Biofuels and Feedstock Potential

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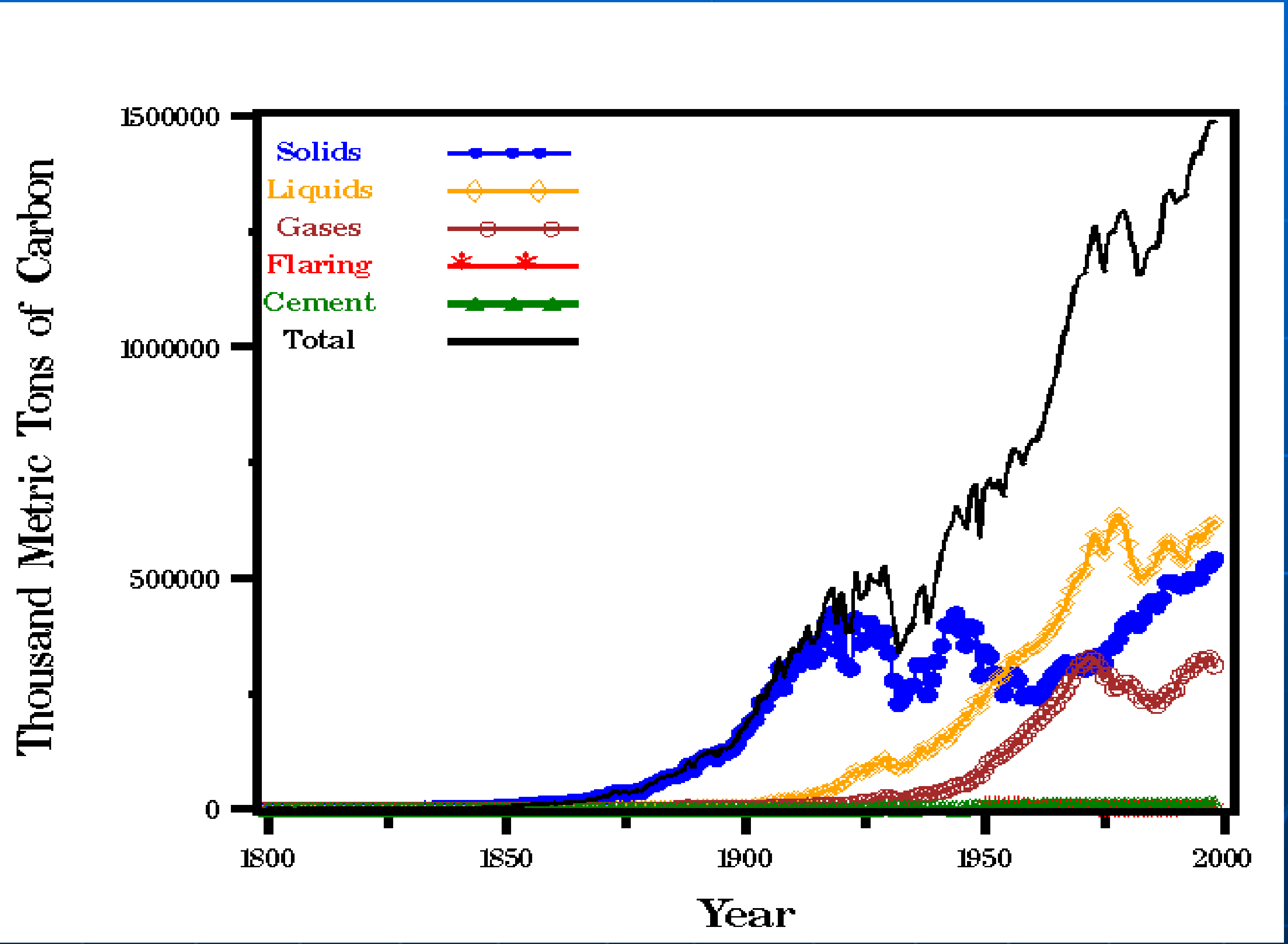
Outline

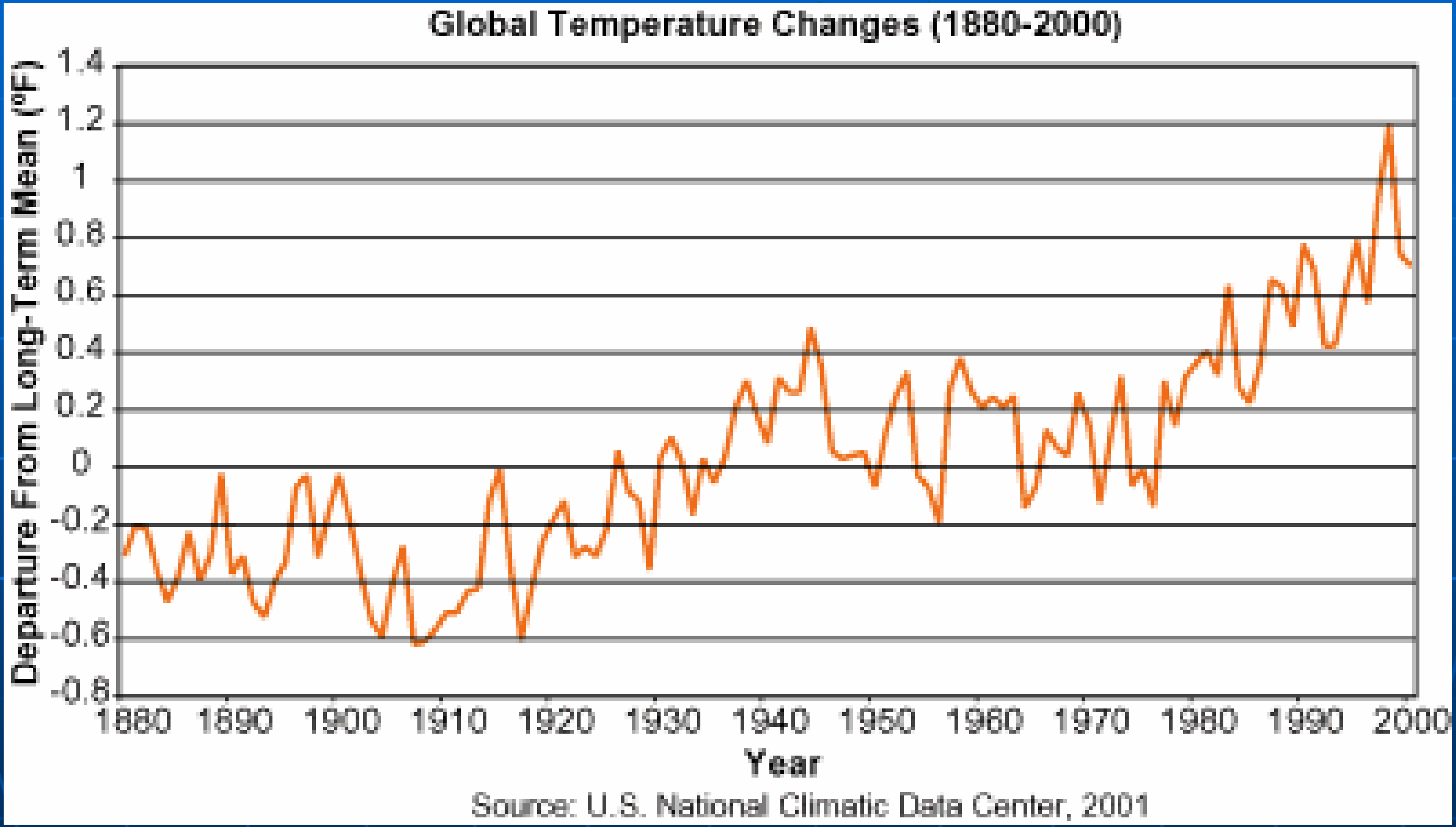
- Energy Consumption
- Drivers for Biofuels
- Biofuel Processes
- Feedstock Options
- Competition for Land Usage

Industrial Revolution & Energy Consumption

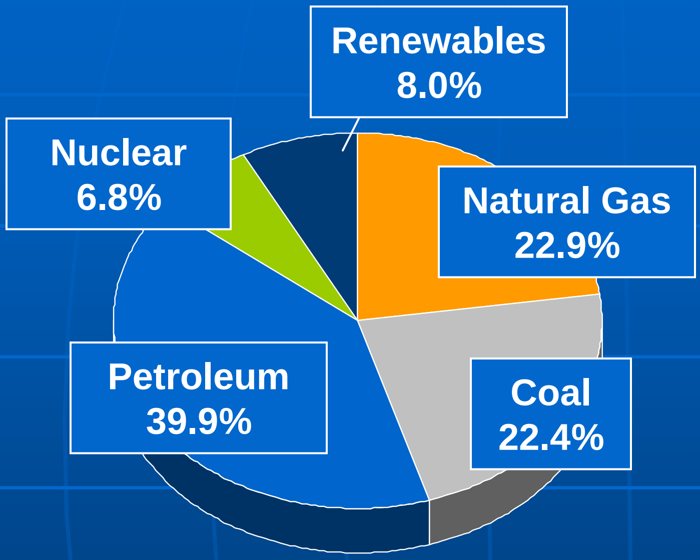


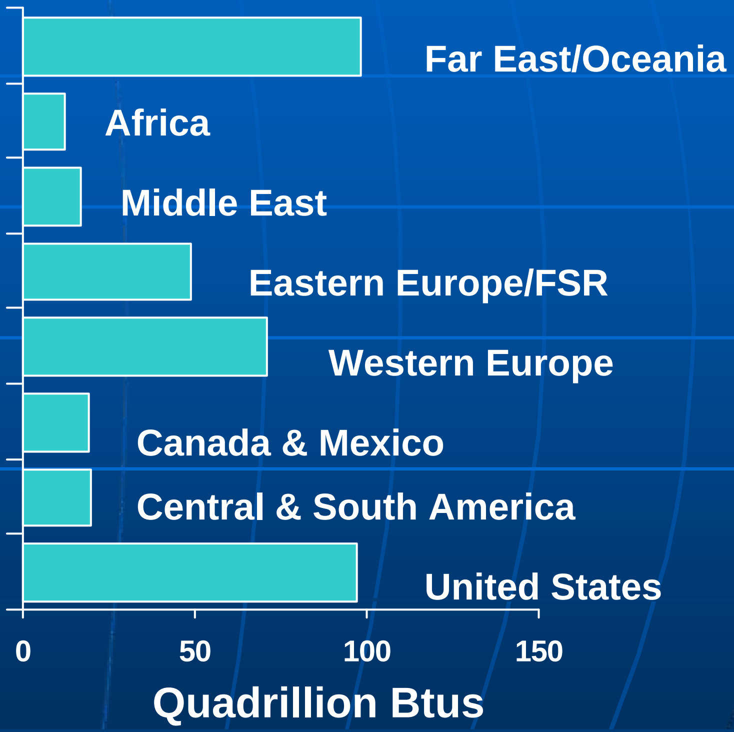
http://cdiac.esd.ornl.gov/trends/emis/em_cont.htm

