

Introduction to Plants for Bioproducts

Plant Science 345
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Outline

- What are bioproducts?
- Why is there interest in bioproducts ?
 - Economic, environmental, and social costs of fossil-fuel dependence
- How can bioproducts help?
- Issues surrounding the use of plants for bioproducts
- What you will learn in this course.

What are bioproducts?

- **Industrial and consumer goods** manufactured wholly or in part **from renewable biomass**
- Renewable biomass may be from agricultural crops, trees, marine plants, micro-organisms, and some animals
- May include biochemicals, bioenergy, biofuels, biomaterials, and health or food products

Classification of natural resources



Renewable natural resources

- Sunlight
- Wind energy
- Wave energy
- Geothermal energy



Renewable bioresources

- Agricultural crops
- Fresh water
- Forest products
- Soils



Nonrenewable natural resources

- Crude oil
- Natural gas
- Coal
- Copper, gold, and other metals

Bioresources are resources that are renewable within a short time span – thus, they are ideal for the production of bioproducts

Bioproducts aren't new...

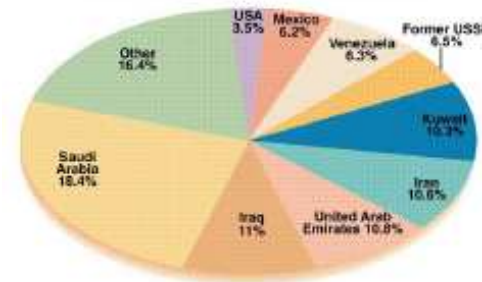
- Until about 200 years ago, humans relied almost exclusively on bioproducts to fulfill their food, material and energy needs
- Since the industrial revolution, our societies have been increasingly dependent on fossil-fuel energy, for heat, electricity and transportation.
- The advent of petroleum refining (ca. 1850) further expanded the applications for petroleum by-products in industrial and consumer goods.

Fossil fuels – non renewable natural resources

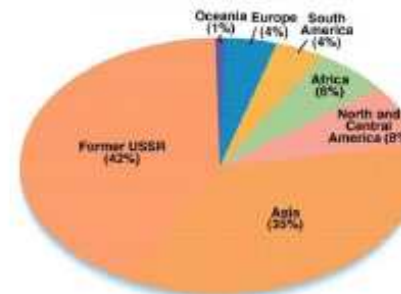
- Petroleum/Oil
- Natural gas
- Coal

*petroleum is the most important to our society, since it is the basis for transportation, and few suitable substitutes are widely and cheaply available.

