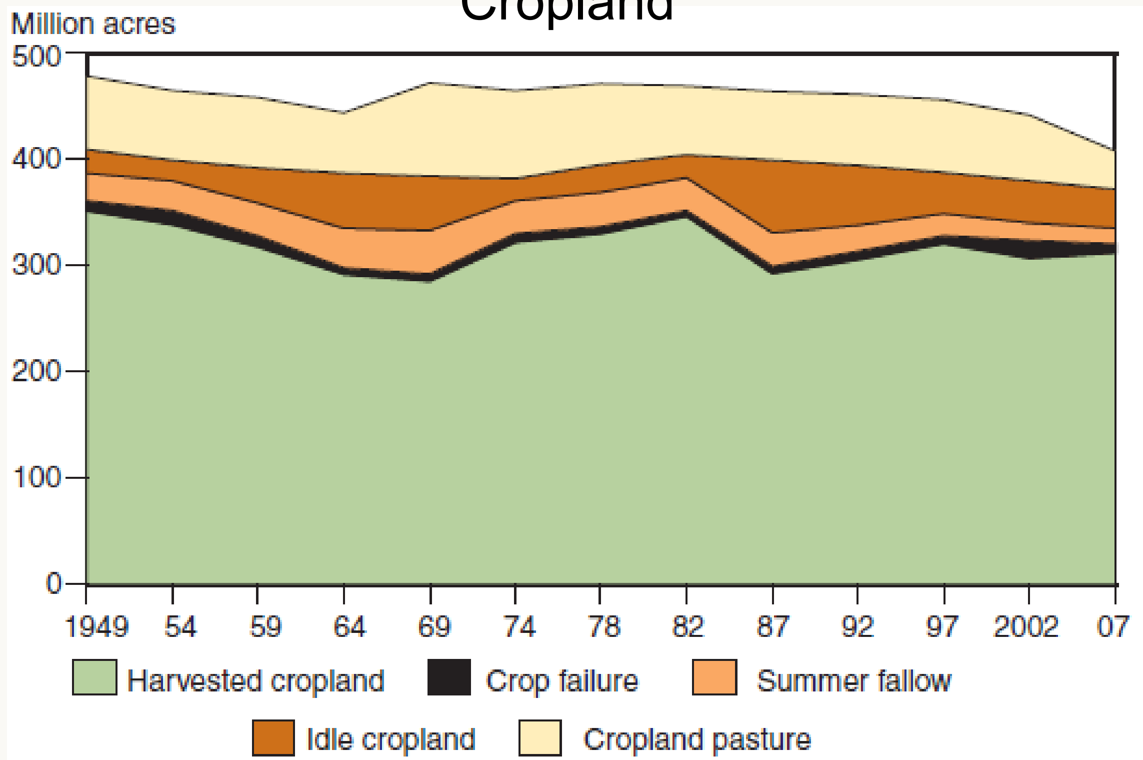
2007 US Land Use: 2.3 Billion Acres
18% is cropland

Allocated Use	% of Total
Forest-use Land	30
Grassland	27
Cropland	18
Parks, National Defense Areas, Transportation	14
Other	9
Urban Areas	3
	101

Cropland



Nickerson, Cynthia, Robert Ebel, Allison Borchers, Fernando Carriazo, *Major Use of Land in the United States,* 2007, EIB-89, USDA Economic Research Service, Dec, 2011