Industrial Revolution & Temperature Change



Facts and Figures: World Energy Use



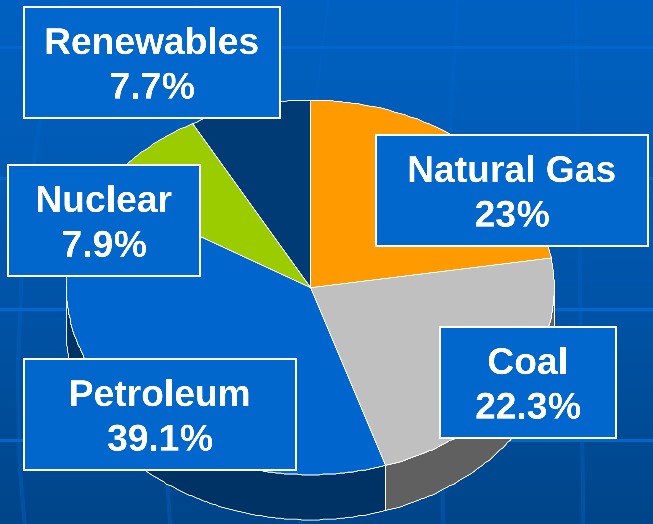


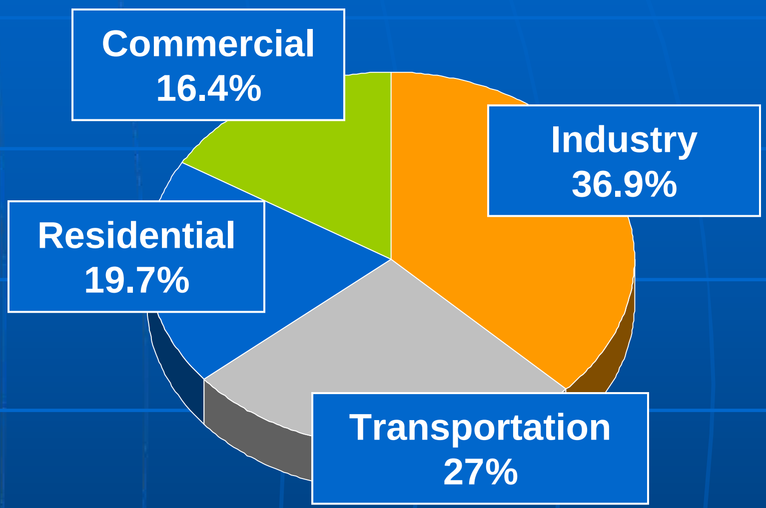
World Energy Use
400 Quads

Population ~ 6.5 billion

61.5 million Btu/capita

Facts & Figures: U.S. Energy Use





U.S. Energy Use

106 Quads

Population ~ 300 million

353 million Btu/capita

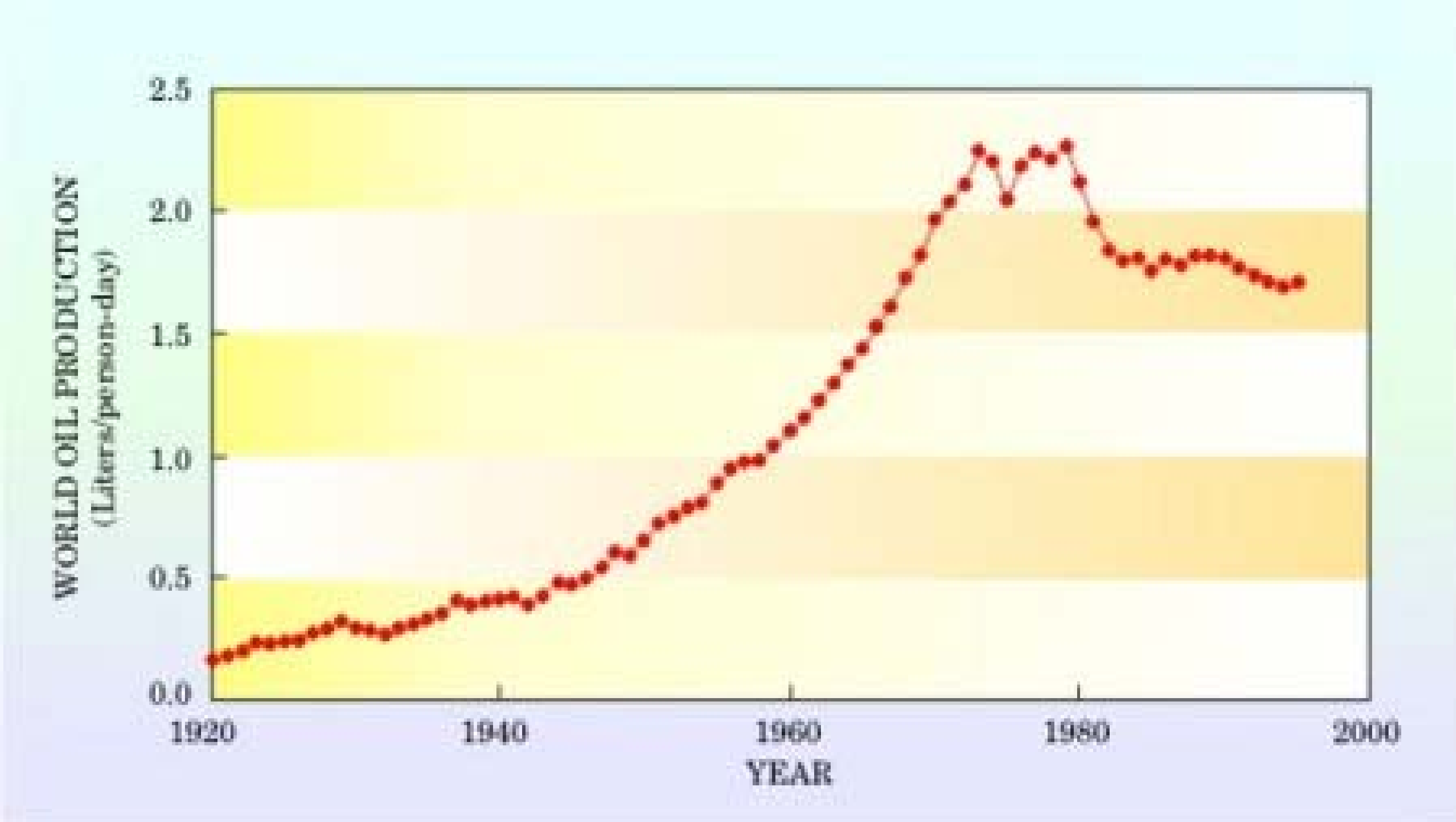
10^{15} BTU = 1 QUAD

A burning Match	1 BTU
A stick of Dynamite	2,000
100 hrs of TV	28,000
1 gallon of Gasoline	125,000
Annual food for one Person	3,500,000
Heat St Louis House/Year	90,000,000
Apollo 17 to the Moon	5,600,000,000
Hiroshima Atomic Bomb	80,000,000,000
Oklahoma energy/year	1,000,000,000,000,000
US Energy consumption	106,000,000,000,000,000
World Energy consump	400,000,000,000,000,000

Peak Oil

- Defined as the point in time when production rate begins to decline. Usually coincides with ~ 50% of oil remaining in an oil field.
- American peak was reached in 1973.
- Global peak predicted in 2010-2020.

Daily Oil Production per Person-Day



AA Bartlett, Math. Geol. **32**, 1 (2000)

Drivers for Renewable Fuels

- Global population growth
  1803, 1927, 1960, 1974, 1987, 1999
- Improved quality of life
- Fossil fuel availability
- Security/independence
- Climate change
- Energy policy

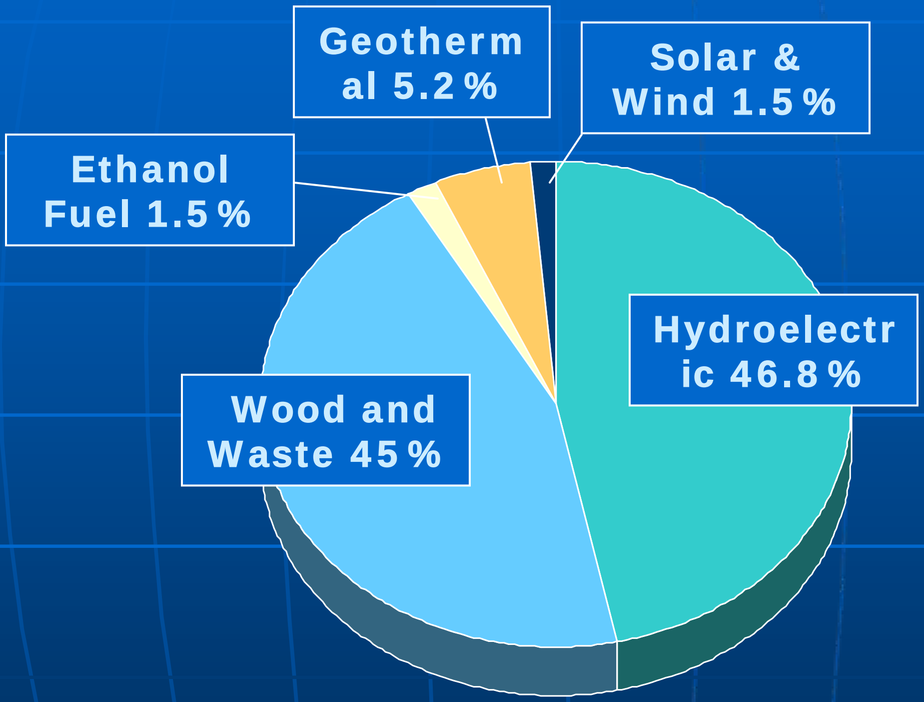
The President's Proposed Energy Policy

Jimmy Carter
Televised speech April 18, 1977

"Tonight I want to have an unpleasant talk with you about a problem unprecedented in our history. With the exception of preventing war, this is the greatest challenge our country will face during our lifetimes. The energy crisis has not yet overwhelmed us, but it will if we do not act quickly.

It is a problem we will not solve in the next few years, and it is likely to get progressively worse through the rest of this century…We simply must balance our demand for energy with our rapidly shrinking resources. By acting now, we can control our future instead of letting the future control us."