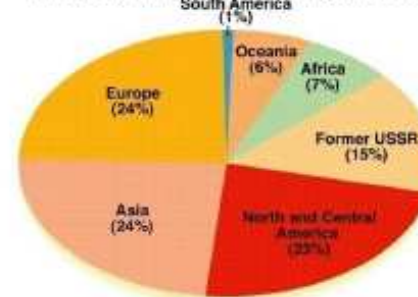
Recoverable Oil Reserves



Natural Gas Reserves



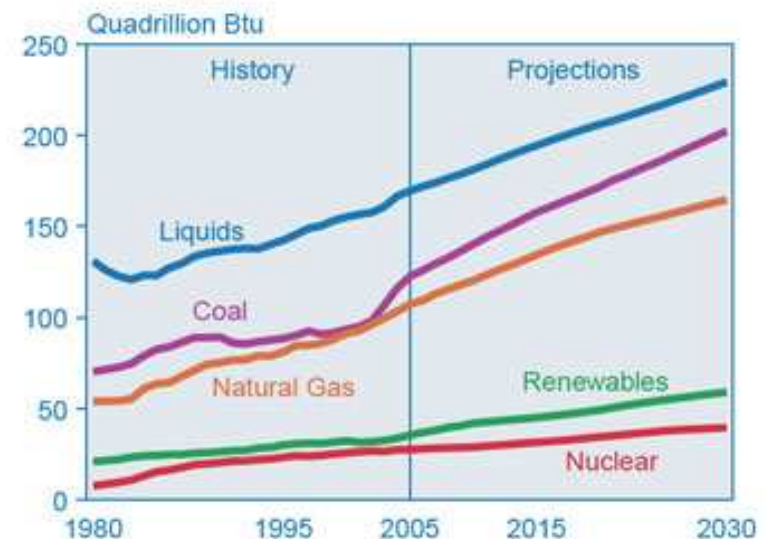
Proven-in-Place Coal Reserves



The rise of petroleum

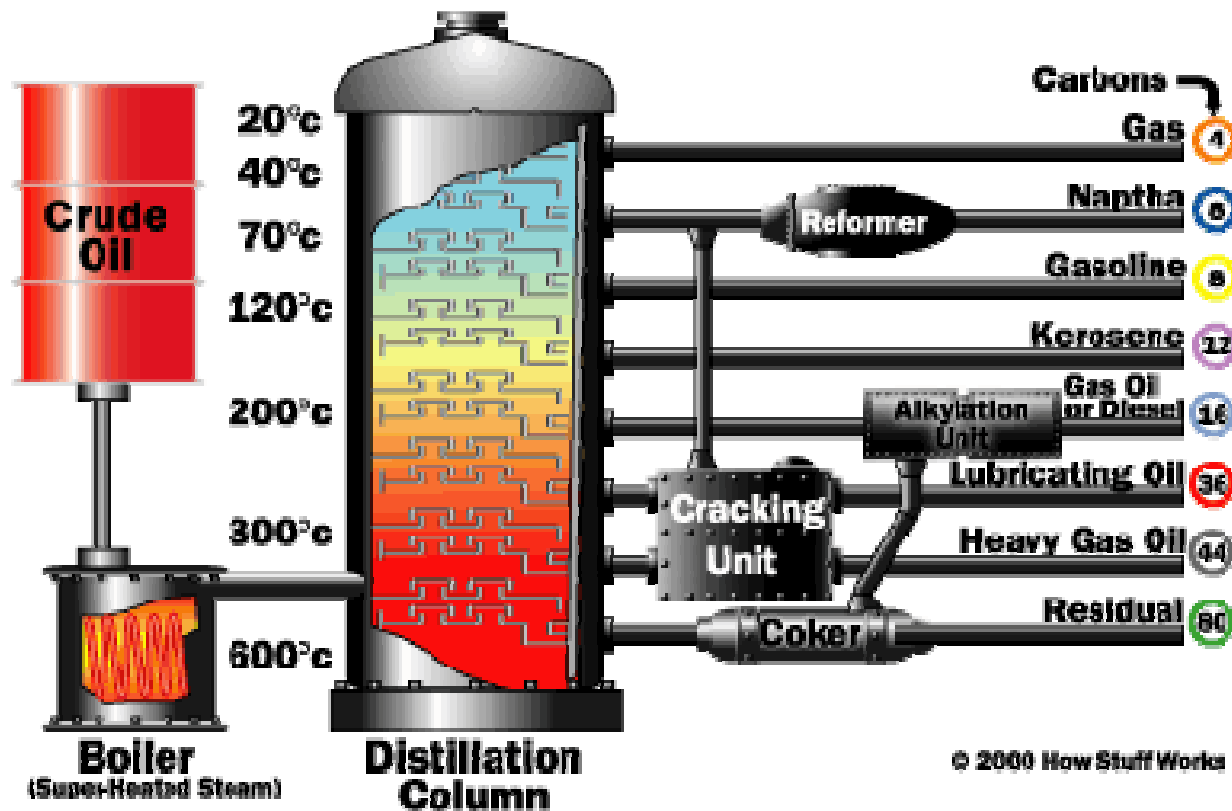
- Today - petroleum provides >85% of the world's energy
 - High energy density
 - Easily transportable
 - Highly amenable to manufacturing processes
 - **For now...**relatively abundant
- Consumption is still increasing worldwide

Figure 2. World Marketed Energy Use by Fuel Type, 1980-2030



Sources: 2005: Energy Information Administration (EIA), *International Energy Annual 2005* (June-October 2007), web site www.eia.doe.gov/iea. Projections: EIA, *World Energy Projections Plus* (2008).

Introduction to petroleum refining



- Crude oil is fractionated by distillation, then chemically processed to produce various products

Uses of petroleum distillates

- Liquid transportation fuels
- Lubricants
- Heating oil
- Raw materials for the chemical synthesis industry, including plastics, polymers, solvents.

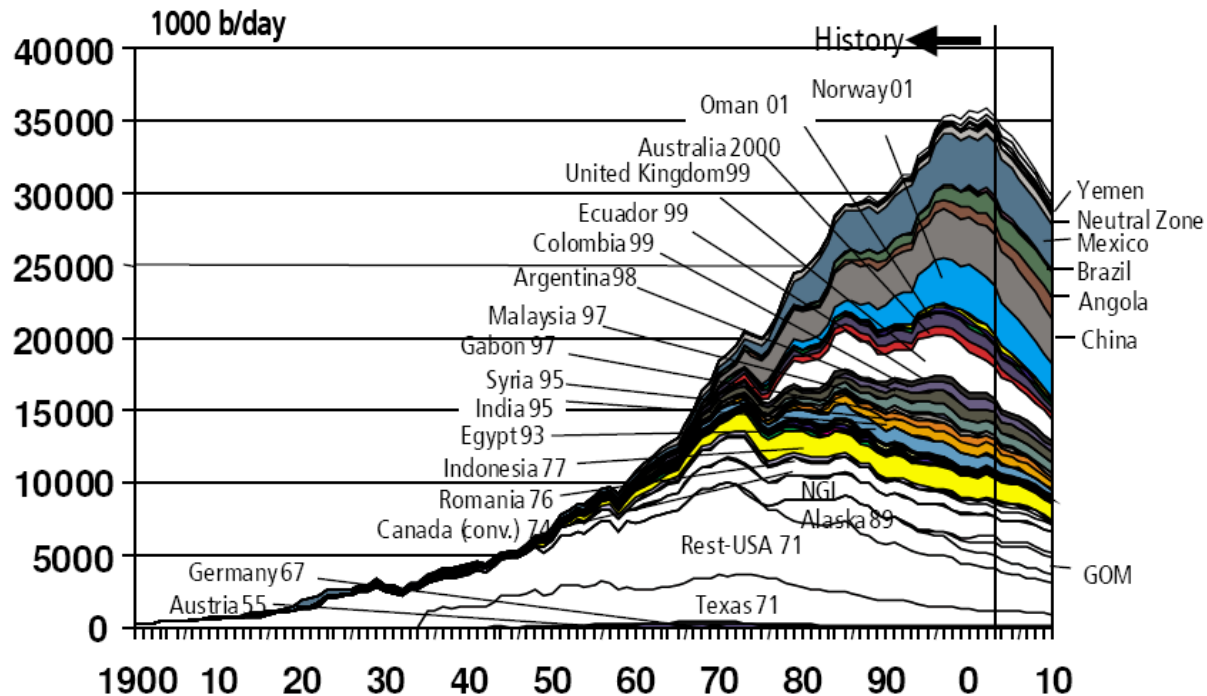


Petroleum refining leads to many products from a single raw material – we can learn from this as we consider the emerging concept of “biorefining”. This will be covered in a future lecture.