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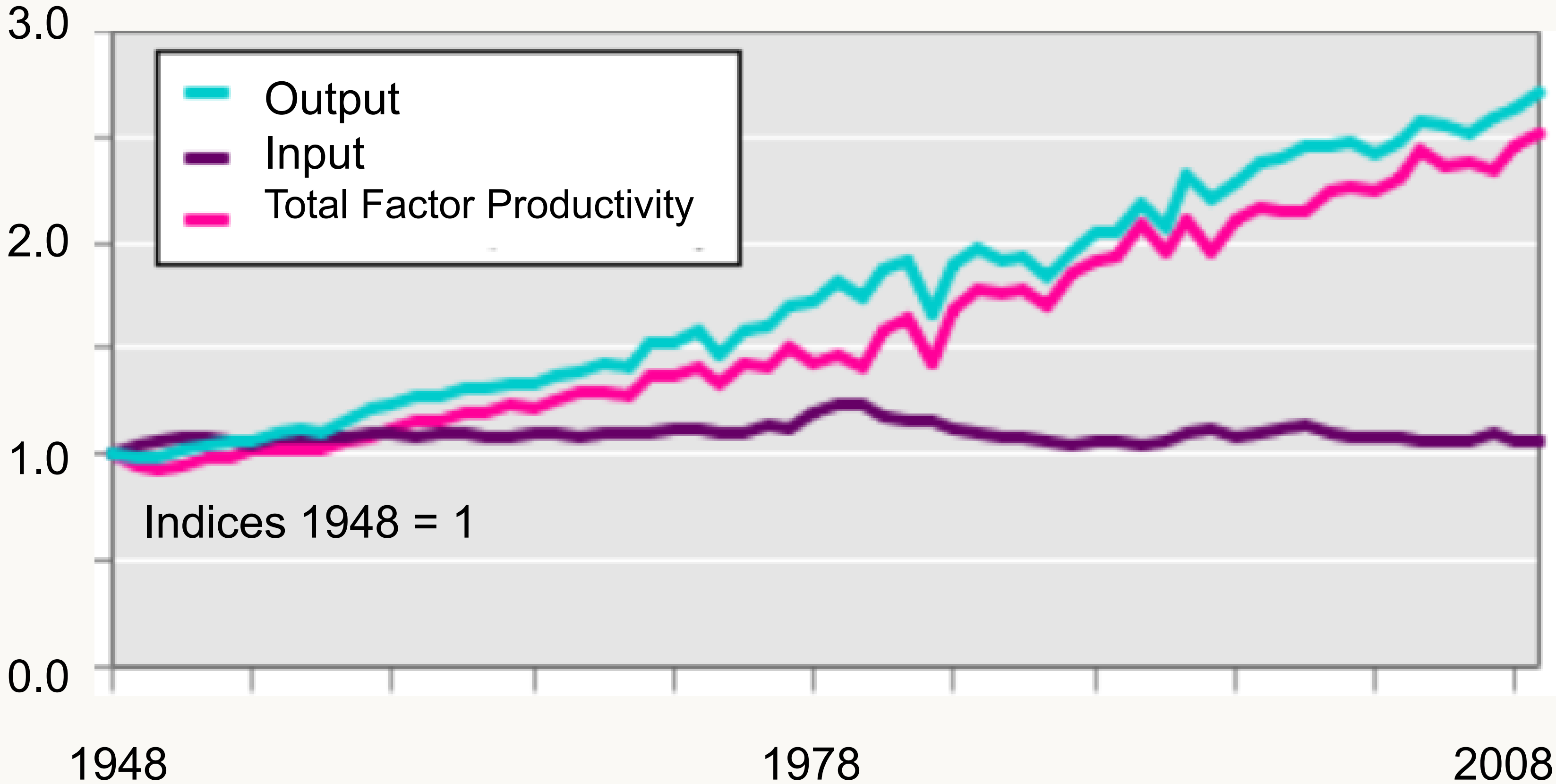
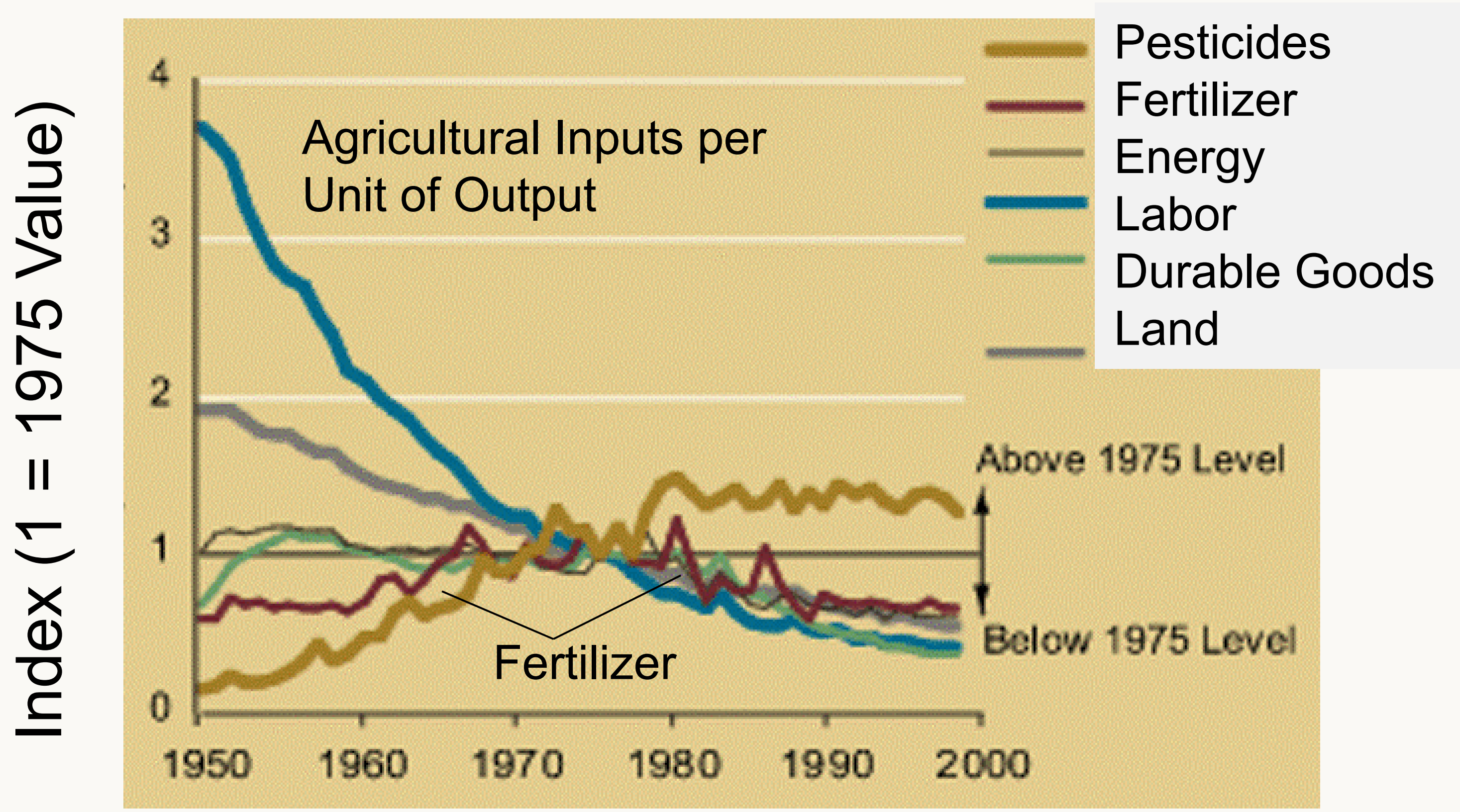
Agricultural Productivity