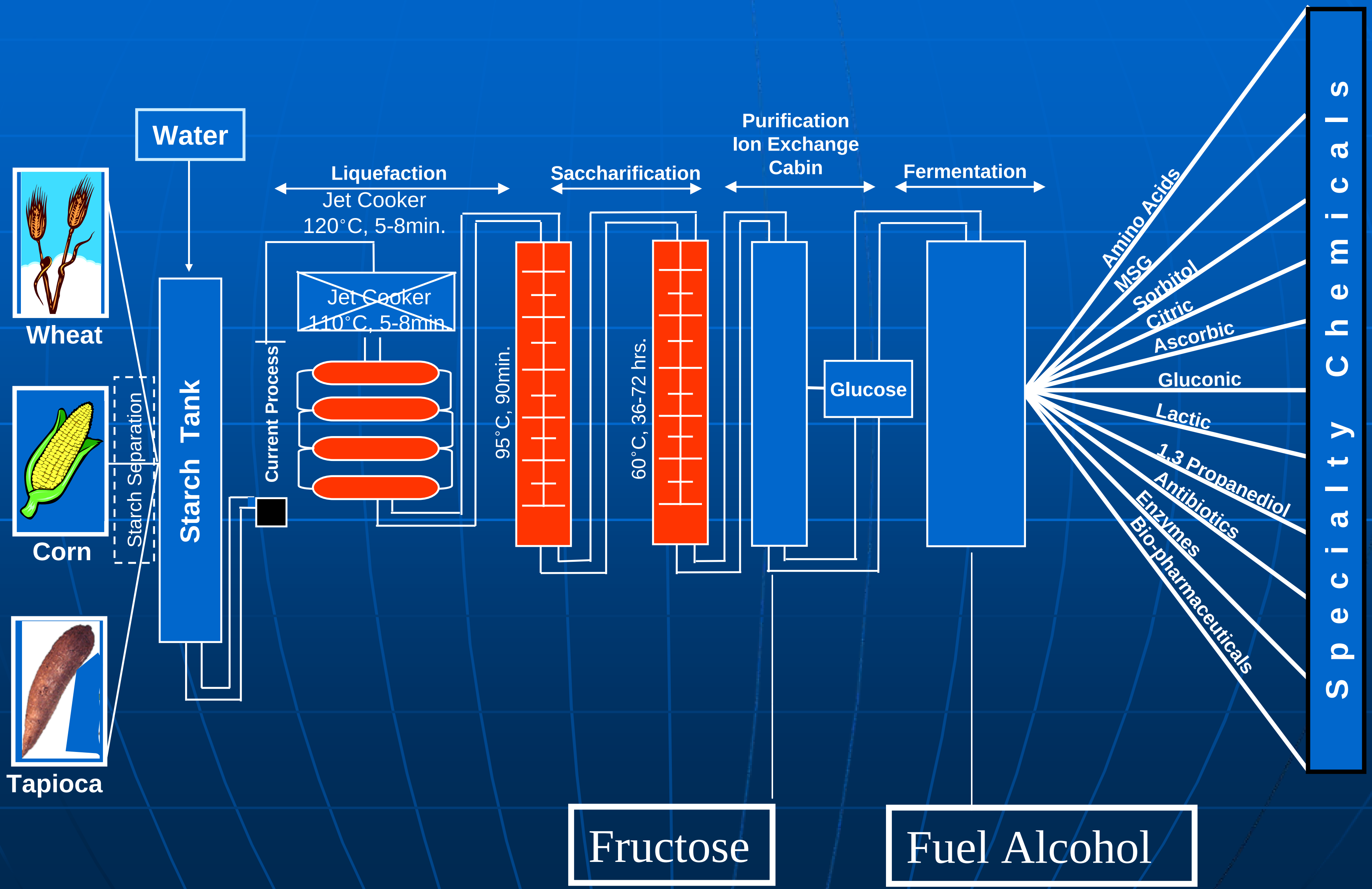
U.S. Consumption of Renewable Energy



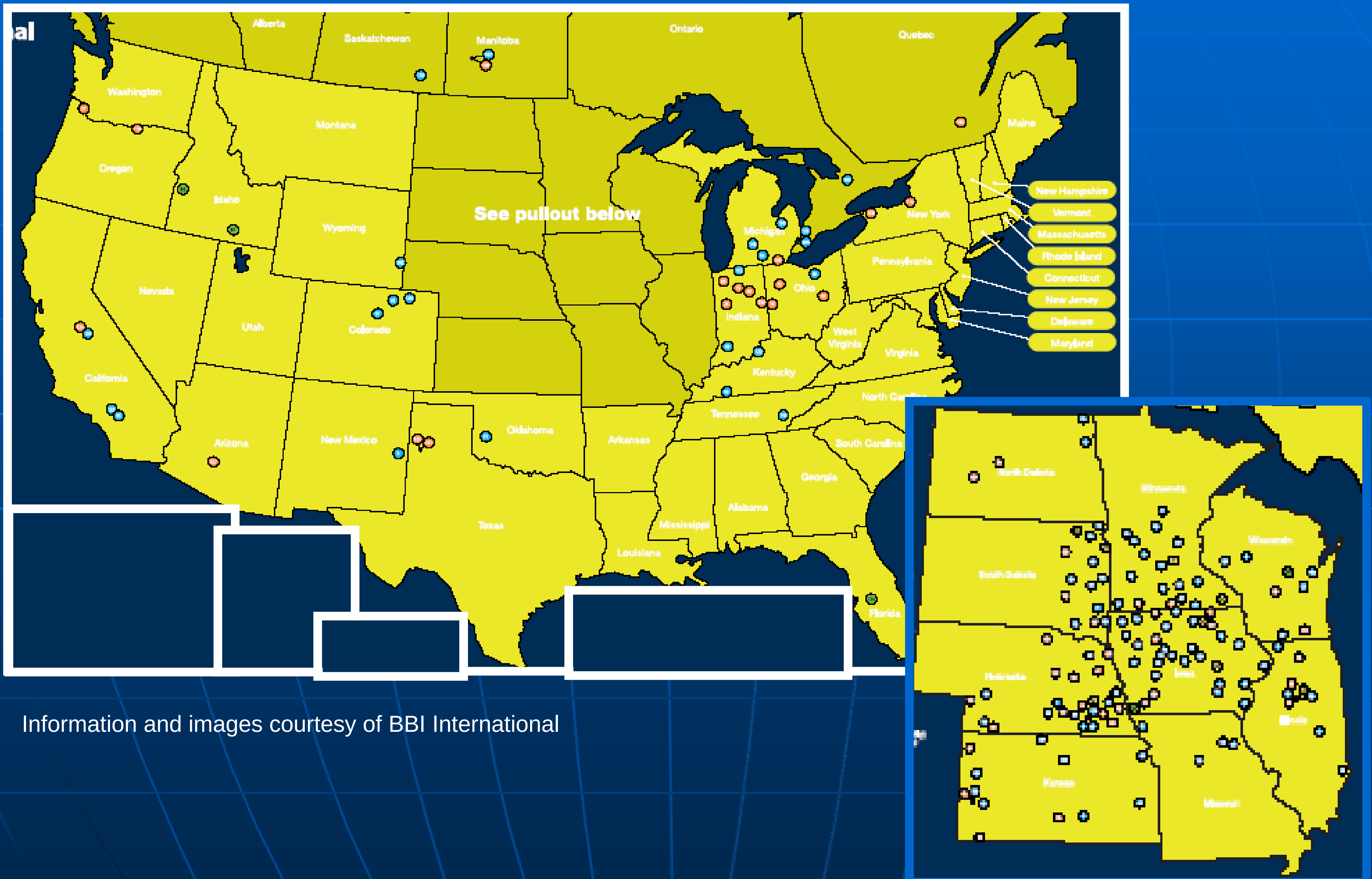
Total Renewable Energy Use 7.5 Quads

7.7% of U.S. Energy Consumption

Process for Converting Starch to Biochemicals



Current Status - Ethanol

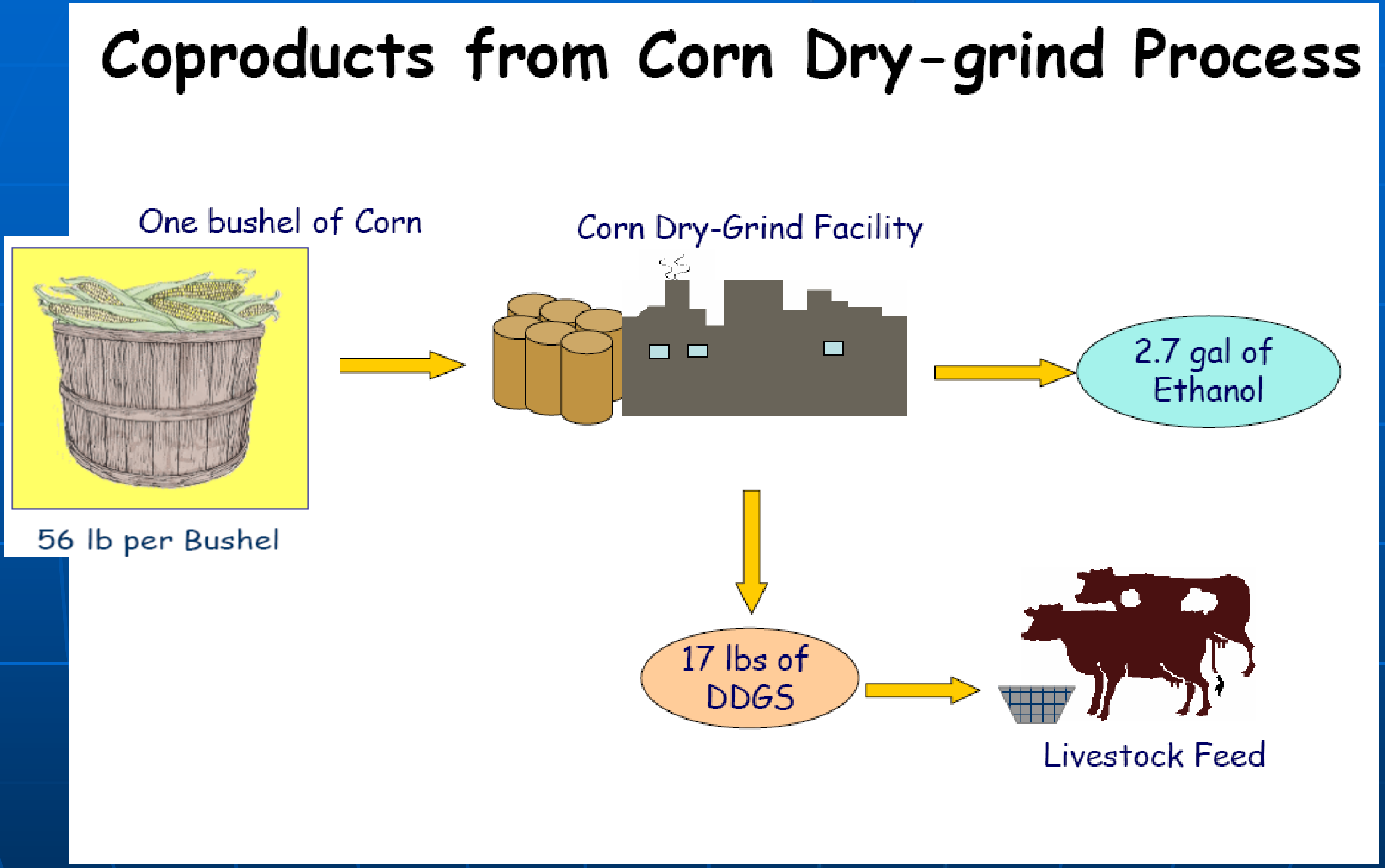


Information and images courtesy of BBI International

Ethanol Industry at a Glance

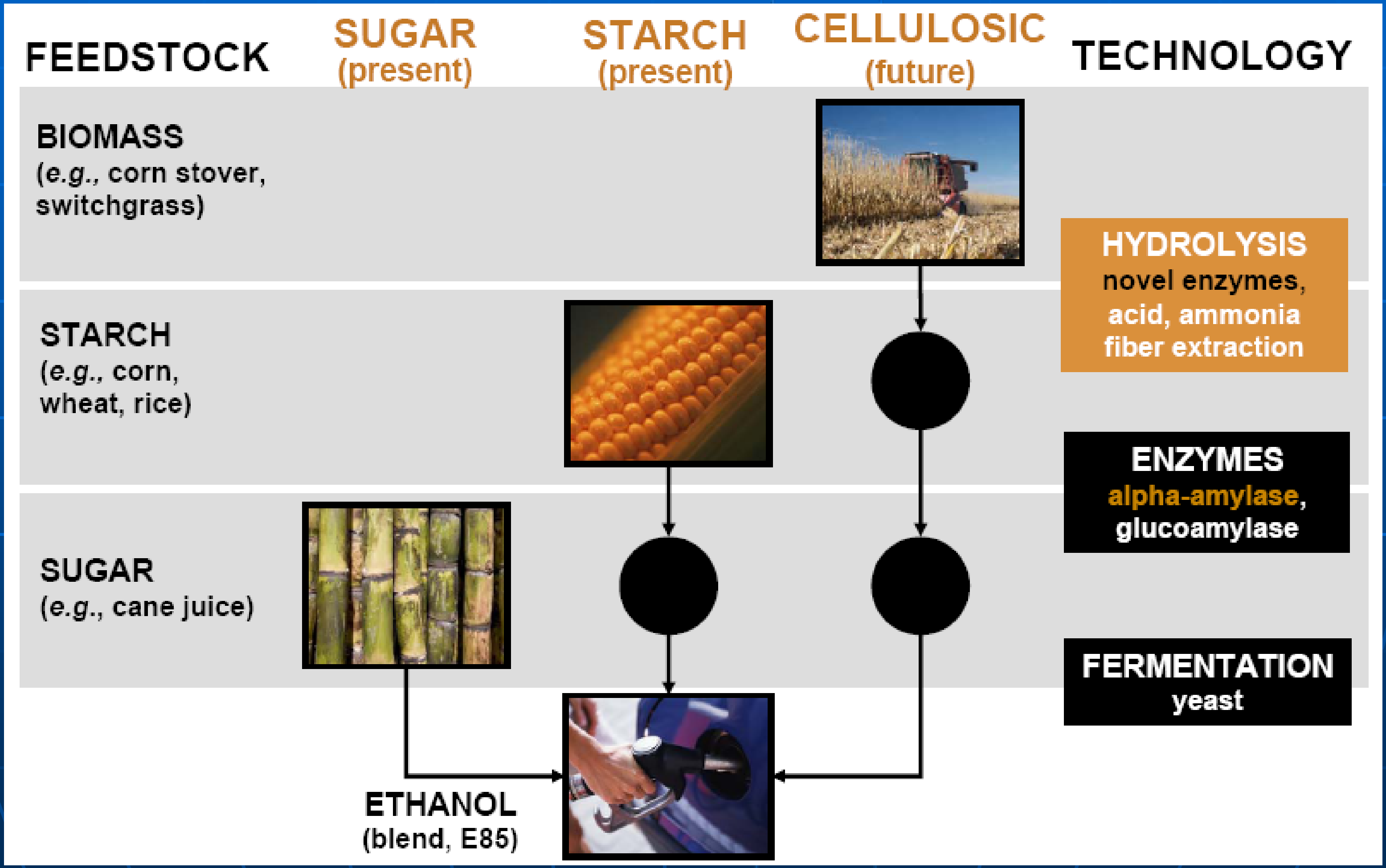
- Number of operating ethanol plants: >120
- Plants under construction or expansion: 86
- Announced plants: 300*
- 2006 production: 4.6 billion gallons