The fall of petroleum

- Petroleum (and other fossil fuels) are finite.
- Although experts disagree about when fossil fuel reserves will run out, it is inevitable given our insatiable hunger for energy and fossil fuel-derived products
- The pressure is on to develop renewable alternatives to sustain us in the post-petroleum era

The fall of petroleum

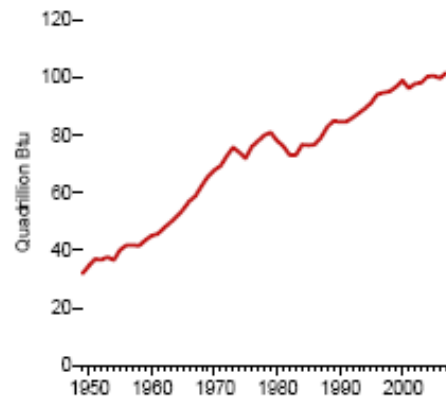


Source: Industry database, 2003 (IHS 2003)
OGJ, 9 Feb 2004 (Jan-Nov 2003)

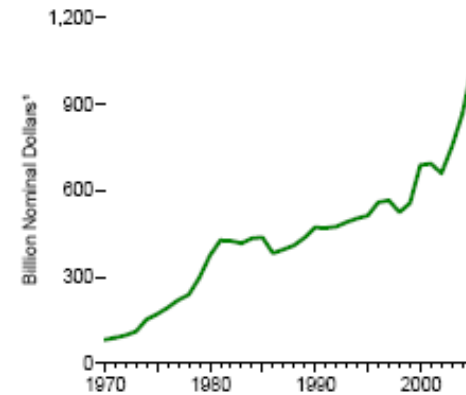
- It is estimated that oil production in many regions of the world has already peaked and is beginning to decline

The economic cost of fossil fuel dependence

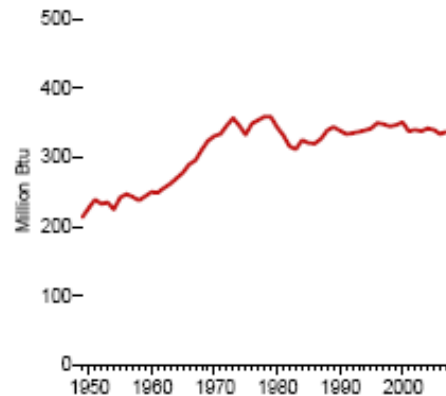
Energy Consumption, 1949-2007



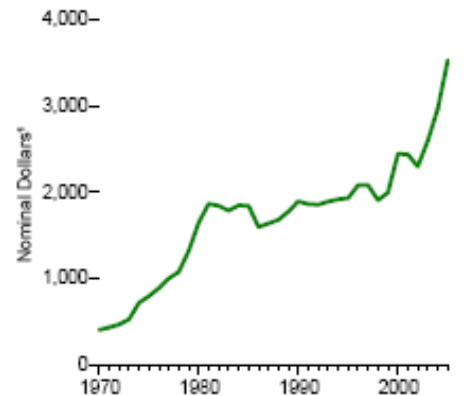
Energy Expenditures, 1970-2005



Energy Consumption per Person, 1949-2007



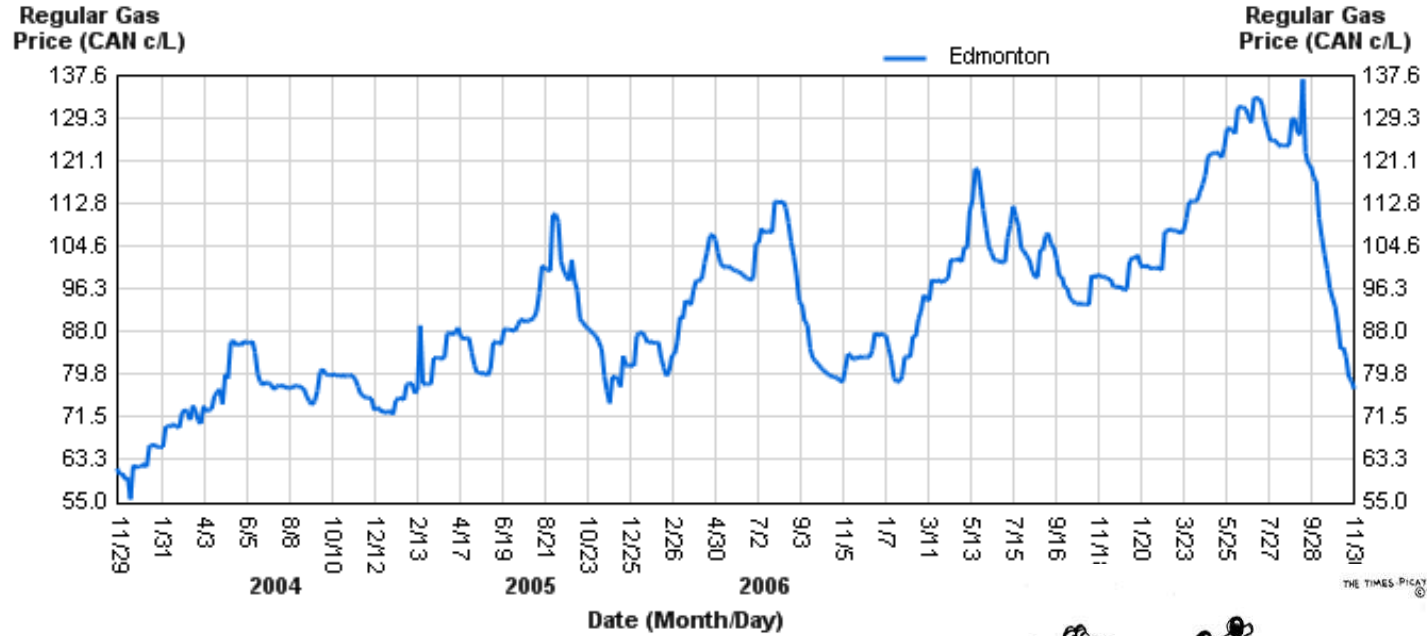
Energy Expenditures per Person, 1970-2005