Source: USDA ERS

US Input / Output Ratios since 1950: fertilizers and pesticides are important



Source: USDA ERS

Agriculture depends on Chemical Industry for Fertilizer: Ammonia Synthesis

$$\frac{1}{2}N_2 + \frac{3}{2}H_2 \rightleftarrows NH_3 \ ; \quad \Delta H_{298K} = -45.7\,\text{kJ/mol}$$

Feedstocks:

- N_2 from air,
- H_2 from natural gas, naptha or heavy oil

Energetics (high pressure, temperatures, recycle require energy)

- Exothermic
- Rate favored by high temperature (1000 to 3000 C)
- Equilibrium favored by low temperature and high pressure

Role of Catalysis (Haber chemistry; process by Bosch; BASF)

- 1909 Os, reaction at 600 C,175 atm (80 g NH_3)
- 1913 Fe / Al_2O_3 / K catalyst, 400 – 700 C, 300 atm (30 tons NH_3)
- Other catalysts / processes developed (plants at 1500 tons / day)

from Modak, Resonance, 2002

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Ammonia Production (2010)

est. 80 % used for fertilizing crops.

Global Total Produced: 131 million metric tons (32% from China)

US total consumed: 14.7 million metric tons

Produced in US: 8.3 million metric tons
Imported: 6.4
Price: $390 / ton

43 % imported [1]

Currently depends on natural gas, a non renewable resource.