- Projected production capacity: 9.5 BGPY at end of 2007 (RFS Program mandate 7.5 BG by 2012)
- Size: Newer plants 100 MGPY
- Process: dry or wet
- Daily water usage – 1.5 million gallons
- Historic feedstock percentage:

Corn	97
Sorghum	2
Other	1



Using Corn in Modified Corn Processing – David Johnston

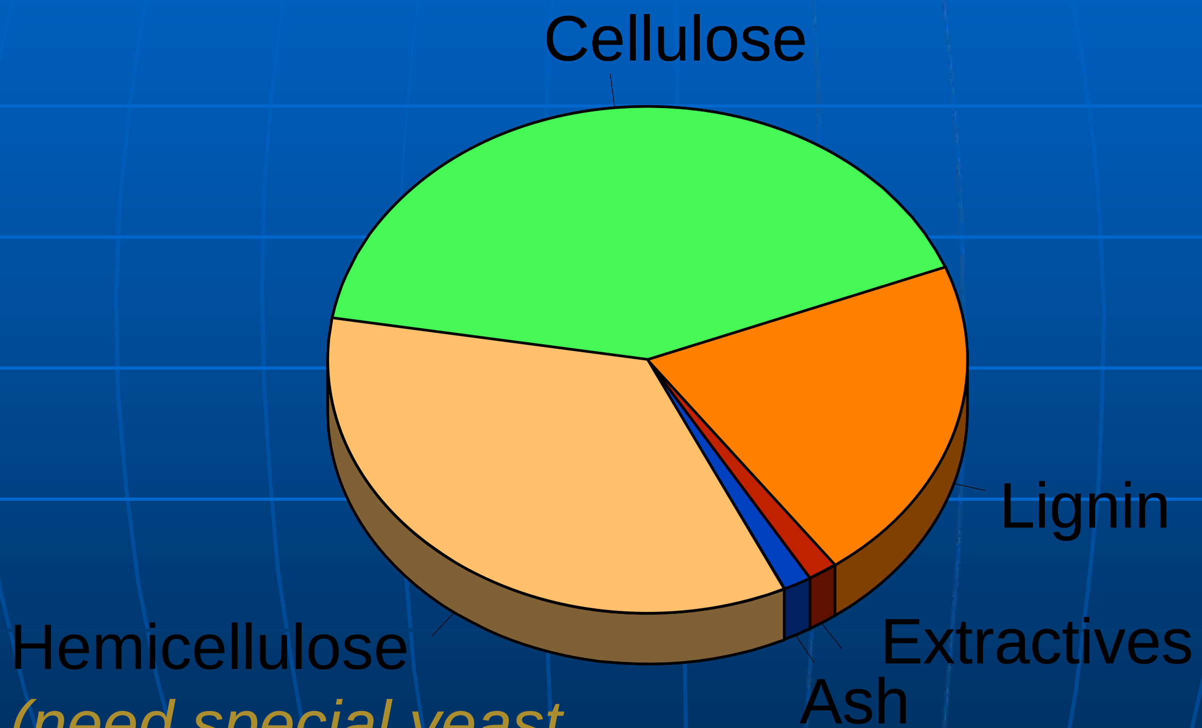
Carbohydrate Bioconversion



Cellulosic Ethanol

- More abundant, underutilized resource
  - Processing co-products
  - Crop residues
  - Dedicated energy crops
- Pretreatment process needed
- New enzyme systems
- 5-carbon sugars need to be fermented