- People are spending more on energy
- Estimates vary; from 5-20% of per capita income is spent on energy

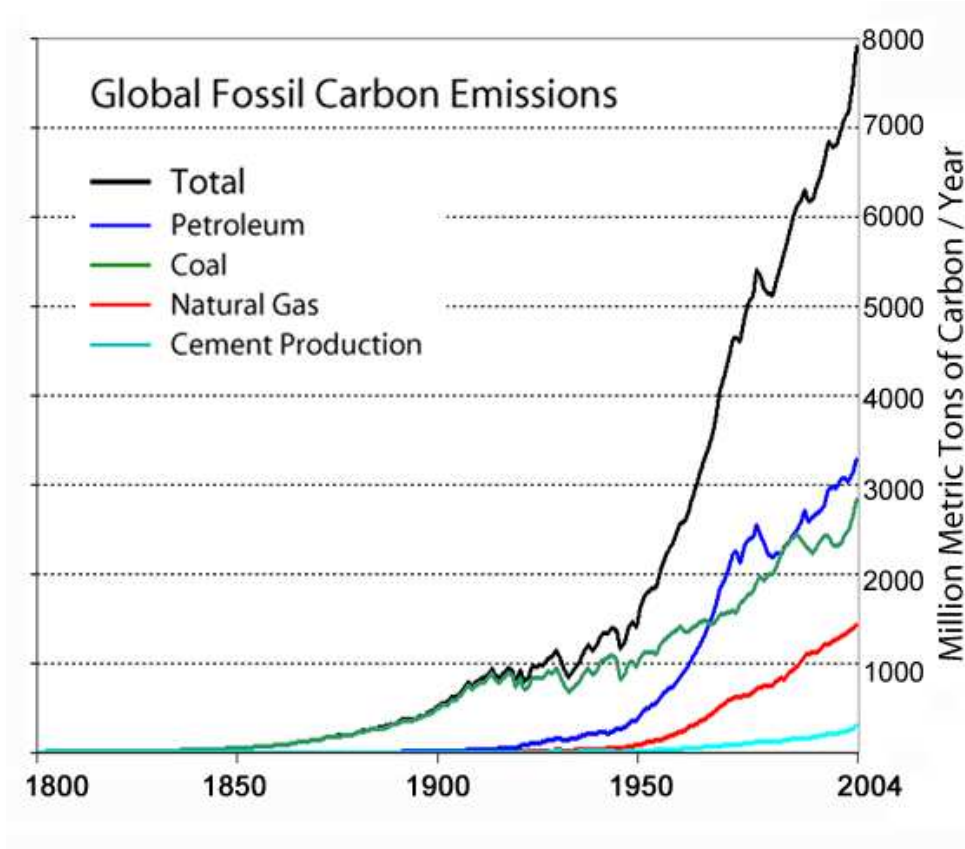
Gas prices in Edmonton – 2003-2008

60 Month Average Retail Price Chart

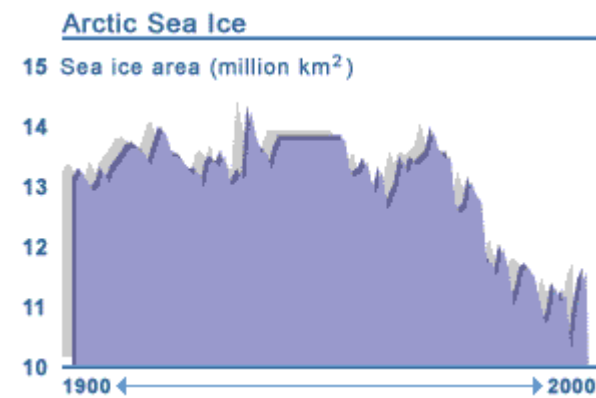
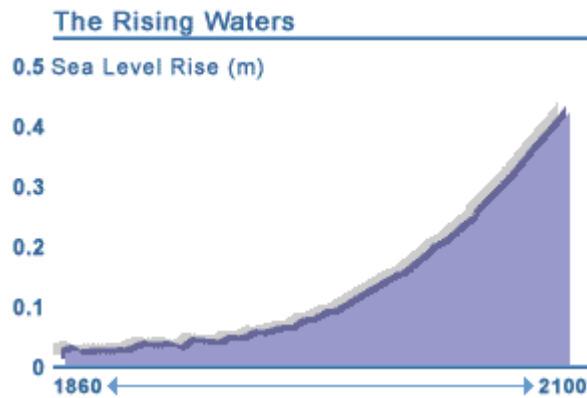
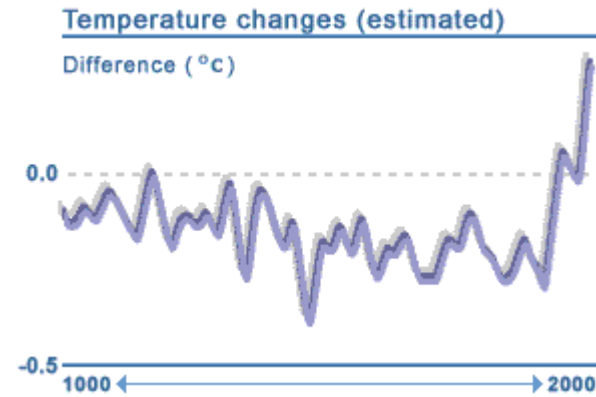
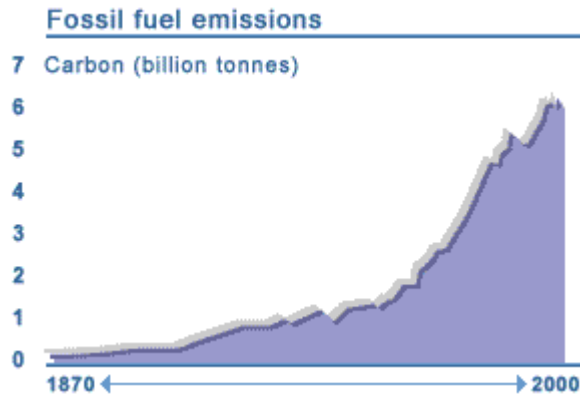