[1]U.S. Geological Survey, Mineral Commodity Summaries, January 2011

Companies and customer

Seed Producers

- Dow Agrosciences
- Monsanto
- Dupont
- Syngenta
- Bayer

(Biotech)
Chemical Enterprise

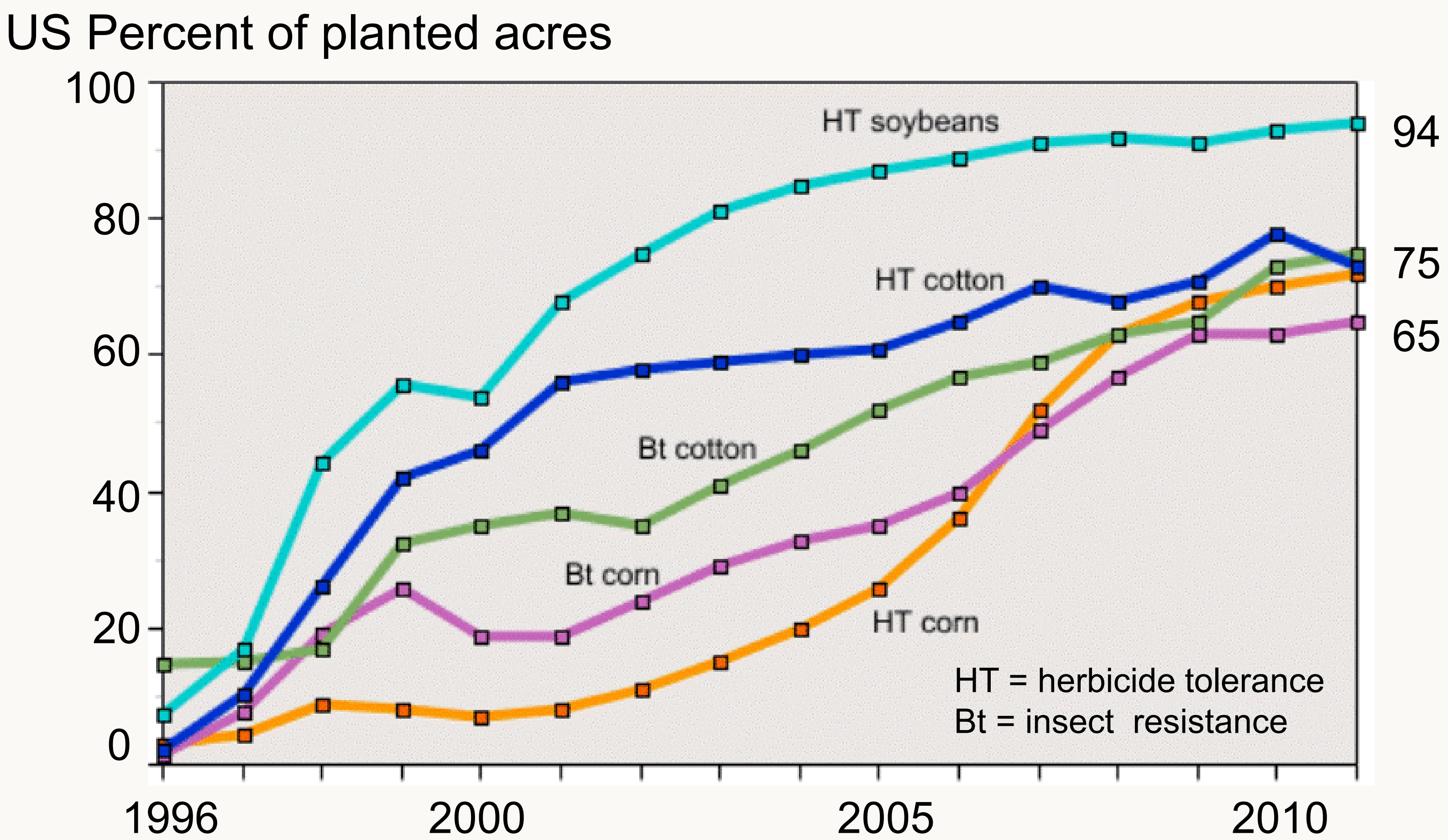
GMO Crops

- Soybeans
- Maize
- Sugar Beet
- Potato
- Cotton

Agriculture

Industry websites; GMO Compass, Genius GmbH, 2008

Increase in Genetically Engineered Crops



Fernadez-Cornejo, USDA, ERS, July 1, 2011

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Energy consumed in Agriculture

US Energy Consumed and CO2 emitted (snapshot, 2005)

	Energy, quads	CO_2, Tg emissions
Agriculture	1 +	69
All Sectors	95	5874
Total US	96	5943

+Does not include fertilizer, pesticide inputs

Fuel vs Food Debate?

US agriculture and Forestry Greenhouse Gas Inventory, 1990-2005, USDA

Biomass (Cellulose) is Part of Agriculture

a. Agricultural residues
   Global, US Midwest
b. Wood
   Upper Midwest US, Canada (hardwoods)
   Southeast US (softwoods)
   Europe (softwoods, hardwoods)
c. Purposely grown energy crops
   Brazil
   US – still to be determined
   Africa?

Feedstocks for the Chemical Enterprise: Cornstalks

1 to 2 tons (dry basis) / acre

with permission, Shinners, 2009

Purposely Grown Switchgrass

Warm-season perennial grass

Low fertility requirement

Tolerant of poor soils

High yield (5-7 ton/acre)

Photos courtesy of Department of Agronomy, Purdue University

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Biorefineries and the Chemical Enterprise

Bio(chemical) refinery:

1. Produce energy from renewable domestic raw materials (energy goal)
2. Establish robust biobased industry (economic goal)
3. Establish off-take contracts.

Biorefineries with diversified product portfolios could offer great potential for agriculture to capture added value, and a higher return on investment, while achieving energy and economic goals simultaneously.

Bozell and Petersen, 2010

Agriculture gives back:
Biochemical and Chemical Conversion

Transformation through Intermediates (sugars)

"Biochemical conversion"

main difference is in the primary catalysis system

Reduction to building blocks (CO, H_2)

"Thermochemical conversion"

David Dayton, NREL, IEA, 2007

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Red Ocean / Blue Ocean

Red Ocean: is where every industry is today: there is a defined market, defined competitors, and a typical way to run a business in any industry.

Blue Ocean: On the other hand, is where everyone would like to be. It is where you create uncontested markets and capture new demand, is where you break the value-cost trade-off and is where you make the competition irrelevant.