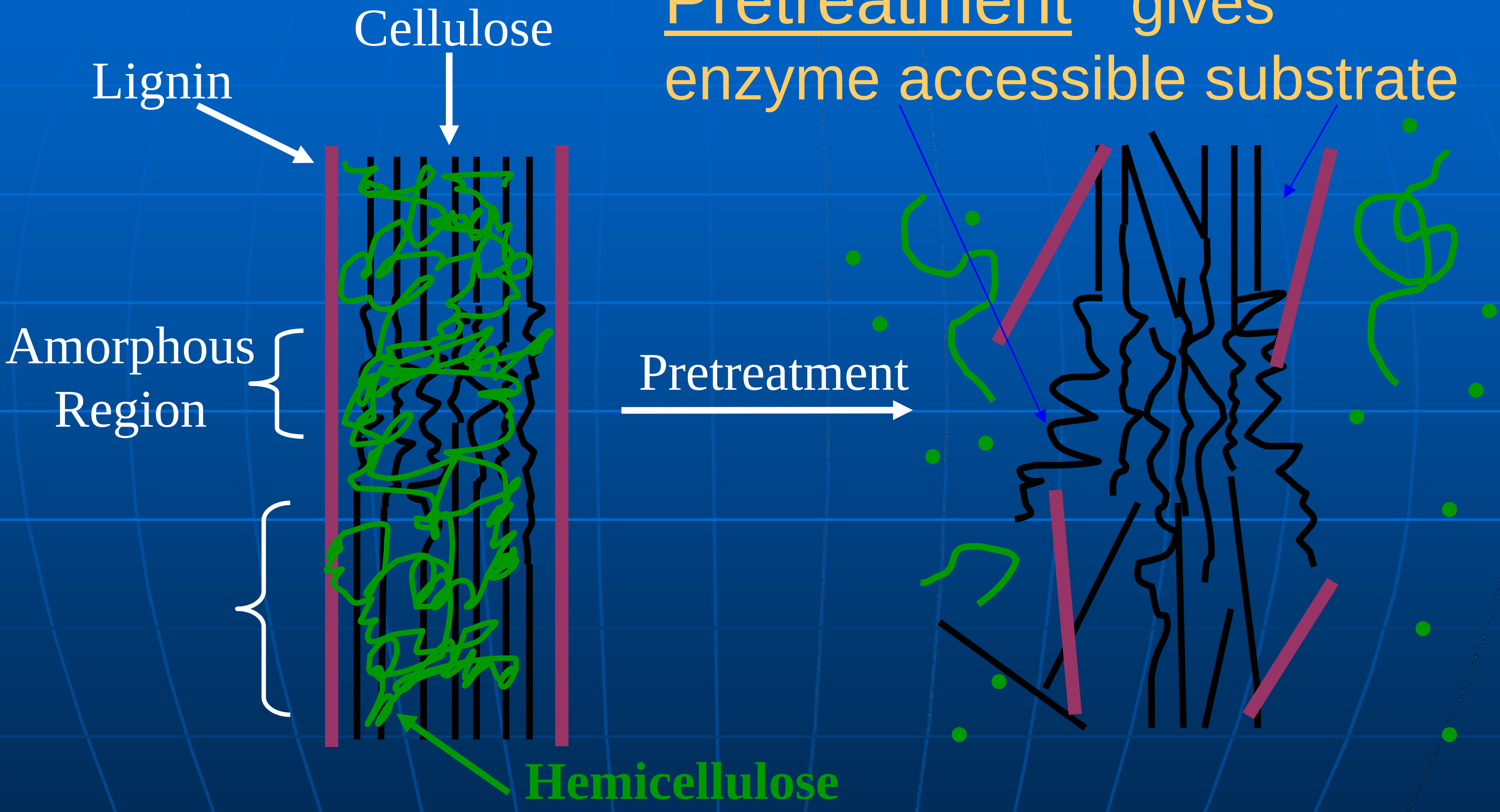
Components of plant cell walls



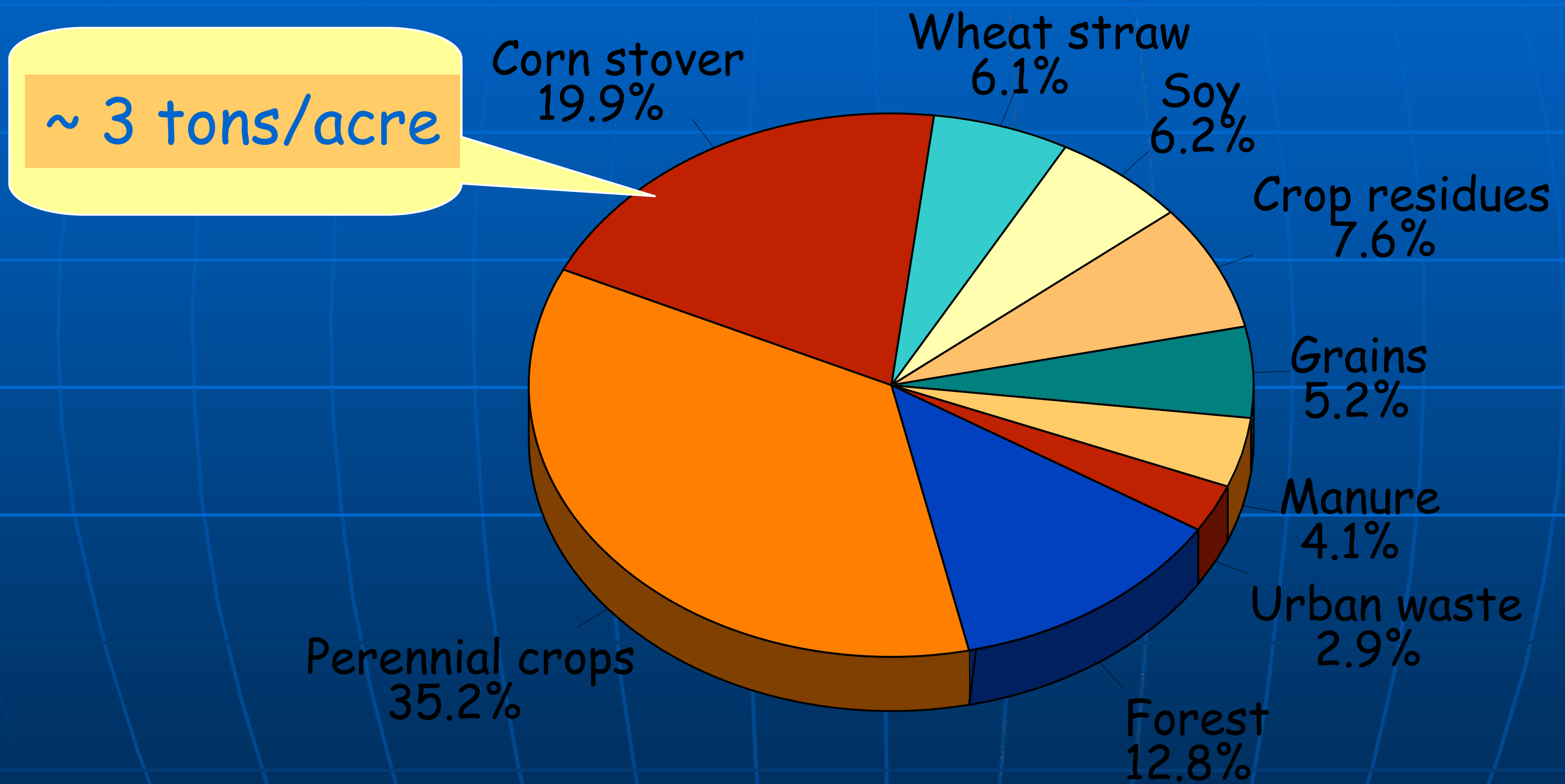
(need special yeast to convert to ethanol)

Chapple, 2006; Ladisch, 1979

Pretreatment gives enzyme accessible substrate



US Biomass inventory = 1.3 billion tons



From: Billion ton Vision, DOE & USDA 2005

Net Energy Balance

Product	Energy Out/Energy In	
Gasoline	0.81	
Ethanol from grain	1.3	(In-place technology)
Ethanol from grain	1.67	(Optimum technology)
Ethanol from cellulose	2.00	(Conservative estimates)
Diesel	0.83	
Bio-diesel	3.2	

Source: Congressional Research Service, RL32712, May 18, 2006

Cellulosic Ethanol
Energy Balance Estimates

- 5 years ago – 10-12 Ratio
- 2-3 years ago - 3-5 Ratio
- Current Estimate - 2.0

Why?

Improved recognition of costs associated with harvest, transportation & storage.

Harvest Issues

- Multiple passes thru field
- Soil compaction
- Organic matter retention
- Density of biomass limits transport
- Moisture content of biomass

Transportation Issues

- Density of Biomass
- Handling steps add costs
- Biomass form should be easily conveyed at plant location

Efficient transportation for bulky crops

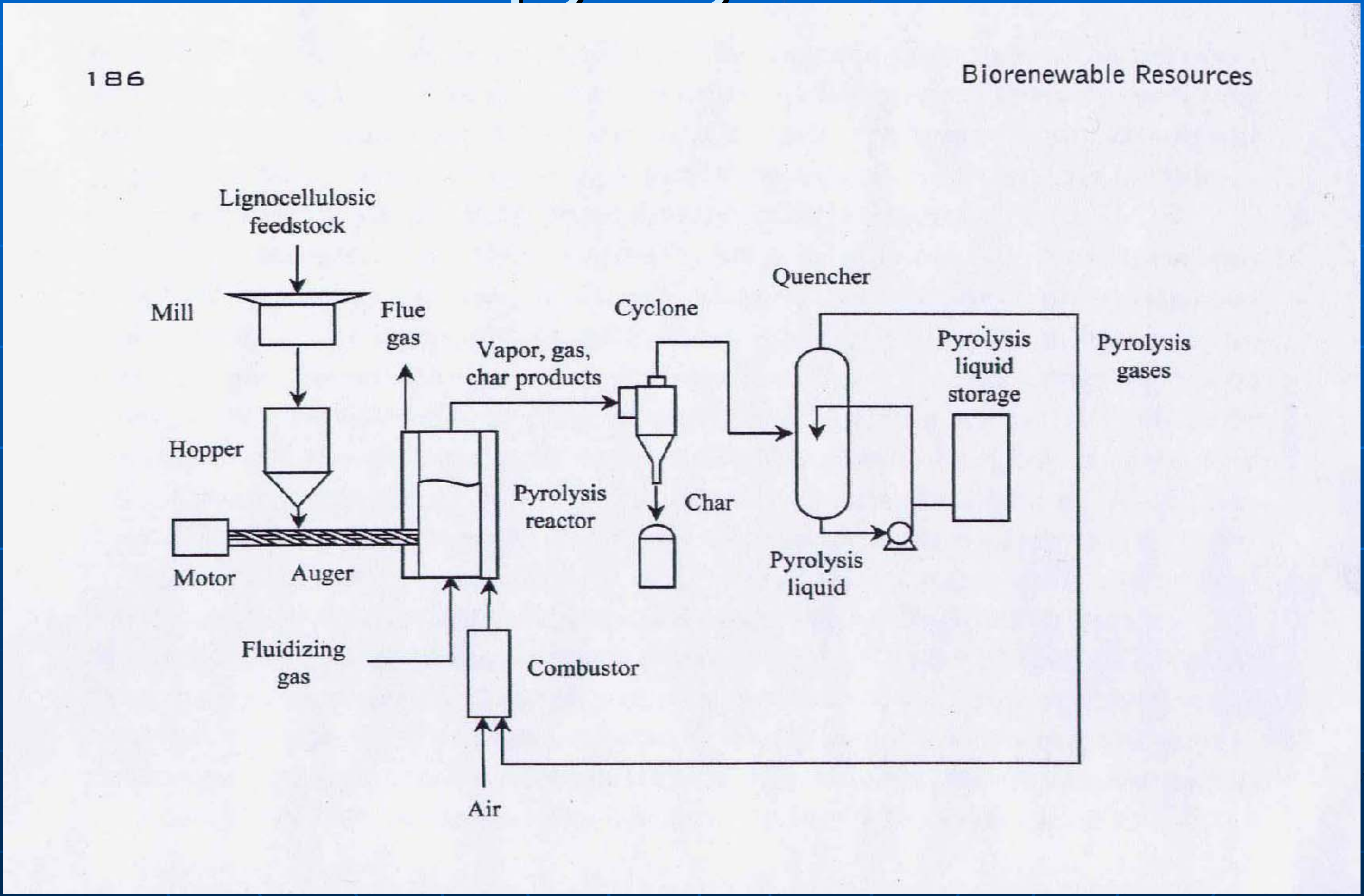
Storage Issues

- Storage Location
  * In field
  * Satellite depots
  * Conversion plant
- Change in composition
- Protection from elements

Conclusions on Cellulosic Biomass Conversion

- Each time biomass is handled adds costs.
- New machinery will be required to manage costs.
- New process management paradigms needed.
- Six demonstration plants have been approved for federal funding.

Fast-pyrolysis Plant.



Biorenewable Resources, Robert C Brown

Products of Fast Pyrolysis

	White Spruce	Poplar
Product Yields (wt %, mf)		
Water	11.6	12.2
Char	12.2	7.7
Gas	7.8	10.8
Pyrolytic Liquids	66.5	65.7
Gas Composition (wt %, mf)		
Hydrogen	0.02	--
CO	3.82	5.34
CO2	3.37	4.78
Hydrocarbons	0.62	0.69
Pyrolytic Liquid Composition (wt %, mf)		
Saccharides	3.26	2.43
Anhydrosugars	6.45	6.77
Aldehydes	10.14	14.04
Furans	0.35	--
Ketones	1.24	1.4
Alcohols	2.0	1.17
Carboxylic Acids	11.01	8.52
Pyrolytic Lignin	20.6	16.2
Phenols, Furans, etc.	11.4	15.2

Biorenewable Resources, Robert C Brown

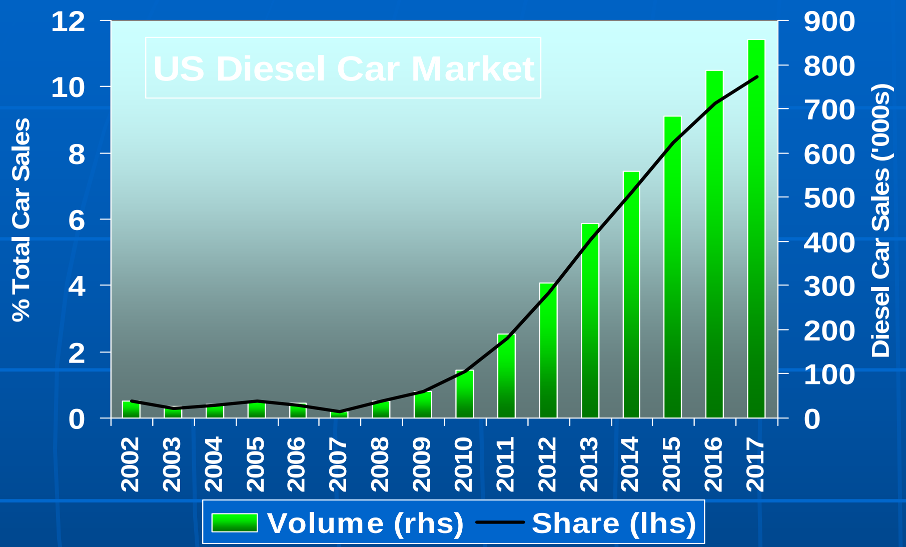
World Transport Vehicle Trends – Diesel

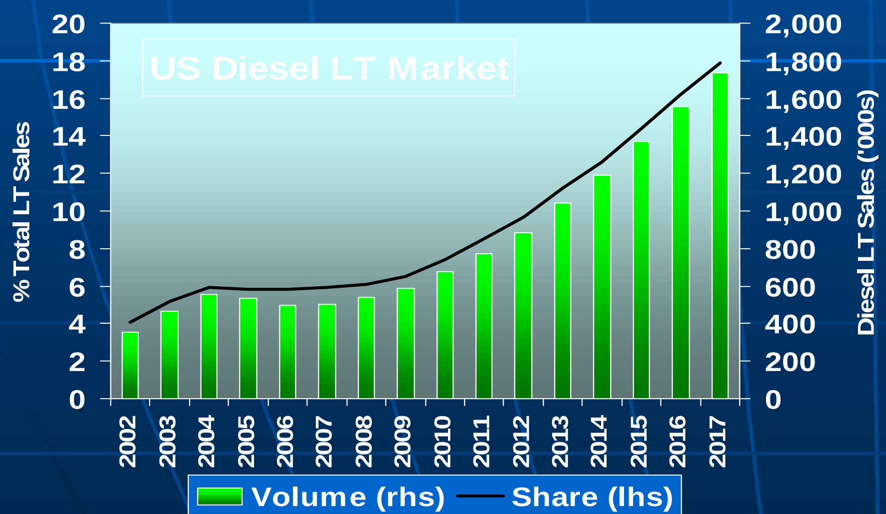
Direct Impact on Biofuels Production and Demand