The environmental costs of fossil fuel dependence

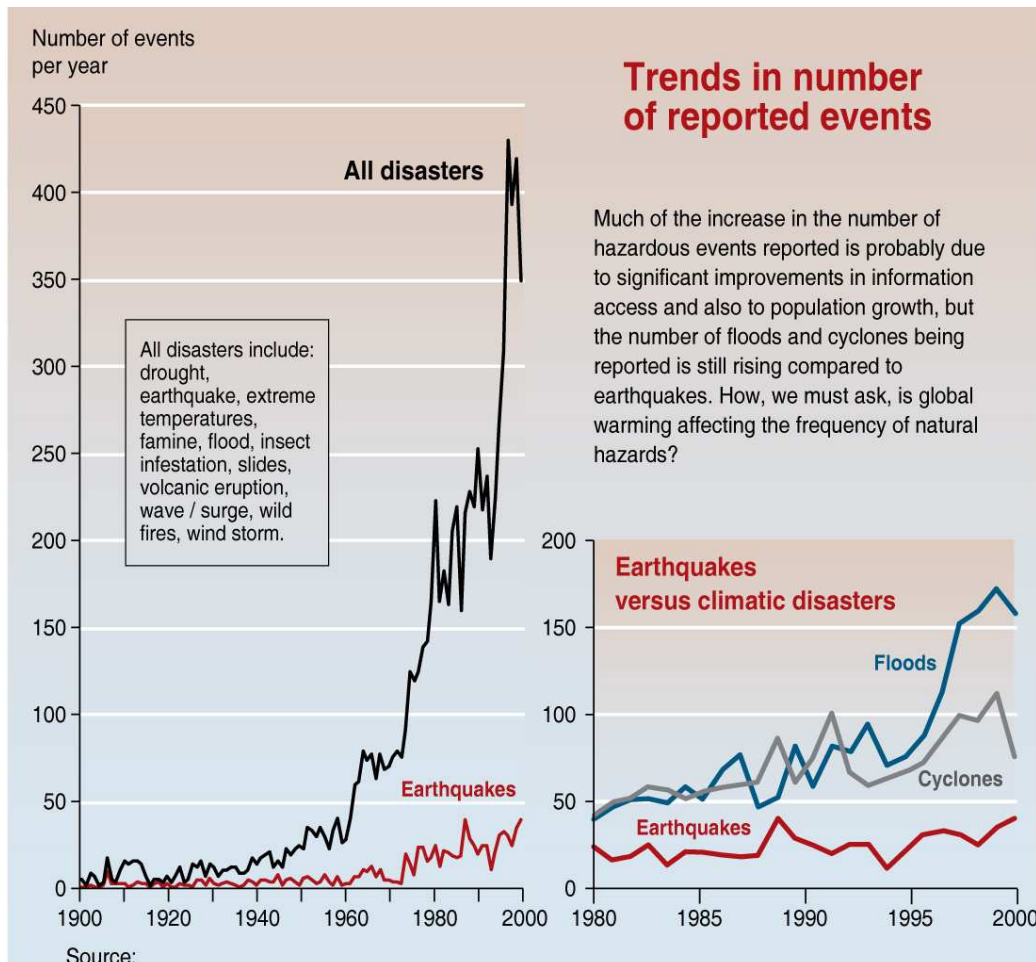
- Since the industrial revolution, carbon emissions have increased more than they have in any other point in human history
- Carbon emissions are a major driver of global climate change



Increasing fossil fuel emissions are correlated with rising temperatures, rising sea level, and a decline in arctic sea ice



Global warming has been implicated in an increase in severe weather and flooding



Other environmental costs of our dependence on fossil fuels

- Wildlife habitat destruction
- Accidental exposure to chemicals (i.e. oil spills, gas leaks)