Chan Kim & Renee Mauborgne, Blue Ocean Strategy, 2005

Agricultural Markets in the Americas

What can be done?

Red Ocean

- Grain / Sugar / Vegetable Oils
  - Food (People)
  - Feed (Animals)

Blue Ocean Strategy Thinking

- Cellulosic Biomass
  - Liquid Fuels
    - Ethanol Biofuel
    - Organic Molecules
  - Chemicals
    - Organic Molecules
    - Acids Aldehydes

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MASCOMA FRONTIER RENEWABLE RESOURCES

Mascoma's CBP Process

Consolidated Bioprocessing ("CBP") Technology

Feedstock

→

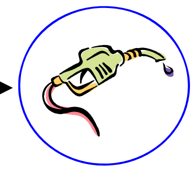
CBP

Simple Pretreatment → Bioprocessing and Distillation

Direct microbial conversion of cellulosic biomass to ethanol

→

Ethanol



Value Drivers

- Ethanol market & infrastructure in place
- Federal mandates for price and volume

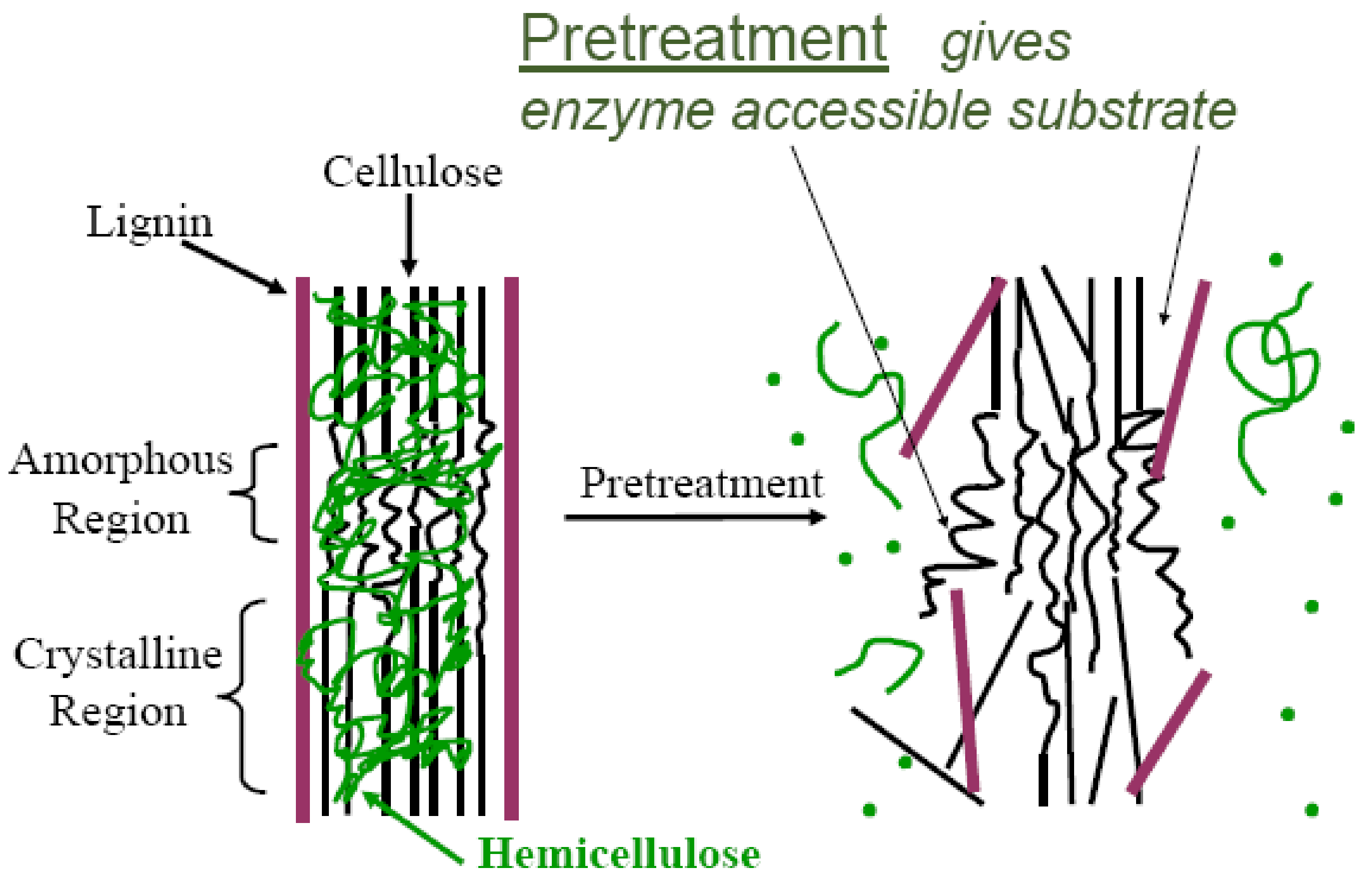
Technology Advantages

- Little to no additional enzymes
- Single tank fermentation

Economic Advantages

- Low operating costs
- Low capital costs

Pretreatment Principles (step 2)