- Global diesel volume has grown by 40% in 5 years
  - US market 2007 << 1%; 2017 ~ 12%
  - Eastern Europe 2007 15%; 2017 ~ 50%
- Conditions for further expansion of diesel look right
  - High energy prices (diesel 33% more efficient versus gasoline)
  - Diesel technology has come of age
  - Global focus on CO_2
- US will need diesel to hit fuel economy targets

One Driver: World Transport Vehicle Trends – Diesel

Direct Impact on Biofuels Production and Demand





- Global share of diesel market has increased 40% in the last 5 years
- Conditions for further expansion of diesel look right:
  - Global focus on CO_2 & Energy Security
    - ✓ High energy prices (diesel ~33% more efficient versus gasoline)
    - ✓ Diesel technology has improved (not dirty diesels anymore)

Where are the oilseed feedstocks going to come from to "fuel" this increase?

Renewable Oil Resources

- **Agricultural-based Feedstocks**
  - USA production per year (2006):
    - 26.2 billion lbs of major vegetable oils
    - 11.3 billion lbs of fats (animal & grease)
  - Global production per year (2006):
    - 246 billion lbs of major vegetable oils
    - 24 billion lbs of fats (animal & grease
    - ~ 270 billion pounds (**135 million tons**)

Drivers for Biofuels – Govt. Mandates

- US – Renewable Fuels Standard; 35 billion gallons by 2017 (20% of projected total consumption)

- EU – 5.75% by 2010; 10% by 2020; 25% by 2030

- China – 36 B gal diesel used in 2006; 1.8 B gal biodiesel (from animal fat - low grade)

  Plans 90 B gal biodiesel in 2007

- China has said it aims to use 200,000 tons of biodiesel by 2010 and 2 million tons (**604 billion gallons**) by 2020.

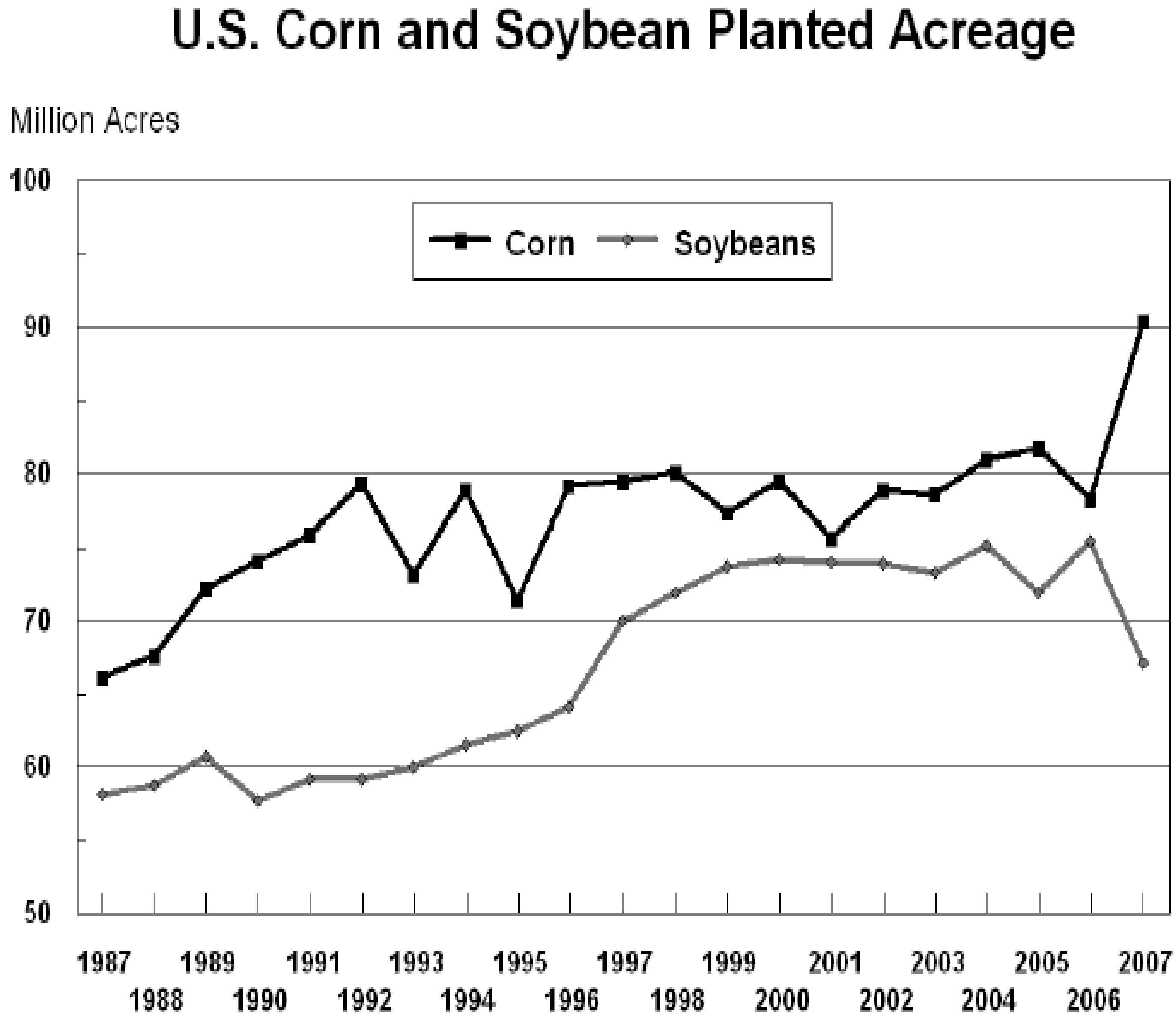
  Why? Energy Security, "Peak Oil" & Climate Change

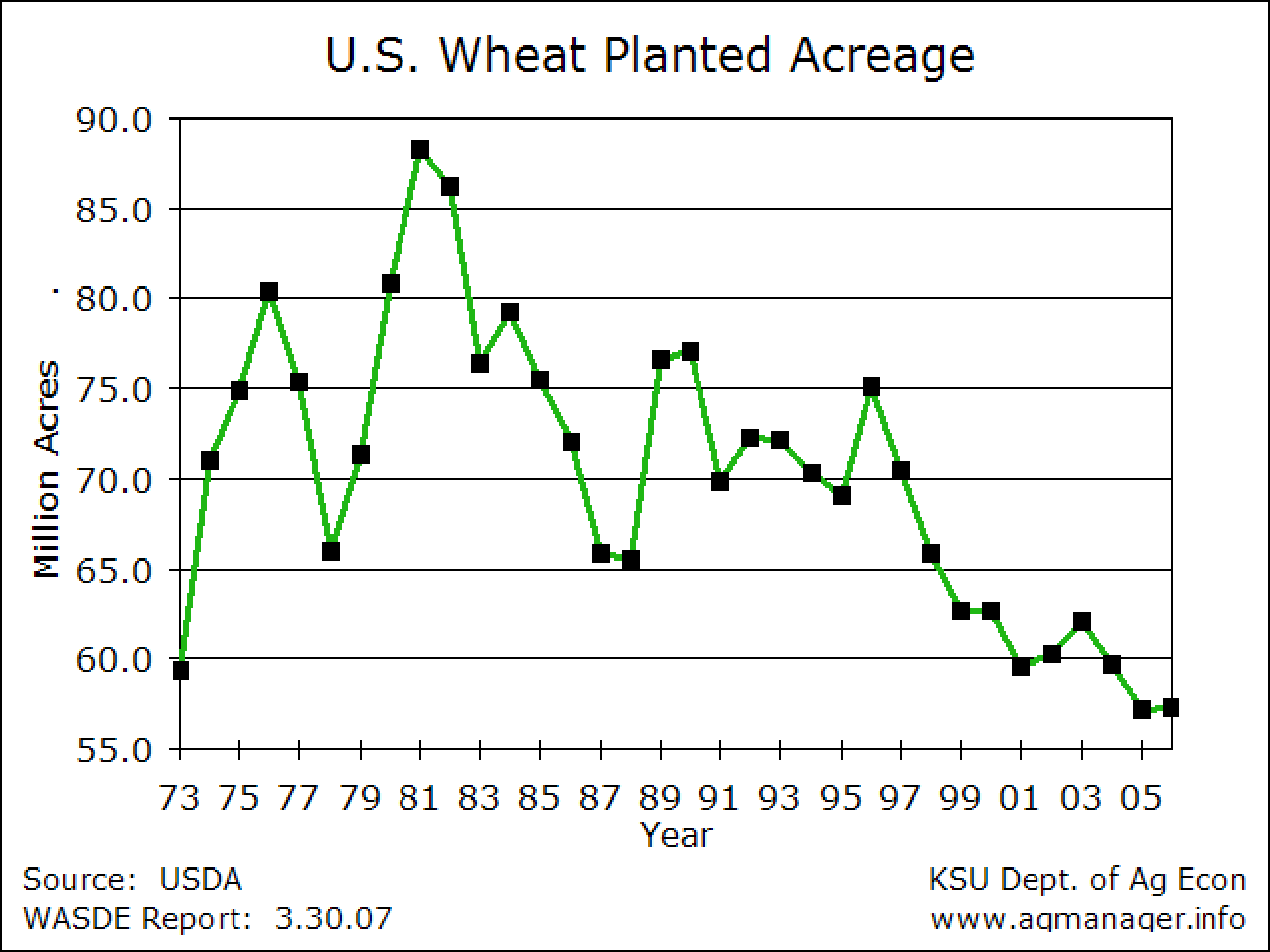
How will these intersect with market forces, where exactly will the feedstocks come from, and at what price?