The social/political cost of fossil fuel dependence

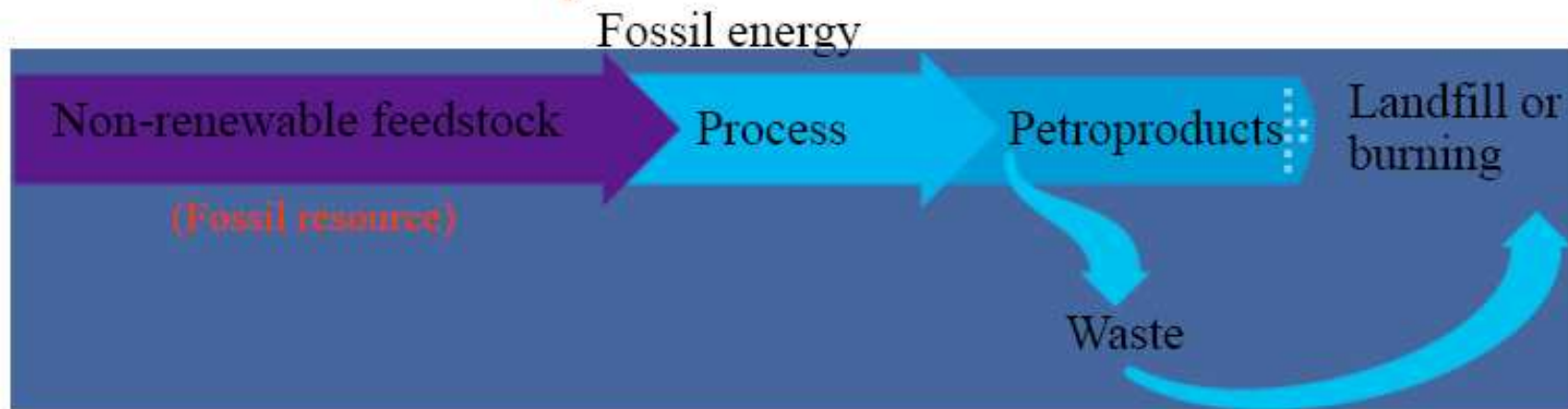
- Much of the world's remaining oil supply lies in the world's most politically unstable regions
 - Price spikes
 - War
- Many developing economies are crippled by the fact that they must sell cheap agricultural commodities for expensive oil

How can bioproducts help?

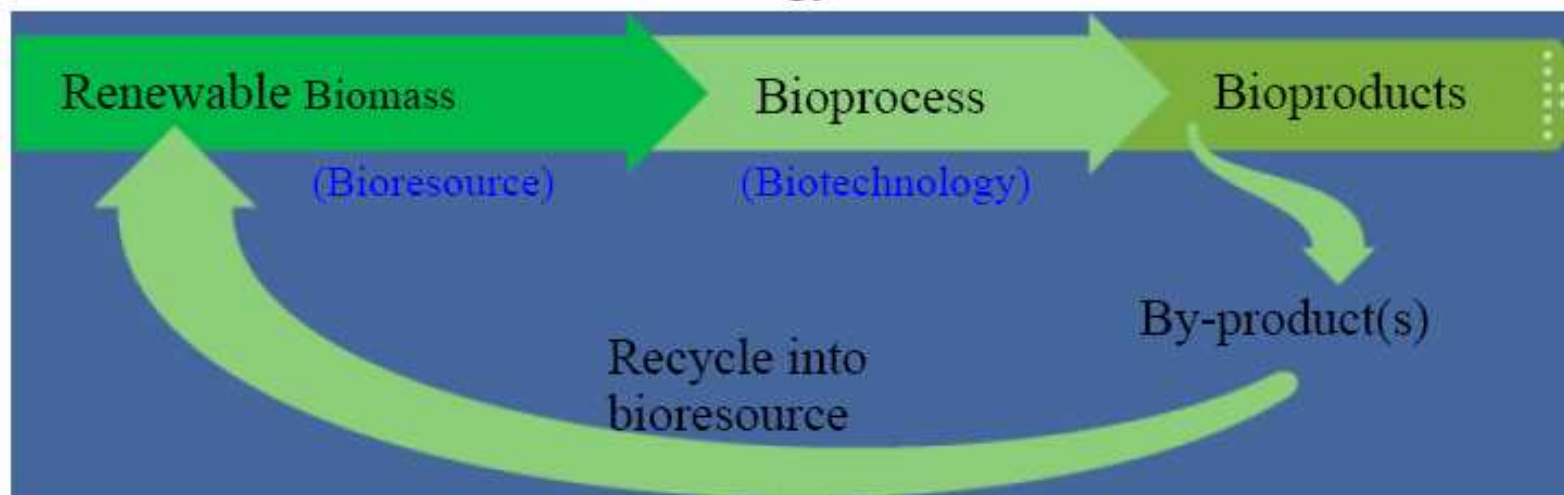
- Provide fuel and industrial feedstocks that are:
 - Renewable
 - Environmentally and economically sustainable
 - Produced domestically
- Replace the petroleum economy with a sustainable “bioeconomy”
- “Close” the carbon cycle – more later.

The emerging bioeconomy

Conventional economy



Biobased economy



The emerging bioeconomy



Biological production

- Genomics
- Enzymes
- Metabolism
- Composition



Biomass

- Trees
- Grasses
- Energy Crops
- Agricultural Residues
- Animal Wastes
- Municipal Waste



Processing

- Enzymatic hydrolysis
- Fermentation
- Bioconversion
- Chemical Conversion
- Combustion



End-Uses

Products

- Plastics
- Functional Monomers
- Solvents
- Chemical Intermediates
- Adhesives
- Hydraulic Fluids
- Paints
- Dyes, Pigments, and Ink
- Detergents
- Paper
- Horticultural products
- Fiber boards

Fuel (diesel and ethanol)

Power (electricity)