Mosier et al, 2005

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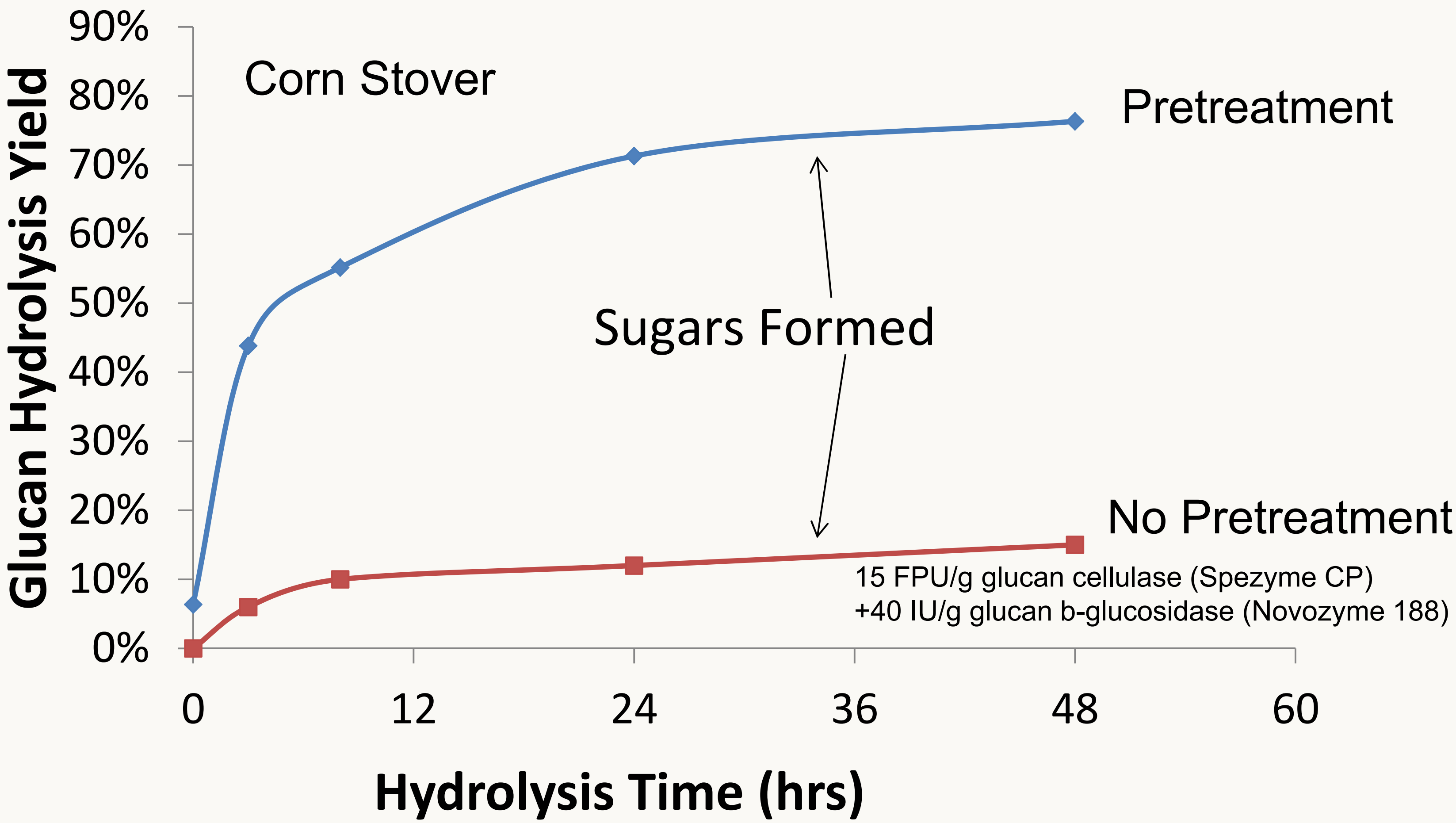
Technology benefit of pretreatment: enhanced hydrolysis yields