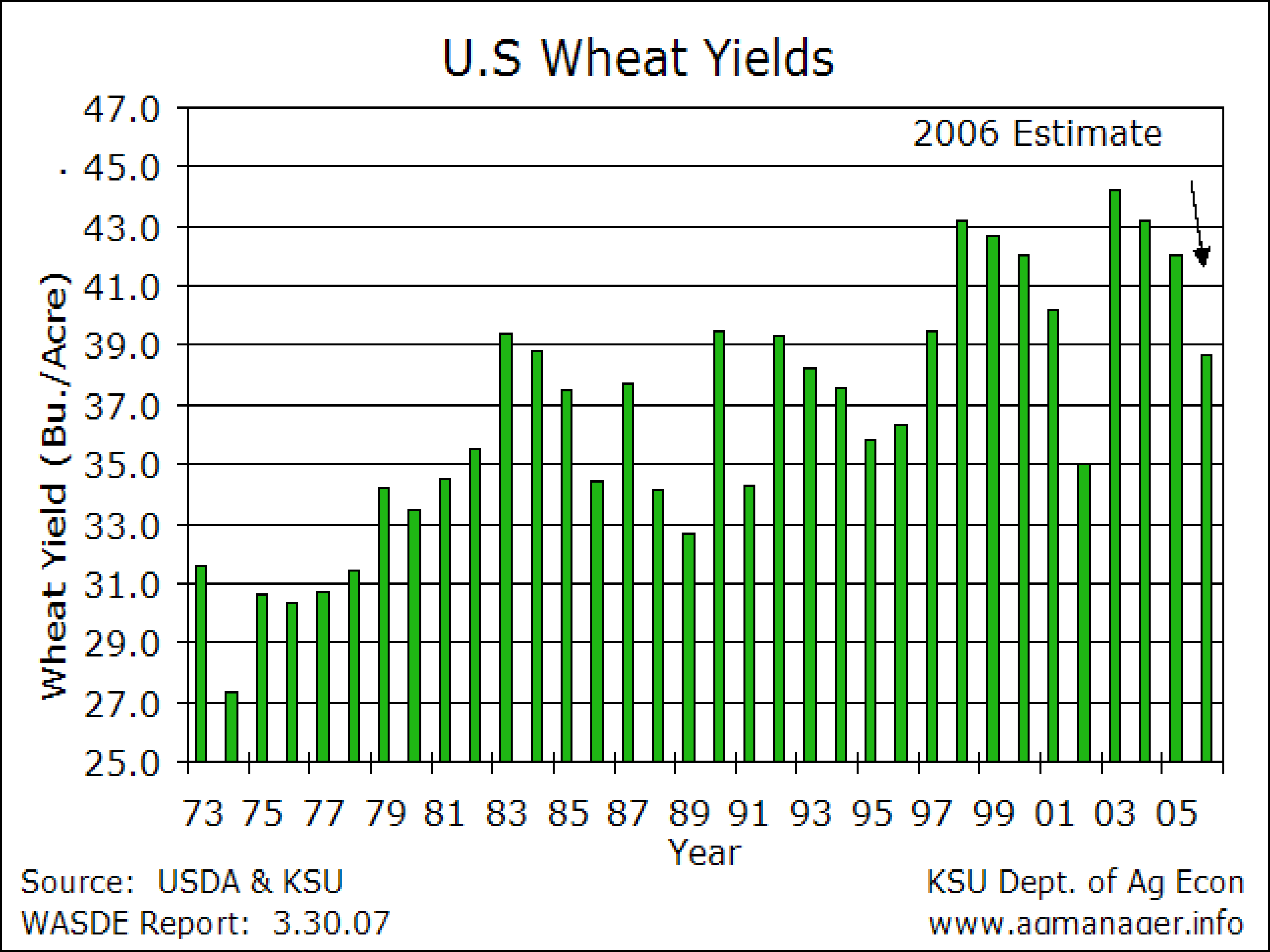
Acreage in Crops
(Millions of acres)

	5 yr. Ave.	07/08 USDA	08/09, Projected
Corn	79.6	93.6	88.0
Soybeans	74.2	63.7	70.0
Hay	62.4	61.8	61.8
Wheat	59.5	60.4	62.2
Cotton	14.1	10.9	10.0
Grain Sorghum	6.1	7.7	7.4
Principle Crops	297.9	298.1	299.4
CRP	37.0	35.9	34.9

Total crop land in the United States – 441.6 million acres


U.S. Corn and Soybean Planted Acreage
Million Acres
100
90
80
70
60
50
Corn
Soybeans
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007


U.S. Wheat Planted Acreage
Million Acres
90.0
85.0
80.0
75.0
70.0
65.0
60.0
55.0
73
75
77
79
81
83
85
87
89
91
93
95
97
99
01
03
05
Year
Source: USDA
WASDE Report: 3.30.07
KSU Dept. of Ag Econ
www.agmanager.info


U.S Wheat Yields
2006 Estimate
Wheat Yield (Bu./Acre)
47.0
45.0
43.0
41.0
39.0
37.0
35.0
33.0
31.0
29.0
27.0
25.0
73 75 77 79 81 83 85 87 89 91 93 95 97 99 01 03 05
Year
Source: USDA & KSU
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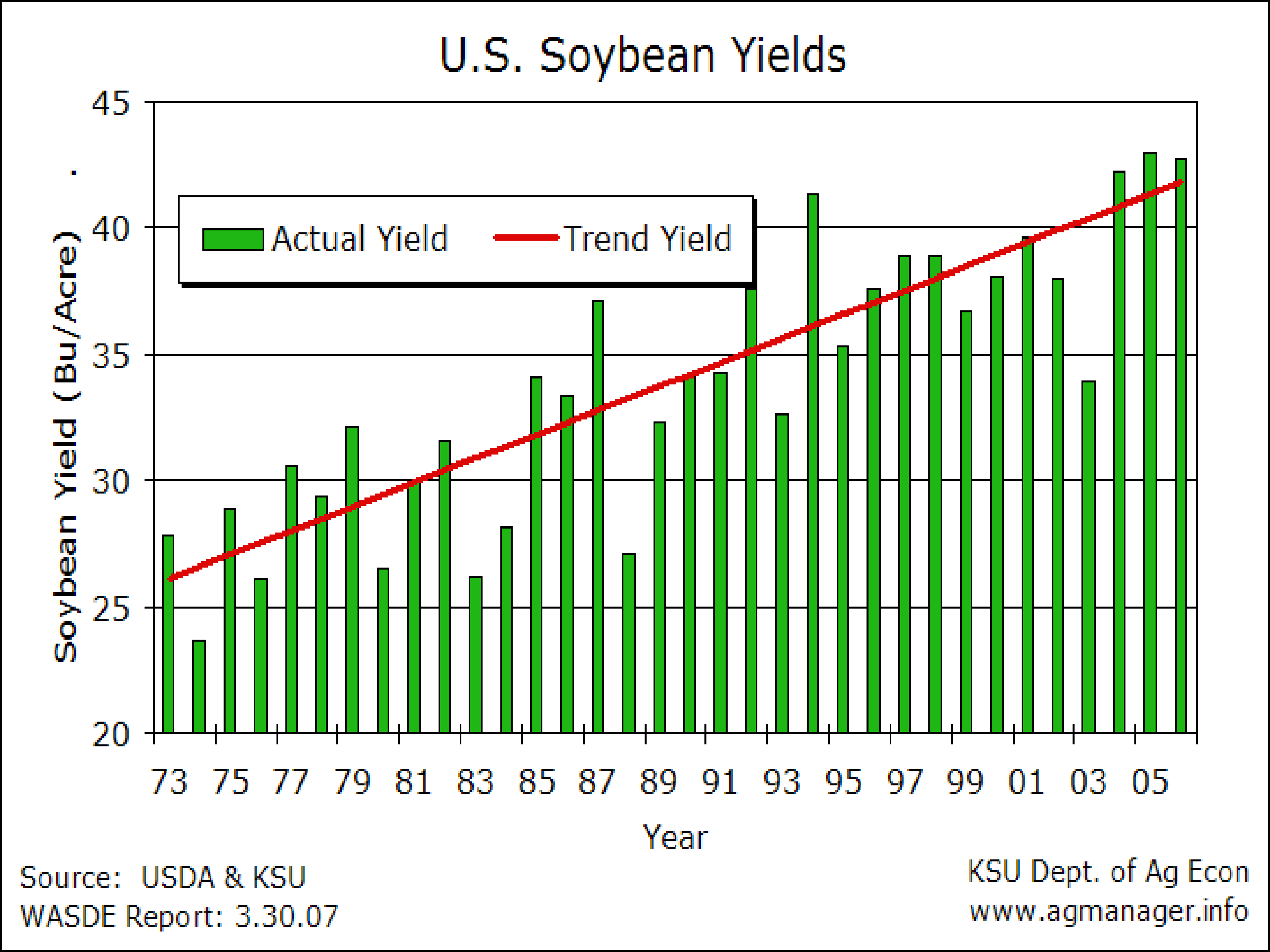
U.S. Soybean Yields
Actual Yield
Trend Yield
Soybean Yield (Bu/Acre)
45
40
35
30
25
20
73
75
77
79
81
83
85
87
89
91
93
95
97
99
01
03
05
Year
Source: USDA & KSU
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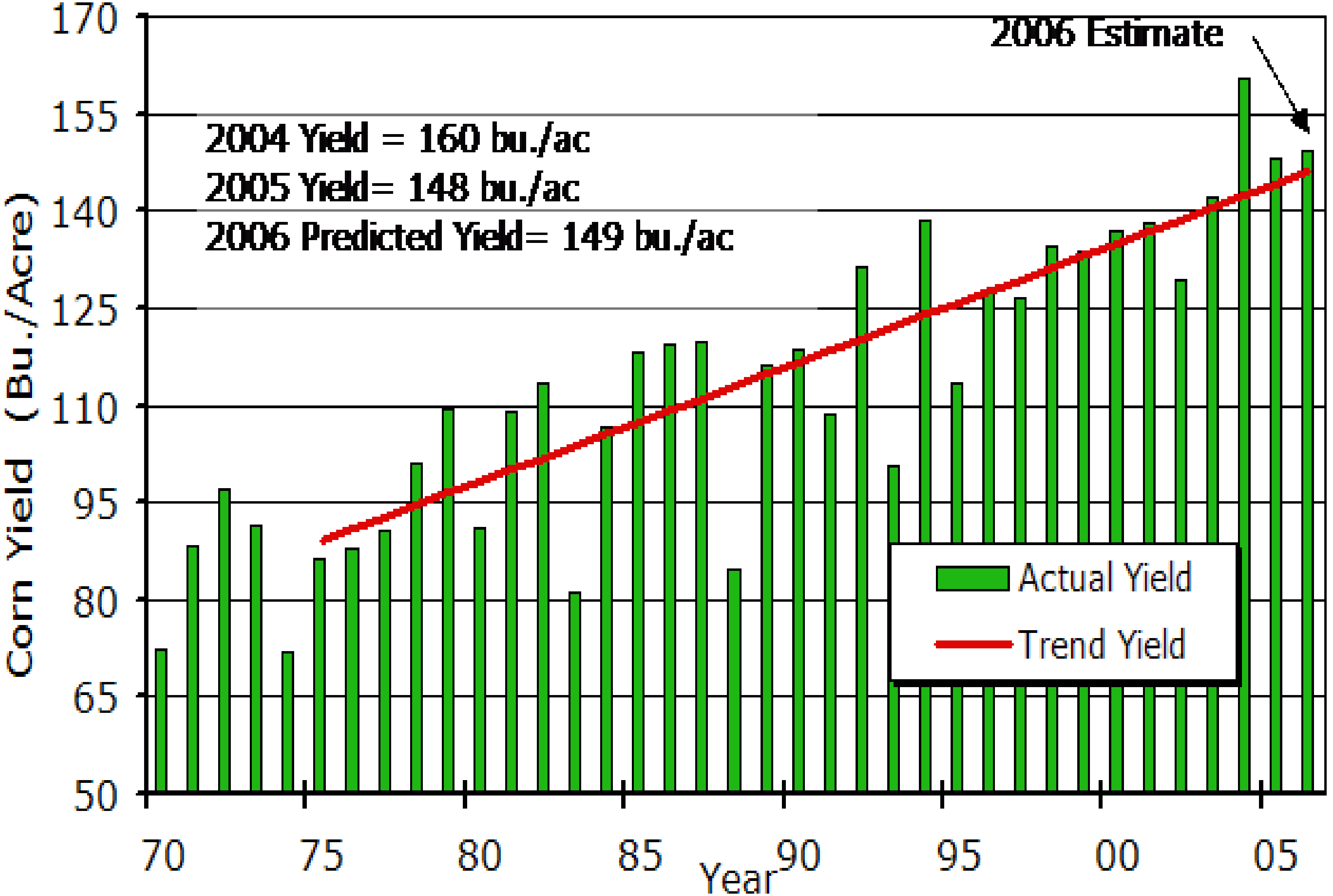
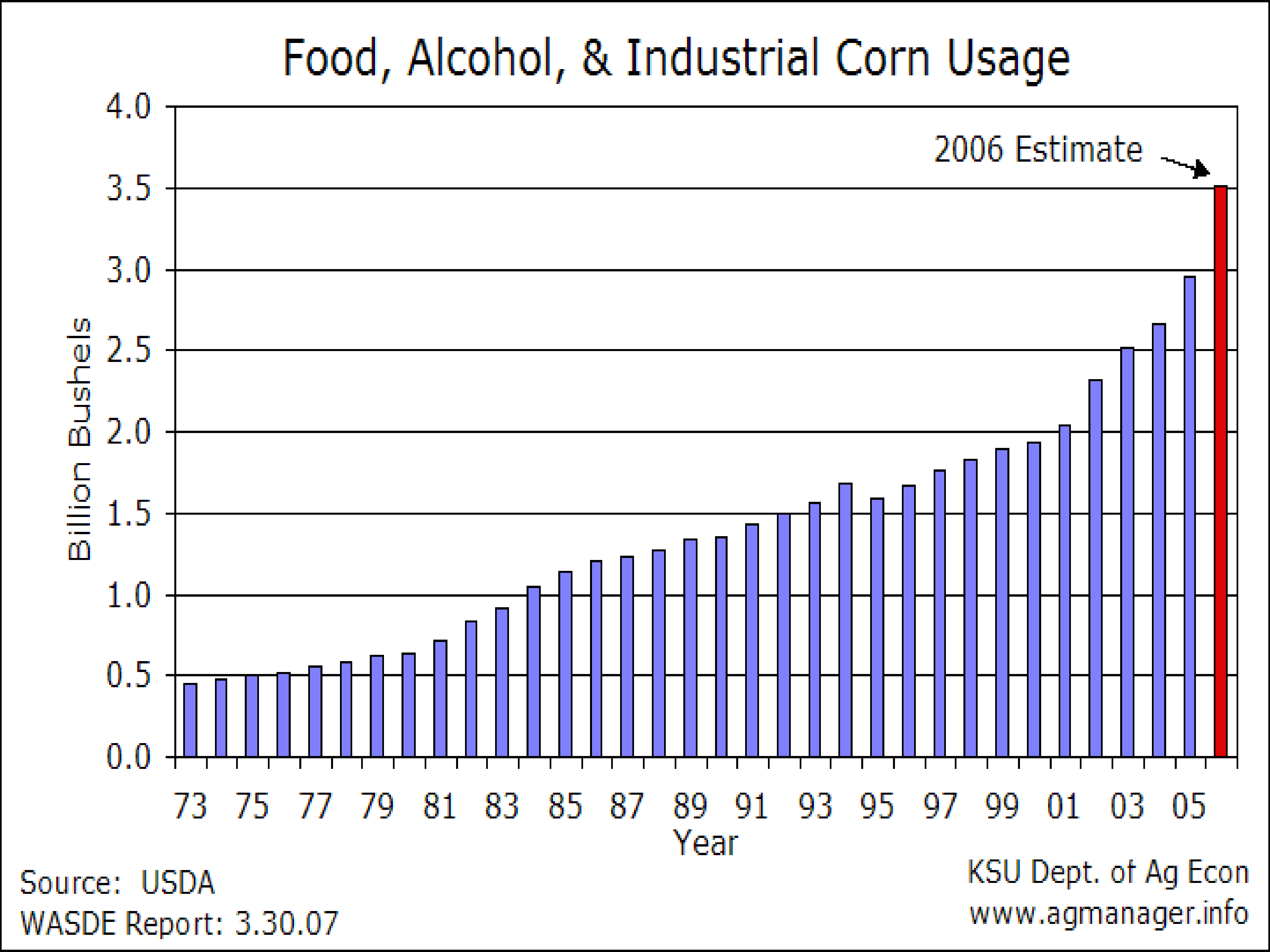
U.S. Corn Yield