Plants for bioproducts

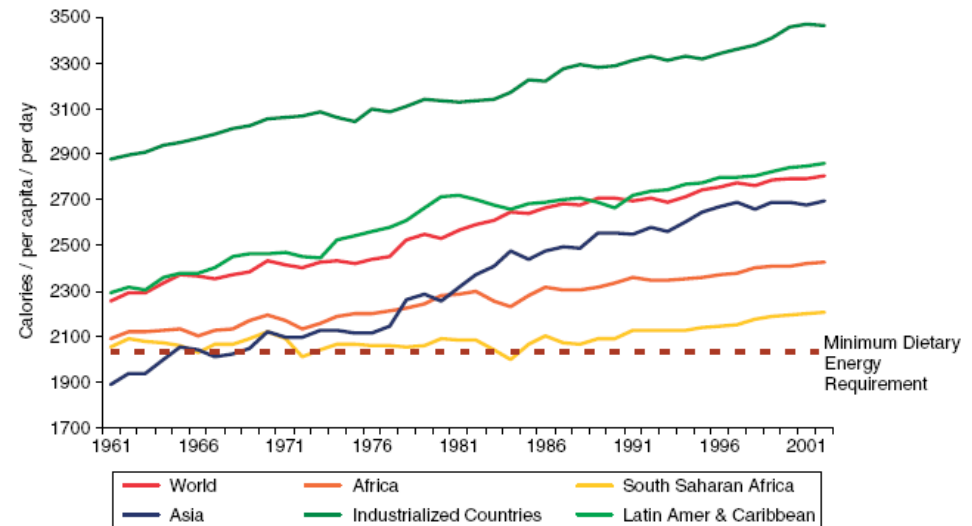
- Plants are a major source of renewable biomass for bioproducts
- Plants also represent a remarkable chemical diversity – many potential applications!
- Using crops, we can capitalize on existing agricultural production and processing infrastructure
- Add value to agricultural commodities – benefits to producers



Will plant bioproducts endanger food security?

- Humans require ~ 2000 calories, and 50g of protein per day
- In US, demand is 205 trillion calories, 5.1 trillion grams of protein/year
- Top 3 US crops **alone** (corn, soy, wheat) provide 1300 trillion cal & 51 trillion g protein/yr

Calories produced per capita compared to minimum dietary requirement



Where do the rest of the calories go?

- In the US, most agricultural production (including exports) is fed to livestock
- Ruminants (beef and dairy cattle) account for 70% of this consumption



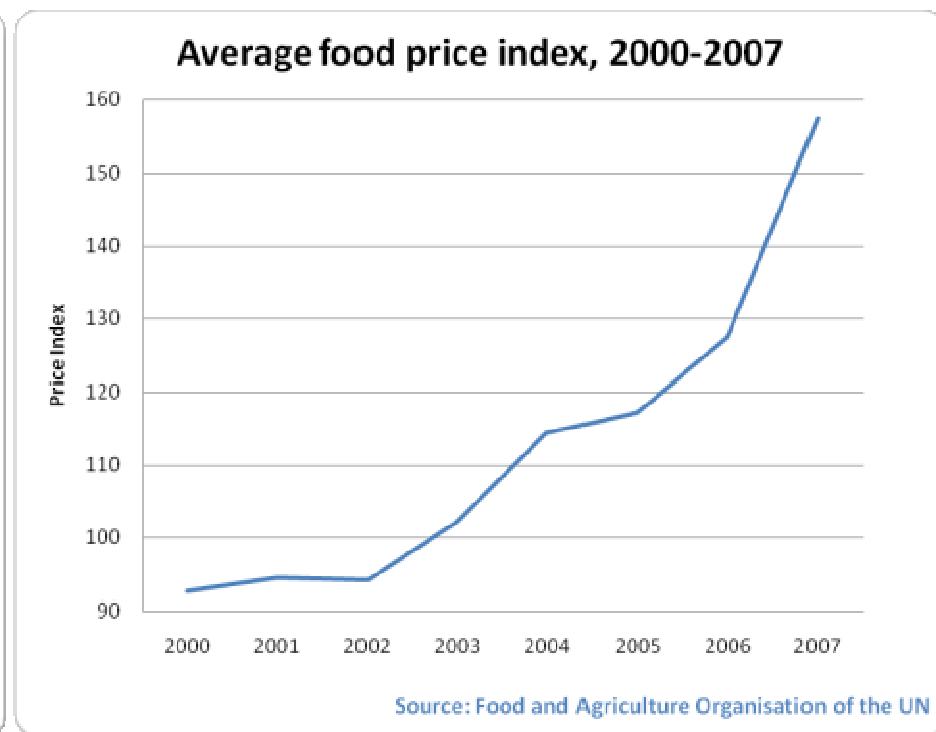
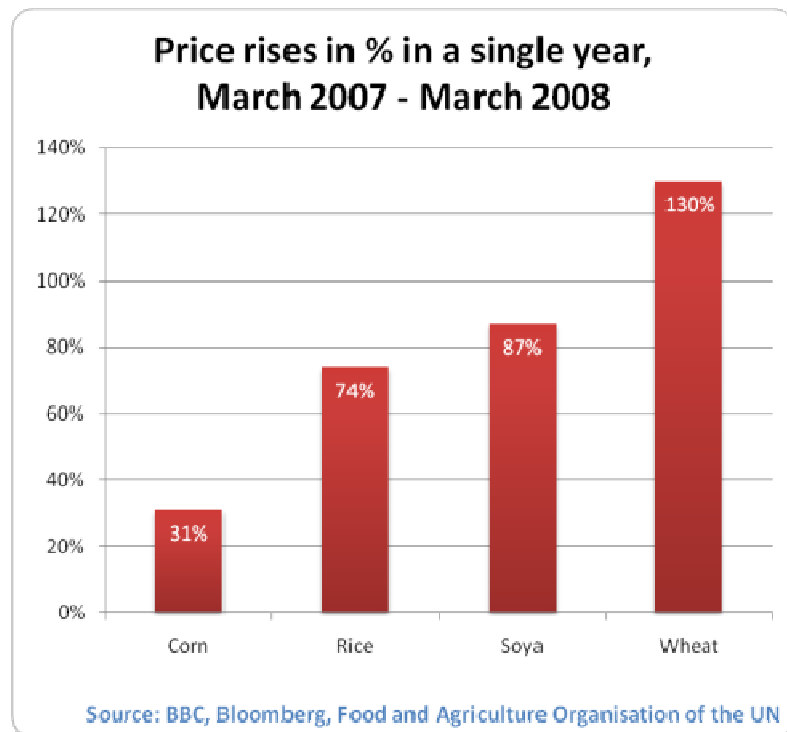
Grain and forage inputs per kilogram of animal product produced