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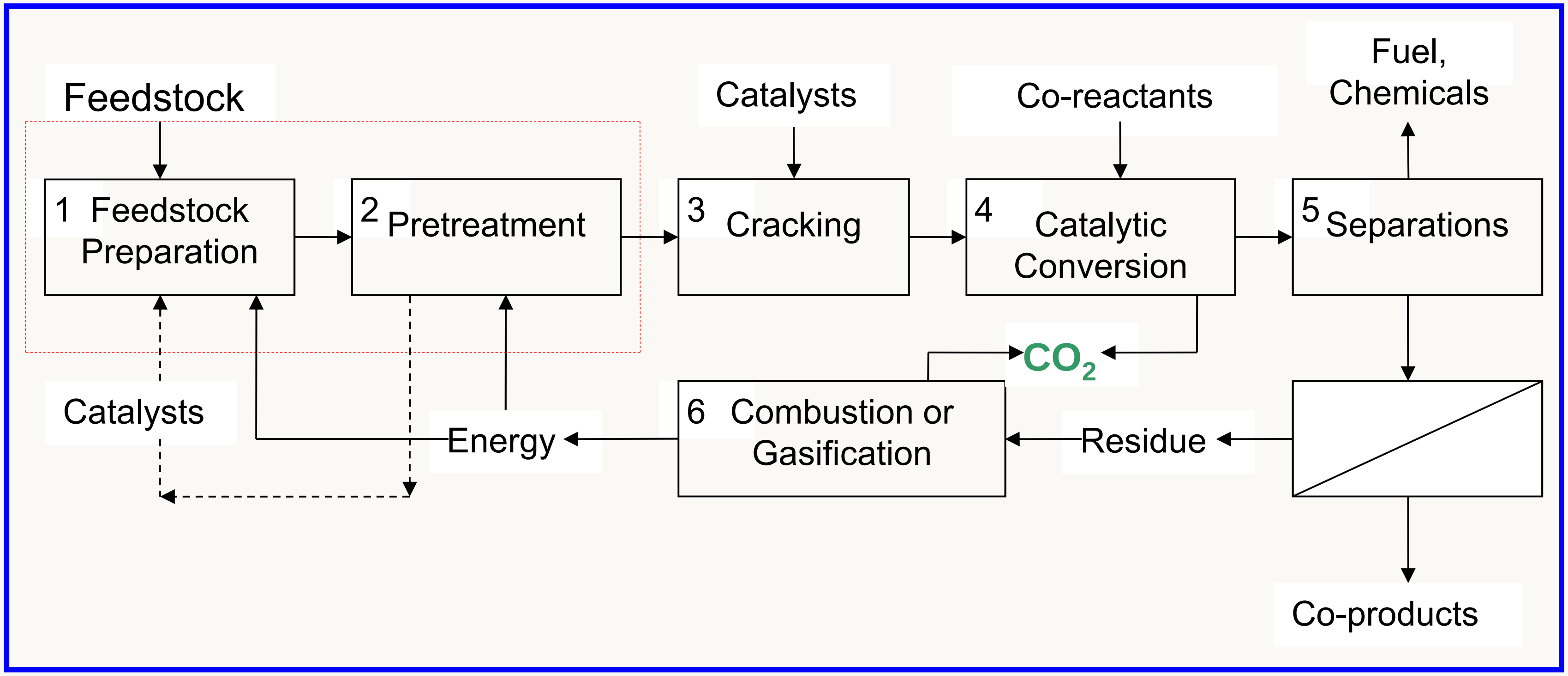
Thermochemical Conversion of Cellulose: familiar to the Chemical Enterprise



High temperatures / pressures, inorganic catalysts, requires low moisture feedstocks

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Potential Market Demand

Global Industrial Chemical Production

80 million tons of industrial chemicals / yr.

Utilizes 3 billion barrel-of-oil equivalents (crude oil, naphtha, and natural gas).

Petrochemical types:

Base chemical building blocks, intermediate chemicals, and polymers derived from building blocks

Look for oxygenated chemicals, derived from sugars with high margin in the future ("green" image, from renewable feedstocks)

Burk, 2010; Wetzel et al, 2006.

Furans (precursor for levulinic acid, THF)