Source: USDA & KSU
WASDE Report: 1.12.07

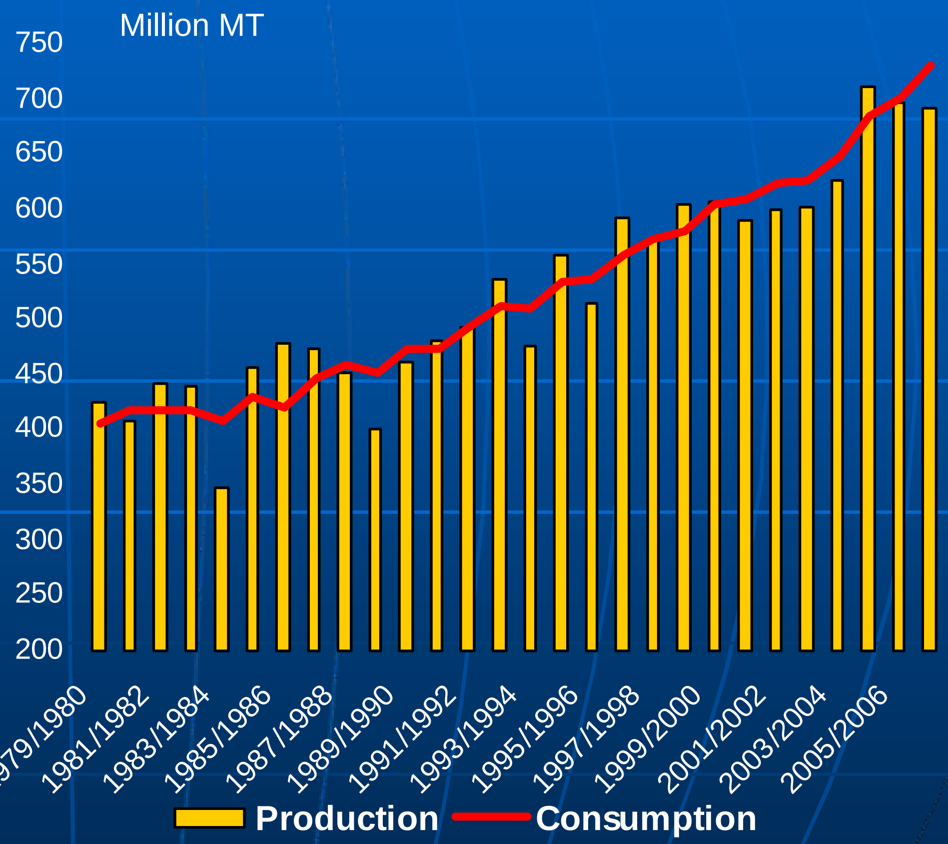
KSU Dept. of Ag Econ
www.agmanager.info



Food, Alcohol, & Industrial Corn Usage
2006 Estimate
Billion Bushels
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
73
75
77
79
81
83
85
87
89
91
93
95
97
99
01
03
05
Year
Source: USDA
WASDE Report: 3.30.07
KSU Dept. of Ag Econ
www.agmanager.info

World Corn Use Outpaces Production

- **Consumption in 2006/07 is forecast to increase 3% setting a new record.**
- **Production down from 2005/06.**
- **Stocks forecast to be second lowest in 34-years.**



US Acreage for Biodiesel

- 74 million A of soybeans produced ~10 million tons of soy oil.
- This would convert to ~ 9 million tons of biodiesel = 2.7 B gal

- Current US consumption of diesel is 52 B gal.
- 2006 biodiesel production was 250 million gal.
- 10 million A = 360 million gal

Biofuel Acreage Demand

- Starch-based EtOH –
  35 million A = 15.1 B gal
- Cellulosic EtOH (dedicated energy crop);
  75 million A = 18 B gal
- Cellulosic EtOH (crop residues)
  100 million A = 8 B gal
- Biodiesel –
  10 million A = 360 million gal
  Import oil and animal = 640 mil gal

- Total of 120 million A = 42.1 B gal
  renewable fuels.
- 120/442 = 27% of crop land

Summary

- 140 B gal gasoline consumed/yr
- 52 B gal diesel consumed/yr

- Replace 30% of gasoline demand
- Replace 2 % of diesel demand

  - with crops from 27 % of crop land.

Conclusions

- Biobased resources will supplement energy requirements, but not replace petroleum.
- Competition for grain and acreage.
- Carryover is historically low; weather will become key driver for food prices.
- All renewable energy resources needed – no silver bullet.
- Reduction of energy demand will be required.

Thank You

?? QUESTIONS ??

Energy Content of Fuels

	MJ/liter	BTU/US gal
Diesel	**40.9**	**147,000**
Gasoline	**32**	**125,000**
Butanol	**29.2**	**104,949**
E 10	28.06	120,900
LPG	22.2	95,475
Ethanol	**19.59**	**84,400**
Methanol	15	62,800

Additional Reading on Energy and Resource Consumption

- *The End of Oil* – Paul Roberts (2004)

  A great overview. As a technical and business writer, Roberts covers the range of topics that affect us as we approach and pass peak oil for the world.
- *Beyond Oil: The View from Hubber's Peak* – Kenneth Deffeyes (2005)

  A petroleum engineer explains Hubbert's Peak for oil production and outlines a path forward with reduced oil availability.
- *Twilight in the Desert: The Coming Saudi Oil Shock and the World Economy* – Mathew Simmons (2005).

  Simmons is an investment banker specializing in energy. He lives in Houston and has visited Saudia Arabia many times. His book explains why the aging Saudi oil fields are at or near peak.
- *The Hype About Hydrogen* – Joseph Romm (2005)

  As a past Undersecretary of Energy, Romm speaks to the many overlooked deficiencies of hydrogen as a fuel. (It is an energy carrier, not a source.) He argues that hydrogen is very long term solution – at best.
- *Collapse: How Societies Choose to Fail or Succeed* - Jared Diamond (2005)

  Pulitzer Prize winning (Guns, Germs, and Steel) author Diamond, analyzes societies' patterns of consumption with population expansion. Some transition into sustainable societies – some don't. He draws parallels with today's world society.
- *The Population Bomb* – Paul Erlich (1968)

  A modern-day Malthus with a warning on unlimited population growth. Human population reached its 1st billion in the world around 1803, soon after Malthus issued his warning; above 3.5 billion when Erlich's book was written; above 6.5 billion now – and still ticking.
- "Thoughts on Long-Term Energy Supplies: Scientists and the Silent Lie", *Physics Today*, (July, 2004).

  An article urging scientists to speak up more on what they know about population, energy and limits to expansion. Albert A. Bartlett is emeritus professor of physics at the University of Colorado at Boulder. http://fire.pppl.gov/energy_population_pt_0704.pdf