Livestock	Grain ¹	Forage ²
	<i>kg</i>	<i>kg</i>
Lamb	21	30
Beef cattle	13	30
Eggs	11	—
Swine	5.9	—
Turkeys	3.8	—
Broilers	2.3	—
Dairy (milk)	0.7	1

Pimentel & Pimentel (2003) AJCN 78:(suppl)660S-3S

But what about the rising food prices?

- In 2007-2008, key grain prices rose 30-130%, resulting in a world “food crisis” – many critics blame expansion of biofuels



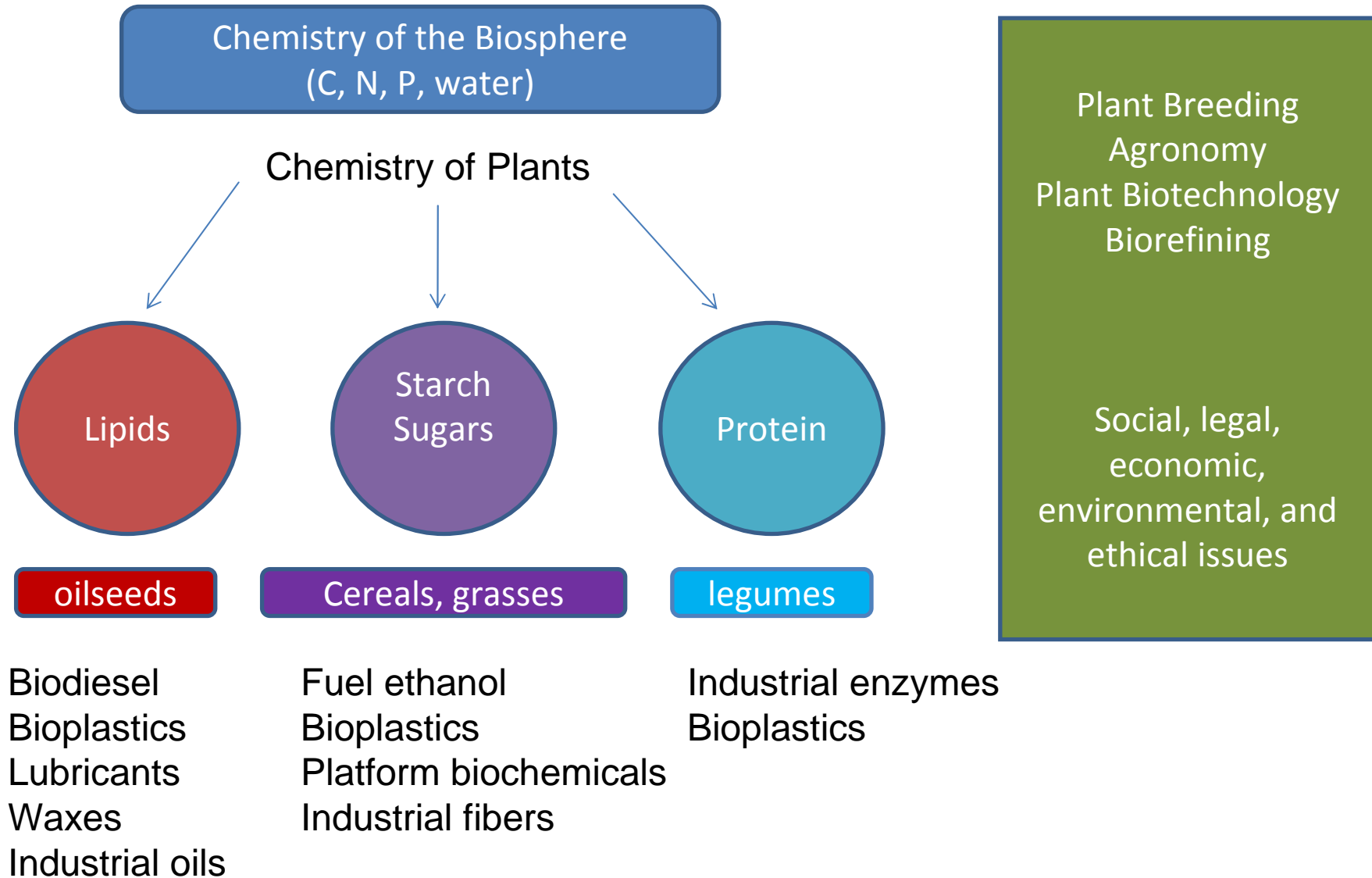
Are biofuels really to blame?

- Only ~5% of the world's cereal production was diverted to biofuels in 2007-08
- Other direct and indirect factors contributing to the crisis include:
 - Record high oil prices
 - Record low food stockpiles
 - Drought in major wheat producing countries in 05-06
 - Doubling of per capita meat consumption in developing countries
 - Decreasing foreign aid to poor countries
 - Crop subsidies

Other issues surrounding bioproducts

- Availability of arable land & sustainability of intensive agricultural production practises
- Concerns about the use of genetically modified organisms
- Arguments about the net energy balance of various bioenergy sources

Course outline



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