Sugar

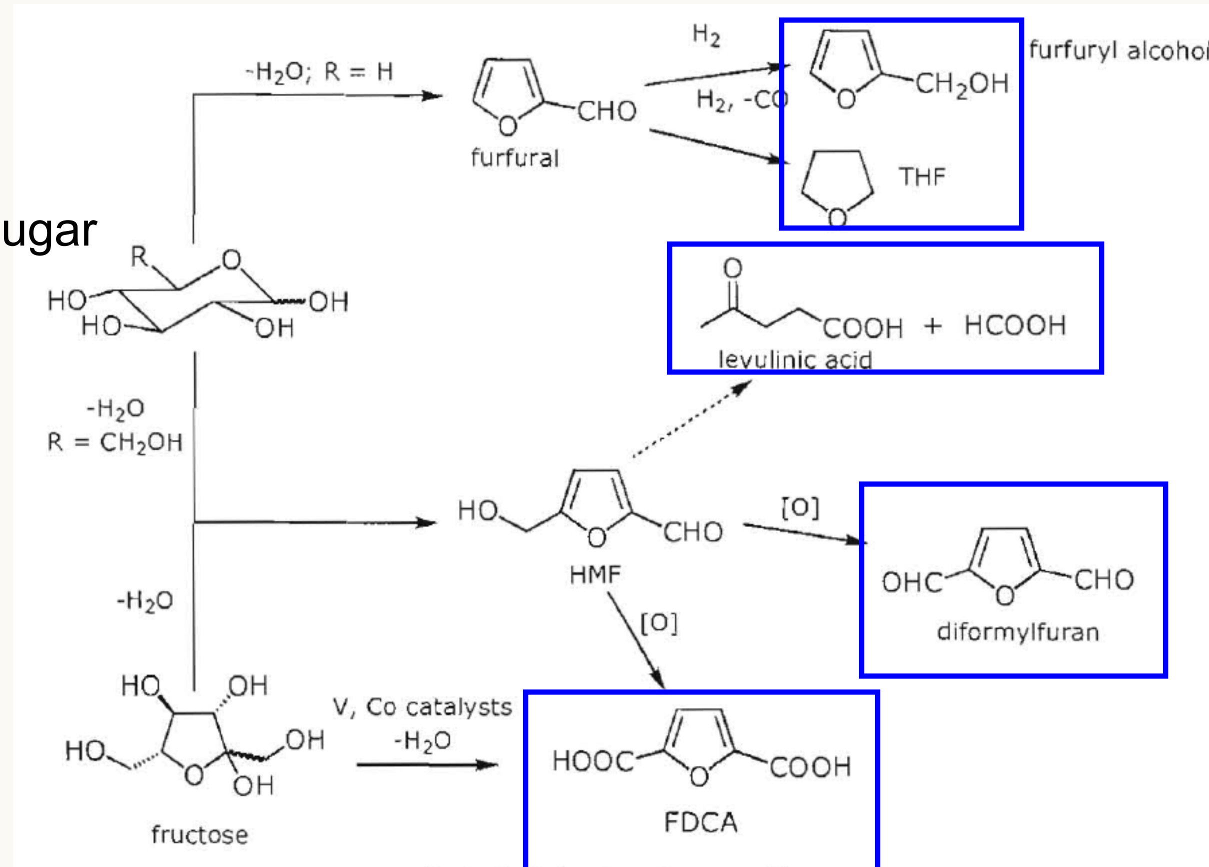

Fig. 2 Synthesis and transformation of furans.

Bozell and Petersen, 2010

Platform Chemicals from Sugars

Sugar derived platform chemicals include

Hydroxymethylfurfural(HMF)
Furfural
Levulinic acid
γ-valerolactone

→

Chemical building blocks
Hydrocarbon fuels

Catalytic conversion to alkanes, and to precursor molecules for use in production of polymers, lubricants, and herbicides.

Bozell and Petersen, 2010

Products from Levulinic Acid
Potential Market Demand (small but significant)

Product	Use	Potential lactic acid market (million lb/year)
Methyltetrahydrofuran (MTHF)	Fuel extender	10,000-100,000
Delta-aminolevulinic acid (DALA)	Biodegradable herbicide	175-350
Diphenolic acid	Polymers	35
Tetrahydrofuran (THF)	Solvent	200
Succinic Acid	Food additives, Pharmaceuticals	1,000
Butanediol	Monomers	200

Bozell et al., 2000, Hayes et al., 2008

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Economic Synergies between Agriculture and the Chemical Enterprise

Agriculture is market for:

- Seeds
- Fertilizers
- Pesticides / herbicides

Agriculture provides hedge for some feedstocks needed by chemical enterprise

- Oil
- Carbohydrates
- Cellulosics
- Fermentation substrates

Translation of science from discovery to commercial scale is critical: requires sustained research and development

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Partnerships (Agriculture and Chemical)

Chemical enterprise (exports of $ 86.9 billion, 2011).
Possible partnerships based on

1. discovery of new processes based on sugars
2. research on utilization of renewable resources
3. business models based on products from agricultural (particularly cellulosic) commodities

Agriculture (In U.S. net balance of trade of $43 billion, 2011; projected $24 billion in 2012)

1. design / grow crops for value-add chemicals
2. continue improvements in productivity
3. business models for year round supply
4. Industrial fermentation capacities

Conclusions

Chemical Enterprise and Agriculture are inter-dependent.

Resources are available to produce both food and chemicals.

1. Land
2. Seeds.
3. Productivity

The Chemical Enterprise will provide production tools to Agriculture, either in the field or in the plant.

Combined impact could be to reduce energy (feedstock) costs, and provide sources of biomass based bioenergy.